Pumping up building decarbonisation: The role of policy awareness in heat pump adoption among Canadian homeowners

by

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Abstract

Heat pumps are a key technology for decarbonising residential buildings, yet their current market share in Canada remains very low at approximately 5%. To promote heat pump adoption, governments in Canada have introduced supportive policies such as purchase subsidies, and it is often assumed that increasing consumer awareness of such policies increases heat pump adoption. Using a survey of Canadian homeowners who do not own heat pumps (*n*=3,138), this study assesses: (1) levels of willingness to adopt air source and ground source heat pumps across Canada; (2) the effect of information provision on willingness to adopt heat pumps, (3) levels of heat pump policy awareness across Canada; (4) whether perceived technical characteristics of heat pumps can be categorized as functional or symbolic, and as private or societal, and (5) the role of policy awareness and other drivers in explaining willingness to adopt heat pumps. The study finds that a third of Canadian homeowners are willing to adopt heat pumps. These homeowners are found predominantly within the Atlantic region and show higher levels of adoption willingness for air source rather than ground source heat pumps. Awareness of existing heat pump supportive policy is low, with only 5% of respondents able to name any policies from memory. Awareness tends to be higher in British Columbia, and for heat pump subsidies and carbon taxes. Policy awareness without cues is a predictor of willingness to adopt air source heat pumps only. When provided with a list of policies to aid reporting, policy awareness is not associated with heat pump adoption. Other significant predictors include perceptions of heat pumps' functionality and their environmental benefits, having a technology-oriented lifestyle, being a younger homeowner, and the financial and inconvenience costs during installation. Based on findings, insights into targeted policy designs to accelerate residential building decarbonisation are provided.

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Chapter 1. Introduction

Residential buildings account for about 17% of global greenhouse gas (GHG) emissions, contributing to accelerating climate change impacts (United Nations Environment Programme, 2020). Canada's residential buildings account for 6% of national emissions (Environment and Climate Change Canada, 2019). To meet emissions reduction commitments, Canada must decrease buildings emissions by at least 50% by the year 2030 and achieve a net-zero emissions building stock by 2050 (United Nations Environment Programme, 2020). While building decarbonisation efforts are increasing, current policies are likely insufficient for Canada to meet its climate targets (Davis et al., 2018; Kuramochi, 2019).

Electric heat pumps have been identified to likely play a key role in reducing GHG emissions from residential buildings in Canada (Bloess et al., 2018; Canadian Institute for Climate Choices, 2021). There are two main types of electric heat pumps: air source and ground source. Air source heat pumps heat homes by extracting heat energy from the outside air and cool homes by transferring heat to the outside air. Ground source heat pumps work similarly except they draw heat from, and vacate heat to, the earth to heat and cool homes (Omer, 2008). Both air source and ground source heat pumps are up to five times more energy-efficient than fossil fuel-based heating systems (e.g., boilers, furnaces) and can help reduce home heating emissions while also potentially providing energy cost savings (Habibi & Hakkaki-Fard, 2019; Natural Resources Canada, 2021). In Canada, it is estimated that heat pumps can reduce home heating-related emissions by 45-89% compared to fossil fuel-based furnaces (Udovichenko & Zhong, 2020).

To encourage heat pump installations, Canada has several consumer-focused heat pump-supporting policies, including education on the benefits of heat pumps, subsidies (in the form of grants and rebates), and low-interest loans. Further, Canada's implementation of carbon pricing financially penalizes the use of fossil fuel-based heating systems, thereby encouraging the adoption of zero emission electric technologies like heat pumps. Similarly, renewable natural gas blending mandates may raise the price of natural gas, in turn incentivizing the use of electric-power heating devices (Dunsky Energy Consulting, 2021). Despite these policies, residential heat pump total market share remains very low at approximately 5%, with air source heat pumps dominating the market over ground source heat pumps (Government of Canada, 2020a).

While emerging research from Europe and Asia provides some insights into potential barriers to heat pump adoption, they may not directly apply to the Canadian context due to the different climates, energy costs, and product market shares in these countries (Jingchao et al., 2018; Karytsas & Choropanitis, 2017; Karytsas & Theodoropoulou, 2014; Su et al., 2019). As such, consumer motivations to adopt heat pumps in Canada are largely unknown. One such unexplored consumer motivation is policy awareness. It is often assumed in the literature that increasing awareness of supportive policies, and particularly incentive-type policies, is important for increasing the adoption of heat pumps. However, published literature examining the role of policy awareness in low-emission technology adoption is limited and tends to focus on electric vehicles (EVs). Given the growing number and stringency of heat pump-supporting policies, it is important to understand if consumer awareness of such policies is an important driver of heat pump adoption.

To begin, there are relatively few studies examining levels of policy awareness for heat pump-supportive policies. Liu and Jin (2019) studied levels of awareness of home energy retrofit policies in Japan, namely prefectural loans and grants for purchasing energy-saving home

equipment. The researchers found that over 35% of respondents had low or very low levels of policy awareness. In a Canadian study, Rhodes et al. (2014) found that 2% of respondents were able to name home energy efficiency regulations when not given cues to aid recall, and 43% were able to when given memory cues. Levels of awareness of low-carbon technology-supportive policies among consumers has been studied mostly in the context of electric vehicles (EVs), where the literature has found that awareness of incentive-like policies tends to be lower among non-owners (Broadbent et al., 2021; Hardman et al., 2020; Krause et al., 2013), though EV-owners display higher awareness of EV-supportive policies (Broadbent et al., 2021).

Similar to the research on levels of awareness for heat pump-supportive policies, there is also relatively little research available on the role of policy awareness in heat pump adoption. Goody (2014) and Owen et al. (2012) found that awareness of purchase subsidies was a significant factor in consumers' decision to adopt a heat pump in Canada and England, respectively. Further, there are no revealed preference (historical) studies that explicitly examine the role of policy awareness in past consumer decisions to adopt a low-emission heating technology. Once again, most existing research has taken place in the context of EV adoption, and the role of policy awareness in EV adoption is not well understood. On the one hand, research suggests that consumers with greater awareness of EV-supportive policies are more willing to adopt EVs. For example, Krause et al. (2013) found that 82% of survey respondents were more likely to consider adopting an EV if a subsidy were in place. Lane et al. (2018) found that awareness of supportive EV policies was positively associated with intent to purchase EVs in the United States. In New Zealand, the Netherlands, and Portugal, Broadbent et al. (2021) and Samsom (2020) respectively found that the more EV-supportive policies consumers were aware of, the more likely they were to consider purchasing an EV. On the other hand, Hardman et al. (2020) and Krause et al. (2013) did not find a statistically significant relationship between awareness of financial incentives and information policies and willingness to adopt an EV.

The existing research has multiple limitations. First, the studies that examined the role of policy awareness in heat pump adoption used small, non-representative samples (i.e., less than 20 homeowners) to interview homeowners who had already installed heat pumps. As a result, the findings may lack replicability and generalizability for policy-making at national and sub-national levels. Second, these studies tended to assess narrow sets of psychological and/or contextual drivers of technology adoption behaviour, limiting the reliability of results for government policy-making (Stern, 2000). Third, most studies focused on incentive-like policies (e.g., subsidies), ignoring the potential importance of other more compulsory types of policies (e.g., carbon pricing and regulations) in influencing technology adoption. Given that governments often use a mix of different policies for political acceptability and other reasons, understanding the role of consumer awareness of these different policies in willingness to adopt heat pumps can help tailor government policy decisions (International Energy Agency, 2011; Kern et al., 2019). Finally, most existing research examined either air source or ground source heat pumps, instead of comparatively studying the adoption drivers and barriers for both systems. The higher uptake levels for air source than ground source heat pumps in Canada suggest that the variables that motivate adoption may differ between the systems (Natural Resources Canada, 2021). Understanding these differences may be valuable for designing tailored policies that target the adoption of each system.

Using a survey of Canadian homeowners who do not own heat pumps (n=3,138), the key objectives of this study are to assess: (1) levels of consumer willingness to adopt heat pumps across Canada and by Canadian province, (2) the effect of information provision on willingness

to adopt heat pumps, (3) levels of consumer awareness of heat pump-supportive policies across Canada and by Canadian province, (4) whether perceived technical characteristics of heat pumps can be categorized as functional or symbolic, and as private or societal, and (5) the role of consumer awareness of heat pump-supportive policies in the willingness to adopt heat pumps among Canadian homeowners. This study is organized as follows. Chapter 2 reviews policy instruments available to support heat pump adoption across Canada. Chapter 3 reviews the literature on the role of policy awareness in consumer willingness to adopt low-emission technologies. Chapter 4 describes the conceptual framework. Chapter 5 explains the methodology for data collection and analysis. Chapter 6 discusses the results. Chapter 7 concludes with policy implications.

Chapter 2. Policy instruments to support heat pump adoption

Different policies can target consumer adoption of heat pumps and other low-emission heating technologies, including educational programs, subsidies, government procurement, emissions taxes, performance standards, and command-and-control regulations (Goulder & Parry, 2008; McAndrew et al., 2021). Most jurisdictions in Canada offer more than one of these policies to promote residential emissions reductions, with some specifically targeting the adoption of heat pumps (Table 1). The objective of this study is to examine consumer-focused policies, and therefore excludes supply-focused policies such as building codes. For the purpose of this study, 'policy' is defined as provincial government actions aimed at decarbonizing residential home heating and/or promoting the adoption of heat pumps. This definition also includes private utility provider actions for the policy types of information, subsidies, and loans for heat pumps. This study focuses on policies offered at the provincial levels because: (1) few heat pump-supporting policies are offered at the federal level, and (2) provincial governments generally have greater jurisdictional authority over residential emissions sources and funding than municipal governments, though some municipalities have recently started to offer their own supporting policies (CleanBC, 2021e). During the survey design stage, the federal government introduced a national subsidy program to support home energy efficiency upgrades that was highly publicized and named multiple times in this study's open-ended question assessing policy awareness without cues (Government of Canada, 2021b). For this reason, the program was incorporated into the measure of policy awareness without cues (see Chapter 5.3).

Table 1. Heat pump-supportive policies in Canadian provinces as of July 2021*

Province	Education	Subsidy for heat pumps	Loan programs	Carbon tax	Renewable natural gas mandate	Home emissions regulation
Newfoundland and Labrador	Yes	No	Yes	Yes**	No	No
Prince Edward Island	Yes	Yes	Yes	Yes	No	No
Nova Scotia	Yes	Yes	No	No***	No	No
New Brunswick	Yes	Yes	No	Yes	No	No
Quebec	Yes	Yes	No	No***	Yes	No
Ontario	No	No	No	Yes	No	No
Manitoba	Yes	No	Yes	Yes	No	No
Saskatchewan	No	No	No	Yes	No	No
Alberta	No	No	No	Yes	No	No
British Columbia	Yes	Yes	Yes	Yes	Yes	No

*Policy information taken from CleanBC (2018, 2021a, 2021b, 2021d, 2021c), Efficiency Nova Scotia (2021a, 2021b, 2021c), Government of Canada (2018a, 2021a), Government of Newfoundland (2018), Government of Quebec (2021), Hydro Quebec (2021), Regulation respecting the quantity of renewable natural gas to be delivered by a distributor (2020), Manitoba Hydro (2021), Maritime Electric (2021), New Brunswick Power (2021), Nova Scotia Power (2021), Prince Edward Island (2021b, 2021a), Save Energy New Brunswick (2021), TakeCHARGE (2021b, 2021a).

**Carbon tax does not apply to home heating fuels.

*** Nova Scotia and Quebec use a cap-and-trade scheme instead of carbon tax.

Educational programs, subsidies, and low-interest loans are non-compulsory policies that incentivize pro-environmental purchase decisions without imposing penalties for non-compliance (Goulder & Parry, 2008; Rhodes, 2016). Consumer awareness of these policy types is crucial for their effectiveness (e.g., to be incentivized by the availability of a subsidy, a homeowner must be aware of it). Educational policies involve developing and disseminating information on the financial, environmental, and/or moral benefits of technology adoption (Jaccard, 2006). In the current study, a jurisdiction was classified as providing education if (a) they prominently featured information on the benefits of heat pumps on government or utility provider websites, and (b) these materials did not include information on available subsidies. As of July 2021, seven of the ten Canadian provinces utilized educational policies to encourage the adoption of heat pumps (Table 1). An example of an educational policy is TakeCHARGE in Newfoundland and Labrador, a government hub for energy efficiency, which has heat pumps prominently featured on their webpage for residences (TakeCHARGE, 2021b).

With subsidies, the government pays a portion of the purchase price to reduce consumers' cost for adopting technologies (Rosenow et al., 2016). As of July 2021, five of the ten provinces in Canada offered this policy type to promote the adoption of heat pumps. While not controlled for in this study, it is worth noting that subsidy programs vary notably between provinces in terms of subsidy size, public availability of information, and the clarity of said information. This may be a barrier to homeowners' ability to afford heat pumps and/or understand how much financial support they would receive, and therefore to their willingness to adopt a heat pump. For example, the same category of heat pump could be eligible for a subsidy of up to $6,000 from the British Columbia government and $400 from the government of New Brunswick (CleanBC, 2021b; Save Energy New Brunswick, 2021). Furthermore, provinces such as British Columbia and Prince Edward Island provide more information on subsidy amounts and how the program is implemented (e.g., eligibility requirements, program process) (CleanBC, 2021b; Prince Edward Island, 2021b). However, the information could be difficult to understand due to its complexity, such as rebate amounts varying in British Columbia based on the municipality a homeowner resides in, how many eligible home energy retrofits they are completing, and whether they are participating in a home energy evaluation program (CleanBC, 2021b). Finally, only estimates of rebate amounts were available on these webpages, such that homeowners would not know exactly how much financial assistance they would receive until after completing a home energy consultation or installation of a heat pump (CleanBC, 2021b; Efficiency Nova Scotia, 2021a; Government of Quebec, 2021; Prince Edward Island, 2021b).

Low-interest loans provide consumers access to capital to assist with the purchase of heat pumps (Rosenow et al., 2016). This policy type was available in four provinces in July 2021 to help consumers purchase heat pumps. In British Columbia, for example, loans are available through both the Government of British Columbia and FortisBC, a natural gas provider (CleanBC, 2021d).

Carbon taxes and regulations on technologies and fuels are compulsory and mandate participation (Rhodes, 2016). While consumer awareness of these policies is not necessarily required for them to be effective (Xiang & Lawley, 2019), awareness of the compulsory policy types included in this paper may be relevant for influencing consumer choices. For example, a carbon tax increases the cost of carbon-emitting activities (e.g., burning fossil fuels for home heating), which incentivizes consumers to reduce their emissions through actions such as adopting low-emission technologies (Rosenow et al., 2016; Stern, 1999). Under Canada's Greenhouse Gas Pollution Pricing Act, provinces were required to implement a carbon pricing

plan by April 1st, 2019 or have the federal carbon pricing imposed upon them (Environment and Climate Change Canada, 2020). Quebec and Nova Scotia are the only jurisdictions without a carbon tax, as they use cap-and-trade schemes that target industrial emitters instead of consumers (Government of Canada, 2018b; Government of Nova Scotia, 2014).

Regulatory policies set legally-enforceable minimum requirements for technologies or fuels and penalize those who do not comply (Rhodes, 2016; Rosenow et al., 2016). An example of a regulatory policy that may influence consumer choice is a renewable natural gas (RNG) standard, which mandates that a certain percentage of natural gas content used in buildings comes from renewable sources (Cyrs et al., 2020). This increases the cost of using natural gas for home heating, which can incentivise switching to electric heating devices such as heat pumps that do not face this additional cost (Dunsky Energy Consulting, 2021). As of July 2021, this policy type was only found in British Columbia and Quebec, requiring 15% RNG by 2030 in BC and 5% RNG by 2025 in Quebec (CleanBC, 2018; Regulation respecting the quantity of renewable natural gas to be delivered by a distributor, 2020). Home emissions regulations are another type of regulatory policy that can be implemented to reduce emissions in the residential home heating through influencing consumer choice. They can be imposed to limit the total amount of GHGs a home is allowed to produce (Park et al., 2017), which can incentivize performing retrofits to reduce emissions and avoid paying fines. While no province in Canada currently uses this policy, some Canadian municipalities (i.e., City of Vancouver) are exploring its feasibility. For these reasons, this study tests for this novel and potentially important policy for decarbonising residential buildings. Other regulations that target suppliers and are less relevant for consumer choice, such as building codes, have been excluded.

Chapter 3. Policy awareness and consumer adoption of low-emission technology

3.1. Levels of policy awareness

For the purposes of this study, policy awareness is considered low when approximately 50% of respondents or fewer display some type of awareness of a policy. Awareness of voluntary policies is generally low. Educational policies, for example, are often not well-known among consumers. Hardman et al. (2020) surveyed individuals in California who had recently considered purchasing an EV, and found that 50% were aware of advertisements for EVs and 25% were aware of other educational programs. Among New Zealand drivers, less than 15% of EV non-owners were aware of an EV information website, and 43% of EV owners were aware of this website (Broadbent et al., 2021).

Awareness of incentive policies such as subsidies is also low. Hardman et al. (2020) found 50% of their Californian sample were aware of state-provided purchase and use incentives. Likewise, Broadbent et al. (2021) found that approximately 30% of potential EV adopters in New Zealand were aware of a government subsidy program for EVs. Krause et al. (2013) found that 5.5% of urban American adults with driver's licenses were aware of available state and municipal subsidies. In a Canadian study, Kitt (2019) found that 22% of citizens from British Columbia were aware of available provincial EV subsidies when not given cues to aid recall, compared to 42% when given cues. In Quebec, the proportions were 45% and 61%, respectively. Liu and Jin (2019) examined awareness of home retrofit incentive policies among Japanese households participating in a home energy audit program. Specifically, almost 40% of the sample had low or very low awareness of a grant for installing energy saving and energy storage equipment, and 52% were unaware of a loan program for installing similar technologies.

Research indicates that public awareness is higher for carbon taxes, compared to other policy types. Rhodes et al. (2014) found that public awareness of British Columbia's climate policies is low overall, but the public is most aware of the carbon tax due to its saliency (i.e., high cost visibility). When asked to name policies currently in place in British Columbia, 26% of respondents named the carbon tax while the rest of the respondents were unable to name any other policy. The same pattern was found when respondents were asked to select current policies from a list of real and 'false' policies: 69% of respondents correctly selected the carbon tax while most could not correctly identify other types of climate policies. Using a similar methodology in their survey of EV policy awareness in British Columbia, Alberta, Ontario, and Quebec, Kitt (2019) found that awareness was highest for the carbon tax. Approximately 31% of respondents could name the carbon tax as a current policy without any cues, while correct selections of the carbon tax once given cues ranged from 69% correct in Ontario to 87% correct in Alberta. Similarly, Long et al. (2020) found that the carbon tax was the most-named policy type when cues were not provided (44% of respondents) and when they were provided (69% to 87% of respondents). However, Liu and Jin (2019) found that Japanese households completing home energy retrofits were least aware of the carbon tax compared to other supportive policies, with approximately 60% of their sample having low awareness of this policy. The authors suggested that the low stringency of the carbon tax contributed to low awareness. Japan's carbon tax is one of the lowest among developed countries at JPY 289 (CAD $3.15) per tonne of CO2e compared to Canada's 2020 tax of CAD $30 per tonne of CO2e (Environment and Climate Change Canada, 2020; Kojima & Asakawa, 2021).

Compared to the carbon tax, public awareness of regulations is lower. Among New Zealand car buyers, 50% of EV owners and less than 25% of EV non-owners were aware of "clean car" regulations (Broadbent et al., 2021). In the North American context, research

suggests that awareness of regulations varies by regulation type. Long et al. (2020) assessed public awareness of EV regulations in Canada and found less than 5% of respondents could name a regulation when not given cues. When given cues, 53% or fewer respondents were aware of a vehicle emissions standard being in place and less than 40% of respondents were aware of all other regulation types assessed.

3.2. Role of policy awareness in heat pump adoption

Research on the role of policy awareness in the adoption of heat pumps is in its infancy. Although heat pump adoption studies have called for educational policies to address awareness barriers (Karytsas, 2018; Karytsas & Choropanitis, 2017), there is no published literature confirming the statistical significance of consumer awareness of educational policies for higher heat pump adoption.

While the role of educational policy awareness in heat pump adoption is inconclusive, the effect of subsidy awareness in heat pump adoption is somewhat clearer. Goody (2014) and Owen (2012) are some of the few studies that found an association between higher homeowner awareness of purchase grants and heat pump adoption; however, these studies lacked representativeness and had small sample sizes. Goody (2014) interviewed 17 households in rural southwestern Ontario who installed ground source heat pumps, and found that nine of eleven households who were not previously motivated to install this system did so after becoming aware of the available subsidies. Similarly, Owen et al. (2012) interviewed six households in the United Kingdom (U.K.) who adopted air source heat pumps and found that five of six households decided to install heat pumps instead of other heating technologies because subsidies and/or loans were available.

There is some limited evidence for the role of awareness of loan programs in supporting the adoption of low-emission technology. As described above, Owen et al. (2012) found that awareness of loans and/or subsidies encouraged five out of six households to install an air source heat pump instead of other heating technologies. There is no research examining the association between awareness of carbon taxes or regulations and heat pump adoption.

Chapter 4. Conceptual framework: Attitude-Behaviour-Context theory

This study employs Stern's Attitude-Behaviour-Context (ABC) theory to test the role of policy awareness in consumer adoption of heat pumps. The theory posits that pro-environmental behaviour, such as adopting a low-emission technology, is the result of an interaction between attitudinal (internal) and contextual (external) factors (Guagnano et al., 1995; Stern, 2000). Studies examining willingness to adopt heat pumps have found that numerous variables are associated with technology adoption. For example, Goody (2014) found that 27 characteristics spanning across financial, environmental, technical, social, and visual categories influenced consumers' willingness to adopt heat pumps.

The ABC theory considers four categories of variables associated with pro-environmental behaviours: attitudinal, contextual, personal capability, and habitual (Stern, 2000). Attitudes comprise the internal characteristics that influence pro-environmental behaviour, such as norms, beliefs, and values. Contextual characteristics consist of external factors that support or hinder behaviour, such as policies, interpersonal influences, and the costs of performing a behaviour. Personal capability includes characteristics such as individuals' knowledge, skills, and income, and is typically measured through socio-demographics. Because the purchase of a heat pump is not a routine behaviour, habitual factors have been excluded from the study's framework.

Stern (1999) expanded on the ABC theory to emphasize the relationship between awareness of policies and pro-environmental behaviour. He proposed that making consumers aware of incentives (e.g., subsidies) is an effective way to encourage pro-environmental behaviour, if incentives are set at an appropriate level. While he does not explicitly consider awareness of carbon taxes, he appears to conceptualize energy taxes as a form of incentive policy in that they encourage choosing options that minimize costs. Although Stern (1999) does not include awareness of environmental regulations in the ABC theory, regulations are part of Canada's heat-pump supportive policy mix, and awareness of certain regulation types may have a role in consumer choice (Canadian Institute for Climate Choices, 2021; Dunsky Energy Consulting, 2021). As such, the study uses awareness of the suite of current consumer-focused policy types shown in Table 1 as a contextual factor that influences consumers' willingness to adopt heat pumps.

Stern's (1999) ABC extension is supported by the Knowledge Deficit Model, which assumes that providing information to individuals will translate into behaviour change (Miller, 2001). In the context of the current study, it is suggested that lacking awareness of heat pump-supporting policies (i.e., a knowledge deficit) may be impeding the willingness to adopt heat pumps (Karytsas & Choropanitis, 2017; MacAdam, 2019; Miller, 2001).

Attitudinal characteristics included in the framework are values, ecological worldviews, and lifestyles that are likely to increase willingness to adopt heat pumps. Values (i.e., biospheric, openness to change), support for climate policies, and ecological worldviews have been positive predictors of pro-environmental behaviour, while traditional and egoistic values have been negative predictors (Axsen et al., 2016; Dietz et al., 2005; Long et al., 2019; Rhodes, 2016; Rhodes et al., 2014; Steg et al., 2005). Having a technology- and environment-oriented lifestyle has been positively associated with willingness to adopt EVs and ground source heat pumps (Axsen et al., 2012; Karytsas & Theodoropoulou, 2014).

Contextual characteristics hypothesized to have an association with heat pump adoption include social, home, economic, technical, and policy characteristics. Knowing someone who owns a heat pump has been positively associated with willingness to adopt one (Karytsas, 2018). In terms of home characteristics, older homes have been negatively associated with willingness

to adopt heat pumps, while having other energy-efficiency retrofits in a home has been positively associated (Michelsen & Madlener, 2012; Wilson et al., 2018). The economic-technical characteristics measured through perceived investment and operating costs have had, respectively, negative and positive associations with willingness to adopt heat pumps (Karytsas & Choropanitis, 2017; Mahapatra & Gustavsson, 2009; Rouvinen & Matero, 2013). Familiarity with heat pumps and perceptions of their environmental benefits, operating ease, and performance (e.g., perceived effectiveness of the heating system) are other technical characteristics that have been associated with higher willingness to adopt heat pumps (Karytsas & Choropanitis, 2017; Karytsas & Theodoropoulou, 2014; Mahapatra & Gustavsson, 2009).

To explore and organize perceived technical characteristics of heat pumps, this study adapted Axsen and Kurani's (2012) framework of classifying technical characteristics as functional or symbolic, and as private or societal. Functional characteristics refer to the physical capabilities and benefits of a technology (e.g., effectiveness in heating and cooling a home, improving air quality), while symbolic characteristics refer to the social meanings assigned to the technology (e.g., expressing values). These characteristics can be located at the private level (e.g., effective home heating benefits an individual or household) or societal level (e.g., improved air quality benefits a society). Previous research has found these categories of technical characteristics can motivate adoption of EVs (Axsen et al., 2013; Axsen & Kurani, 2012; Noppers et al., 2015).

In terms of personal capabilities, consumers who are female, younger, wealthier, more educated, and from larger households have been more likely to adopt heat pumps and other pro-environmental technologies (Das et al., 2018; Karytsas, 2018; Lillemo et al., 2013; Mahapatra & Gustavsson, 2007, 2008; Michelsen & Madlener, 2016; Owen et al., 2012). Finally, geographic location also influenced heat pump adoption, with individuals living in more fossil fuel resource-dependent regions being less likely to adopt heat pumps and other pro-environmental technology (Das et al., 2018; Mildenberger et al., 2016).

Chapter 5. Method

5.1 Data collection

This study used a 35-minute web-based survey to collect primary data from a representative sample of 3,138 Canadian homeowners who do not own heat pumps as either their primary or secondary home heating system. This sample consisted of 2,246 detached homeowners, and 892 semi-detached, townhouse, and duplex homeowners. Some respondents were intentionally oversampled, including 100 residents of British Columbia, 100 residents of Alberta, 200 residents of Saskatchewan and Manitoba, and 200 residents of the Atlantic provinces of Nova Scotia, Prince Edward Island, New Brunswick, and Newfoundland and Labrador, to allow analysis of regional differences. The survey was administered by a market research company in June-July 2021. Respondents could choose to take the survey in English or French.

When compared to Canada's Census data, the final sample was older, more male-represented, higher-earning, and more educated (Table 2). However, these differences may represent a difference in the population of homeowners compared to the general population. Provincial sampling was overall representative of the distribution of Canada's population, although Quebec was underrepresented and Manitoba was overrepresented. Corrective weights were not applied for any variables that diverged from Census data because the study's goal was to sample homeowners and not the general population, and thus deviations from Census data may represent true differences in the population of homeowners compared to the general population.

Table 2. Socio-demographics of sample compared to Canadian Census

Socio-demographic variables	Sample %	Census %*
Province/territory		
Prince Edward Island	0.3%	0.4%
Newfoundland and Labrador	1.7%	1.5%
Nova Scotia	3.1%	2.6%
New Brunswick	2.3%	2.1%
Quebec	17.0%	23.2%
Ontario	36.4%	38.3%
Manitoba	7.5%	3.6%
Saskatchewan	3.8%	3.1%
Alberta	14.1%	11.6%
British Columbia	13.9%	13.2%
Age		
19 to 34	10.9%	20.7%
35 to 54	32.6%	27.2%
55 and over	56.6%	30.8%
Gender		
Male	55.3%	49.1%
Female	44.7%	50.9%
Highest Level of Education		
High school or less	18.1%	35.2%
Apprenticeship or trades certificate or diploma	5.8%	10.7%
College, CEGEP, or other non-university certificate or diploma	23.1%	22.4%
University certificate or diploma below the Bachelor's level	6.8%	24.0%

Socio-demographic variables	Sample %	Census %*
University certificate, diploma, or degree at the Bachelor's level or higher	32.0%	20.9%
Post-secondary above a Bachelor's level	14.3%	7.6%
Household size		
1 person	14.2%	28%
2 people	47.7%	34%
3 people	18.0%	15%
4 or more	20.1%	22%
Annual household income		
Less than $50,000	19.4%	34.8%
$50,000 to $99,999	40.6%	32.8%
$100,000 to $149,999	24.1%	17.7%
$150,000 to $199,999	10.4%	7.9%
$200,000 and over	5.6%	6.8%

* Census data were taken from Statistics Canada (2016c, 2016a, 2016b, 2016e, 2016d).

The survey consisted of six sections (see Appendix A for a full questionnaire) including a quasi-experiment where participants were asked to rate their willingness to adopt heat pumps before and after being given information on heat pump technical characteristics in Sections 1 and 4, respectively. The first section assessed respondents' current home heating system and home characteristics, as well as their willingness to adopt a heat pump when their existing heating system needs to be replaced. The second section collected data on the policy context, including respondents' policy awareness without and with cues per Rhodes et al. (2014), Long et al. (2020), and Kitt (2019). The third section assessed perceptions of heat pumps' technical characteristics (e.g., functionality, alignment with personal values) (Sustainable Transportation Action Research Team, 2017). The fourth section contained a discrete choice experiment on heating technologies which was not part of this study, although the home heating technology guide read by respondents in this section is used in the quasi-experiment on the role of information provision in willingness to adopt heat pumps (see Chapter 5.2). The fifth section assessed a set of attitudinal characteristics, including values, worldviews, lifestyle, and policy support using Likert scales (Dietz et al., 2007; Dunlap et al., 2000; Kitt et al., 2021; Rhodes et al., 2014; Schwartz, 1992; Steg et al., 2005; Sustainable Transportation Action Research Team, 2017). The final section collected socio-demographic information including income, age, and province.

5.2 Willingness to adopt heat pumps and the effect of information provision

Because air source and ground source heat pumps are different technologies with different rates of adoption in Canada, willingness to adopt each type of heat pump were treated as separate dependent variables. To assess levels of willingness to adopt air source and ground source heat pumps (dependent variables) in Canada and by province (objective 1), a scale was adapted from Rhodes et al. (2014) for Section 1 of the survey. Respondents were asked to report their willingness to adopt a heat pump when their existing system needs to be replaced on a Likert-type scale ranging from "1- very unwilling," "2 – unwilling," "3 – undecided," "4 – willing," and "5 - very willing," with the option of "prefer not to answer." Willingness to adopt heat pumps in homes with existing electrified heating systems compared to fossil-fuel heating systems was not controlled for in this study. This is because heat pumps are still a highly efficient technology compared to other electric heating systems (e.g., electric baseboard)

(Natural Resources Canada, 2021), and this study's objective is to examine willingness to replace existing, less-efficient heating systems with an electric heat pump once a home's existing heating system is at the end of its lifetime and needs to be replaced. Frequency distributions were used to analyze levels of willingness to adopt each type of heat pump. Because the data were skewed, analyses of variance (ANOVAs) with the Welch test of significance and Games-Howell post-hoc tests were used to analyze differences in willingness to adopt between provinces.

To test the effect of technical information provision on willingness to adopt (objective 2), Rhodes et al.'s (2014) method was adapted. Specifically, the same willingness to adopt question and five-point Likert scale from Section 1 of the survey questionnaire was repeated in Section 4 of the survey after respondents read the technology guide. Due to skewed data, a Wilcoxon signed-rank test was used to assess for differences in mean willingness to adopt air source and ground heat pumps pre- and post-information provision. Post-information provision levels of willingness to adopt were only used in the quasi-experiment.

5.3. Levels of policy awareness

To assess levels of policy awareness in Canada and by province (objective 3), the study employed an open-ended question to measure policy awareness without cues, and a multiple-choice question to assess policy awareness with cues per Rhodes et al. (2014), Kitt (2019), and Long et al. (2020). This study uses these two measures because they represent different types of awareness. Policy awareness without cues measures respondents' ability to free-recall current policies from memory, and utilizes the recall process of memory (Cleary, 2018). In comparison, policy awareness with cues measures respondents' ability to discriminate between 'real' and 'false' policies on a list, and utilizes the recognition process of memory (Cleary, 2018). Providing cues tends to aid memory performance (Cleary, 2018), and so this study aimed to explore whether respondents correctly identified policies at greater rates when given cues.

For policy awareness without cues, respondents were asked to name policies from memory that were currently in place in their province without being given any cues to aid recall, or select "I cannot think of any policies currently in place in my province." Answers were marked as 'correct' if they named a policy or policy type that was currently implemented per the policy matrix in Table 1 and per the coding frame (Table 3). Additionally, responses naming a temporary federal subsidy program introduced during survey data collection were marked as 'correct,' as this policy was highly publicized and available in each province, and naming it represented a level of awareness that this study aimed to capture. Frequency distributions were used to describe the percentage of respondents who correctly identified at least one policy (i.e., 'policy-aware respondents'), and those who only identified incorrect policies or selected "I cannot think of any policies" (i.e., 'policy-unaware respondents'). To test for significant differences in levels of policy awareness between Canadian provinces, policy awareness without cues was converted into a nominal binary variable before running a chi-square test of independence. The levels of this binary variable were 'policy aware' and 'policy unaware' respondents.

Table 3. Bilingual coding frame for policy awareness without cues (open-ended question)

Policy type	English codes	French codes
Subsidy/rebate for purchasing low-emission heating systems	Subsidy, grant, rebate	Subvention, bourse, rabais
Loan/financing program	Loan, financing	Prêt, financement
Education	Advertising, education	Advertisement, education, publicité
Carbon tax	Carbon tax	Taxe sur le carbone
Renewable natural gas mandate	Renewable natural gas mandate, biogas mandate	Mandat gaz naturel renouvelable, mandat biogaz
Home emissions regulation	Home emissions regulation	réglementation sur les émissions domestiques

For policy awareness with cues, respondents were tasked with identifying policies that were currently in place in their province from a list of real and 'false' policies (Table 4). This list of real and 'false' policies was selected from a review of current implemented and announced policies across Canada as well as a literature review. Responses were coded as 'correct' or 'incorrect' per the policy matrix in Table 1, which was created using secondary sources. Specifically, answers were coded as 'correct' if respondents selected "I know this policy is in place in my province" for policies that were currently in place in their province and "I know this policy is not in place in my province" for policies not currently in place in their province. Unlike the previous policy awareness without cues question, this coding frame did not include the federal subsidy program. Frequency distributions were used to describe levels of policy awareness with cues in Canada and by province, and once again aggregated respondents who only reported incorrect policies or who selected the "I don't know about this policy" option. To test for significant differences between provinces, policy awareness with cues was treated as a continuous variable, and due to the skewed data, an ANOVA with the Welch test of significance and Games-Howell post-hoc test were used to test for differences between provinces.

Table 4. List of policies and definitions provided to respondents

Policy type	Policy definition
Subsidy/rebate for purchasing low-emission heating systems	a grant given for purchasing and/or installing a low-emission heating system (for example, this could be a discount given at the point of sale or a tax rebate)
Loan/financing program	a program that provides loans to help with the costs of purchasing and installing low-emission heating systems (for example, a low-interest loan program)
Education	an information program that aims at encouraging you to voluntarily choose to purchase, install, or use a low-emission heating system (for example, mail pamphlets, TV commercials, and/or online ads that provide information on the financial or environmental advantages of using low-emission heating systems)
Carbon tax	a tax applied to all fossil fuels such as natural gas and oil based on how much carbon they release when burned (for example, a carbon tax would be added to a natural gas or oil bill when paying for home heating)
Renewable natural gas mandate	a regulation on natural gas providers requiring them to blend in a certain amount of renewable natural gas in natural gas used for home heating (for example, making a natural gas mixture that is made up of 15% biogas)
Home emissions regulation	a regulation that limits the amount of greenhouse gas emissions a house is allowed to emit from home heating and water heating. To comply, homeowners can improve the energy efficiency of their home, switch to low-emission heating systems, or pay a fine

5.4 Determining perceived technical characteristics of heat pumps

We categorize perceived technical characteristics of heat pumps per Axsen and Kurani's (2012) framework of functional, symbolic, private, and/or societal characteristics of technologies to help reduce the 22 individual heat pump technical characteristic items we assessed into more concise categories. To achieve this, an exploratory factor analysis was performed on variables relating to perceived technical characteristics (objective 4). Factor analysis is a statistical technique that uses correlations between variables to reduce them into a smaller number of index variables (Berman & Wang, 2017). Maximum likelihood factor analyses were used to extract three to nine factors to determine the best eigenvalue cut-off (Costello & Osborne, 2005). Oblique rotation was used, which allows for some correlations between factors and thus provides more accurate results for behavioural research. Items that had factor loadings less than 0.3 and that cross-loaded onto other factors were removed. The formed specific index variables were then used in the regression model, thereby reducing the number of independent variables used and controlled for in the multiple regressions (see Chapters 6.4 and 6.5).

5.5 Relationship between policy awareness and willingness to adopt heat pumps

Using the newly formed variables from the factor analysis described above, multiple linear regression models were estimated to assess the relationship between policy awareness and willingness to adopt heat pumps (objective 5) while controlling for the independent variables described in Table 5. Multiple linear regression is a statistical technique that allows researchers to examine the impact of independent variables on a dependent variable (Berman & Wang, 2017). For the purposes of conducting this regression, some variable types were converted into

continuous variables (see Table 5 for more detail) while nominal variables were converted into dummy variables. All attitudinal variables and perceived policy support were converted into continuous variables by computing an aggregate score across all items or policy types. When creating dummy variables, provinces were recoded into regions to reduce the number of variables used in the regression and to align with hypotheses around willingness to adopt in resource-dependent regions (Das et al., 2018; Mildenberger et al., 2016). Due to their different technical characteristics and uptake levels in Canada, willingness to adopt air source and ground source heat pumps were treated as separate dependent variables, with two separate regressions being run. The regressions only used willingness-to-adopt data from before the technical heat pump information intervention, as this data represented a baseline level of willingness to adopt before respondents were given technical information. Missing values were replaced with an average procedure in SPSS prior to running regressions. For policy awareness without cues, correct responses were recoded as 'policy aware' while incorrect and "I don't know about this policy" responses were recoded as 'policy unaware.' Results were reviewed to detect and correct for outliers, goodness of fit, and multicollinearity. As part of model re-fitting, variables were removed based on their correlations with other variables (Pearson's $r<0.5$) and if they were theorized to be correlated based on past literature, and if they were consistently non-significant in forward and backward stepwise regressions that were performed in addition to the main regressions that used the 'enter' method in SPSS.

Table 5. Independent variables used in regression models

Variable name	Hypothesized relationship	Variable specification in Survey	Variable specification in Analysis	Measurement
Main variables				
Policy awareness (without cues)	+	Nominal	Nominal	Open-ended, with option "I can't think of any policies currently in place in my province"
Policy awareness (with cues)	+	Nominal	Continuous	"I know this policy is in place," "I know this policy is not in place," or "I do not know about this policy"
Attitudinal variables				
Values		Ordinal	Continuous	Five-point scale from "not important at all" to "extremely important"(Schwartz, 1992)
Traditional values	-			
Egoistic values	-			
Biospheric values	+			
Openness to change	+			
Ecological Worldviews (NEP)	+	Ordinal	Continuous	Five-point scale from "strongly disagree" to "strongly agree" (Dunlap et al., 2000)
Policy support	+	Ordinal	Continuous	Five-point scale from "strongly oppose" to "strongly support" (Rhodes et al., 2014)
Technology-oriented lifestyle	+	Ordinal	Continuous	Five-point scale from "never" to "very frequently" (Sustainable Transportation Action Research Team, 2017)
Environment-oriented lifestyle	+	Ordinal	Continuous	Five-point scale from "never" to "very frequently" (Sustainable Transportation Action Research Team, 2017)
Contextual variables				
Knowing a heat pump owner	+	Nominal	Nominal	"Yes" or "No" (Karytsas, 2018)
Familiarity with heat pumps	+	Ordinal	Continuous	Four-point scale from "I've never heard of this" to "I've heard of this, and know a lot"
Home characteristics (age, size)		Continuous	Continuous	Selections from lists
Home characteristics (energy efficiency)	+	Nominal	Nominal	"Yes" or "no"
Perceived technical characteristics		Ordinal	Continuous	Five-point scale from "strongly disagree" to "strongly agree" (Sustainable Transportation Action Research Team, 2017)
Functional characteristics	+			
Symbolic characteristics	+			
Installation characteristics	-			
Socio-demographics variables				
Age*	+	Continuous	Continuous	Six categories from "19 to 24" to "65 and over"
Income	+	Continuous	Continuous	Eight categories from "without income" to "$300,000 and over"
Education*	+	Nominal	Nominal	Ten categories from "no certificate, diploma, or degree" to "doctorate or PhD degree"
Gender	+ (female only)	Nominal	Nominal	"Male," "female," and "other" option
Household size*	+	Nominal	Nominal	Five categories from "Only myself" to "5 or more people"
Region (province)*		Nominal	Nominal	Ten provinces
Alberta and the Prairie provinces	-			

*For these variables, an "I don't know" or "Prefer not to answer" option was not provided.

Chapter 6. Results and Discussion

6.1 Willingness to adopt heat pumps and the effect of information provision

For the purposes of describing these results, "willing" and "very willing" responses are reported together as "willing," while "unwilling" and "very unwilling" responses will be reported as "unwilling." Figure 1 shows descriptive levels of willingness to adopt air source heat pumps in Canada and by province pre-information provision. Nationally, 34% of homeowners are willing to adopt an air source heat pump when their existing heating system needs to be replaced, and 46% are undecided.

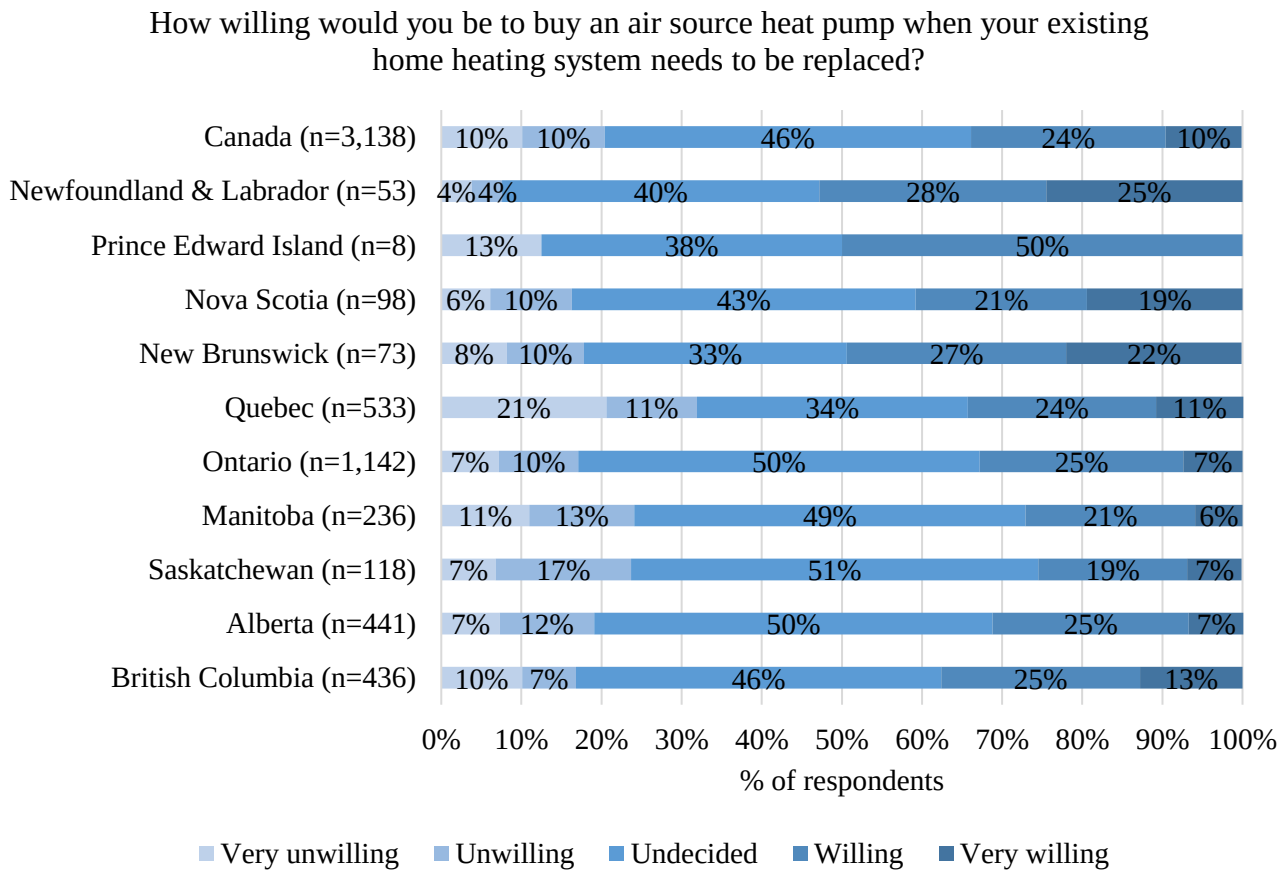

Figure 1. Willingness to adopt air source heat pumps across Canada and by province

A one-way ANOVA using the Welch test of significance finds statistically significant differences in mean willingness to adopt air source heat pumps across Canadian provinces ($F(9,164.61)=5.29$, $p < 0.001$). As a reminder, willingness to adopt was measured using a five-point Likert scale with a midpoint value of "3 – undecided." Table 6 shows the results of a Games-Howell post-hoc test demonstrating that Newfoundland and Labrador (M=3.66), New Brunswick (M=3.46), Nova Scotia (M=3.38), and British Columbia (M=3.24) are significantly more willing to adopt air source heat pumps. Provinces that are significantly less willing to adopt air source heat pumps are Quebec (M=2.94), Manitoba (M=2.99), Saskatchewan (M=3.02), and

Alberta (M=3.12). Broadly, homeowners in the Atlantic region of Canada display more willingness to adopt air source heat pumps than the Central-Western region of Canada (Manitoba, Saskatchewan, and Alberta). Indeed, previous research has found that more resource-dependent regions such as Canada's central provinces are less likely to adopt pro-environmental technology (Das et al., 2018; Mildenberger et al., 2016). That being said, all means cluster around the midpoint value of willingness to adopt, suggesting that homeowners are still mostly undecided on their willingness to adopt air source heat pumps.

Table 6. ANOVA results for provincial willingness to adopt air source heat pumps

Province	N	Mean	SE
Newfoundland and Labrador	53	3.66 [defgh]	0.14
Prince Edward Island	8	3.25	0.37
Nova Scotia	98	3.38 [df]	0.11
New Brunswick	73	3.46 [df]	0.14
Quebec	533	2.94 [abcei]	0.06
Ontario	1142	3.16 [ad]	0.03
Manitoba	236	2.99 [abci]	0.07
Saskatchewan	118	3.02 [a]	0.09
Alberta	441	3.12 [a]	0.05
British Columbia	436	3.24 [df]	0.05

[a] denotes a statistically significant difference from Newfoundland and Labrador ($p < 0.10$)
[b] denotes a statistically significant difference from Nova Scotia ($p < 0.10$)
[c] denotes a statistically significant difference from New Brunswick ($p < 0.10$)
[d] denotes a statistically significant difference from Quebec ($p < 0.10$)
[e] denotes a statistically significant difference from Ontario ($p < 0.10$)
[f] denotes a statistically significant difference from Manitoba ($p < 0.10$)
[g] denotes a statistically significant difference from Saskatchewan ($p < 0.10$)
[h] denotes a statistically significant difference from Alberta ($p < 0.10$)
[i] denotes a statistically significant difference from British Columbia ($p < 0.10$)

Figure 2 depicts levels of willingness to adopt ground source heat pumps in Canada and by province pre-information provision. Across Canada, 30% of homeowners are willing to adopt a ground source heat pump when their existing system needs to be replaced and 45% are undecided.

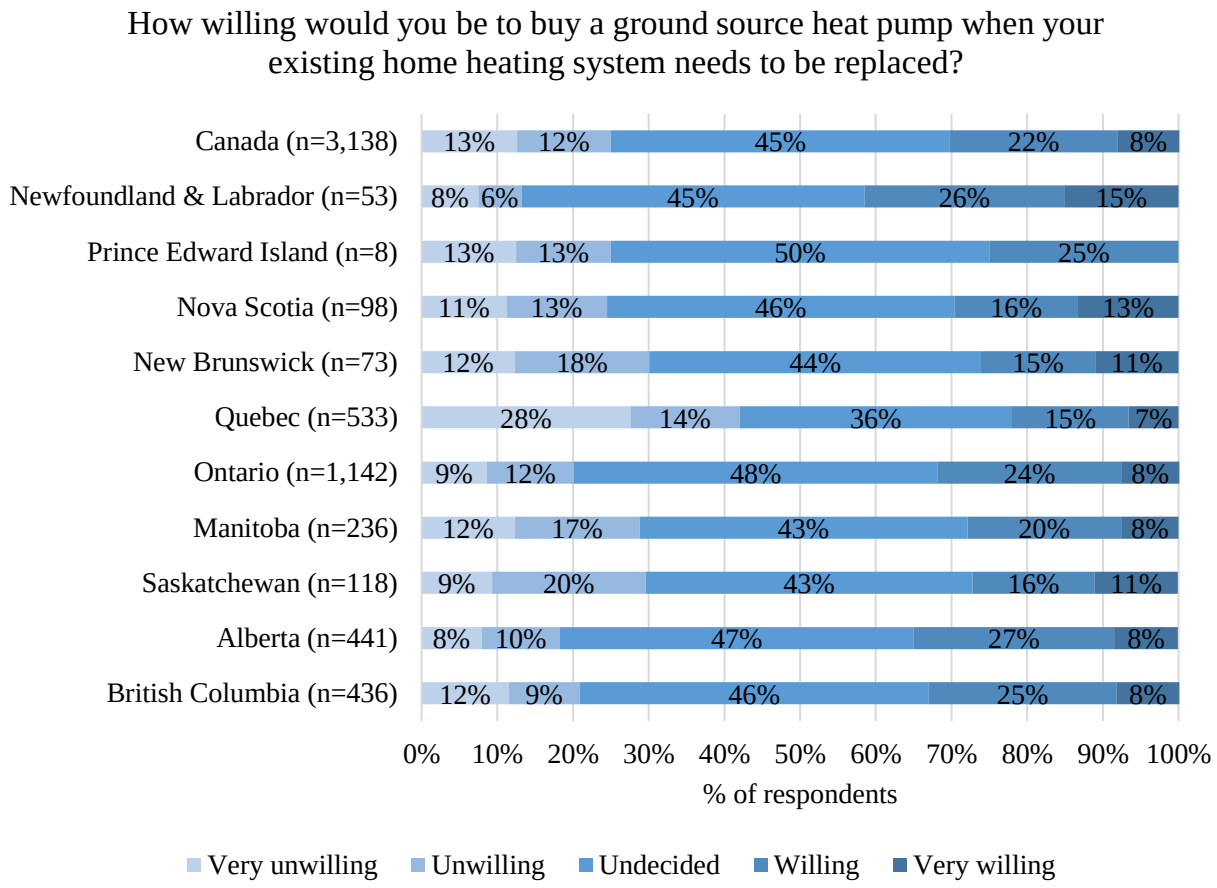

Figure 2. Willingness to adopt ground source heat pumps in Canada and by province

With regards to provincial differences in willingness to adopt ground source heat pumps, a one-way ANOVA using the Welch test of significance finds a statistically significant difference in willingness to adopt ground source heat pumps between provinces ($F(9,164.66)=10.08$, $p < 0.001$). A Games-Howell post-hoc test reveals that Quebec ($M=2.59$) is the only province that statistically differs from other provinces, and is significantly less willing to adopt ground source heat pumps (Table 7). This suggests that homeowners in Quebec are uniquely unwilling to adopt this type of heat pump, which is perhaps not surprising given that most home heating in this province is powered by renewable electricity (Government of Canada, 2020b; Statistics Canada, 2013). This may minimize some key motivators for adopting an electric heat pump, such as environmental benefits. As such, it may be more valuable to focus policy efforts to increase adoption on other provinces.

Table 7. ANOVA results for provincial willingness to adopt ground source heat pumps

Province	N	Mean	SE
Newfoundland and Labrador	53	3.36 [a]	1.06
Prince Edward Island	8	2.88	0.99
Nova Scotia	98	3.07 [a]	1.13
New Brunswick	73	2.95	1.13
Quebec	533	2.59	1.22
Ontario	1142	3.11 [a]	1.00
Manitoba	236	2.95 [a]	1.08
Saskatchewan	118	2.99 [a]	1.09
Alberta	441	3.17 [a]	1.00
British Columbia	436	3.09 [a]	1.06

[a] denotes a statistically significant difference from Quebec ($p < 0.05$)

6.2. Effect of information provision

As a reminder, the survey asked homeowners to indicate their willingness to adopt a heat pump on a five-point Likert scale with a midpoint value of "3 – undecided" before and after reviewing a technology guide containing information about heat pumps (Figure 3). A Wilcoxon signed ranks test finds that willingness to adopt air source heat pumps significantly increased after providing heat pump technical information ($M_{before}=3.13$, $M_{after}=3.22$, $Z= -4.76$, $p < 0.001$), while willingness to adopt ground source heat pumps decreased after information provision ($M_{before}=3.01$, $M_{after}=2.82$, $Z=-10.02$, $p < 0.001$). This suggests that learning technical information on air source heat pumps can increase willingness to adopt, but is not important for increasing willingness to adopt ground source heat pumps. This latter finding is in contrast to Karytsas and Theodoropolou (2014), who found that technical familiarity with low-carbon heating systems is positively associated with willingness to adopt ground source heat pumps. Future research could explore what specific information was important in changing levels of willingness to adopt air source heat pumps to better understand this result. For example, Caird et al. (2012) found that perceptions of noise are a barrier to adopting air source heat pumps. Perhaps learning in the technical guide that air source heat pumps produce a level of noise similar to an air conditioner addressed the noise concern and increased willingness to adopt. For ground source heat pumps, perhaps learning about the installation process, which tends to be more disruptive compared to installing air source heat pumps (Karytsas & Choropanitis, 2017), decreased willingness to adopt.

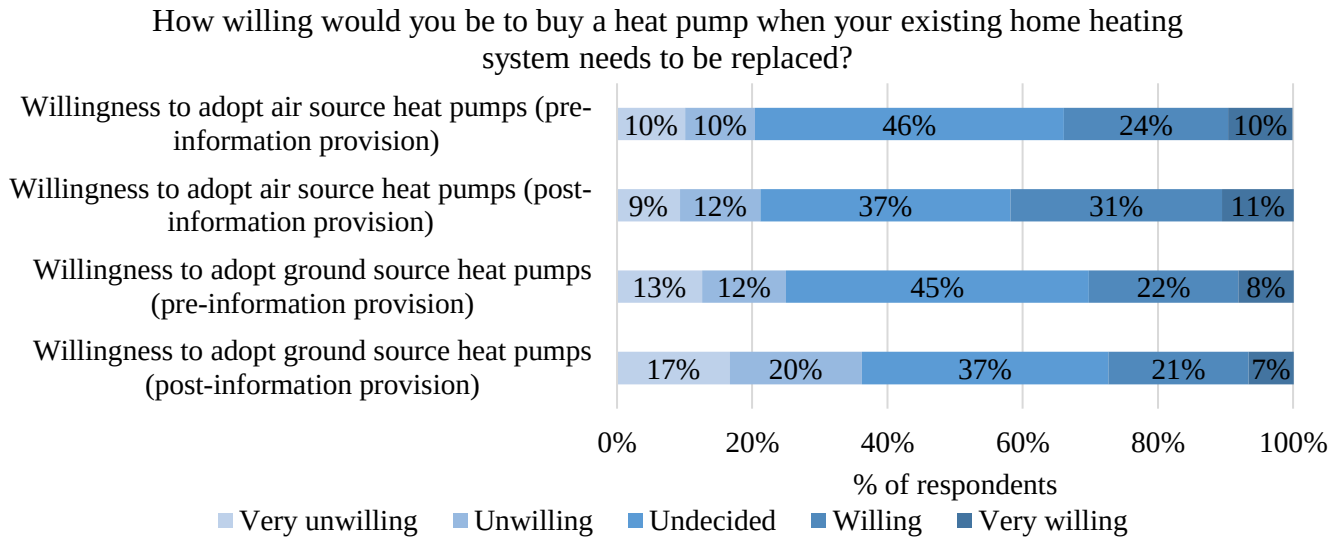

Figure 3. Effect of information provision on willingness to adopt heat pumps

6.3. Levels of policy awareness

Figure 4 shows the percentage of respondents in Canada and within each province who correctly identified at least one policy when not given cues (open-ended question) and when given cues (multiple-choice question format). Nationally, when not provided any cues, the majority of respondents (95%) do not correctly identify any heat pump-supportive policies currently in place in their province. When provided with cues, more respondents (71%) are able to correctly identify at least one heat pump-supportive policy currently in place in their province. However, 29% of respondents are still unable to correctly identify any policies even after being provided with cues in the form of a list of policy types and definitions. The increase in awareness once given cues suggests that respondents are aware of policies and can better identify them when provided with memory cues. Alternately, it is possible that respondents can more successfully guess which policies are and are not in place in their province in the multiple-choice question format compared to the open-ended format. The finding that policy awareness without cues is low is consistent with previous research. For example, Krause et al. (2013) found that 5.5% of the general public were aware of EV-supportive policies, which is very similar to the findings in the current study. Furthermore, Rhodes et al. (2014), Long et al. (2020), and Kitt (2019) respectively found that 73%, 95%, and 55% of respondents were unable to name any climate and/or EV policies when not given cues. The increase in awareness once provided with cues is also similar to Rhodes et al. (2014), who found that 22% of respondents remained unable to name any climate policies once provided with cues. Compared to previous research on levels of policy awareness, this study's findings suggest that awareness without cues for heat pump-supportive policies is low compared to policies targeting other pro-environmental behaviour.

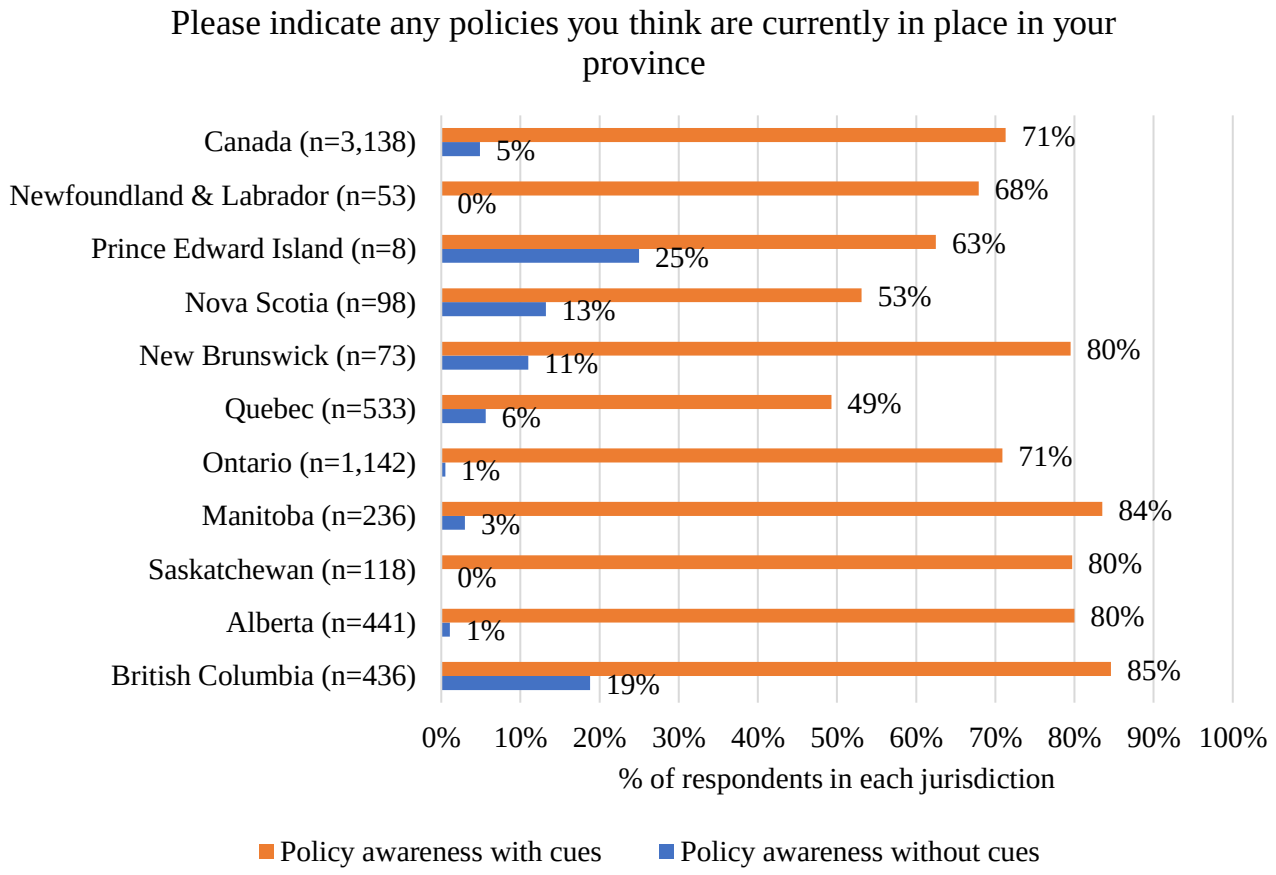

Figure 4. Percentage of policy-aware respondents, without cues and with cues

A chi-square test of independence finds a significant relationship between policy awareness without cues and province ($X^2(9, 3138) = 281.32$, $p < 0.001$). The effect size for the finding is moderate (Cramer's V=0.3). Post-hoc tests using the Bonferroni correction reveal that British Columbia (19%) and Nova Scotia (13%) have significantly higher policy awareness without cues compared to other provinces, while Alberta (1%) and Ontario (1%) are significantly less aware. The finding is similar to Long et al. (2020) where respondents from British Columbia had higher policy awareness without cues for zero-emission vehicle mandates compared to other provinces.

With regards to levels of provincial policy awareness with cues, a one-way ANOVA using the Welch test of significance finds a statistically significant difference between mean policy awareness with cues and province ($F(9,164.33)=29.97$, $p < 0.001$). Mean policy awareness reflects the average number of correct policies identified per respondent in each province. Table 8 shows the results of a Games-Howell posthoc test, which reveals that British Columbia (M=2.09), Manitoba (M=1.80), and Alberta (M=1.52) have significantly higher policy awareness with cues compared to other provinces, while Quebec (M=0.93), Nova Scotia (M=0.95), and Ontario (M=1.05) have significantly lower policy awareness. British Columbia's higher policy awareness without and with cues may be because they have the most heat pump-supportive provincial policies (Table 1), or because of their longer history of climate policy implementation

compared to the rest of Canada. Similarly, Ontario and Nova Scotia's low levels of awareness could reflect the few heat pump-supportive policies available in these provinces. Ontario's lower awareness is consistent with previous research that found this province had lower awareness of the carbon tax compared to British Columbia and Alberta; however, Quebec's lower awareness is inconsistent with previous research that Quebec had higher awareness of EV subsidies compared to British Columbia (Kitt, 2019; Long et al., 2020). Future research could explore drivers of regional policy awareness levels, both overall and by policy type, to better understand regional differences.

Table 8. ANOVA results for policy awareness with cues and province

Province	N	Mean	SE
Newfoundland and Labrador	53	1.26 [i]	0.16
Prince Edward Island	8	2.38	0.82
Nova Scotia	98	0.95 [cfhi]	0.11
New Brunswick	73	1.48 [bdei]	0.13
Quebec	533	0.93 [cfghi]	0.05
Ontario	1142	1.05 [cfhi]	0.03
Manitoba	236	1.80 [bdeg]	0.09
Saskatchewan	118	1.36 [dfi]	0.12
Alberta	441	1.52 [bdei]	0.07
British Columbia	436	2.09 [abcdegh]	0.07

[a] denotes a statistically significant difference from Newfoundland and Labrador ($p < 0.10$)
[b] denotes a statistically significant difference from Nova Scotia ($p < 0.10$)
[c] denotes a statistically significant difference from New Brunswick ($p < 0.10$)
[d] denotes a statistically significant difference from Quebec ($p < 0.10$)
[e] denotes a statistically significant difference from Ontario ($p < 0.10$)
[f] denotes a statistically significant difference from Manitoba ($p < 0.10$)
[g] denotes a statistically significant difference from Saskatchewan ($p < 0.10$)
[h] denotes a statistically significant difference from Alberta ($p < 0.10$)
[i] denotes a statistically significant difference from British Columbia ($p < 0.10$)

It is interesting that Manitoba and Alberta are among the most policy-aware provinces when they offer fewer or the same number of heat pump-supportive policies as other provinces. A potential explanation is residents of Manitoba and Alberta may receive more messaging around the carbon tax due to their reliance on the oil and gas sector, and this carbon tax awareness is driving the higher mean awareness. In fact, in the current study's sample, 67% of respondents from Manitoba and 72% of respondents from Alberta are aware of the carbon tax when provided with cues. The only province with greater carbon tax awareness is British Columbia, where the first provincial carbon tax was implemented over a decade ago, with 74% of respondents being carbon tax-aware when provided with cues. Further support for this explanation for Alberta specifically is the finding by Kitt (2019) that Alberta had higher awareness of the carbon tax (87% of respondents compared to 69% in Ontario), although unlike the current study, they found that Alberta's awareness was higher than British Columbia's (72%). Alberta's lower carbon tax awareness in the current study relative to Kitt (2019) may reflect that Canadians link the carbon tax more explicitly to driving than home heating.

This study also examined levels of awareness by policy type (Figure 5). When not given cues, 4% of respondents correctly name subsidies, compared to less than 1% for all other policy types. When given cues, 57% of respondents correctly identify whether the carbon tax is in place

or not in place in their province, compared to a correct identification rate of 12-20% for all other polices. Other research has found similar patterns whereby awareness is higher for subsidies and the carbon tax compared to other policy types. For example, when respondents were not given cues, Kitt (2019) found that over 22% and 33% of respondents were respectively aware of current EV subsidies and the carbon tax, compared to almost no awareness for other policy types. When given cues, over 42% and 69% were respectively aware of subsidies and the carbon tax, compared to between 14% and 53% for other policy types. Rhodes et al. (2014) found that the carbon tax was the most-identified climate policy, with 26% of respondents able to correctly identify it without cues and 69% with cues, compared to almost no awareness for all other policies. In the current study, more respondents may have reported subsidies when not given cues because this policy type is often available for home energy retrofits and heat pump purchases, and are thus easier to recall. Alternately, respondents may have been more likely to assume that government subsidies were available for heat pumps, and therefore the higher awareness for subsidies could reflect successful guessing. Regarding the carbon tax, awareness may have been lower when not given cues because Canadian homeowners do not think of carbon taxes as home heating policies. However, once respondents see it included on the list of policies, they identify it at greater rates because awareness of the carbon tax is relatively high in Canada due to its salience from political and media coverage (Boutron, 2020; Mildenberger et al., 2016; Rhodes et al., 2014). In fact, levels of awareness for the carbon tax and all other heat pump-supportive policies are lower than the EV-supportive and climate policies studied by Kitt (2019) and Rhodes et al. (2014), suggesting that homeowners may be less aware of how these emissions-reductions policies apply to home heating compared to other contexts.

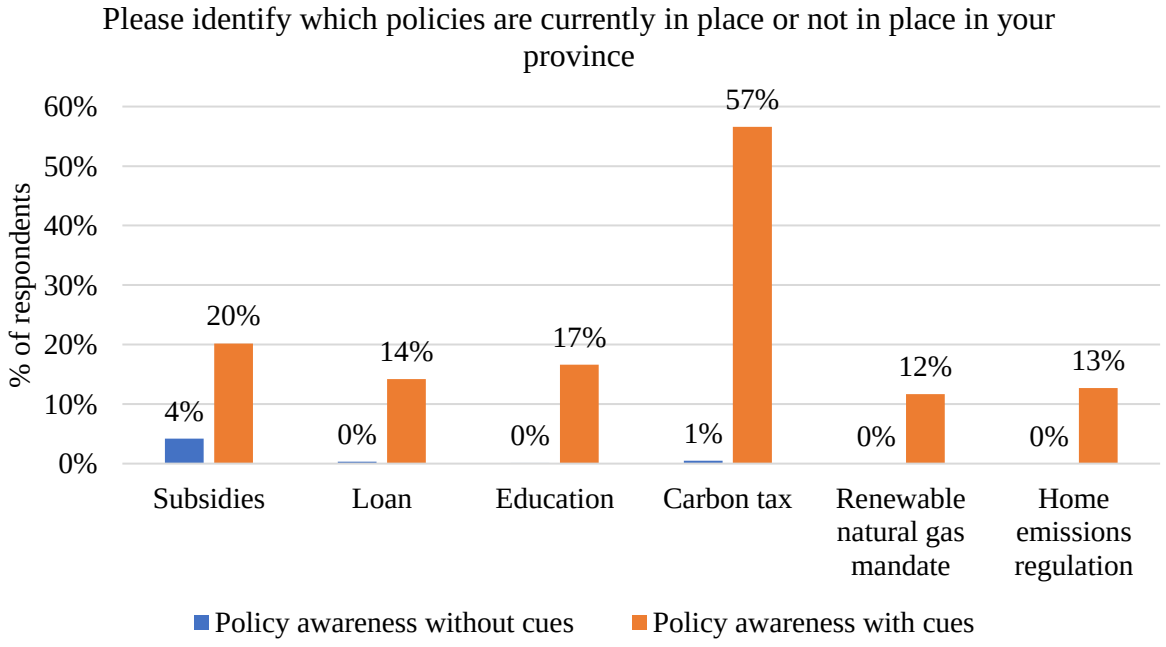

Figure 5. Levels of awareness for heat pump-supportive policy types in Canada

6.4. Determining perceived technical characteristics of heat pumps

Table 9 shows the results of the factor analysis for air source heat pumps' technical characteristics. These perceptions loaded onto three factors, two of which align with the symbolic and functional categories from Axsen and Kurani's (2012) framework. Specifically, symbolic air source heat pump characteristics comprise both the private and societal social meanings assigned to the technology, such as perceiving it to help express values, connect with like-minded people, and send a message to the government and heating/cooling companies. Functional characteristics refer to private-level characteristics of heat pumps, such as their perceived effectiveness, ease of use, and ease of maintenance, as well as their societal-level characteristics such as fighting climate change, improving air quality, and reducing dependence on oil and gas (i.e., their environmental benefits). The third factor, installation characteristics, refers to the initial financial and inconvenience costs to adopting an air source heat pump. It is not a distinct factor in Axsen and Kurani's (2012) framework, which suggests that this category of perceived technical characteristics is unique to heat pumps and not other low-carbon technologies.

Table 9. Air source heat pump technical characteristics factors

Technology characteristics	1 Symbolic characteristics	2 Functional Characteristics	3 Installation characteristics
allow you to express your values	**0.72**	0.50	
be a status symbol	**0.73**		
help you connect with like-minded people	**0.86**	0.37	
make a positive impression on others	**0.90**	0.43	
be an inspiration to others	**0.90**	0.49	
send a message to the government	**0.82**	0.52	
send a message to heating/cooling companies	**0.77**	0.54	
be effective in heating your home	0.34	**0.72**	
be effective in cooling your home		**0.68**	
be easy to use		**0.59**	
be easy to maintain	0.32	**0.60**	
help to fight climate change	0.52	**0.69**	
be an effective way to improve indoor air quality	0.48	**0.73**	
be an effective way to improve outdoor air quality	0.52	**0.64**	
help reduce our dependence on oil and natural gas	0.45	**0.63**	
be too expensive to purchase			**0.86**
be too expensive to install			**0.98**
be too disruptive to install			**0.53**

Table 10 shows the results of the factor analysis for perceived ground source heat pump technical characteristics, which produced a five-factor model. Once again, installation

characteristics is a loaded factor. However, unlike air source heat pumps, functional characteristics load onto private-functional and societal-functional factors. Private-functional characteristics comprise the technical characteristics located at the individual or household level, such as their effectiveness and ease of use. Societal-functional characteristics refer to the collective benefits of heat pumps, such as helping to fight climate change, improving air quality, and reducing dependence on oil and gas (i.e., their environmental benefits). Similarly, symbolic characteristics for ground source heat pumps load onto private-symbolic and societal-symbolic factors. Private-symbolic characteristics comprise expressing one's values and inspiring others by adopting a ground source heat pump, and societal-symbolic characteristics comprise sending a message to the government and heating/cooling companies by adopting this technology.

Overall, the found perceived technical characteristics of air source and ground source heat pumps can be categorized as functional and symbolic similar to the Axsen and Kurani (2012) framework. However, perceived characteristics related to installing heat pumps seems to be a novel factor. Furthermore, functional and symbolic characteristics can be further distinguished at the private and societal level for ground source heat pumps, but not for air source heat pumps. This suggests that there may be more nuance to how functional and symbolic characteristics are perceived in ground source heat pumps that may be worth exploring in future research.

Table 10. Ground source heat pump technical characteristics factors

	Factors*				
Technical characteristics	1 Private – symbolic characteristics	2 Societal – functional characteristics	3 Installation characteristics	4 Private-functional characteristics	5 Societal – symbolic characteristics
allow you to express your values	**0.84**	0.57		0.34	0.62
be a status symbol	**0.84**	0.44			0.51
help you connect with like-minded people	**0.92**	0.51			0.58
make a positive impression on others	**0.94**	0.56		0.32	0.59
be an inspiration to others	**0.91**	0.58		0.34	0.66
increase your quality of life	0.53	**0.74**		0.57	0.46
help to fight climate change	0.46	**0.83**		0.52	0.47
be an effective way to improve indoor air quality	0.47	**0.77**		0.56	0.44
be an effective way to improve outdoor air quality	0.51	**0.77**		0.48	0.45
help reduce our dependence on oil and natural gas	0.42	**0.78**		0.50	0.49
be too expensive to purchase			**0.91**		
be too expensive to install			**0.99**		
be too disruptive to install			**0.64**		

	Factors*				
Technical characteristics	1 Private – symbolic characteristics	2 Societal – functional characteristics	3 Installation characteristics	4 Private-functional characteristics	5 Societal – symbolic characteristics
be effective in heating your home		0.56		**0.87**	
be effective in cooling your home		0.53		**0.85**	
be easy to use		0.45		**0.57**	
send a message to the government	0.79	0.60		0.33	**0.87**
send a message to heating/cooling companies	0.74	0.61		0.34	**0.96**

* Factor loadings of less than 0.3 are not shown

6.5. Role of policy awareness in willingness to adopt heat pumps

Lastly, the study examines the role of policy awareness in explaining willingness to adopt among homeowners who do not own heat pumps. The regressions use willingness to adopt data from before the technical information provision intervention, as this data represents a baseline level of willingness to adopt. Table 11 shows the results of two multiple linear regression models that assessed the role of policy awareness in willingness to adopt air source and ground source heat pumps (dependent variables), while controlling for other independent variables categorized by the ABC framework (see Appendix B for descriptive data and bivariate correlations of all variables used in regressions). No data outliers were detected, as all Cook's D values were less than 1.0, which suggests no observations were unduly influencing the analysis (Berman & Wang, 2017). Model fit is the same for both the air source and ground source heat pump regressions ($R^2_{adj} = 0.25$). Multicollinearity was not detected as all VIF values were less than 4.3 and all tolerances were greater than 0.23, whereas multicollinearity may be present if VIFs are greater than 5 and tolerances are less than 0.2 (O'Brien, 2007).

Table 11. Regression results for willingness to adopt heat pumps

	Air source heat pumps		Ground source heat pumps	
Variables	Standardized *B*	SE	Standardized *B*	SE
Main variables				
Policy awareness without cues (reference: policy unaware respondents)	0.04**	0.08	0.007	0.08
Policy awareness with cues	-0.01	0.01	0.02	0.01
Attitudinal variables				
Traditional values	0.01	0.04	-0.01	0.04
Biospheric values	0.01	0.03	0.02	0.03
Egoistic values	-0.05**	0.03	-0.02	0.03
Openness to change values	0.04*	0.03	0.01	0.03
Ecological worldviews (NEP)	-0.03	0.004	-0.002	0.004
Policy support (score)	0.04**	0.03	0.06**	0.03
Technology-oriented lifestyle	0.08***	0.02	0.08***	0.03
Environment-oriented lifestyle	0.03	0.03	0.01	0.03
Contextual variables				
Knows a heat pump owner (reference: does not know a heat pump owner)	0.04**	0.04	-0.04**	0.05
Familiarity with air source heat pumps	0.02	0.02	N/A	N/A
Familiarity with ground source heat pumps	N/A [†]	N/A	-0.02	0.02
Home Age	0.02	0.007	0.06***	0.007
Energy Efficiency - Home has undergone energy efficient retrofits (reference: home has not undergone energy efficiency retrofits)	0.02	0.04	0.01	0.04
Air source heat pump symbolic characteristics (Factor 1)	0.001	0.02	N/A	N/A
Air source heat pump functional characteristics (Factor 2)	0.37***	0.03	N/A	N/A
Air source heat pump installation characteristics (Factor 3)	-0.09***	0.02	N/A	N/A
Ground source heat pump Private-symbolic characteristics (Factor 1)	N/A	N/A	0.02	0.03
Ground source heat pump Societal- functional characteristics (Factor 2)	N/A	N/A	0.06*	0.04
Ground source heat pump Installation characteristics (Factor 3)	N/A	N/A	-0.14***	0.02
Ground source heat pump Private-functional characteristics (Factor 4)	N/A	N/A	0.26***	0.03
Ground source heat pump Symbolic-societal characteristics (Factor 5)	N/A	N/A	0.02	0.03
Socio-demographic variables				

	Air source heat pumps		Ground source heat pumps	
Variables	Standardized *B*	SE	Standardized *B*	SE
Age	-0.1***	0.01	-0.14***	0.01
Income	0.03*	0.02	0.03*	0.02
Education	0.004	0.008	0.03*	0.008
Gender - Female (reference: male)	0.0003	0.04	0.03	0.04
Household Size	0.03*	0.02	0.04**	0.02
Province – Quebec (reference: Atlantic provinces ††)	-0.18***	0.07	-0.19***	0.08
Province – Ontario (reference: Atlantic provinces ††)	-0.08**	0.07	-0.008	0.07
Province – Prairie Provinces††† (reference: Atlantic provinces ††)	-0.06**	0.08	-0.02	0.08
Province – Alberta (reference: Atlantic provinces ††)	-0.02	0.08	0.04*	0.08
Province – British Columbia (reference: Atlantic provinces ††)	-0.06**	0.08	-0.01	0.08

* Significant at p < 0.10 level
**Significance at p < 0.05 level
*** Significance at p < 0.001 level
† N/A refers to variables that were not applicable for that heat pump type.
†† "Atlantic provinces" refers to the Canadian provinces of Prince Edward Island, Newfoundland and Labrador, Nova Scotia, and New Brunswick.
††† "Prairie provinces" refers to the Canadian provinces of Manitoba and Saskatchewan.

The regression analyses show that policy awareness without cues is a significant predictor for willingness to adopt air source heat pumps, but not ground source heat pumps. This suggests that being aware of available policies without requiring cues to recall them (i.e., being able to recall them from memory) can increase willingness to adopt air source heat pumps. Policy awareness with cues is not a significant predictor for willingness to adopt either type of heat pump, suggesting that this type of policy awareness is not important for increasing heat pump adoption. These mixed findings are both consistent with and in contrast to previous research. To begin, policy awareness without cues as a significant predictor of willingness to adopt air source heat pumps is consistent with previous research that indicated policy awareness is a predictor of willingness to adopt heat pumps and EVs (Broadbent et al., 2021; Goody, 2014; Owen et al., 2012; Samsom, 2020). In contrast, the non-significance of policy awareness without cues in willingness to adopt ground source heat pumps, and the non-significance of policy awareness with cues in willingness to adopt both types of heat pumps, are in opposition to this previous research. However, these latter findings of non-significance are consistent with Hardman et al. (2020) and Krause et al. (2013), who found that policy awareness was not a statistically significant predictor in willingness to adopt EVs. The findings also somewhat contradict the knowledge deficit concept and common assumption in the literature that policy awareness is an important accelerator in the adoption of heat pumps and other pro-environmental behaviour (Karytsas, 2018; Karytsas & Choropanitis, 2017; MacAdam, 2019; Miller, 2001; Stern, 1999). Specifically, the findings suggest that while policy awareness has a role in

willingness to adopt heat pumps, its role is limited to certain types of policy awareness (i.e., without cues) and heat pump systems (i.e., air source heat pumps). Given these mixed results, it may be valuable for future research to study the role of policy awareness to better understand its role in willingness to adopt heat pumps. For example, it may be valuable to study whether the size of subsidies mediates the relationship between policy awareness and willingness to adopt heat pumps, which previous research has found (Stern, 1999).

The regression analyses reveal several other positive and negative predictors between the stated willingness to adopt heat pumps and independent variables. Positive predictors for both air source and ground source heat pumps include perceptions of their functionality (e.g., effectiveness in heating and cooling a home, environmental benefits), having a technology-oriented lifestyle, policy support, household income, and household size. There are some positive predictors that are unique to each heat pump type. For air source heat pumps specifically, positive predictors are knowing a heat pump owner and being more open to change. For ground source heat pumps, homeowners with older homes, who have more education, and reside in Alberta are more willing to adopt this type of heat pump. It is also worth noting that for ground source heat pumps specifically, functional characteristics can be further categorized at the private and societal level, with each of these factors being significant and positive predictors. These findings are consistent with much of the previous literature, such as perceived functionality of heat pumps, policy support, knowing a heat pump owner, and greater familiarity with heat pumps being positive predictors (Karytsas, 2018; Mahapatra & Gustavsson, 2009; Rhodes, 2016). It is somewhat surprising that residing in Alberta is a positive predictor of willingness to adopt ground source heat pumps, as previous research suggested that resource-dependent regions such as Alberta would be less willing to adopt pro-environmental behaviour (Das et al., 2018; Mildenberger et al., 2016). A possible explanation is that Albertans do not connect heat pumps to reducing oil and gas resource dependency, and instead perceive this technology in the context of heat pumps' energy efficiency and potential for producing household energy cost savings.

Negative predictors for air source and ground source heat pumps include being older, having greater perceptions that heat pumps have high installation costs (i.e., financial and inconvenience costs), and residing in Quebec. The first two predictors are consistent with previous research (Karytsas, 2018; Mahapatra & Gustavsson, 2009; Michelsen & Madlener, 2016; Rouvinen & Matero, 2013), while Quebec's low willingness to adopt could be explained by the fact that this province has a majority-electrified heating grid powered by renewable electricity (Government of Canada, 2020b; Statistics Canada, 2013), which could reduce the motivations to switch to heat pumps. Negative predictors for air source heat pumps include having higher egoistic values and residing in Ontario, the Prairie provinces and British Columbia when the Atlantic provinces are the reference category. It is perhaps not surprising that most regions in Canada are less willing to adopt air source heat pumps when compared to the Atlantic region, as this is consistent with the current study's earlier findings that mean levels of willingness to adopt air source heat pumps are significantly higher in Atlantic Canada. For ground source heat pumps, an additional negative predictor is knowing a heat pump owner, in contrast to being a positive predictor for air source heat pumps. Perhaps homeowners are more aware of the disadvantages for ground source heat pumps (e.g., high installation costs) when they know an owner of this type of heat pump, which decreases their willingness to adopt them. Conversely, homeowners may be more aware of the benefits of air source heat pumps (e.g., lower installation costs) when they know an air source heat pump owner, and are thus more willing to adopt them. Future research should examine this in more detail.

Chapter 7. Conclusions and policy implications

This study has several shortcomings that could be addressed in future research. First, the study focuses mostly on provincial policies. Future research should explore whether awareness of federal and/or municipal policies plays a role in willingness to adopt heat pumps. Second, the study examines policy actions of governments and utility companies only. The role of other actors and/or policies in willingness to adopt heat pumps should be explored. For example, Karytsas and Choropanitis (2017) found that addressing low heat pump knowledge among contractors through training is an important avenue for increasing adoption. Third, the conducted quasi-experiment on the effect of technical heat pump information on willingness to adopt lacked random assignment, which may have limited the validity and generalizability of the results. Future research could use random assignment to conduct a true experiment and to provide different types of technical information to different control groups. Fourth, the study used a composite score to study policy support, whereas studying these variables by policy type could provide more detailed insights given that some of the studied policies were incentive- (e.g., subsidies) and disincentive-based (e.g., carbon tax). Finally, the survey method might have resulted in biases such as the acquiescence bias (i.e., the survey was long and participants may have fatigued), order effects, social desirability bias, and sampling bias.

Despite the listed limitations, the study provides important contributions to academic literature and climate policy-making to accelerate heat pump adoption. First, the study finds that while Canadians are somewhat more willing to adopt air source than ground source heat pumps, the majority are willing or undecided on their willingness to adopt either type of heat pump. As such, a majority of Canadian homeowners could be persuaded to adopt heat pumps with the use of targeted policies and behavioural interventions. Using insights from the regression analyses, policymakers looking to increase adoption among homeowners could target those who are younger, do not reside in Quebec, have technology-oriented lifestyles, have higher income, have larger households, and are more supportive of policies. Policies should also aim to increase these homeowners' confidence that heat pumps are effective in heating and cooling homes, minimize financial and inconvenience costs during heat pump installation through subsidies, and/or offset barriers by highlighting the environmental benefits (i.e., societal-functional characteristics) of heat pumps. If policy-makers wish to increase the adoption of air source heat pumps specifically, they can additionally target homeowners with higher openness to change values and lower egoistic values. Policies could aim to increase homeowners' technical familiarity with heat pumps, which this study's quasi-experiment found significantly increased willingness to adopt air source heat pumps. Policies could also leverage the value of knowing a heat pump owner by connecting potential adopters of air source heat pumps with heat pump owners or sharing testimonials from heat pump owners. Providing testimonials from consumers who have utilized a product or service is a behaviourally-informed 'nudging' intervention that can increase a desired behaviour (Howes & Sallot, 2013; Spillinger & Parush, 2012; Tucker & Yu, 2017). To increase the adoption of ground source heat pumps, policies can additionally target homeowners who are more educated, have older homes, and reside in Alberta.

Second, the study finds that willingness to adopt each type of heat pump varies between provinces. The Atlantic region of Canada and British Columbia are significantly more willing to adopt air source heat pumps than Quebec and the Central-western Canada. For ground source heat pumps, provinces do not significantly differ in their willingness to adopt aside from Quebec, which is significantly less willing to adopt this type of heat pump. These results can help policy-makers decide which regions and system types to prioritize in adoption campaigns. For example,

policy-makers could leverage Atlantic Canada's greater willingness to adopt air source heat pumps by focusing policy efforts on increasing adoption of air source rather than ground source heat pumps. Conversely, the fact that Quebec is more unwilling to adopt both air source and ground source heat pumps, and already has a mostly renewable-electrified home heating grid, indicates that there may be more benefit to focusing heat pump adoption policy efforts on other provinces. Similarly, Central-western Canada is less willing to adopt air source heat pumps, so policy-makers may choose to target the adoption of ground source heat pumps. Furthermore, policy-makers aiming to increase adoption in Central-western Canada might plan for more compulsory policies, or multi-stage policies that first increase positive perceptions of heat pumps before attempting to increase adoption behaviour through the use of tailored policies (e.g., targeting homeowners with technology-oriented lifestyles).

Third, the study finds that levels of heat pump-supportive policy awareness are generally low across Canada but are higher among homeowners in British Columbia, which could be explained by this province offering a greater number of heat pump-supportive policies and having a longer history of climate policies compared to other parts of Canada. Awareness is highest for subsidies and carbon taxes; however, awareness of carbon taxes is lower than in similar studies by Rhodes et al. (2014) and Kitt (2019), suggesting that homeowners may not connect carbon taxes to home heating. Future research could examine whether making homeowners more aware that the carbon tax applies to home heating could incentivize switching to heat pumps and other low-carbon heating systems. However, awareness of more compulsory policy types, such as the carbon tax, may not be necessary for them to be effective (Xiang & Lawley, 2019).

Finally, regression analyses demonstrate that policy awareness has a limited role in increasing willingness to adopt heat pumps among homeowners who do not own heat pumps. Specifically, policy awareness without cues is a significant predictor of willingness to adopt air source heat pumps, but is not a significant predictor of willingness to adopt ground source heat pumps. Policy awareness with cues is not a significant predictor for willingness to adopt either type of heat pump. This finding somewhat contradicts the knowledge deficit principle and common assumption that increasing consumers' awareness of supportive policies is key to accelerating heat pump adoption behaviour (Karytsas & Choropanitis, 2017; MacAdam, 2019; Miller, 2001; Stern, 1999), in that its role in increasing heat pump adoption is only significant for certain types of policy awareness (i.e., policy awareness without cues) and certain types of heat pumps (i.e., air source heat pumps). Furthermore, policy awareness without cues was not among the strongest drivers of willingness to adopt air source heat pumps, suggesting that other drivers are more important for increasing adoption. These findings have implications for future research, such as exploring the role of other policy characteristics besides simple awareness in willingness to adopt heat pumps. For example, the size of a heat-pump supporting subsidy or rebate, the availability and clarity of public information on the subsidy, and the complexity of these programs (e.g., whether they require a retrofit consultation) may be barriers to adoption. Subsidy size may be particularly valuable to study, as previous research has found this to mediate the association between awareness of subsidies and pro-environmental behaviour such as willingness to adopt heat pumps (Stern, 1999). Beyond subsidies, communication materials and channels through which policies are framed, and/or stringency of carbon pricing are other potentially influential policy design characteristics to study. It may also be valuable to examine other policy types not included in this study. For example, behaviourally-informed 'nudging' policies, defined as policies that incorporate insights about human behaviour to remove barriers to

socially desirable behaviours and disincentivize socially damaging ones, may produce more effective, longer-term changes compared to more traditional policies (International Energy Agency, 2021). These findings also hold important implications for policy-makers. First, the fact that adoption drivers and barriers adhere to the attitudinal, contextual, and sociodemographic variables hypothesized by the ABC theory confirm the importance of using a behavioural approach that considers a multitude of motivations when targeting consumer behaviour through policies and programming (Stern, 2000). Second, policy interventions based on homeowner education about existing policies may only be effective for increasing willingness to adopt air source heat pumps, and may not be the most effective driver to increase adoption. Policy-makers seeking higher heat pump adoption may need to consider other statistically significant drivers of potential adoption, including perceptions of their functionality and environmental benefits (i.e., private- and societal-functional characteristics), perceptions of their installation costs, having a technology-oriented lifestyle, and being a younger homeowner. Considering these characteristics in tailored policy designs may be more effective in national and sub-national efforts to decarbonise residential buildings. Future research could explore levels of public support for such tailored policies in order to ensure their long-term implementation and effectiveness in emissions reductions.

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Appendix A. Canadian home heating survey questionnaire

Canadian Home Heating Survey

In Canada, home heating is essential. Our winters are long and cold, and our autumns and springs are often chilly too. Home heating involves keeping the insides of our houses at a comfortable temperature during this cold season. A wide range of technologies can be used for home heating such as a furnace, boiler, heat pump, fireplace, or baseboard heaters. These technologies can use different energy sources like oil, natural gas, propane, renewable natural gas, electricity, or wood.

Through this survey we want to learn more about the home heating technologies Canadians prefer and why they prefer them. We're going to ask you about your current home heating system and your opinions on different features of home heating systems. We'll also ask you to play our Home Heating Choice Game, where you'll get to pick the best home heating system for you from a set of options.

As you complete this survey, **we encourage you to consult with other members of your household** to answer certain questions. Your **"household"** includes you as well as any people you live with who you consult to make important decisions. If you live alone, then you are the **"household."**

Section 1: Your home heating system

In this first section, we're going to ask you about your home's heating system. At any point in this section, please feel free to consult your household to answer these questions.

Throughout this survey we use the term "**heating system**" to describe a technology or appliance that keeps the air inside your home warm when it's cold out. A heating system could be a furnace, a boiler, or a set of electric baseboard heaters, for example.

Sometimes, two or more heating systems are used to heat a home. In this survey, a **primary (or main) heating system** is one that provides all or most of the heat for warming your home. A **secondary heating system** is one that provides some amount of heat for warming your home, but not as much as your primary one. For example, a home might use a gas furnace as its primary heating system and a fireplace as its secondary heating system.

First, we're going to ask you some questions about your house.

1.1 What is your primary province or territory of residence?
- Alberta
- British Columbia
- Manitoba

- New Brunswick
- Newfoundland
- Nova Scotia
- Ontario
- Price Edward Island
- Quebec
- Saskatchewan
- Northwest Territories
- Nunavut
- Yukon

1.1C Could you please indicate your age group?
- 19 to 24 years
- 25 to 34 years
- 35 to 44 years
- 45 to 54 years
- 55 to 64 years
- 65 years and over

1.1D Could you please indicate the gender identity you identify with?
- Male/Man
- Female/Woman
- None of the above. I identify as: _____
- Prefer not to answer

1.1E Do you own or rent your home?
- I own my home
- I rent my home [Selecting this option results in survey termination]
- Other [Selecting this option results in survey termination]

1.1B What type of home do you live in?
- Detached
- Semi-detached
- Townhouse/rowhouse
- Duplex

1.2 When was your house originally built? Please indicate the approximate decade if you're uncertain.
- 1800-1849
- 1850-1899
- 1900-1909
- 1910-1919
- 1920-1929
- 1930-1939
- 1940-1949
- 1950-1959
- 1960-1969
- 1970-1979
- 1980-1989
- 1990-1999
- 2000-2009
- 2010-2020

- Prefer not to answer

1.3 For how many years have you owned your home? Please indicate the approximate number of years if you're uncertain.

[ ] years

1.3B How long do you expect to reside in your home? Please indicate the approximate amount of time if you are uncertain.

- 5 years or less
- 5 to 10 years
- 10 to 15 years
- 15 to 25 years
- 25 years or more
- Prefer not to answer

1.3C Do you have any rental or Airbnb units in your home?

- Yes
- No
- Prefer not to answer

1.4 What is the total **heated** living area of your home?
*Please indicate the approximate area if you're uncertain. Please **do not include** the floor space of any garages or decks that are not heated or rental units in your house that are heated with a separate heating system.*

[ ]

- Square feet (ft^2)
- Square metres (m^2)
- I don't know

Now, we're going to ask you about your primary (main) heating system.

1.5 Which of the following provides all or most of the heating in your home?

- Furnace
- Boiler
- Electric baseboard heaters
- Air source heat pump
- Ground source heat pump
- Fireplace
- Wood-burning or pellet stove
- Other _____
- I don't know

[Question 1.6 is only given to respondents who select "Air source heat pump" or "Ground source heat pump" in question 1.5.]

1.6 How does your heat pump distribute heat around your house?

- It heats air which is blown through a system of air ducts and vents
- It heats air using a unit mounted within a room (i.e. mini-split)

- It heats water which is pumped to radiators or an in-floor radiant heat system
- Prefer not to answer

[Question 1.6B is given to respondents who select "Air source heat pump" or "Ground source heat pump" in question 1.5.]

1.6B Did you purchase your heat pump?

- Yes
- No, it was already installed in my home

[Question 1.6C and 1.6D is given to respondents who select "Yes" in question 1.6B.]

1.6C How much did you pay for your heat pump? Please include the cost of the heat pump as well as installation costs.

$ [ ]

- Prefer not to answer

1.6D Did you receive any subsidies or rebates from government or energy utilities for purchasing your heat pump?

- Yes
- No
- Prefer not to answer

[Question 1.6E is given to respondents who select "Yes" in question 1.6D.]

1.6E In total, how much were the subsidies/rebates in Canadian dollars?

$ [ ]

- Prefer not to answer

[Questions 1.6F to 1.6L are given to respondents who select "Yes" in 1.6B.]

1.6F When installing your heat pump, did you perform any energy efficiency retrofits to your home (e.g. improved insulation, new energy-saving windows or doors, etc.)?

- Yes
- No
- Prefer not to answer

1.6G Was purchasing and installing a heat pump recommended by someone you trust? Select all that apply:

- Yes, a family member
- Yes, a friend
- Yes, a colleague
- Yes, a heating/cooling contractor or company
- Yes, my local government
- Yes, my provincial/territorial government,
- Yes, my federal government
- No
- Prefer not to answer

1.6H What did your home use as its primary heating system before you installed your latest heat pump?

- Furnace
- Boiler
- Electric baseboard heaters
- Air source heat pump
- Ground source heat pump
- Fireplace
- Wood-burning or pellet stove
- Other _____
- Prefer not to answer

1.6I Did installing a heat pump result in your household switching energy sources for home heating?

- Yes, from natural gas to electricity
- Yes, from oil to electricity
- Yes, from propane to electricity
- Yes, from wood to electricity
- No
- Other _____
- Prefer not to answer

1.6J Compared to your previous heating system, how has your heat pump changed your annual home heating costs?

- They are more than they were previously
- They are less than they were previously
- They are the same
- Prefer not to answer

1.6K Do you use your heat pump for air conditioning (i.e. to cool your home in warmer months)?

- Yes
- No
- Prefer not to answer

1.6L Before installing your heat pump, did you have an air conditioner or air conditioning system for cooling your home?

- Yes
- No
- Prefer not to answer

[In 1.7, "Electricity and natural gas" option is only given to respondents who select "Air source heat pump" in question 1.5. For all other respondents, this option does not appear.]

1.7 What type of energy or fuel does this heating system use?

- Electricity
- Natural gas
- Electricity and natural gas
- Oil
- Propane
- Wood/pellets
- Other _____
- Prefer not to answer

[Only respondents that choose “Natural gas” or “Electricity and natural gas” in 1.7 are given 1.7B.]

1.7B Does the natural gas supplied to your home contain renewable natural gas (i.e. biogas)?
- o Yes
- o No
- o I don’t know

[Only respondents that choose “Yes” in 1.7B are given 1.7C.]

1.7C What percent of your natural gas supply is renewable natural gas (i.e. biogas)
- o 0 to 5%
- o 5 to 10%
- o 10 to 15%
- o 15 to 25%
- o 25 to 50%
- o 50 to 75%
- o 75 to 100%
- o I don’t know

[Only respondents that choose “Semi-detached”, “Townhouse/rowhouse”, or “Duplex” in 1.1B are given 1.7D.]

1.7D Is your primary home heating system shared with any of the homes your home is attached to?
- o Yes
- o No
- o Prefer not to answer

1.8 How many years old is your primary heating system?
Please indicate the approximate age if you’re uncertain.

[ ] years

- o I don’t know

1.9 When do you expect to replace this heating system?
- o Less than 1 year
- o 1 to 2 years
- o 3 to 5 years
- o 6 to 10 years
- o 11 to 15 years
- o 16 years or more
- o I don’t know

1.10 Have you started shopping for or thinking about your options for a replacement for your current heating system?
- o Yes
- o No

1.11 What secondary heating system (if any) does your home use?
Your secondary heating system is one that provides some amount of heating in your home, although not as much as your primary one.

- My home does not have a secondary heating system
- Furnace
- Boiler
- Electric baseboard heaters
- Air source heat pump
- Ground source heat pump
- Fireplace
- Wood-burning or pellet stove
- Other _____
- I don't know

[Question 1.12 is only given to respondents who select "Air source heat pump" or "Ground source heat pump" in question 1.11.]

1.12 How does this heat pump distribute heat around your house?

- It heats air which is blown through a system of air ducts and vents
- It heats air using a unit mounted within a room (i.e. mini-split)
- It heats water which is pumped to radiators or an in-floor radiant heat system
- Prefer not to answer

[Question 1.12B is only given to respondents who select "Air source heat pump" or "Ground source heat pump" in question 1.11.]

1.12B Did you purchase your heat pump?

- Yes
- No, it was already installed in my home

[Questions 1.12C and 1.12D are only given to respondents who select "Yes" in 1.12B.]

1.12C How much did you pay for your heat pump? Please include the cost of the heat pump as well as installation costs.

$ [ ]

- Prefer not to answer

1.12D Did you receive any subsidies or rebates from government or energy utilities for purchasing your heat pump?

- Yes
- No
- Prefer not to answer

[Question 1.12E is given to respondents who select "Yes" in question 1.12D.]

1.12E In total, how much were the subsidies/rebates in Canadian dollars?

$ [ ]

- Prefer not to answer

[Questions 1.12F to 1.12L are only given to respondents who select "Yes" in 1.12B.]

1.12F When installing your heat pump, did you perform any energy efficiency retrofits to your home (e.g. improved insulation, new energy-saving windows or doors, etc.)?

- Yes
- No
- Prefer not to answer

1.12G Was purchasing and installing a heat pump recommended by someone you trust? Select all that apply:

- Yes, a family member
- Yes, a friend
- Yes, a colleague
- Yes, a heating/cooling contractor or company
- Yes, my local government
- Yes, my provincial/territorial government,
- Yes, my federal government
- No
- Prefer not to answer

1.12H What did your home use as its secondary heating system before you installed your latest heat pump?

- My home did not have a secondary heating system
- Furnace
- Boiler
- Electric baseboard heaters
- Air source heat pump
- Ground source heat pump
- Fireplace
- Wood-burning or pellet stove
- Other _____
- Prefer not to answer

1.12I Did installing a heat pump result in your household switching energy sources for home heating?

- Yes, from natural gas to electricity
- Yes, from oil to electricity
- Yes, from propane to electricity
- Yes, from wood to electricity
- No
- Other _____
- Prefer not to answer

1.12J Compared to your previous heating system, how has your heat pump changed your annual home heating costs?

- They are more than they were previously
- They are less than they were previously
- They are the same
- Prefer not to answer

1.12K Do you use your heat pump for air conditioning (i.e. to cool your home in warmer months)?

- Yes
- No

- Prefer not to answer

1.12L Before installing your heat pump, did you have an air conditioner or air conditioning system for cooling your home?
- Yes
- No
- Prefer not to answer

[Question 1.13 is not given to respondents who select "My home does not have a secondary heating system" in 1.11. "Electricity and natural gas" option in 1.13 is given to respondents who select "Air source heat pump" in question 1.11. For all other respondents, this option does not appear.]

1.13 What type of energy or fuel does this secondary heating system use?
- Electricity
- Natural gas
- Electricity and natural gas
- Oil
- Propane
- Wood/pellets
- Other _____
- Prefer not to answer

[Only respondents that choose "Natural gas" or "Electricity and natural gas" in 1.13 are given 1.13B.]

1.13B Does the natural gas supplied to your home contain renewable natural gas (i.e. biogas)?
- Yes
- No
- I don't know

[Only respondents that choose "Yes" in 1.13B are given 1.13C.]

1.13C What percent of your natural gas supply is renewable natural gas (i.e. biogas)
- 0 to 5%
- 5 to 10%
- 10 to 15%
- 15 to 25%
- 25 to 50%
- 50 to 75%
- 75 to 100%
- I don't know

1.14 What type of water heater does your home use?
- Heat pump with storage tank
- Heat pump without storage tank
- Storage tank (gas or electric)
- Tankless or 'on-demand' (gas or electric)
- Solar thermal
- Condensing
- Other _____
- Prefer not to answer

1.15 What type of energy or fuel does this water heater use?

- Electricity
- Natural gas
- Oil
- Propane
- Wood/pellets
- Other_____
- Prefer not to answer

1.16 Is your home connected to a natural gas grid?

- Yes
- No
- Prefer not to answer

[Question 1.17 is only given to respondents that answer "No" or "I don't know" in 1.16]

1.17 Is natural gas available on your street? In other words, is there a natural gas line buried under your street?

- Yes
- No
- Prefer not to answer

1.18 What type of air conditioning (if any) does your home use for cooling your home during warmer months?

- My home doesn't have an air conditioning system
- Central ducted air conditioner
- Window air conditioner(s)
- Portable air conditioner(s)
- Heat pump
- Other _____
- Prefer not to answer

[In 1.19, {ENERGY} is replaced by the answer to 1.7 (for example, electricity, natural gas, oil, etc.). If respondents choose "electricity and natural gas" please ask this question twice, once for each energy type (i.e. one question for electricity and one question for natural gas, for example.]

1.19 How much do you estimate your household spends on {ENERGY} utility bills annually?
Please indicate the approximate amount if you're uncertain. If you aren't able to estimate an approximate amount, you can choose "Prefer not to answer." Please feel free to consult your household to help answer this question.

$_____

- Prefer not to answer

[In 1.20, {ENERGY} is replaced by the answer to 1.13 (for example, electricity, natural gas, oil, etc.). If the answer for 1.13 is the same as the answer for 1.7, do not ask question 1.20 and SKIP to question 1.21.]

1.20 How much do you estimate your household spends on {ENERGY} utility bills annually?

Please indicate the approximate amount if you're uncertain. If you aren't able to estimate an approximate amount, you can choose "Prefer not to answer." Please feel free to consult your household to help answer this question.

$_____

- o Prefer not to answer

In Canada, it can be difficult for some households to estimate their home heating costs because many services may be included on one bill. For example, natural gas bills may include home heating, water heating, and cooking. As a guide, on average in Canada, 50 to 60% of a household's home energy use for all fuel types combined (natural gas, electricity, etc.) is for home heating.

1.21 How much do you estimate your household spends on **home heating** annually?
Please indicate the approximate amount if you're uncertain. If you aren't able to estimate an approximate amount, you can choose "Prefer not to answer." Please feel free to consult your household to help answer this question.

$_____

- o Prefer not to answer

1.22 To what degree are you familiar with the level of energy efficiency of the following features of your home?

	Not familiar	**Somewhat familiar**	**Familiar**	**Very familiar**	**Prefer not to answer**
Wall insulation	○	○	○	○	○
Windows	○	○	○	○	○
Heating system	○	○	○	○	○
Water heater	○	○	○	○	○

1.23 To your knowledge, has your home undergone any energy efficient retrofits or upgrades since it was first built (for example, improved energy-saving wall insulation)?

- o Yes
- o No
- o I don't know

1.24 Which of the following features does your home have and who paid for each feature?

	No, my home does not have this feature	**Yes, previous owners or builders paid for this feature**	**Yes, my household paid for this feature**	**I don't know**
Energy-saving exterior wall insulation	○	○	○	○
Energy-saving interior wall insulation	○	○	○	○

	No, my home does not have this feature	Yes, previous owners or builders paid for this feature	Yes, my household paid for this feature	I don't know
Double- or triple-paned windows	○	○	○	○
Weather-stripping on exterior doors	○	○	○	○
Programmable thermostat	○	○	○	○

1.25 How familiar are you with the following heating technologies?
For example, do you know how they heat your home and what makes them different from each other?

Air source heat pump:
- ○ Before this survey, I've never heard of this
- ○ I've heard of this, but I'm not familiar with details
- ○ I've heard of this, and know some details
- ○ I've heard of this, and know a lot
- ○ Prefer not to answer

Ground source heat pump:
- ○ Before this survey, I've never heard of this
- ○ I've heard of this, but I'm not familiar with details
- ○ I've heard of this, and know some details
- ○ I've heard of this, and know a lot
- ○ Prefer not to answer

1.26 We want to know if you would be willing to buy a heat pump when your existing heating system needs to be replaced. Please try to answer the question as you would in a typical year (i.e. once the COVID-19 pandemic is over), if that makes a difference in your decision.

To heat your home, **air source heat pumps** extract heat energy from the outside air and transfer it to inside a house. This sounds odd! However, even in winter there is heat energy in the outside air. Air source heat pumps extract this heat, boost its temperature, and then transfer this heat to the inside of a home.

Ground source heat pumps, on the other hand, extract heat energy from under the ground, which remains at a constant temperature throughout the year. Once they extract the heat energy, ground source heat pumps boost the temperature of the heat and then transfer the heat inside a home.

How willing would you be to buy a heat pump when your existing home heating system needs to be replaced?

	Very unwilling	Unwilling	Undecided	Willing	Very willing	Prefer not to answer
Air source heat pump	○	○	○	○	○	○
Ground source heat pump	○	○	○	○	○	○

Section 2: Home heating policies

In this section, we'd like to hear your thoughts and opinions on provincial/territorial policies aimed at promoting low-emission heating systems. A **policy** is any action taken by the government to try and achieve a specific goal, such as implementing programs and regulations. A low-emission heating system is one that produces much lower greenhouse gas emissions than a regular system. Greenhouse gases come from the burning of fossil fuels—such as natural gas and oil—and contribute to climate change. In this survey, the term "low-emission" also includes heating systems that produce no emissions (often called "zero-emission" systems). Examples of low-emission heating systems could be an electric furnace, an electric heat pump, electric baseboard heaters, or a furnace or boiler running on 100% renewable natural gas (i.e. biogas).

2.1 **Could you please list any policies that your provincial/territorial government currently uses to encourage people to purchase, install, or use a low-emission heating system?** There is space below for you to list up to five policies.
If you can't think of any, that's okay. Please select "I can't think of any low-emission heating policies currently used by the government in my province/territory."

- ○ I can't think of any policies currently used by the government in my province or territory

2.2 Please read these short descriptions of common policies for promoting low-emission home heating systems:

- **Subsidy/rebate for purchasing low-emission heating systems** – a grant given for purchasing and/or installing a low-emission heating system (for example, this could be a discount given at the point of sale or a tax rebate).
- **Subsidy for home energy efficiency retrofit** – a grant given for making your home more energy efficient (for example, a grant for replacing your doors, windows, or wall insulation with more energy efficient materials).
- **Loan/financing program** – a program that provides loans to help with the costs of purchasing and installing low-emission heating systems (for example, a low-interest loan program).
- **Education** – an information program that aims at encouraging you to voluntarily choose to purchase, install, or use a low-emission heating system (for example, mail pamphlets, TV commercials, and/or online ads that provide information on the financial or environmental advantages of using low-emission heating systems).
- **Carbon tax** – a tax applied to all fossil fuels such as natural gas and oil based on how much carbon they release when burned (for example, a carbon tax would be added to a natural gas or oil bill when paying for home heating).
- **Renewable natural gas mandate** – a regulation on natural gas providers requiring them to blend in a certain amount of renewable natural gas in natural gas used for home heating (for example, making a natural gas mixture that is made up of 15% biogas)
- **Home emissions regulation** – a regulation that limits the amount of greenhouse gas emissions a house is allowed to emit from home heating and water heating. To comply, homeowners can improve the energy efficiency of their home, switch to low-emission heating systems, or pay a fine.

[These policy definitions starting from "Please read these short…" to "...or pay a fine" are kept at the top of each page in questions 2.2-2.4.]

Based on these definitions and your own knowledge, please indicate which policies you think are currently in place in your province or territory:

	I know that this policy is in place in my province/territory	**I know that this policy is NOT in place in my province/territory**	**I don't know about this policy**
1) Subsidy/rebate for purchasing low-emission heating systems	○	○	○
2) Subsidy for home energy efficiency retrofit	○	○	○
3) Loan/ financing programs for purchasing low-emission heating systems	○	○	○
4) Education programs on low-emission heating systems for homeowners	○	○	○
5) Carbon tax	○	○	○

	I know that this policy is in place in my province/territory	I know that this policy is NOT in place in my province/territory	I don't know about this policy
6) Renewable natural gas mandate	○	○	○
7) Home emissions regulation	○	○	○

2.3 [The preamble from 2.2. with policy definitions is repeated here]

When your current home heating system needs to be replaced, how much more likely would you be to buy a low-emission heating system if each policy were in place in your province/territory?
By "very unlikely" we mean that policy is not likely to encourage you to buy a low-emission heating system, while "very likely" means that it is very likely to encourage you to buy one. Please feel free to consult with your household as you would if your heating system actually needed to be replaced.

	Very unlikely	Unlikely	Neutral	Likely	Very likely	Prefer not to answer
1) Subsidy/rebate for purchasing low-emission heating systems	○	○	○	○	○	○
2) Subsidy for home energy efficiency retrofit	○	○	○	○	○	○
3) Loan/ financing programs	○	○	○	○	○	○
4) Education programs on low-emission heating systems for homeowners	○	○	○	○	○	○
5) Carbon tax	○	○	○	○	○	○
6) Renewable natural gas mandate	○	○	○	○	○	○

	Very unlikely	Unlikely	Neutral	Likely	Very likely	Prefer not to answer
7) Home emissions regulation	○	○	○	○	○	○

2.4 [The preamble from 2.2. is repeated here.]

In a referendum, if you were asked to vote on these policies, how much would you support or oppose your provincial or territorial government putting in place or continuing each policy?
By "strongly oppose" we mean you would not want your government to put in place and/or continue that policy, while "strongly support" means you would want that policy to be put in place or continue.

	Strongly oppose	Oppose	Neutral	Support	Strongly support	Prefer not to answer
1) Subsidy/rebate for purchasing low-emission heating systems	○	○	○	○	○	○
2) Subsidy for home energy efficiency retrofit	○	○	○	○	○	○
3) Loan/ financing programs	○	○	○	○	○	○
4) Education programs on low-emission heating systems for homeowners	○	○	○	○	○	○
5) Carbon tax	○	○	○	○	○	○
6) Renewable natural gas mandate	○	○	○	○	○	○
7) Home emissions regulation	○	○	○	○	○	○

Section 3. Technology characteristics

3.1 In this section we're going to ask you about your perception of air source heat pumps and ground source heat pumps. First, think about **air source heat pumps**. In cold months, air source heat pumps extract heat energy from the outside air and transfer it to inside a house. This sounds odd! However, even in winter there is heat energy in the outside air. Air source heat pumps extract this heat, boost its temperature, and then transfer this heat to the inside of a home.

Think about purchasing, installing, and using an **air source heat pump** in your home. To what extent do you believe that it would:

	Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly Agree**	**Prefer not to answer**
1) be effective in heating your home	○	○	○	○	○	○
1b) be effective in cooling your home	○	○	○	○	○	○
2) be too expensive to purchase	○	○	○	○	○	○
3) be too expensive to install	○	○	○	○	○	○
4) be too disruptive to install	○	○	○	○	○	○
5) make excessive noise	○	○	○	○	○	○
6) be easy to use	○	○	○	○	○	○
7) be easy to maintain	○	○	○	○	○	○
8) be less expensive to use than your current heating system	○	○	○	○	○	○
9) increase your quality of life	○	○	○	○	○	○
10) help to fight climate change	○	○	○	○	○	○
11) be an effective way	○	○	○	○	○	○

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	Prefer not to answer
to improve indoor air quality						
12) be an effective way to improve outdoor air quality	○	○	○	○	○	○
13) help reduce our dependence on oil and natural gas	○	○	○	○	○	○
14) have a worse environmental impact than a conventional oil-based or natural gas-based heating system	○	○	○	○	○	○
15) allow you to express your values	○	○	○	○	○	○
16) be a status symbol	○	○	○	○	○	○
17) help you connect with like-minded people	○	○	○	○	○	○
18) make a positive impression on others	○	○	○	○	○	○
19) be an inspiration to others	○	○	○	○	○	○
20) send a message to the government	○	○	○	○	○	○
21) send a message to heating/cooling companies	○	○	○	○	○	○

3.2 Now, think about **ground source heat pumps**. In cold months, they extract heat energy from under the ground, which remains at a constant temperature throughout the year. Once they extract the heat energy, ground source heat pumps boost the temperature of the heat and then transfer it inside your home.

Think about purchasing, installing, and using a **ground source heat pump** in your home. To what extent do you believe that it would:

	Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly Agree**	**Prefer not to answer**
1) be effective in heating your home	○	○	○	○	○	○
1b) be effective in cooling your home	○	○	○	○	○	○
2) be too expensive to purchase	○	○	○	○	○	○
3) be too expensive to install	○	○	○	○	○	○
4) be too disruptive to install	○	○	○	○	○	○
5) make excessive noise	○	○	○	○	○	○
6) be easy to use	○	○	○	○	○	○
7) be easy to maintain	○	○	○	○	○	○
8) be less expensive to use than your current heating system	○	○	○	○	○	○
9) increase your quality of life	○	○	○	○	○	○
10) help to fight climate change	○	○	○	○	○	○
11) be an effective way to improve indoor air quality	○	○	○	○	○	○
12) be an effective way	○	○	○	○	○	○

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	Prefer not to answer
to improve outdoor air quality						
13) help reduce our dependence on oil and natural gas	○	○	○	○	○	○
14) have a worse environmental impact than a conventional oil-based or natural gas-based heating system	○	○	○	○	○	○
15) allow you to express your values	○	○	○	○	○	○
16) be a status symbol	○	○	○	○	○	○
17) help you connect with like-minded people	○	○	○	○	○	○
18) make a positive impression on others	○	○	○	○	○	○
19) be an inspiration to others	○	○	○	○	○	○
20) send a message to the government	○	○	○	○	○	○
21) send a message to heating/cooling companies	○	○	○	○	○	○

3.3 Do you know anyone who has an air source or ground source heat pump?

- Yes
  - Who are these people? Select all that apply.
    - ☐ Family
    - ☐ Friends
    - ☐ Neighbours
    - ☐ Colleagues
    - ☐ Community leaders
    - ☐ People I follow on social media
    - ☐ Other
- No
- Prefer not to answer

[Questions 3.4 to 3.7 will only appear for individuals who selected "Yes" in 1.6B or 1.12B.]

We're interested in learning about your reasons for purchasing and installing a heat pump. We're first going to ask you about factors that encouraged you to purchase and install a heat pump, then we're going to ask you about factors that were discouraging and acted as potential barriers.

3.4 When you were replacing your previous heating system, which (if any) of the following heat pump factors **encouraged** you to choose a heat pump? Select all that apply.

- Effectiveness in heating your home
- Effectiveness in cooling your home
- Being able to heat and cool your home with one system
- Purchase price
- Installation cost
- Operating cost (i.e. home heating bills)
- Financial incentives (for example, subsidies or rebates)
- Installation process (for example, quick installation with few additional retrofits needed)
- Finding a contractor who could perform the installation
- Level of noise produced by the heat pump
- Ease of use of system
- Amount of regular maintenance to maintain the system
- Using a heating system powered by electricity
- Level of energy efficiency
- Low or zero greenhouse gas emissions produced
- Home air quality improvements
- Knowing someone who owned or recommended installing a heat pump (e.g. a friend)
- Having information on heat pumps and their benefits (for example, through advertisements)
- Bylaws that made it easy to install a heat pump
- Having the interior/exterior space to install a heat pump
- Other _____
- Prefer not to answer

[3.5 is not given for those who selected "Prefer not to answer" in 3.4. Respondents can only select one option in 3.5.]

3.5 Which of the following was the **most important** encouraging factor in choosing to purchase and install a heat pump?

- Effectiveness in heating your home
- Effectiveness in cooling your home

- Being able to heat and cool your home with one system
- Purchase price
- Installation cost
- Operating cost (i.e. home heating bills)
- Financial incentives (for example, subsidies or rebates)
- Installation process (for example, quick installation with few additional retrofits needed)
- Finding a contractor who could perform the installation
- Level of noise produced by the heat pump
- Ease of use of system
- Amount of regular maintenance to maintain the system
- Using a heating system powered by electricity
- Level of energy efficiency
- Low or zero greenhouse gas emissions produced
- Home air quality improvements
- Knowing someone who owned or recommended installing a heat pump (e.g. a friend)
- Having information on heat pumps and their benefits (for example, through advertisements)
- Bylaws that made it easy to install a heat pump
- Having the interior/exterior space to install a heat pump
- Other _____
- Prefer not to answer

3.6 When replacing your old heating system, which (if any) of the following potential factors **discouraged** you from choosing a heat pump? Select all that apply.

- Effectiveness in heating your home
- Effectiveness in cooling your home
- Purchase price
- Installation cost
- Operating cost (i.e. home heating bills)
- Lack of financial incentives (for example, subsidies or rebates)
- Installation process (for example, very inconvenient with many additional home retrofits needed)
- Finding a contractor who could perform the installation
- Level of noise produced by the heat pump
- Ease of use of system
- Amount of regular maintenance to maintain the system
- Using a heating system powered by electricity
- Not knowing anyone who owns or recommends installing a heat pump
- Difficulty finding information on heat pumps and their benefits
- Bylaws that made it difficult to install a heat pump
- Not having the interior/exterior space to install a heat pump
- Other _____
- Prefer not to answer

[3.7 is not given to respondents who picked "Prefer not to answer" in 3.6. Respondents can only select one option in 3.7].

3.7 Which of the following **discouraged you the most** from installing a heat pump?

- Effectiveness in heating your home
- Effectiveness in cooling your home
- Purchase price
- Installation cost

- Operating cost (i.e. home heating bills)
- Lack of financial incentives (for example, subsidies or rebates)
- Installation process (for example, very inconvenient with many additional home retrofits needed)
- Finding a contractor who could perform the installation
- Level of noise produced by the heat pump
- Ease of use of system
- Amount of regular maintenance to maintain the system
- Using a heating system powered by electricity
- Not knowing anyone who owns or recommends installing a heat pump
- Difficulty finding information on heat pumps and their benefits
- Bylaws that made it difficult to install a heat pump
- Not having the interior/exterior space to install a heat pump
- Other _____
- Prefer not to answer

[Respondents that select "Air source heat pump" or "Ground source heat pump" in 1.5 do not complete section 4.]

Section 4: Home heating choice game

You're now going to play a home heating choice game. For this game, please **assume that you want to replace your current primary heating system**. In the game you'll choose between different replacement heating systems that are suitable for your home. You'll make a choice six times, each time with different heating systems to choose from. In each game, keep in mind your home heating budget and the heating system features that are important to you. Please try to answer these questions as you would in a typical year (i.e. once the COVID-19 pandemic is over). Feel free to consult your household as you would if you were actually deciding on what heating system to install in your home. If you live alone, then you are your "household."

The heating technologies you will choose between are:

- **Furnace**
- **Baseboard heaters**
- **Air source heat pump**
- **Ground source heat pump**

In the choice game, **please assume that the new furnace runs on the fuel type that your current furnace does**. For example, if your current furnace is powered by natural gas, assume that the new furnace is also powered by natural gas. In the choice game, please assume the heat pumps and baseboard heaters run on **electricity**.

[The sentences above in green are given to respondents that receive Technology Guide #1. For respondents that receive Technology Guide #2, the following sentences are instead given: "In the choice game, **please assume that the new boiler runs on the fuel that your current boiler does**. For example, if your current boiler is powered by natural gas, assume that the new boiler is also powered by natural gas." Respondents that receive Technology Guide #3, are not given these sentences.]

[These options are just an example. In the survey, the above options will be generated based on the current heating system the respondent has in their home. More on this below.]

Before playing the game, please read our ***Home Heating Technology Guide***, which provides a brief overview of these heating systems. It is very important that you read the information contained in the guide and look at its pictures/diagrams. Please carefully review the information, even if you feel you're already familiar with some or all of the details. When performing the choice game, **we want you to keep in mind the information you read in the *Technology Guide***. Throughout the choice game, you will be able to refer back to ***Technology Guide*** by clicking a link at the bottom of each page.

[Three different versions of the Technology Guide are used in this survey. The version a respondent receives is dependent on their answers to questions 1.5. Respondents that answer (1) "Furnace" in 1.5, or (2) "Prefer not to answer" in 1.5 receive Technology Guide #1.]

Technology guide #1

Heating Technology Guide

Furnace

- A furnace uses a fuel or energy source to heat up air that is blown throughout a home through ducting and air vents.
- Well-maintained furnaces last 15 to 20 years on average.

Electric baseboard heaters

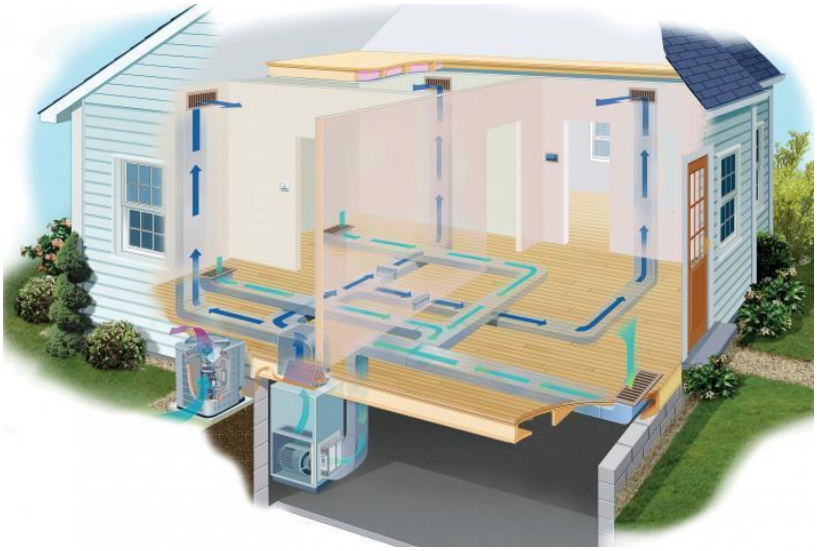
- Electric baseboard heaters warm a room by using electricity to heat up elements in units installed along baseboards.
- Individual units are installed in each room of a house where heating is required.
- Large rooms may require multiple units.
- Heat moves passively out of the units. Heat is not actively blown around a room.
- Well-maintained electric baseboards last 20+ years on average.

Air source heat pump

- In cold months, air source heat pumps extract heat energy from the outside air and transfer it to inside a house.
- This sounds odd! However, even in winter there is heat energy in the outside air. Air source heat pumps extract this heat, boost its temperature, and then transfer this heat to the inside of a home.
- They can be integrated into central air ducted systems formerly heated by furnaces.
- An air source heat pump system includes the installation of a fan unit outside a house (similar in size and construction to an air conditioner), and a unit inside the house to blow air around a house through ducting (similar in size to a small furnace).
- In warm months, they work in reverse and blow cooled air around a house. Because they can cool and heat homes, air source heat pumps eliminate the need for a separate air conditioning unit.
- When heating or cooling a house, the outside unit produces a noise level like an outdoor air conditioning unit.
- They typically run on electricity, although some models can run on natural gas.
- In climates that often go below -15 degrees Celsius, cold-climate air source heat pumps are available that boost efficiency in extremely cold temperatures. However, some

models may require a back-up heating system to keep a house warm during the coldest periods of the year.

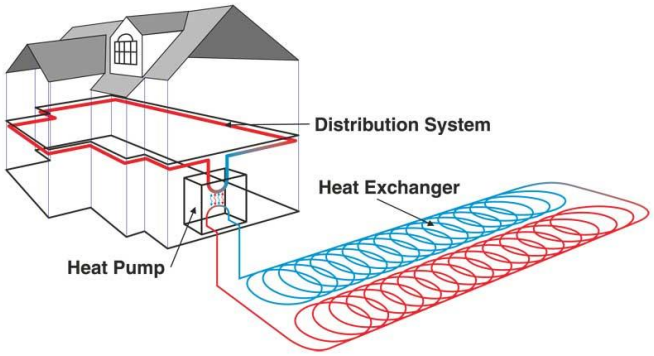
- Well-maintained air source heat pumps last 15 to 20 years on average.
- The picture below shows an example of what an air source heat pump system looks like. You can see the fan unit outside the house and the unit inside the house that moves air through your ducting.



https://www.etmechanical.ca/ducted-heat-pump/

Ground source heat pump

- Ground source heat pumps work like air source heat pumps except they extract heat from under the ground, not the air.
- In cold months, they extract heat energy from under the ground (which maintains a constant temperature year-round), boost the temperature of the heat, and then transfer the heat inside a house.
- In warm months, they work in reverse and blow cooled air around a house. Because they can cool and heat homes, ground source heat pumps eliminate the need for a separate air conditioning unit.
- They can be integrated into forced air ducted systems formerly heated by furnaces
- A ground source heat pump system includes the installation of a unit inside your house to blow air around your home through ducting (similar in size to a small furnace), and heat exchanger coils in your front or backyard.
- The installation of the heat exchanger coil requires that your front or back yard is dug up for so that the coils can be laid horizontally 1 to 2 metres underground.
- When operating, it produces little to no outdoor noise.
- The indoor components of a well-maintained ground source heat pump lasts 15 to 20 years on average. The underground coils last 50+ years on average.
- This picture below shows what a ground source heat pump system looks like. You can see the heat exchanger coils underground and the unit inside that pumps warm air around your ducting.



https://www.greenbuildingadvisor.com/article/is-this-ground-source-heat-pump-plan-workable

[Respondents that answer "Boiler" in 1.5 receive Technology Guide #2.]

Technology Guide #2

Heating Technology Guide

Boiler

- A boiler uses a fuel or energy source to heat up water that is distributed throughout a house through pipes to radiators or in-floor radiant heating systems.
- Well-maintained boilers last 15 to 20 years on average.

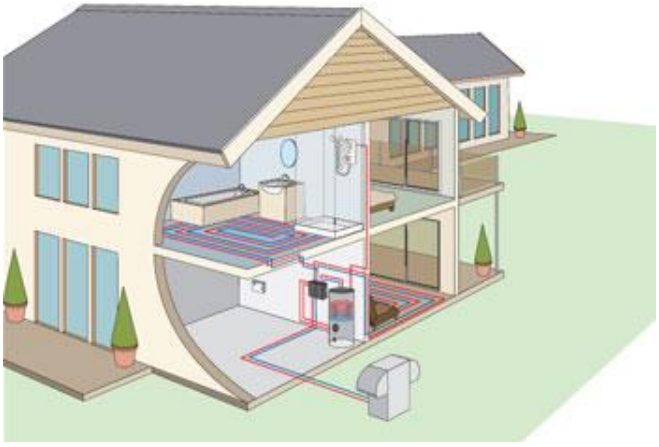
Electric baseboard heaters

- Electric baseboard heaters warm a room by using electricity to heat up elements in units installed along baseboards.
- Individual units are installed in each room of a house where heating is required.
- Large rooms may require multiple units.
- Heat moves passively out of the units. Heat is not actively blown around a room.
- Well-maintained electric baseboards last 20+ years on average.

Air source heat pump

- In cold months, air source heat pumps extract heat energy from the outside air and transfer it to inside a house.
- This sounds odd! However, even in winter there is heat energy in the outside air. Air source heat pumps extract this heat, boost its temperature, and then transfer this heat to the inside of a home.
- This heat can be integrated into water distribution systems formerly heated by boilers, sending heat around the house through pipes in its existing heating system.
- An air source heat pump system includes the installation of a fan unit outside a house (similar in size and construction to an air conditioner), and a unit inside the house to transfer the heat to a hot water tank.
- When heating a house, the outside unit produces a noise level like an outdoor air conditioning unit.
- They typically run on electricity, although some models can run on natural gas.
- In climates that often go below -15 degrees Celsius, cold-climate air source heat pumps are available that boost efficiency in extremely cold temperatures. However, some models may require a back-up heating system to keep a house warm during the coldest periods of the year.

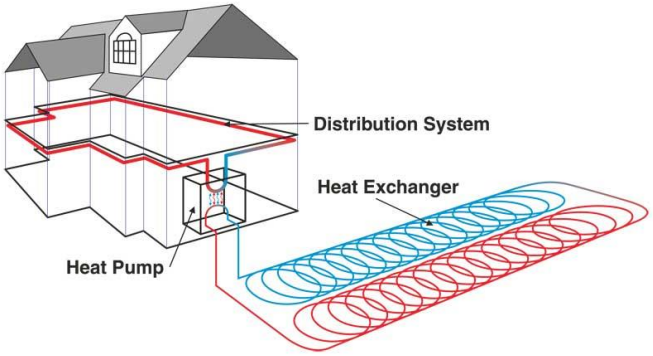
- Well-maintained air source heat pumps last 15 to 20 years on average.
- The picture below shows an example of what an air source heat pump system looks like. You can see the fan unit outside the house and the unit inside the house that moves heat through pipes.



http://www.pet.ie/air-to-water-heat-pumps.html

Ground source heat pump

- Ground source heat pumps work like air source heat pumps except they extract heat from under the ground, not the air.
- In cold months, they extract heat energy from under the ground (which maintains a constant temperature year-round), boost the temperature of the heat, and then transfer the heat inside a house.
- They can be integrated to water distribution systems formerly heated by boilers.
- A ground source heat pump system includes the installation of a unit inside your house to pump and transfer heat to and from a hot water tank and a heat exchanger coil in your front or backyard.
- The installation of the heat exchanger coil requires that your front or back yard is dug up for so that the coils can be laid horizontally 1 to 2 metres underground.
- When operating, it produces little to no outdoor noise.
- The indoor components of a well-maintained ground source heat pump lasts 15 to 20 years on average. The underground coils last 50+ years on average.
- This picture below shows what a ground source heat pump system looks like. You can see the heat exchanger coils underground and the unit inside that uses water to pump the heat around your heating pipes.



https://www.greenbuildingadvisor.com/article/is-this-ground-source-heat-pump-plan-workable

[Respondents that answer “Electric baseboard heaters”, “Fireplace”, “Wood-burning or pellet stove” or “Other” in 1.5 receive Technology Guide #3.]

Technology Guide #3

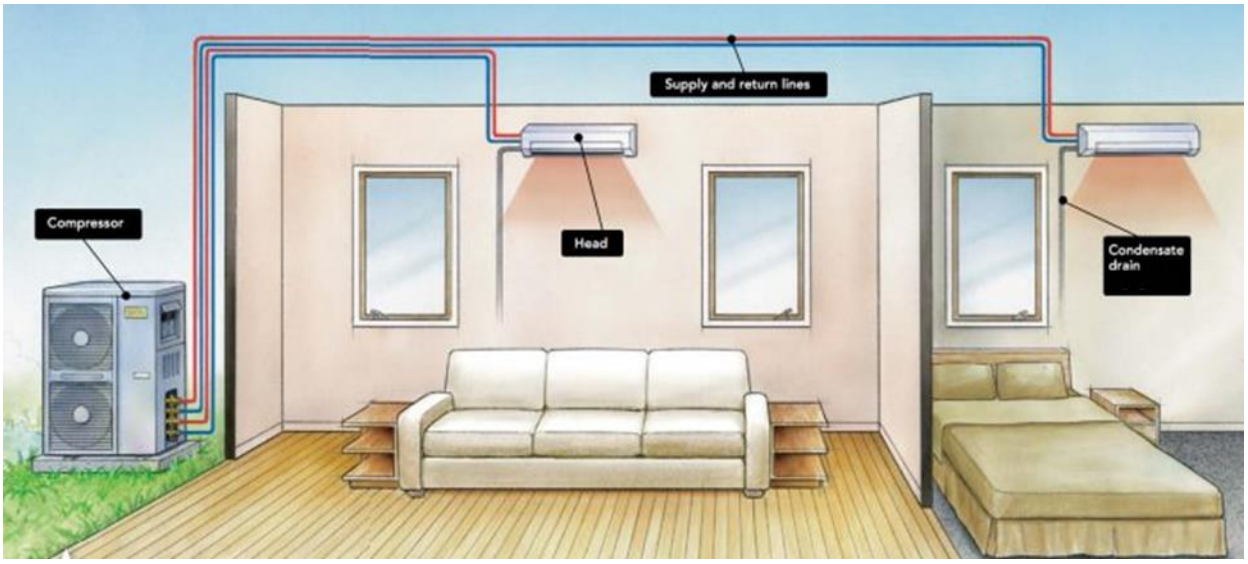
Heating Technology Guide

Electric baseboard heaters

- Electric baseboard heaters warm a room by using electricity to heat up elements in units installed along baseboards.
- Individual units are installed in each room of a house where heating is required.
- Large rooms may require multiple units.
- Heat moves passively out of the units. Heat is not actively blown around a room.
- Well-maintained electric baseboards last 20+ years on average.

Air source heat pump

- In cold months, air source heat pumps extract heat energy from the outside air and transfer it to inside a house.
- This sounds odd! However, even in winter there is heat energy in the outside air. Air source heat pumps extract this heat, boost its temperature, and then transfer this heat to the inside of a home.
- They be integrated into homes that have no existing forced air ducting or water distribution heating systems.
- An air source heat pump system includes the installation of a fan unit outside your house (similar in size and construction to an air conditioner) and multiple blower units which are mounted in each room or area of a home.
- These blower units are typically mounted high on the wall and actively blow air around a room.
- In warm months, they work in reverse and blow cool air. Because they can heat and cool homes, they eliminate the need for a separate air conditioning unit.
- When heating or cooling a house, the outside unit produces a noise level like an outdoor air conditioning unit.
- They typically run on electricity, although some models can run on natural gas.
- In climates that often go below -15 degrees Celsius, cold-climate air source heat pumps are available that boost efficiency in extremely cold temperatures. However, some models may require a back-up heating system to keep a house warm during the coldest periods of the year.
- Well-maintained air source heat pumps last 15 to 20 years on average.
- The picture below shows an example of what an air source heat pump system looks like. You can see the fan unit outside the house and the blower units mounted on the walls inside.



https://www.finehomebuilding.com/2019/03/07/high-performance-hvac-2

[After respondents have read the Technology Guide, in order to continue, respondents must check a box that reads: "**I have read the ENTIRE *Home Heating Technology Guide*.**"]

It's now time to begin the choice game. We will ask you to make a choice between these replacement heating systems six different times. Each time, all or some of the following features of the heating systems will change:

1. **Purchase price** – this price includes the cost to purchase the heating system as well as the labour costs to fully install it.
2. **Rebate** – a rebate will vary from $0 to $10,000, depending on the heating system. These rebates could come from your federal, provincial, regional, and/or local government. The rebate will be in green text and it will be deducted from the purchase price so that you can evaluate the final upfront cost of the replacement heating system.
3. **Annual heating cost** – the yearly cost of running the heating system will be shown relative to your current yearly heating costs. This cost may be less expensive, more expensive, or the same as your current home heating costs.
4. **Installation hassle** – the level of inconvenience when installing the new heating system, both in terms of the amount of time it will take to complete the installation as well as the scope of renovations required to install the new system in your house and/or yard. This feature ranges from *low* to *very high*:
    - **Low** – less than one day of installation time and little to no additional renovations required.
    - **Medium** – a full day or longer of installation time with some construction to your walls, floors, ceilings, ducting, piping, and/or wiring systems in your home and/or yard.
    - **High** – two or more days of installation time with more substantial construction to walls, floors, ceilings, ducting, piping, and/or wiring systems in your home and/or yard.
    - **Very high** – a week or more of installation time with more substantial construction to walls, floors, ceilings, ducting, piping, and/or wiring systems in your home and/or yard.

["Very high" and its description are only given to respondents that receive ground source heat pumps in their choice sets.]

5. **Back-up system required?** – If a heating system isn't powerful enough, particularly during the coldest days and nights of the year, a back-up heating system might be required. This back-up system could be your existing primary or secondary heating systems or a newly installed back-up

system such as a furnace, boiler, baseboard heaters, space heaters, or fireplace—whichever suits your home the best. The cost of purchasing, installing, and operating this back-up system is included in the purchase price and annual heating cost attributes. This attribute can be "Yes" or "No" for Air Source Heat Pumps. For all other heating systems, it will always be "No".

During the game, you can click a link to return to these feature descriptions.

Now it's time to begin making your six choices. Please remember:

- You're assuming that **you want to replace the heating system** currently in your home.
- The heating systems in the game are **new replacements** for your primary heating system.
- The heating systems in the game have all been customized to be **suitable for your home**.
- The heat pumps and baseboard heaters in the game run on electricity.
- Keep in mind your **real home heating budget**.
- You can consult your household at any time in this choice game, as you would if you were actually making a decision on what heating system to install in your home. If you live alone, then you are your "household."
- Keep in mind the attributes you read about in the ***Technology Guide***.

Examine the first choice game below:

4.1 **If these were the heating system options available to you on the market today, which option would you choose to replace your current home heating system?**
*Using the information provided, please select the heating system type that you are **most likely to buy**. Then click "Next" to confirm your choice.*

Choice 1 of 6

Heating system type	Purchase price & subsidy	Annual heating cost	Installation hassle	Back-up system required?	I CHOOSE
Furnace	$3,000 - $0 **$3,000**	**25% less** than your current costs	Medium	No	☐
Air source heat pump	$11,000 - $5,000 **$6,000**	**Same** as your current costs	Medium	Yes	☐
Ground source heat pump	$25,000 -$10,000 **$15,000**	**50% less** than your current costs	Very High	No	☐
Baseboard heaters	$10,000 - $1,000 **$9,000**	**Triple** your current costs	High	No	☐

NEXT

Click HERE to revisit the *Home Heating Technology Guide*, or click HERE to revisit the feature explanations.

Now it's time to make another choice. You'll see that some or all of the heating system features have changed.

4.2 **If these were the heating technology options available to you on the market today, which option would you choose to replace your existing home heating appliance?**
*Using the information provided, please select the heating system type that you are **most likely to buy**. Then click "Next" to confirm your choice.*

Choice 2 of 6

Heating system type	Purchase price & subsidy	Annual heating cost	Installation hassle	Back-up system required?	I CHOOSE
Furnace	$5,000 - $0 **$5,000**	**50% more** than your current costs	Low	No	☐
Air source heat pump	15,000 -$5,000 **$10,000**	**25% more** as your current costs	Medium	No	☐
Ground source heat pump	$30,000 -$10,000 **$20,000**	**75% less** than your current costs	High	No	☐
Baseboard heaters	$7,500 - $500 **$7,000**	**Double** your current costs	High	No	☐

NEXT

Click HERE to revisit the *Home Heating Technology Guide*, or click HERE to revisit the feature explanations.

[We list two example choice sets above. In the survey, respondents completed six choice sets.]

4.7 Which of the following statements best summarizes your experience with the choice game you just completed?

- ○ I did not understand this game
- ○ I mostly understood the game, but I was unclear about some things
- ○ I understood this game

4.8 Now that you've read the *Technology Guide* and played the Home Heating Choice Game, **how willing would you be to buy a heat pump when your existing home heating system needs to be replaced?**
Please try to answer the question as you would in a typical year (i.e. once the COVID-19 pandemic is over), if that changes your decision. You're also free to consult your household in answering this question.

	Very unwilling	**Unwilling**	**Undecided**	**Willing**	**Very willing**	**Prefer not to answer**
Air source heat pump	○	○	○	○	○	○
Ground source heat pump	○	○	○	○	○	○

Section 5. Your values, beliefs, and worldviews

Thank you for answering our questions on heating technologies! This next section is going to focus on your values, beliefs, and worldviews in general.

5.1 How much do you personally trust each of the following organizations?

	No trust a all	**Low trust**	**Somewhat trust**	**High trust**	**Prefer not to answer**
1) Federal government	○	○	○	○	○
2) Provincial/ territorial government	○	○	○	○	○
3) Scientists employed by government					
3B) Electric utilities	○	○	○	○	○
3C) Natural gas utilities					
4) Fossil fuel industry	○	○	○	○	○
5) Clean tech/ renewable energy companies	○	○	○	○	○
6) Scientists employed by industry	○	○	○	○	○
7) Non-profit environmental groups	○	○	○	○	○
8) Scientists employed by environmental groups	○	○	○	○	○
9) Academic journals and magazines	○	○	○	○	○
10) Scientists employed by universities	○	○	○	○	○

5.2. How important are each of these values in your life?

	Not important at all	**Not important**	**Moderately important**	**Important**	**Extremely important**	**Prefer not to answer**
1) Family security, safety for loved ones	○	○	○	○	○	○
2) Honoring parents and elders, showing respect	○	○	○	○	○	○

	Not important at all	Not important	Moderately important	Important	Extremely important	Prefer not to answer
3) Self-discipline, self-restraint, resistance to temptation	○	○	○	○	○	○
4) Respecting the earth (living in harmony with other species)	○	○	○	○	○	○
5) Unity with nature (fitting into nature)	○	○	○	○	○	○
6) Environmental protection (preserving nature)	○	○	○	○	○	○
7) Social justice (correcting injustice, care for the less privileged)	○	○	○	○	○	○
8) Equality (equal opportunities for all)	○	○	○	○	○	○
9) Helping others (working for the welfare of others)	○	○	○	○	○	○
10) A world of peace (free of war and conflict)	○	○	○	○	○	○
11) Authority (the right to lead or command)	○	○	○	○	○	○
12) Influence (having an impact on people and events)	○	○	○	○	○	○
13) Wealth (material possessions, money)	○	○	○	○	○	○
14) A varied life, filled with challenge, novelty, and change	○	○	○	○	○	○
15) An exciting life, stimulating experiences	○	○	○	○	○	○
16) Curiosity, many interests, desire to explore	○	○	○	○	○	○

5.3. To what extent do you agree or disagree with the following statements about natural environments?

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Prefer not to answer
1) The so-called "ecological crisis" facing humankind has been greatly exaggerated	○	○	○	○	○	○

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Prefer not to answer
2) If things continue on their present course, we will soon experience a major ecological catastrophe	○	○	○	○	○	○
3) Humans have the right to modify the natural environment to suit their needs	○	○	○	○	○	○
4) Humans are severely abusing the environment	○	○	○	○	○	○
5) When humans interfere with nature, it often produces disastrous consequences	○	○	○	○	○	○
6) The balance of nature is very delicate and easily upset	○	○	○	○	○	○
7) The earth is like a spaceship with limited room and resources	○	○	○	○	○	○
8) We are approaching the limit of the number of people the earth can support						○

5.4. How much do you agree or disagree with the following statements about climate change?
We would like to hear your thoughts regardless of whether you know a lot or a little about climate change. Climate change (or global warming) is the warming of the Earth's atmosphere due to increased greenhouse gas emissions from activities like burning natural gas and oil.

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Prefer not to answer
1) More species will be lost in my province due to climate change	○	○	○	○	○	○
2) More species will be lost in the world due to climate change	○	○	○	○	○	○
3) Health problems in my province will increase due to climate change	○	○	○	○	○	○
4) Health problems in the world will increase due to climate change	○	○	○	○	○	○
5) The economy in my province will suffer due to climate change	○	○	○	○	○	○

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Prefer not to answer
6) The world economy will suffer due to climate change	○	○	○	○	○	○
7) The standard of living of many people in my province will decrease due to climate change	○	○	○	○	○	○
8) The standard of living of many people in the world will decrease due to climate change	○	○	○	○	○	○

5.5. How much do you agree with the following statements about human responsibility for climate change?

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Prefer not to answer
1) I am jointly responsible for climate change	○	○	○	○	○	○
2) My contribution to climate change is negligible	○	○	○	○	○	○
3) In principle, individuals on their own cannot contribute to the reduction of climate change	○	○	○	○	○	○

5.6. How much do you agree or disagree with the following statements?

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Prefer not to answer
1) I feel personally obliged to reduce my carbon emissions as much as possible	○	○	○	○	○	○
2) I feel guilty when I use fossil fuels in my daily life	○	○	○	○	○	○
3) People like me should do everything they can to reduce their carbon emissions	○	○	○	○	○	○
4) I would be a better person if I reduced my carbon emissions	○	○	○	○	○	○
5) I feel obliged to consider the environment and nature in my daily behaviour	○	○	○	○	○	○

5.7. How frequently do you engage in the following activities?
Think about how often you engage in these activities, or how much time you devote to these activities, in a typical year. By typical year, we mean what is "normal" for you when COVID-19 social distancing measures are not in place.

	Never	**Rarely**	**Occasionally**	**Frequently**	**Very frequently**	**Prefer not to answer**
1) Researching new technologies	○	○	○	○	○	○
2) Shopping for new technologies	○	○	○	○	○	○
3) Talking about new technologies	○	○	○	○	○	○
4) Working on or tinkering with technology	○	○	○	○	○	○
5) Thinking about protecting the environment	○	○	○	○	○	○
6) Trying to help the environment through daily actions	○	○	○	○	○	○
7) Attending environmental meetings	○	○	○	○	○	○
8) Engaging in environmental conservation activities	○	○	○	○	○	○
9) Promoting environmental conservation (talking to people about the environment)	○	○	○	○	○	○

Section 6. Your household details

In this last section, we'd like to learn a little more about you. This survey is anonymous, and the information in this section will be used only for statistical purposes.

6.3. What is the highest level of education you have completed?

- No certificate, diploma or degree
- High school certificate or equivalent
- Apprenticeship or trades certificate or diploma
- College, CEGEP or other non-university certificate or diploma
- University certificate or diploma below bachelor level
- Bachelor's degree
- University certificate or diploma above bachelor level
- Degree in medicine, dentistry, veterinary medicine or optometry
- Master's degree
- Doctorate or PhD degree

6.4 How many people live in your household **(including yourself)**?

- Only myself
- 2 people
- 3 people
- 4 people
- 5 or more people

6.5 What is your approximate annual household income in a typical year (i.e. pre-COVID-19 pandemic)? *By household income we mean total income from all members of your household. Please feel free to consult your household to answer this question.*

- Without income
- $1 to $49,999
- $50,000 to $99,999
- $100,000 to $149,999
- $150,000 to $199,999
- $200,000 to $249,999
- $250,000 to $299,999
- $300,000 and over
- Prefer not to answer

6.6 Could you please indicate your work status in a typical year (i.e. pre-COVID-19 pandemic)?

- Employed or self-employed
- Unemployed
- Not in the labour force (students, homemakers, retired workers, seasons workers in an 'off' season who were not looking for work, and persons who could not work because of a long-term illness or disability)

[Only respondents that answer "Employed or self-employed" in 6.6, are given 6.7]

6.7. Which of the following industries best describes your employment sector?

- Agriculture, forestry, fishing and hunting
- Mining and oil and gas extraction
- Renewable energy/clean energy

- Utilities
- Construction
- Manufacturing
- Wholesale trade
- Retail trade
- Transportation and warehousing
- Information and cultural industries
- Finance and insurance
- Real estate and rental and leasing
- Professional, scientific and technical services
- Management of companies and enterprises
- Administrative and support, waste management and remediation services
- Educational services
- Health care and social assistance
- Arts, entertainment and recreation
- Accommodation and food services
- Public administration / public service
- Other occupations

6.8 Which, if any, of the following political parties do you most identify with at the federal level?

- Conservative
- Liberal
- New Democratic Party (NDP)
- Bloc Québécois
- Green Party
- Undecided
- No political affiliation
- Other (please specify): _____

6.9 How often do you vote in elections?

- Never
- Sometimes
- Most of the time
- Always

6.10 Which of the following categories best describes the area where you live?

- Urban (city centre with dense housing)
- Suburban (just outside a city, with more spread out housing)
- Rural (far away from a city, with very spread out housing)

6.11 What is your postal code?

You have finished the survey!

Thank you for taking the time to complete the Canadian Home Heating Survey. We truly value the information you have provided. Your responses will contribute to our analysis and understanding of Canadians' preferences for home heating technologies.

Appendix B. Descriptive statistics and correlations for variables used in multiple linear regressions

Table B1. Descriptive statistics for variables used in multiple linear regressions.

	Air source heat pumps		Ground source heat pumps	
	Mean	Std. Deviation	Mean	Std. Deviation
Dependent variables				
Willingness to adopt air source heat pumps	3.13	1.06	ǂ ǂ	ǂ ǂ
Willingness to adopt ground source heat pumps	ǂ	ǂ	3.01	1.08
Main Variables				
Policy awareness (without cues)	n/a	n/a	n/a	n/a
Policy awareness (with cues)	1.32	1.34	1.32	1.34
Attitudinal variables				
Traditional values	4.46	0.53	4.46	0.53
Egoistic values	4.15	0.76	4.15	0.76
Biospheric values	3.26	0.79	3.26	0.79
Openness to change	3.80	0.79	3.80	0.79
Ecological Worldviews (NEP)	5.90	5.82	5.90	5.82
Policy Support	3.67	0.75	3.67	0.75
Technology-oriented lifestyle	1.63	0.86	1.63	0.86
Environment-oriented lifestyle	1.64	0.84	1.64	0.84
Contextual variables				
Knows a heat pump owner (reference: does not know a heat pump owner) HP owner_Yes	n/a	0.43	n/a	0.43
Familiarity with air source heat pumps	1.99	0.94	ǂ ǂ	ǂ ǂ
Familiarity with ground source heat pumps	ǂ	ǂ	1.97	0.91
Home Age	n/a	n/a	n/a	n/a
Energy Efficiency - Home has undergone energy efficient retrofits (reference: home has not undergone energy efficiency retrofits)	n/a	n/a	n/a	n/a
Air source heat pump symbolic characteristics (Factor 1)	0.00	0.94	ǂ ǂ	ǂ ǂ
Air source heat pump functional characteristics (Factor 2)	0.00	0.91	ǂ ǂ	ǂ ǂ
Air source heat pump installation characteristics (Factor 3)	0.00	0.95	ǂ ǂ	ǂ ǂ
Ground source heat pump Private-symbolic characteristics (Factor 1)	ǂ	ǂ	0.00	0.95

Ground source heat pump Societal-functional characteristics (Factor 2)	†	†	0.00	0.92
Ground source heat pump Installation characteristics (Factor 3)	†	†	0.00	0.96
Ground source heat pump Private-functional characteristics (Factor 4)	†	†	0.00	0.91
Ground source heat pump Symbolic-societal characteristics (Factor 5)	†	†	0.00	0.94
Socio-demographic variables				
Age	n/a	n/a	n/a	n/a
Income	n/a	n/a	n/a	n/a
Education	n/a	n/a	n/a	n/a
Gender - Female (reference: male)	n/a	n/a	n/a	n/a
Household Size	n/a	n/a	n/a	n/a
Province – Quebec (reference: Atlantic provinces††)	n/a	n/a	n/a	n/a
Province – Ontario (reference: Atlantic provinces††)	n/a	n/a	n/a	n/a
Province – Prairie Provinces††† (reference: Atlantic provinces††)	n/a	n/a	n/a	n/a
Province – Alberta (reference: Atlantic provinces††)	n/a	n/a	n/a	n/a
Province – British Columbia (reference: Atlantic provinces††)	n/a	n/a	n/a	n/a

† denotes a variable that was specific to ground source heat pumps, and therefore not used in air source heat pump regression

† † denotes a variable that was specific to air source heat pumps, and therefore not used in ground source heat pump regression

n/a denotes when means were not applicable due to being a binary, dummy, or ordinal variable.

Table B2. Correlation matrix for dependent and independent variables in air source heat pump multiple linear regression.

	Willingness to adopt	Policy awareness (without cues)	Policy awareness (with cues)	Traditional values	Biospheric values	Egoistic values	Openness to change	Policy support	Ecological worldviews	Technology-oriented lifestyle	Environment-oriented lifestyle	Knows a heat pump owner	Familiarity with air source heat pump	Home age	Energy Efficiency	Symbolic characteristics	Functional characteristics	Installation characteristics	Age	Income	Education	Gender – female (reference: male)	Household Size	Province – Quebec	Province – Ontario	Province – Prairie provinces	Province - Alberta	Province - British Columbia
Dependent variable																											
Willingness to adopt air source heat pumps	-																										
Main variables																											
Policy awareness without cues (reference: policy unaware respondents)	.09***	-																									
Policy awareness with cues	.07***	.20***	-																								
Attitudinal variables																											
Traditional values	.02	.02*	.01	-																							
Biospheric values	.14***	.02	-.01	.35***	-																						
Egoistic values	.06***	-.01	-.01	.30***	.25***	-																					
Openness to change	.15***	.05**	.04**	.16***	.32***	.41***	-																				
Policy Support	.27***	.05**	.06***	.03*	.35***	.10***	.21***	-																			
Ecological worldviews (NEP)	.15***	.02	.01	-.03**	.46***	.01	.17***	.45***	-																		
Technology-oriented lifestyle	.22***	.05**	.14***	.0**	.1***	.19***	.31***	.15***	.05***	-																	
Environment-oriented lifestyle	.22***	.05**	.13***	.04**	.47***	.17***	.28***	.36***	.37***	.44***	-																
Contextual variables																											
Knows a heat pump owner (reference: does not know a heat pump owner)	.09***	.11***	.13***	-.01	.05**	-.02	.07***	.02	.00	.16***	.13***	-															
Familiarity with air source heat pumps	.09***	.11***	.16***	.01	.03*	.02	.08***	.02	-.02	.23***	.12***	.41***	-														
Home Age	-.01	-.01	-.07***	-.08***	.05**	-.07***	.00	.02*	.09***	-.06***	.02	.05**	.02*	-													
Energy Efficiency - Home has undergone energy efficient retrofits	.03*	.02	.07***	-.02	.02	-.03*	.00	.04**	.03**	.02	.07***	.06***	.10***	.34***	-												

(reference: home has not)																															
Symbolic characteristics (Factor 1)	.28***	-.01	.03*	.06***	.29***	.29***	.22***	.43***	.27***	.22***	.36***	-.09***	-.06***	-.02	.01	-															
Functional characteristics (Factor 2)	.43***	.10***	.06***	.09***	.31***	.19***	.23***	.52***	.35***	.21***	.33***	.09***	.12***	.00	.01	.58***	-														
Installation characteristics (Factor 3)	-.15***	-.03**	.03**	.03**	-.05**	-.05**	-.06***	-.15***	-.05**	-.09***	-.08***	-.11***	-.12***	.05**	-.01	-.10***	-.12***	-													
Socio-demographic variables																															
Age	-.16***	.01	.00	.14***	.03**	-.03*	-.11***	-.11***	-.05**	-.15***	-.07***	.11***	.19***	.13***	.12***	-.16***	-.11***	.03**	-												
Income	.09***	.06***	.03**	-.05**	-.09***	.00	.11***	.06***	-.01	.13***	.02	-.01	.02*	-.14***	.00	.00	.00	-.11***	-.18***	-										
Education	.08***	.04**	.06***	-.10***	-.02*	-.02	.10***	.12***	.06***	.19***	.17***	.04**	.05**	-.03*	.01	.02*	.03**	-.09***	-.09***	.30***	-										
Gender - Female (reference: male)	-.01	-.02	-.08***	.04**	.12***	-.03**	-.06***	.08***	.09***	-.24***	.04**	-.12***	-.25***	.01	-.03*	.04**	.02	.06***	-.13***	-.10***	-.08***	-									
Household Size	.11***	.00	.02	.02	-.03**	.05**	.01	.05**	-.03**	.12***	.06***	-.06***	-.09***	-.13***	-.04**	.10***	.05**	-.03*	-.38***	.25***	.06***	.02	-								
Province – Quebec (reference:Atlantic provinces [†])	-.08***	.02	-.13***	.04**	.11***	.08***	.12***	.09***	.04**	.05**	.07***	.17***	.16***	.09***	-.03**	-.06***	.06***	-.04**	-.04**	-.03**	-.04**	-.05**	-.05**	-							
Province – Ontario (reference:Atlantic provinces [†])	.02	-.15***	-.15***	-.02	-.01	.00	.00	.00	.02	.02	-.02	-.18***	-.11***	.02	.04**	.06***	.01	.00	-.02*	.09***	.06***	.01	.06***	-.34***	-						
Province – Prairie Provinces [††] (reference:Atlantic provinces [†])	-.05**	-.05**	.09***	.00	-.03**	-.05**	-.06***	-.02*	-.02	-.08***	-.03**	-.03**	-.07***	.08***	.10***	.00	-.08**	.06**	.02	-.07***	-.05**	.04**	-.01	-.16***	-.27***	-					
Province – Alberta (reference:Atlantic provinces [†])	-.01	-.07***	.06***	-.02	-.08***	-.06***	-.04**	-.08***	-.09***	.01	-.03*	-.12***	-.14***	-.13***	-.04**	-.05**	-.13***	.02*	.01	.04**	.02*	-.01	.00	-.18***	-.31***	-.14***	-				
Province – British Columbia (reference:Atlantic provinces [†])	.04**	.26***	.23***	-.01	-.03*	.02	-.02	.01	.01	.00	.00	.06***	.07***	-.13***	-.07***	.03**	.06***	.00	.02	.01	.01	.01	.01	-.18***	-.30***	-.14***	-.16***	-			

* p < 0.10
** p < 0.05
*** p < 0.001

[†] "Atlantic provinces" refers to the Canadian provinces of Prince Edward Island, Newfoundland and Labrador, Nova Scotia, and New Brunswick.

[††] "Prairie provinces" refers to the Canadian provinces of Manitoba and Saskatchewan.

Table B3. Correlation matrix for dependent and independent variables in ground source heat pump multiple linear regression.

	Willingness to adopt	Policy awareness (without cues)	Policy awareness (with cues)	Traditional values	Biospheric values	Egoistic values	Openness to change	Policy support	Ecological worldviews	Technology-oriented lifestyle	Environment-oriented lifestyle	Knows a heat pump owner	Familiarity ground source heat pump	Home age	Energy Efficiency	Private-symbolic characteristics	Societal-functional characteristics	Installation characteristics	Private-functional characteristics	Societal-symbolic characteristics	Age	Income	Education	Gender – female (reference: male)	Household Size	Province – Quebec	Province – Ontario	Province – Prairie provinces	Province - Alberta	Province - British Columbia
Dependent variable																														
Willingness to adopt ground source heat pumps	-																													
Main Variables																														
Policy awareness without cues (reference: policy unaware)	.02	-																												
Policy awareness with cues	.06***	.20***	-																											
Attitudinal variables																														
Traditional values	-.02	.02*	.01	-																										
Biospheric values	.12***	.02	-.01	.35***	-																									
Egoistic values	.06***	-.01	-.01	.30***	.25***	-																								
Openness to change	.12***	.05**	.04**	.16***	.32***	.41***	-																							
Policy support	.25***	.05**	.06***	.03*	.35***	.10***	.21***	-																						
Ecological worldviews (NEP)	.15***	.02	.01	-.03**	.46***	.01	.17***	.45***	-																					
Technology-oriented lifestyle	.19***	.05**	.14***	.03**	.12***	.19***	.31***	.15***	.05**	-																				
Environment-oriented lifestyle	.19***	.05**	.13***	.04**	.47***	.17***	.28***	.36***	.37***	.44***	-																			
Contextual variables																														
Knows a heat pump owner (reference: does not know a heat pump owner)	-.05**	.11***	.13***	-.01	.05**	-.02	.07***	.02	.00	.16***	.13***	-																		
Familiarity with ground source heat pumps	-.02	.07***	.20***	-.05**	-.01	-.03**	.08***	.00	-.04**	.26***	.14***	.38***	-																	
Home Age	.00	-.01	-.07***	-.08***	.05**	-.07***	.00	.02*	.09***	-.06***	.02	.05**	.02	-																
Energy Efficiency - Home has undergone energy efficient retrofits (reference: home has not)	.02	.02	.07***	-.02	.02	-.03*	.00	.04**	.03**	.02	.07***	.06***	.13***	.34***	-															
Private-symbolic characteristics (Factor 1)	.27***	-.01	.02	.04**	.27***	.27***	.20***	.38***	.24***	.22***	.36***	-.05**	-.04**	-.02*	.01	-														
Societal- functional characteristics (Factor 2)	.34***	.06***	.06***	.05**	.34***	.18***	.22***	.54***	.41***	.22***	.38***	.05**	.04**	.03*	.03*	.63***	-													

Installation characteristics (Factor 3)	-.17***	.03**	.08***	.00	-.08***	-.09***	-.06***	-.10***	-.03*	-.04**	-.07***	.08***	.10***	.07***	.03*	-.18***	-.03*	-														
Private-functional characteristics (Factor 4)	.35***	.06***	.08***	.04**	.21***	.10***	.19***	.38***	.23***	.23***	.27***	.15***	.16***	.00	.01	.37***	.72***	.05**	-												
Symbolic-societal characteristics (Factor 5)	.24***	.00	.04**	.05**	.27***	.18***	.18***	.41***	.29***	.18***	.33***	-.05**	-.02	.00	.03**	.71***	.64***	-.10***	.35***	-											
Socio-demographic variables																															
Age	-.22***	.01	.00	.14***	.03**	-.03*	-.11***	-.11***	-.05**	-.15***	-.07***	.11***	.17***	.13***	.12***	-.16***	-.10***	.09***	-.08***	-.06***	-										
Income	.10***	.06***	.03**	-.05**	-.09***	.00	.11***	.06***	-.01	.13***	.02	-.01	.06***	-.14***	.00	.01	.01	-.05**	.02	.00	-.18***	-									
Education	.10***	.04**	.06***	-.10***	-.02*	-.02	.10***	.12***	.06***	.19***	.17***	.04**	.09***	-.03*	.01	.04**	.07***	-.04**	.04**	.04**	-.09***	.30***	-								
Gender - Female (reference: male)	.04**	-.02	-.08***	.04**	.12***	-.03**	-.06***	.08***	.09***	-.24***	.04**	-.12***	-.29***	.01	-.03*	.03*	.02	-.02	-.04**	.03**	-.13***	-.10***	-.08***	-							
Household Size	.15***	.00	.02	.02	-.03**	.05**	.01	.05**	-.03**	.12***	.06***	-.06***	-.06***	-.13***	-.04**	.10***	.05**	-.05**	.05**	.04**	-.38***	.25***	.06***	.02	-						
Province – Quebec (reference: Atlantic provinces†)	-.17***	.02	-.13***	.04**	.11***	.08***	.12***	.09***	.04**	.05**	.07***	.17***	.07***	.09***	-.03**	-.02	.03*	.07***	.07***	-.03**	-.04**	-.03**	-.04**	-.05**	-.05**	-					
Province – Ontario (reference: Atlantic provinces†)	.07***	-.15***	-.15***	-.02	-.01	.00	.00	.00	.02	.02	-.02	-.18***	-.07***	.02	.04**	.03**	.02*	-.04**	-.04**	.07***	-.02*	.09***	.06***	.01	.06***	-.34***	-				
Province – Prairie Provinces†† (reference: Atlantic provinces†)	-.02	-.05**	.09***	.00	-.03**	-.05**	-.06***	-.02*	-.02	-.08***	-.03**	-.03**	-.02	.08***	.10***	.01	-.02	.06***	-.02	.00	.02	-.07***	-.05**	.04**	-.01	-.16***	-.27***	-			
Province – Alberta (reference: Atlantic provinces†)	.06***	-.07***	.06***	-.02	-.08***	-.06***	-.04**	-.08***	-.09***	.01	-.03*	-.12***	-.06***	-.13***	-.04**	-.04**	-.08***	-.01	-.06***	-.03**	.01	.04**	.02*	-.01	.00	-.18***	-.31***	-.14***	-		
Province – British Columbia (reference: Atlantic provinces†)	.03**	.26***	.23***	-.01	-.03*	.02	-.02	.01	.01	.00	.00	0.06***	.05**	-.13***	-.07***	.02*	.03**	-.04**	.03**	.01	.02	.01	.01	.01	.01	-.18***	-.30***	-.14***	-.16***	-	

* p < 0.10
** p < 0.05
*** p < 0.001

† "Atlantic provinces" refers to the Canadian provinces of Prince Edward Island, Newfoundland and Labrador, Nova Scotia, and New Brunswick.
†† "Prairie provinces" refers to the Canadian provinces of Manitoba and Saskatchewan.