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# Characterizing air source heat pump market segments: A Canadian case study

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Electric air source heat pumps (ASHPs) appear to be a key technology for decarbonizing space heating in existing residential buildings, yet their current market share in much of North America remains low. To explore how the potential future ASHP market may differ from the present one, we use a subset of data from the *Canadian Home Heating Survey* ($n$ = 461) to provide a comprehensive characterization of three market segments of British Columbian homeowners: Pioneers (heat pump owners), Potential Early Mainstream buyers (homeowners currently willing to purchase an ASHP), and Late Mainstream buyers (homeowners currently unwilling to purchase an ASHP). We assess variable associations with market segments according to the Attitude-Behavior-Context theory, which posits that pro-environmental behavior is shaped by attitudinal, contextual, and socio-demographic factors. We also compare how market segmentation changes before and after respondents receive technical information on different home heating systems. Relative to Pioneers and the Potential Early Mainstream (PEM), we find that the Late Mainstream (LM) are generally lower income, lower educated, less environmentally- and technologically-oriented in their lifestyles, less open to change, less familiar with heat pumps and home energy efficiency, more negative in their perceptions about heat pumps, and less aware and supportive of policies aimed at reducing residential emissions. We also find that after respondents read technical information about home heating systems, approximately 10% of heat pump non-owners shift from the LM to the PEM; however, within the PEM, there is little growth in high willingness to adopt.

KEYWORDS

**heat pump, home heating, market segmentation, residential decarbonization, climate policy, attitude-behavior-context theory**

## Introduction

Hundreds of millions of households around the world use fossil fuels to warm their homes during the cold season. An essential piece of the global decarbonization challenge is shifting these households away from fossil fuels toward zero emission alternatives. A key pathway in this transition is to electrify home heating, replacing furnaces and boilers with electric alternatives such as resistance heating and heat pumps. Recent energy-economy modeling studies have identified heat pumps in particular as important technologies for decarbonizing

existing residential buildings (Bataille et al., 2015; IEA, 2019; Dion et al., 2021). Likewise, leading scholars, environmental organizations, and governments worldwide have identified these emerging technologies as instrumental in the low-carbon transition (IEA, 2020).

There are two primary types of electric heat pumps: air source heat pumps (ASHPs) and ground source heat pumps (GSHPs). ASHPs draw heat from the outside air while GSHPs draw heat from below ground. Heat pumps have an advantage over electric resistance heating in that they can deliver more heat per unit of electricity input. For example, with 1 kWh of electricity input, a heat pump can extract and deliver ∼3kWh of heat from the ambient air or ground to the inside of a home (depending on conditions), reducing energy use and thus operating costs. Due to their underground installations however, GSHPs tend to require much higher installed capital costs relative to ASHPs, especially in existing buildings, and both of these usually have substantially higher installation costs than resistance heating.

Recognizing their emissions and energy use savings, national, sub-national, and local governments in North America and Europe have introduced policies aimed at incentivizing ASHP adoption. The Canadian province of British Columbia (BC) for example has introduced information programs, loans, and subsidies for ASHP purchases and installations, as well as carbon taxation and natural gas regulations that increase the costs of operating heating systems fueled by natural gas or oil (Government of BC., 2021a). Relative to other Canadian provinces, BC is particularly well-suited for rapid ASHP adoption in existing buildings. The bulk of BC's population resides in a relatively mild climate suitable for standard ASHP use while other regions of Canada often require more expensive "cold climate" versions of the technology. BC citizens also rank highly in their relative concern for the environment and combatting climate change (Rhodes et al., 2014). And in addition to the policies mentioned above, the BC Government and the City of Vancouver are also introducing zero emission new building regulations that may have positive spillover effects for heat pump adoption in existing buildings (City of Vancouver., 2020; Government of BC., 2021a).

Even with its mild climate, climate-concerned citizenry, and history of climate policy, BC's current heat pump market is small, with less than 10% of households using the technology (Government of BC., 2021b). Prominent modeling studies indicate that this market share needs to rise to approximately 40% by 2040 and over 60% by 2050 for BC to meet its net-zero by 2050 target (Dion et al., 2021). Policies implemented to date have not been sufficient to drive widespread heat pump adoption in existing buildings (Carlson, 2022).

To design and implement more effective policies for promoting heat pump adoption, it is important to understand how heat pump market segments differ. A market segment is a group of consumers who share one or more definable characteristics. For example, a common way of delineating market segments is to compare consumers of interest (e.g., potential heat pump owners) to other consumers in the market (e.g., current heat pump owners). Understanding market segmentation allows policymakers to craft policy messaging to specific groups, target policies to key demographics, and outline the scope of the challenge in decarbonizing a sector (Axsen et al., 2015). Unlike the zero-emission vehicle and rooftop solar literatures, which have a rich history of market segmentation evaluation, we are unaware of similar academic research for heat pumps.

A common goal of government policy is to shift the market segmentation of a particular pro-environmental technology of interest. For example, a policy may aim to move individuals from a "heat pump disinterested" market segment to a "heat pump interested" one. It is currently not well understood how heat pump information programs influence market composition. Information programs, or education materials more generally, are one of the most common policies for encouraging voluntary heat pump purchases and installments–particularly at the local government level–and they are often paired alongside subsidy and financing programs. Information can be in the form of mail pamphlets, TV commercials, or online ads that detail the technical, financial, or environmental advantages of using heat pumps. Although they continue to be promoted by governments at all levels, to date, there is no empirical research on how information influences willingness to adopt heat pumps and market composition.

In this study, we use data from an online survey of British Columbian homeowners to assess how ASHP market segments differ from each other across an array of attitudinal, contextual, and socio-demographic factors relevant to policymaking. We compare these groups both before and after individuals receive information about home heating systems to assess how this information provision influences the size and composition of these segments. We conclude by highlighting key findings, identifying areas for future research, and summarizing takeaways for policymakers.

The research questions for this study are as follows:

(1) How do air source heat pump market segments in southern British Columbia differ in terms of attitudinal, contextual, and socio-demographic factors?
(2) How does the composition of these groups change after individuals receive information about home heating systems?
(3) What are the potential policy implications when considering the size and composition of these groups?

# Literature review

## Market segmentation

Traditionally, research has focused on "innovativeness" as the key metric for pro-environmental technology market segmentation (Peters and Dütschke, 2014). Rogers (2010) "diffusion of innovations" model is a prominent framework that segments buyers into innovators, early adopters, early majority, late majority, and laggards. The only published study to date on home heating market segmentation uses this framework to assess Italian consumer classes for low emission heating technologies (Franceschinis et al., 2017). While the "diffusion of innovations" model is popular, it has been criticized for focusing too heavily on technological innovativeness and being too limited in its representation of other human motives (Axsen and Kurani, 2012). Other factors, such as environmental, economic, and social motivations may also play a role (Heffner et al., 2007). More recently, researchers have used more holistic measures of market segmentation, such as Axsen et al.'s (2016) "Pioneers" (current owners), "Potential Early Mainstream" (consumers interested in adopting), and "Late Mainstream" (consumers not interested in adopting) categorization for zero-emission vehicle buyers.

This "Pioneers" vs. "Mainstream" framing has been used by several studies assessing pro-environmental technology market segmentation, primarily in the zero-emission vehicle and rooftop solar research fields (Axsen and Kurani, 2013; Tal and Nicholas, 2013; Axsen et al., 2016; Palm, 2020). No study to date has used this framing for assessing how heat pump owner Pioneers differ from households that are willing to purchase a heat pump (Potential Early Mainstream) or households not willing to purchase a heat pump (Late Mainstream). Governments often use subsidies, loans, and education campaigns to try and promote heat pump adoption. A lack of knowledge on the types of households that belong to Pioneer, Potential Early Mainstream, and Late Mainstream groups may be leading to low subsidy and loan uptake, high free-ridership in subsidy and loan allocation, and suboptimal policy communication messaging and delivery. It also may hinder the ability to predict how different households will respond in both their purchasing behaviors and political support and opposition to incentive, pricing, and regulatory policies.

In addition to mostly ignoring market segmentation (and market heterogeneity in general), previous studies on heat pump adoption motivations are also limited by a focus on a narrow set of explanatory variables. There are many variables that may influence a household's willingness to adopt heat pumps and thus their market segment membership. Previous research, which has a strong European focus, finds that household income, education, and concern for the environment are positively associated with a preference for heat pumps and bio-energy powered systems (e.g., Willis et al., 2011; Michelsen and Madlener, 2012). Some studies also find that living in a detached house is negatively associated with heat pumps, as is house age (e.g., Meles et al., 2019; Troiano et al., 2019). No study, however, incorporates behavioral factors such as trust in institutions, heat pump perceptions, technology- and environmental-oriented lifestyles, and policy awareness and support. These explanatory variables have all be found to be highly significant predictors of technology adoption in assessments of other pro-environmental technologies (Castelfranchi and Falcone, 2010; van der Werff et al., 2013; Kormos et al., 2019).

## Conceptual framework

Pro-environmental behavior, such as adopting a zero-emission technology like a heat pump, can be shaped by multiple "internal" attitudinal and "external" contextual motivations (Wüstenhagen et al., 2007; Hujits et al., 2012). Attitudinal motivations include values, cognitive and affective beliefs, and personal norms that are "internal" to the individual. Contextual motivations include social norms and economic, technology-, and policy-specific contexts (Clark et al., 2003).

To explore the relative importance of these motivations, researchers draw from various theoretical frameworks of pro-environmental behavior (Jackson, 2005). One line of behavioral research focuses primarily on attitudinal motivations by employing "internalist" frameworks, such as the Theory of Planned Behavior, Norm Activation Theory, and Value-Belief-Norm Theory (Ajzen, 1991; Schwartz, 1992; Stern, 1999). These frameworks tend to be weak predictors of behaviors that are constrained by financial, infrastructural, and social factors (Bamberg and Schmidt, 2003; Sopha and Klöckner, 2011). Another line of behavioral research focuses only on "external" factors of behavior such as technical, economic, cultural, and political motivations. Cultural Theory (Thompson et al., 1990), Diffusion of Innovation Model (Rogers, 2010), and Consumer Perceived Value Theory (Eggert and Ulaga, 2002) are examples of "externalist" frameworks that, in contrast to the "internalist" insights, may under appreciate many attitudinal factors in explaining pro-environmental technology adoption.

Most existing studies on heat pump adoption address limited subsets of "external" contextual motivations in isolation from "internal" attitudinal motivations. For example, Rouvinen and Matero (2013), Michelsen and Madlener (2016), and Troiano et al. (2019) study economic, spatial, and home-specific characteristics without considering consumer values and beliefs that may also play a role in shaping preferences for residential heating technology (Sopha and Klöckner, 2011). As a result, studies such as these are not comprehensive and may lack usefulness for effective policymaking.

To assess a holistic set of consumer motivations pertinent to heat pump adoption, we employ an integrative behavioral

framework that combines insights from both the "internalist" and "externalist" approaches. Specifically, we apply Stern's (2000) Attitude-Behavior-Context (ABC) theory to assess a set of variables potentially influencing the market segmentation of heat pump Pioneers, Potential Early Mainstream buyers, and Late Mainstream buyers. ABC theory is among a few integrative models that incorporates both "internal" and "external" characteristics of pro-environmental behavior, which Stern (2000) refers to as attitudinal, contextual, personal capability, and habitual variables. ABC theory has been specifically developed for application in studying pro-environmental behavior and been in use for over 35 years, capturing the evolving nature of pro-environmental behavior research (Ertz et al., 2016).

ABC theory has been applied to a wide array of pro-environmental behavior assessments including GHG policy support (Rhodes et al., 2014, 2015, 2017), low-emission vehicle adoption (He et al., 2021), recycling behavior (Guagnano et al., 1995), organic and local food consumption (Nie and Zepeda, 2011), and energy use and efficiency improvements (Black et al., 1985; Xu et al., 2017), among others. The theory has not yet been applied as a framework for comparing household characteristics across home heating or heat pump market segments. For this reason, the hypothesis is that all types of motivations—attitudinal, contextual, and personal capability motivations—will be associated with consumer willingness to adopt heat pumps and thus market segmentation. Unlike many everyday environmental decisions, purchasing a heat pump is not a routine or habitual behavioral; for this reason, habitual factors have been excluded in this study.

Attitudinal factors, including values, beliefs, personal norms, and lifestyles, have been stable predictors of pro-environmental behaviors (Dahlstrand and Biel, 1997; Dietz et al., 2005). In this study, we include the attitudinal factors of values, ecological worldviews, ascription of climate change responsibility, belief in consequences of climate change, trust in institutions, environmental- and technology-oriented lifestyles, government policy support, and technology perceptions. These factors have been included as attitudinal variables in ABC theory frameworks in previous research (Rhodes et al., 2017; He et al., 2021). Altruistic, biospheric, and openness to change values are often found to be positive predictors of pro-environmental behavior, while traditional and egoistic values are often found to be negative predictors (Dietz et al., 2005; Axsen et al., 2016; Long et al., 2019). Ecological worldviews and beliefs in the human causes and adverse consequences of climate change are typically associated with higher participation in pro-environmental behaviors, including decisions to purchase a low-carbon technology, such as an electric vehicle or heat pump (Kormos et al., 2019; Meles et al., 2019).

Trust in governments, scientists, and zero-emission technology manufacturers appears to play an important role in shaping pro-environmental technology adoption decisions (Kitt et al., 2021). Having technological- and environmental-oriented lifestyles has also been positively associated with willingness to adopt EVs and ground source heat pumps (Axsen et al., 2012; Karytsas and Theodoropoulou, 2014). An association between willingness to adopt heat pumps and support for heat pump-incentivizing policies has not been previously assessed, although support for GHG reducing policies has been found to be associated with other factors associated with pro-environmental behavior such as values and worldviews (Rhodes et al., 2017; Long et al., 2020). In terms of heat pump technology perceptions, positive views on heat pump capital costs, operating costs, environmental benefits, operating ease, and thermal performance have all been associated with willingness to adopt heat pumps (Karytsas and Choropanitis, 2017; Karytsas, 2018).

The second category of factors in the ABC model is contextual variables, including social, economic, technology-, and policy-specific characteristics (He et al., 2021). In this study, we incorporate the contextual factors of home type, age, size, and energy efficiency; heating system type, age, fuel source, operational costs, and presence of a secondary system; air conditioner type; heat pump familiarity; knowing someone with a heat pump; and policy awareness. Dwelling and existing heating system attributes are among the key home-specific characteristics associated with consumer decisions to switch to a renewable energy heating technology (Michelsen and Madlener, 2012; Wilson et al., 2018; Lang et al., 2021). Knowing someone who owns a heat pump has been positively associated with the willingness to adopt the technology (Karytsas, 2018). Policy characteristics such as existence and awareness of policy incentives have explained willingness to adopt pro-environmental technologies in previous research (Rouvinen and Matero, 2013; Lang et al., 2021).

The third category of variables in the ABC theory is personal capability, which includes variables generally assessed through socio-demographic characteristics (Stern, 2000). For personal capability variables, we include gender, age, education level, income, household size, urban/rural location, political party affiliation, and voting frequency in our framework (Rhodes et al., 2014; He et al., 2021). Younger, wealthier, more educated, and female consumers tend to have higher willingness to adopt a pro-environmental technology, including zero-emission heating technologies (Mahapatra and Gustavsson, 2009; Michelsen and Madlener, 2016; Meles et al., 2019). An individual's regional location tends to determine heating technology decisions. Regions that are rural, heavily dependent on carbon intensive industries, and/or have colder climates are less likely to adopt a low-emission heating technology (Braun, 2010; Michelsen and Madlener, 2012).

Stern expanded on the ABC theory to incorporate the relationship between awareness of government policies and pro-environmental behavior (Stern, 1999). This extension of the ABC model is supported by the Knowledge Deficit Model, which

TABLE 1 Socio-demographics of sample compared to Canada Census data for British Columbia.

| Socio-demographic variables | Sample % | Census %* |
|---|---|---|
| Gender (%) | | |
| Male | 57.7 | 49.1 |
| Female | 42.3 | 50.9 |
| Age (%) | | |
| 19–24 | 2.4 | 7.3 |
| 25–34 | 10.6 | 17.3 |
| 35–44 | 10.4 | 16.7 |
| 45–54 | 17.4 | 15.9 |
| 55–64 | 23.0 | 17.7 |
| 65 and over | 36.2 | 25.2 |
| Household size (%) | | |
| 1 person | 11.1 | 29.4 |
| 2 people | 49.7 | 35.3 |
| 3 people | 16.3 | 14.5 |
| 4 people | 15.2 | 12.6 |
| 5 or more people | 7.8 | 8.2 |
| Education (%) | | |
| No certificate, diploma, or degree | 0.9 | 9.6 |
| High school certificate or equivalent | 14.1 | 26.5 |
| Apprenticeship or trades certificate or diploma | 8.0 | 9.1 |
| College, CEGEP, or non-university certificate | 17.4 | 20.9 |
| University certificate below Bachelor level | 8.5 | 3.9 |
| Bachelor's degree | 30.6 | 19.7 |
| University certificate above Bachelor level | 7.4 | 2.1 |
| Degree in medicine, veterinary, or optometry | 0.9 | 0.8 |
| Master's degree | 10.0 | 6.3 |
| Doctorate or PhD | 2.4 | 1.0 |
| Income (%) | | |
| < $50,000 | 15 | 35.3 |
| $50,000–$99.999 | 39.7 | 32.4 |
| $100,000–$149,999 | 27.6 | 17.9 |
| $150,000–$199,999 | 12.8 | 7.9 |
| > $200,000 | 4.8 | 6.5 |

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

posits that providing information to individuals will translate into behavior change (Miller, 2001). There is some evidence that technical familiarity with low-carbon heating systems is associated with ground source heat pump adoption (Karytsas and Theodoropoulou, 2014). We therefore hypothesize that a lack of knowledge about home heating systems (including heat pumps) may impede willingness to adopt ASHPs. We expect that distribution of technical information on home heating systems will increase willingness to adopt heat pump, shifting respondents from the Late Mainstream to the Potential Early Mainstream.

## Methods

This study uses data collected from the *Canadian Home Heating Survey*, a 35-minute online survey administered in the summer of 2021. Respondents were Canadians over the age of 19 that own and reside in a detached home, semi-detached home, townhouse, or duplex. This study focuses on a subset of the data: 461 respondents that live in Climate Zones 4 and 5 of British Columbia as defined in the BC Building Code (Government of BC., 2015a,b). Climate Zone 4 encompasses areas that experience less than 3,000 average heating degree days (HDD) below 18 degrees Celsius annually, while Climate Zone 5 experiences 3,000 to 3,999 HDD per year. Seventy-five percent of our respondents reside in Climate Zone 4 while 25% reside in Climate Zone 5. Most respondents reside in the urban areas around the cities of Vancouver and Victoria. Fifty-five percent reside in Metro Vancouver and 24% reside on Vancouver Island, with the remainder being distributed across Southern British Columbia including the Okanagan, Fraser Valley, and other regions.

Compared to Canada Census data for British Columbia, our sample was relatively more male-represented, older, living in smaller households, more educated, and higher-earning (Table 1). However, because our sample consisted of homeowners over the age of 19, these differences are not unexpected. Our sample was intended to be representative of homeowners, not the general public. Corrective weights were not applied to any variables that diverged from Census averages because these deviations likely represent true differences between homeowners and the general population.

Respondents were sorted into Pioneer, Potential Early Mainstream (PEM), and Late Mainstream (LM) market segments based on two criteria: (1) their current space heating system, and (2) their answer to the following question adapted from Rhodes et al. (2014): *"How willing would you be to buy an air source heat pump when your existing home heating system needs to be replaced?"*. This question was asked near the beginning of the survey after respondents provided information on their household, home, and home energy system. Response categories included "very unwilling", "unwilling", "undecided", "willing", and "very willing".

Segmentation protocol was adapted from Axsen et al. (2016). A respondent was sorted into the Pioneers segment if they stated that they owned an air source or ground source heat pump as their primary or secondary home heating system. Respondents were sorted into the PEM segment if they did not own a heat pump and they answered "willing" or "very willing" to the above willingness question. Respondents were put in the LM segment if they did not own a heat pump and answered "undecided", "unwilling", or "very unwilling" to the above question.

Statistical tests were used to explore how respondent personal capability, contextual, and attitudinal variables were associated with Pioneers, PEM, and LM market segmentation.

TABLE 2 List of policies and policy 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). |
| 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, and/or pay a fine. |

Supplementary Table 1 contains a list of the variables evaluated in this study, including how individual variables were measured in the survey, where they were sourced, how they were statistically analyzed, as well as their hypothesized relationship with segmentation. Variables were chosen for inclusion in the analysis after thorough literature review of both heat pump and other pro-environmental technology adoption literature, as well as consultations with senior and local governments in Canada. We statistically analyzed the bivariate associations of these variables with segmentation for each variable in question using analysis of variance (ANOVA; continuous data) or chi-square (nominal data) tests to assess whether significant differences exist among consumer segments. If a variable was found to significantly differ across groups, *post-hoc* tests were applied to determine which segments differed from each other. Specifically, Tukey HSD tests were applied to ANOVA results and z-tests with Bonferonni adjustment were applied to chi-square results.

Several variables in Supplementary Table 1 require additional context on how they were measured in the survey and/or prepared for statistical analysis. To measure the contextual variable of policy awareness, respondents were given a list of real and "fake" policies in their province, along with brief policy descriptions (Table 2). This list was created from a review of current announced and implemented policies across Canada. Responses 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. For the policy support variable, respondents were asked if they would support or oppose each of the policies in Table 2 if they were to cast a hypothetical vote on these policies being implemented through a referendum. To measure the attitudinal variable of heat pump technology perceptions, we asked respondents how much they agreed with a series of statements regarding an air source heat pump purchase and installation in their house. Response categories ranged from "strongly disagree" to "strongly agree".

Home energy efficiency familiarity was measured by asking respondents about their familiarity with four home features: wall insulation, windows, heating system, and water heater (Jaccard and Dennis, 2006). A home energy efficiency familiarity score was calculated for each respondent by averaging familiarity scores across these four features. Similarly, home energy efficiency was measured by asking respondents whether their home had the following features: energy-saving exterior wall insulation, energy-saving interior wall insulation, double- or triple-paned windows, weather-stripping on exterior doors, and programmable thermostat. A home energy efficiency score was calculated for each respondent by averaging scores across these five efficiency features.

To explore how information provision about home heating systems influences Pioneers, PEM, and LM segmentation, respondents were asked the above willingness question twice, once at the beginning of the survey (as described above) and once near the end of survey after they read a home heating technology guide. The guide consisted of lists of

factual information about home heating systems (furnaces, boilers, air source heat pumps, ground source heat pumps, baseboard heaters) appropriate for replacing respondents' current home heating systems. Pioneers, PEM, and LM market segmentation was formed using this second instance of the willingness question (i.e. post-information) and then compared to segmentation pre-information to explore how information influences household stated willingness to adopt ASHPs.

# Results

## Market segmentation

Seventy-three of our 461 respondents were owners of heat pumps, forming the Pioneers market segment and accounting for 15.8% of the sample. Fifty-five respondents were owners of ASHPs, while 18 owned ground source versions of the technology. In British Columbia, approximately 10% of households own a heat pump (Government of BC., 2021b). The reason why heat pump owners were overrepresented in our sample is likely because the *Canadian Home Heating Survey* included a 200-respondent oversample of heat pump owners across Canada. Some of this oversampling occurred in BC, resulting in a higher-than-representative rate of heat pump ownership for the province. Also, our study focuses on respondents from southern BC, excluding those from northern regions. It is likely that heat pump ownership rates are higher in southern BC than northern BC due to factors such as cost, availability, and climate conditions.

The Potential Early Mainstream market segment, comprised of "willing" and "very willing" heat pump non-owners, accounted for 33.0% of the sample (152 respondents). The Late Mainstream segment, consisting of "undecided", "unwilling", and "very unwilling" respondents, accounted for 51.2% of the sample (236 respondents). In the heat pump non-owner subset of the sample (i.e., PEM and LM segments), 13% answered that they would be "very willing" to purchase an ASHP when their current heating system needs to be replaced, while 26% stated they would be "willing". Forty-six percent of respondents stated they were "undecided", 9% stated they were "unwilling", and 6% stated they were "very unwilling".

## Personal capability variables

Chi-square analysis reveals that gender, age, education level, income level, household size, and location all significantly varied across Pioneers, PEM, and LM groups, as did voting frequency as assessed by ANOVA (Table 3). There was no significant difference across groups in political party affiliation. The LM have a higher proportion of female individuals compared to

TABLE 3 Comparison of market segments across personal capability variables.

| Personal capability variables | Pioneers | Potential Early Mainstream (PEM) | Late Mainstream (LM) |
|---|---|---|---|
| *Sample size* | 73 | 152 | 236 |
| Gender (%)** | | | |
| Male | 65.8 | 62.5 | 52.1 |
| Female | 34.2[a] | 37.5[b] | 47.9[ab] |
| Age (%)* | | | |
| 19–24 | 2.7 | 3.3 | 1.7 |
| 25–34 | 13.7 | 12.5 | 8.5 |
| 35–44 | 6.8 | 14.5 | 8.9 |
| 45–54 | 11 | 19.1 | 18.2 |
| 55–64 | 19.2 | 21.7 | 25 |
| 65 and over | 46.6[a] | 28.9[a] | 37.7 |
| Education (%)** | | | |
| Other | 11 | 9.9[a] | 19.5[a] |
| College, CEGEP, or non-university diploma | 42.5 | 30.3 | 33.5 |
| University degree (Bachelor) | 32.9 | 41.4 | 37.3 |
| Graduate or professional degree | 13.7 | 18.4[b] | 9.7[b] |
| Income (%)* | | | |
| < $50,000 | 9.2 | 9.4[a] | 20.5[a] |
| $50,000–$99.999 | 43.1 | 34.8 | 41.9 |
| $100,000–$149,999 | 30.8 | 30.4[b] | 24.8[b] |
| > $150,000 | 16.9 | 25.4 | 12.9 |
| Household size (%)* | | | |
| 1 person | 6.8 | 9.2 | 13.6 |
| 2 people | 50.7 | 42.8 | 53.8 |
| 3 people | 15.1 | 19.1 | 14.8 |
| 4 people | 16.4 | 21.7[a] | 10.6[a] |
| 5 or more people | 11 | 7.2 | 7.2 |
| Location (%)** | | | |
| Urban | 38.4 | 42.1 | 36.4 |
| Suburban | 41.1 | 49.3 | 55.9 |
| Rural | 20.5[ab] | 8.6[a] | 7.6[b] |
| Voting frequency (mean score, 0–3)*** | 2.77[a] | 2.76[b] | 2.45[ab] |

For chi-square analyses, matching superscript letters (e.g., a, b) denote which column proportions significantly differ from one another at a 0.05 level, as determined by z-tests using Bonferroni-adjusted *p*-values. For ANOVA, matching superscript letters (e.g., a, b) denote which means significantly differ from one another, as determined by Tukey HSD *post-hoc* testing.

*Significant at a 90% confidence level.

**Significant at a 95% confidence level.

***Significant at a 99% confidence level.

Pioneers and the PEM. They also vote less frequently, scoring on average as voting "most of the time" while Pioneers and the PEM score nearer to voting "always".

The PEM are more likely to have received a higher level of education than the LM. *Post-hoc* z-tests reveal that the PEM have a higher proportion of individuals that have received graduate and professional degrees, while the LM have a higher proportion of individuals with a high school degree or no degree as their highest level of education. A similar pattern emerges for household income. The PEM have a higher proportion of respondents earning between $100,000 and $150,000, while the LM have a higher rate of respondents in the $50,000 and less income bracket. The PEM also tend to live in larger households than the LM, scoring particularly high in four-person households.

Our sample of Pioneers tend to be older than the PEM, with a higher proportion of individuals in the 65 and over age bracket. They also tend to be more rurally located than the other two groups.

## Contextual variables

### Housing and heating system

Pioneers, PEM, and LM segments are unique in their housing and heating system characteristics (Table 4). Chi-square analysis reveals that home type, home age, knowing someone with a heat pump, and shopping status for a new home heating system all significantly varied across Pioneers, PEM, and LM segments. Similarly, ANOVAs find that home size, home energy efficiency, familiarity with home energy efficiency features, and familiarity with ASHPs significantly differ across the three groups. There was no significant difference in the following variables: home ownership time, expected home ownership time, presence of a rental unit, heating system type, heating system fuel type, secondary heating system type, reported heating costs, or air conditioner type.

Relative to the LM, Pioneers live proportionally more in detached homes and less in townhouses. They also tend to live in newer homes, particularly more in 2000–2010 era homes relative to the LM. Pioneers live in significantly larger homes than both the PEM and LM: 314 $ft^2$ larger on average than the PEM and 224 $ft^2$ larger than the LM. They also self-report the energy efficiency of their homes to be higher than the other two groups. On average, Pioneers state their homes have three to four of the five home energy efficiency features we listed in the survey, the PEM have approximately three, and the LM have two to three.

Pioneers score highest in their familiarity with home energy efficiency features (wall insulation, windows, heating system, and water heater), followed by the PEM, and then the LM. This

TABLE 4 Comparison of market segments across housing and heating system contextual variables.

| Contextual variables | Pioneers | PEM | LM |
|---|---|---|---|
| Home type (%)** | | | |
| Detached | 77.6[a] | 69.1 | 63.1[a] |
| Semi-detached | 6.6 | 5.3 | 3.4 |
| Townhouse | 9.2[b] | 21.7 | 30.1[b] |
| Duplex | 6.6 | 3.9 | 3.4 |
| Home age (years)*** | | | |
| Pre-1950 | 2.8 | 5.3 | 3 |
| 1950–1959 | 1.4 | 2.7 | 6 |
| 1960–1969 | 0 | 2.7 | 6.8 |
| 1970–1979 | 11.3 | 18.7 | 15 |
| 1980–1989 | 8.5 | 20 | 18.4 |
| 1990–1999 | 22.5 | 19.3 | 22.2 |
| 2000–2010 | 28.2[a] | 18 | 13.7[a] |
| 2011–2021 | 25.4 | 13.3 | 15 |
| Home size ($ft^2$)** | 2,372[ab] | 2,058[b] | 2,038[a] |
| Home energy efficiency (mean score, 0–5)*** | 3.66[ab] | 2.91[a] | 2.66[b] |
| Home energy efficiency familiarity (mean score, 0–16)*** | 11.15[a] | 10.05[a] | 9.12[a] |
| Primary heating system (%) | | | |
| Furnace | N/A | 66.7 | 56.2 |
| Boiler | N/A | 8 | 12.9 |
| Electric baseboard heaters | N/A | 20.7 | 23.6 |
| Other | N/A | 4.7 | 7.3 |
| Secondary heating system (%) | | | |
| Furnace | N/A | 1.3 | 0.9 |
| Boiler | N/A | 2 | 1.3 |
| Electric baseboard heaters | N/A | 14.8 | 13.3 |
| Other | N/A | 46.3 | 38.1 |
| None | N/A | 35.6 | 46.5 |
| Space heating fuel type (%) | | | |
| Natural gas | N/A | 67.1 | 66 |
| Electricity | N/A | 30.9 | 30.2 |
| Other | N/A | 2 | 3.8 |
| Currently shopping for new heating system (%)*** | | | |
| Yes | 23.3[a] | 34.2[b] | 10.6[ab] |
| No | 76.7[c] | 65.8[d] | 89.4[cd] |
| Know someone with a heat pump (%)*** | | | |
| Yes | 66.7[a] | 40.8[a] | 24.7[a] |
| No | 33.3[b] | 59.2[b] | 75.3[b] |
| Air source heat pump familiarity (mean score, 0–3)*** | 1.93[a] | 1.47[a] | 0.94[a] |

For chi-square analyses, matching superscript letters (e.g., a, b) denote which column proportions significantly differ from one another at a 0.05 level, as determined by z-tests using Bonferroni-adjusted *p*-values. For ANOVA, matching superscript letters (e.g., a, b) denote which means significantly differ from one another, as determined by Tukey HSD *post-hoc* testing.

*Significant at a 90% confidence level.

**Significant at a 95% confidence level.

***Significant at a 99% confidence level.

pattern is also observed in knowing someone with a heat pump and heat pump familiarity variables. Pioneers are more likely to know a heat pump owner than the two heat pump non-owner groups, and the PEM are more likely to know a heat pump owner than the LM. Pioneers score higher in ASHP familiarity than the PEM and LM, with the PEM scoring higher than the LM in this variable. In addition to being less familiar with ASHPs, the LM are less likely to be currently shopping for a home heating system relative to Pioneers and the PEM.

### Policy awareness

Market segments significantly differed from each other in policy awareness for all seven policies evaluated (Figure 1). Compared to Pioneers and the PEM, the LM have lower awareness of technology subsidies, loans, and information programs. They also have lower awareness of retrofit subsidies, carbon taxation, renewable natural gas mandates, and building emissions regulation relative to the PEM.

On average, the carbon tax was the policy most often identified correctly by respondents (73.1% correct responses), followed by retrofit subsidies (61.4%) and technology subsidies (52.9%). Respondents showed the lowest level of awareness for the RNG mandate (15.6%) and building emissions regulation (15.6%), two policies that are under development but not yet fully implemented in BC. For both of these policies, over 70% of respondents answered "I don't know" to the question of whether the policy was implemented in their province.

## Attitudinal variables

### Lifestyles, values, and trust

ANOVAs reveal that levels of environmental- and technology-oriented lifestyles, openness to change, and trust in the renewables industry all significantly varied across the Pioneers, PEM, and LM segments (Table 5). *Post-hoc* analyses find that the LM score significantly lower than both Pioneers and the PEM in environmental- and technology-oriented lifestyles and trust in the renewables industry. The LM are also less open to change than the PEM.

There were no significant differences between groups for altruistic, biospheric, egotistic, and traditional values. There were also no significant differences across other environmental

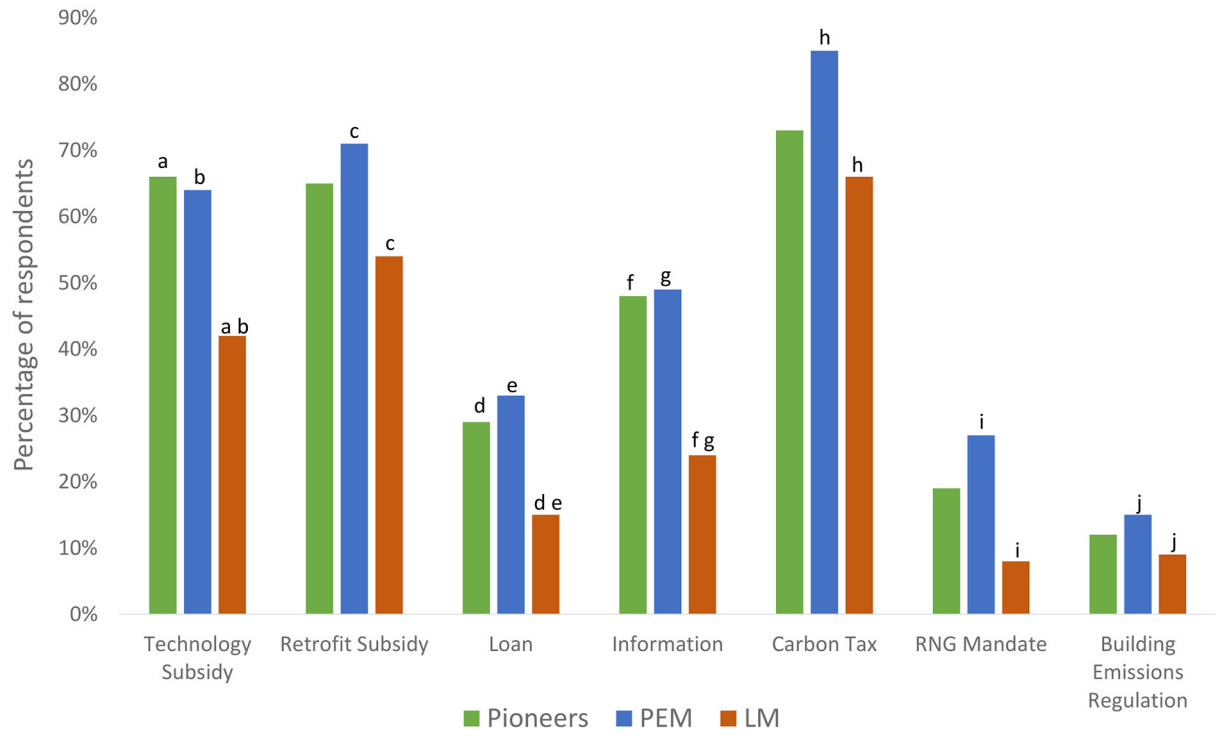


FIGURE 1
Percentage of respondents correctly aware of provincial government policies for Pioneers, Potential Early Mainstream (PEM), and Late Mainstream (LM) market segments. Chi-square analyses finds differences between groups for all policies at a 99% confidence level. Matching letters (e.g., a, b) above bar lines denote which segment proportions significantly differ from one another at a 0.05 level for each individual policy, as determined by z-tests using Bonferroni-adjusted *p*-values.

TABLE 5 Comparison of market segments across lifestyle, values, and trust variables.

| Attitudinal variables | Pioneers | Potential Early Mainstream (PEM) | Late Mainstream (LM) |
|---|---|---|---|
| Environmental-oriented lifestyle (mean score, 0–4)*** | 1.92[a] | 1.82[b] | 1.55[ab] |
| Technology-oriented lifestyle (mean score, 0–4)*** | 1.83[a] | 1.96[b] | 1.46[ab] |
| Openness to change (mean score, 0–4)*** | 2.75 | 2.96[a] | 2.63[a] |
| Trust in renewables industry (mean score, 0–3)** | 2.03[a] | 1.97[b] | 1.81[ab] |

Matching superscript letters (e.g., a, b) denote which means significantly differ from one another, as determined by Tukey HSD *post-hoc* testing.
*Significant at a 90% confidence level.
**Significant at a 95% confidence level.
***Significant at a 99% confidence level.

behavioral indicators including the New Environmental Paradigm (NEP), belief in the consequences of climate change, or the ascription of responsibility for climate change. Other than the renewable energy industry, there were no significant differences in trust for other institutions including the fossil fuel industry, electric and natural gas utilities, federal and provincial governments, ENGOs, academia, or scientists.

### Heat pump technology perceptions

Across our 22 ASHP perception questions included in the survey, Pioneers generally tend to have the most positive perceptions of ASHPs, followed by the PEM, and then the LM (Table 6). *Post-hoc* tests reveal that relative to the PEM and the LM, Pioneers are less prone to believe that ASHPs are expensive to purchase and install, disruptive to install, and noisy. They are more prone to believe that ASHPs are effective for cooling, easy to use and maintain, and a way to increase quality of life. The PEM also believes in these three perceptions more than the LM on average.

Relative to Pioneers and the PEM, the LM believe less that ASHPs are effective for heating, improve indoor air quality, reduce oil and gas dependence, and cost less than their current heating systems. Compared to Pioneers, the LM agree more that heat pumps have a worse environmental impact than oil and gas heating. Relative to the PEM, they believe less that ASHPs help fight climate change, improve outdoor air quality, are a status symbol, and are an inspiration to others.

### Policy support

Market segments significantly differ from each other in policy support for all seven policies evaluated (Figure 2). Compared to Pioneers and the PEM, the LM have significantly lower support for technology and retrofit subsidies, loans, and information programs. They also have significantly lower support for carbon taxation, renewable natural gas mandates, and building emissions regulations relative to the PEM.

On average, the carbon tax faced the highest level of opposition, with 33.2% of respondents stating that they "oppose" or "strongly oppose" the policy. Subsidies, on the other hand, faced the lowest levels of opposition: 1.3% for technology subsidies and 2.2% for retrofit subsidies. Loans and information programs also faced low opposition (5.9 and 3.3% respectively). Regulations fared between carbon taxes and voluntary policies. The RNG mandate received 11.2% opposition and the building emissions regulation faced 16.5% opposition.

## Segmentation before and after information

The above sections presented segmentation results before respondents received detailed information on home heating systems. As described in the Methods section, PEM and LM segments were created by dividing heat pump non-owners based on their stated willingness to adopt an ASHP. Respondents answered this initial willingness question after reading a brief definition of ASHPs. Later in the survey, respondents read a two-page home heating technology guide detailing technical information on air and ground source heat pumps, furnaces, boilers, and electric baseboard heaters. After reading this guide, respondents were asked the willingness to adopt question a second time.

Market segmentation based on the second instance of the willingness to adopt question resulted in a change in composition and size of the PEM and LM groups (Figure 3). Compared to the pre-information segmentation, post-information segmentation results in 41 respondents (10.6% of heat pump non-owners) shifting from the LM to the PEM. The PEM grows from 152 respondents to 193 while the LM declines from 236 respondents to 195. In the LM, the "very unwilling" contingent declines from 9.3% of heat pump non-owners to 4.9%. The "unwilling" grows however, from 5.9 to 9.8%. The "undecided" decline from 45.6% pre-information to 35.6% post-information. In the PEM, the "willing" contingent grows from 26.0 to 35.1% of heat pump non-owners. The "very willing" only experience a small amount of growth, from 13.1 to 14.7%.

TABLE 6 Comparison of market segments across heat pump technology perceptions.

| Heat pump technology perception variables | Pioneers | Potential early mainstream (PEM) | Late mainstream (LM) |
|---|---|---|---|
| Heat pump technology perceptions (mean score, 0–4) | | | |
| Effective in heating home*** | 3.21[a] | 3.07[b] | 2.45[ab] |
| Effective in cooling home*** | 3.34[a] | 3.10[a] | 2.42[a] |
| Too expensive to purchase*** | 1.78[ab] | 2.70[a] | 2.77[b] |
| Less expensive to use than current system | 2.59[a] | 2.63[b] | 2.04[ab] |
| Too expensive to install*** | 1.80[ab] | 2.66[a] | 2.78[b] |
| Too disruptive to install*** | 1.47[ab] | 2.18[a] | 2.40[b] |
| Make excessive noise*** | 1.48[ab] | 2.01[a] | 2.08[b] |
| Easy to use*** | 3.26[a] | 3.03[a] | 2.47[a] |
| Easy to maintain*** | 3.03[a] | 2.58[a] | 2.24[a] |
| Increase quality of life*** | 2.88[ab] | 2.76[a] | 2.19[b] |
| Help fight climate change*** | 2.75 | 2.86[a] | 2.54[a] |
| Effective way to improve indoor air quality*** | 2.82[a] | 2.78[b] | 2.39[ab] |
| Effective way to improve outdoor air quality** | 2.38 | 2.52[a] | 2.27[a] |
| Help reduce dependence on oil and natural gas*** | 3.05[a] | 3.01[b] | 2.69[ab] |
| Worse environmental impact than oil and gas heating*** | 1.12[a] | 1.37 | 1.57[a] |
| Express your values** | 2.14 | 1.30[a] | 2.06[a] |
| Be a status symbol | 1.59 | 1.7 | 1.67 |
| Connect with like-minded people | 1.82 | 1.84 | 1.75 |
| Positive impression on others | 1.97 | 2.03 | 1.84 |
| Inspiration to others* | 2.1 | 2.13[a] | 1.91[a] |
| Send message to government | 2.14 | 2.18 | 1.97 |
| Send message to heating/cooling companies | 2.3 | 2.31 | 2.11 |

Matching superscript letters (e.g., a, b) denote which means significantly differ from one another, as determined by Tukey HSD *post-hoc* testing.
*Significant at a 90% confidence level.
**Significant at a 95% confidence level.
***Significant at a 99% confidence level.

# Discussion

Using Axsen et al.'s (2016) market segmentation framework, our study is the first to characterize heat pump market segments of North American homeowners: Pioneers (heat pump owners), Potential Early Mainstream buyers (homeowners currently willing to purchase an ASHP), and Late Mainstream buyers (homeowners currently unwilling to purchase an ASHP). We find that these segments differ in terms of several personal capability, contextual, and attitudinal variables. We also find that the provision of information about home heating systems appears to alter the size and composition of these groups.

## Pioneers

Overall, we do not find considerable differences between Pioneers and other market segments in terms of personal capability variables. Unlike Pioneers in zero-emission vehicles, another class of pro-environmental consumer technology, ASHP heat pump Pioneers appear to be older on average than the PEM (Axsen et al., 2016). Differences in Pioneer socio-demographics across pro-environmental technologies could be explored in future work. Our relatively small sample size of Pioneers ($n = 73$) may have prevented the discovery of other socio-demographic variables that significantly differ with PEM and LM groups. Research comparing Pioneers with Potential Early and Late Mainstream buyers for other pro-environmental technologies has found for example, that Pioneers tend to have the higher incomes and education levels than other groups (Tal and Nicholas, 2013; Plötz et al., 2014). We found no such difference here, but a larger sample size is needed to validate our results. Although non-significant, our analyses suggest that Pioneers may have higher incomes and education levels than the LM but not the PEM. This would distinguish heat pump market segments from the zero-emission vehicle market, where Pioneers tend to have the highest levels of education and income across the entire market (Axsen et al., 2016).

Pioneers are unique from the PEM and LM across several contextual variables. Relative to these other two market segments, Pioneers are more likely to live in higher energy efficiency homes and be more familiar with the energy efficiency

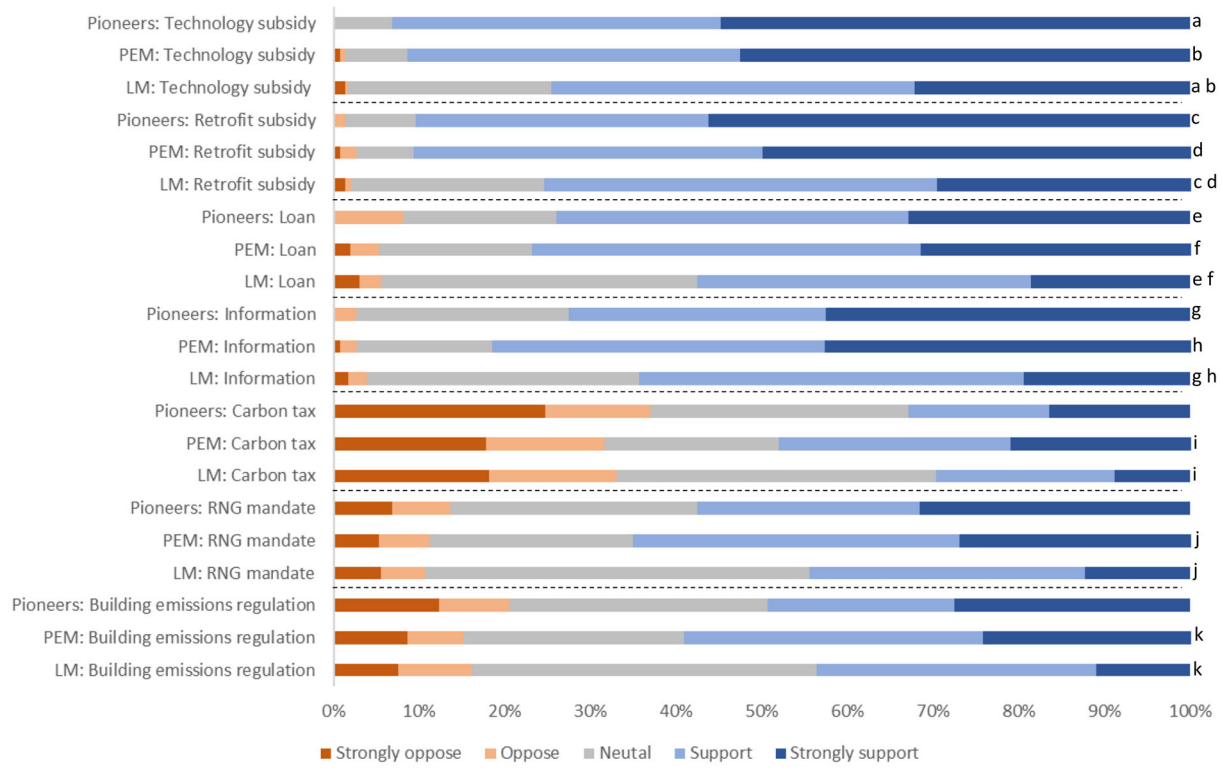


FIGURE 2
Levels of policy support and opposition for Pioneers, Potential Early Mainstream (PEM), and Late Mainstream (LM) market segments. ANOVAs find differences between groups for all policies at a 99% confidence level. Matching letters (e.g., a, b) beside bar lines denote which means significantly differ from one another, as determined by Tukey HSD *post-hoc* testing.

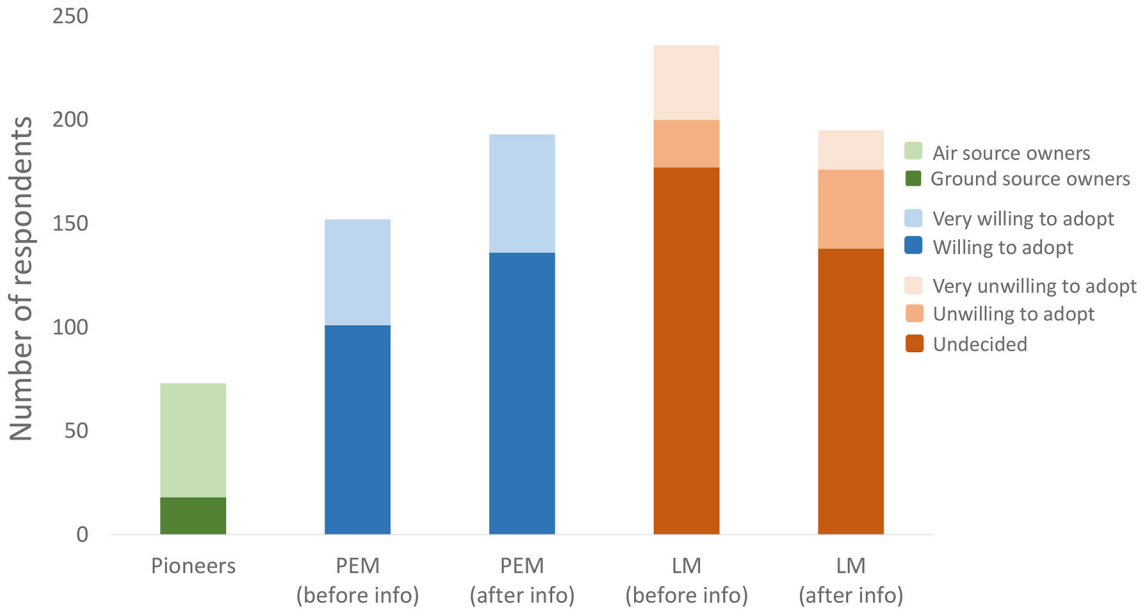


FIGURE 3
Segmentation before and after Potential Early Mainstream (PEM) and Late Mainstream (LM) respondents read an information package on home heating technologies suitable for their homes.

features of their homes. These findings are in line with previous research that has found that the presence of energy-efficiency upgrades in a home is positively associated with willingness to adopt heat pumps (Wilson et al., 2018). We also find that Pioneers are more likely know someone with a heat pump, a trait previously found to be highly associated with heat pump adoption (Karytsas, 2018). Pioneers are also more likely to live in newer homes than the LM, consistent with past associations between owning newer homes and heat pump adoption (Meles et al., 2019; Troiano et al., 2019). We find that Pioneers are more likely to live in detached and larger homes, a result that has not been identified elsewhere and should be explored in future research using larger sample sizes and in other jurisdictions.

Across all attitudinal variables explored, Pioneers only differ from the PEM in their heat pump technology perceptions. Past research has found that positive perceptions about heat pumps' economic costs, environmental benefits, operating ease, and performance tend to be associated with willingness to adopt heat pumps (Karytsas and Theodoropoulou, 2014; Karytsas and Choropanitis, 2017). Our research is supportive of these findings as we find that Pioneers tend to hold the most positive perceptions of ASHPs relative to both the PEM and LM. When compared to the LM, Pioneers generally have higher awareness and support of voluntary policies, though they do not appear to possess higher support for compulsory policies. This observation could be explored in future work. It is possible that Pioneers have greater support for voluntary policies because they took advantage of these when they purchased their heat pump. Their lower support for compulsory policies could be because these instruments influence costs in other energy end-uses such a water heating, cooking, or transportation.

Because we study ASHPs owners post heat pump purchase in a static manner, we are unable to determine whether Pioneers possessed the above-described characteristics before owning a heat pump or if the process of purchasing, installing, and using an ASHP altered their characteristics. For example, were they already knowledgeable about energy efficiency features of their home, perhaps sparking their interest in heat pumps, or did the process of purchasing and using a heat pump make them more familiar with energy efficiency? Future research could survey heat pump owners before and after heat pump purchase, installation, and use to evaluate whether these differences between Pioneers and the PEM and the LM are important precursors to ASHP adoption or simply characteristics that tend to develop over time during ASHP ownership.

## Potential early mainstream and late mainstream buyers

PEM and LM market segments are distinct from one another in personal capability variables. Previous research generally finds that in terms of socio-demographics, consumers who are female, younger, wealthier, more educated, and from larger households are more likely to adopt heat pumps and other pro-environmental technologies (e.g., Willis et al., 2011; Michelsen and Madlener, 2012; Lillemo et al., 2013; Kormos et al., 2019). Our study is broadly supportive of this work, as we find that the PEM is on average wealthier, more educated, and from larger households than the LM. Contrary to previous research, however, we find that female individuals are overrepresented in the LM relative to the PEM. Future research should consider why female individuals appear to be less willing to adopt ASHPs in particular, potentially exploring associations between gender and other explanatory variables. Also unlike previous research, we find no significant difference in age between PEM and LM groups, although sample size may be a limiting factor to identifying this potential association.

PEM and LM market segments do not differ from each other in terms of contextual factors, save for a few variables. European studies find that knowing someone with a heat pump and heat pump familiarity are associated with willingness to adopt the technology (Mahapatra and Gustavsson, 2009; Karytsas, 2018). Our research supports these findings, with the PEM scoring higher in these variables than the LM. These results suggest that governments should strive to spread awareness and knowledge about heat pumps to homeowners, particularly highlighting information on the number of heat pump installations in an individual's neighborhood to boost the sentiment that households may know someone with a heat pump—in this case, a neighbor.

PEM and LM market segments are distinct in their attitudinal characteristics. The LM score lower than Pioneers and the PEM in environmental-oriented lifestyles, which is consistent with findings in the zero-emission vehicle adoption literature (Axsen et al., 2016; Kormos et al., 2019). Interestingly, unlike studies for other pro-environmental technologies we find no significant difference between groups in other environmental concern indicators such as the New Environmental Paradigm, belief in climate change consequences, or ascription of climate change responsibility (Dietz et al., 2005; Castelfranchi and Falcone, 2010; van der Werff et al., 2013). This may suggest that individuals that have purchased or are interested in purchasing heat pumps may not necessarily have stronger environmental beliefs or concern than those disinterested in heat pumps, but they may be more likely act out these beliefs in their everyday activities.

Our finding that the LM score lower than Pioneers and the PEM in technology-oriented lifestyles is also mirrored in the zero-emission vehicle adoption literature (Long et al., 2019). Individuals with technology-oriented lifestyles are interested in experimenting with the newest technology. Although heat pumps have been available for decades, they are still

an emerging technology in Canada and the United States, particularly in colder climates, potentially drawing interest from technology-oriented individuals. A related value, openness to change, was also found to be lower in the LM than in Pioneers and the PEM, a pattern which has been observed for zero-emission vehicles (Axsen et al., 2016). The LM may be less willing to take risks and try new technologies for home heating, especially when it may involve changes to their home and how their heating system is operated.

Our study highlights that policy awareness may be an important variable associated with market segmentation. The LM are less aware and less supportive of policies aimed at decarbonizing existing buildings than the PEM for all policies, and Pioneers for voluntary policies. Future research should evaluate how willingness to adopt ASHPs (and thus market segmentation) changes under different policy conditions, potentially through discrete choice modeling using stated or revealed preference data. The patterns of policy awareness and support observed in this study—namely the high awareness and high opposition for carbon pricing and low awareness and low opposition for regulatory policy—follows a growing body of literature identifying this relationship in different populations (Rhodes et al., 2014; Long et al., 2020). This is the first instance of this relationship being identified in BC homeowners.

## Limitations

We identify several limitations of our study. First, our relatively small sample size ($n = 461$) may not be fully representative of our three market segments. This modest sample size reduced the complexity of the chosen statistical tests, thus explaining our present focus on bivariate analyses. Our present study helps identify how market segments differ from each other, whereas multivariate analyses would help expand on this by assessing the contribution of different variables to market segmentation while controlling for confounding variables.

Second, our study focuses solely on air source heat pumps, ignoring ground source versions of the technology. While ASHPs will likely be the dominant choice for existing buildings in BC, GSHPs may still gain significant market share. Third, our study focuses on homeowners that own and live in their home, which is just one contingent of the heat pump market. Future work could explore market segmentation in other building types and in homes occupied by renters.

Fourth, our quasi-experiment on the effect of home heating system technical information on market segmentation 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 groups. And fifth, although extensive care was taken to provide a rigorous survey instrument, our 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.

## Policy implications

Based on the responses to our question on willingness to adopt ASHPs, there appears to be a large potential demand for ASHPs in southern BC. Before information provision, 26.0% of heat pump non-owners stated they were "willing" and 13.1% "very willing" to adopt an ASHP for their next home heating system. Information about home heating systems appears to improve this already large potential demand, raising the "willing" contingent to 35.1%. However, information provision does not appear to improve high willingness, an important precursor to adoption.

Although heat pump interest appears high, an important finding is that the majority of respondents score low in willingness to adopt heat pumps, even after information provision. This, along with the fact that high willingness sees little improvement, may indicate that information provision alone is not enough to foster a market-wide shift to ASHPs. Decades of real-world evidence supports this notion that voluntary policies are often not sufficient for promoting widespread shifts to alternative (and potentially more expensive) low-emissions technologies (Jaccard, 2020). For this reason, it is likely that governments must augment their information and subsidy policies with carbon pricing and/or regulations to fully decarbonize existing home heating. Results from this study and others highlight the usefulness of regulations for causing a substantial, fairly rapid shift away from fossil fuel-based heating systems. Regulations tend to have low citizen awareness, low opposition, and moderate support, which could make them more politically appealing than carbon pricing, with its high salience and associated high opposition (Rhodes et al., 2014; Long et al., 2020).

Policymakers looking to promote a widespread shift from fossil fuel powered furnaces and boilers to ASHPs must design and communicate policies that reach the Late Mainstream. The LM are significantly less aware and significantly less supportive of current heat pump-supportive policies in BC compared to Pioneers and the PEM. This should be a concern to policymakers both in terms of policy effectiveness and acceptability. For voluntary policies such as subsidies, loans, and information programs to be successful, the LM must be aware of them. And for compulsory policies such as carbon taxation and regulations to be politically acceptable, they must not face high levels of strong opposition. To help foster the success of government policy packages aimed at promoting ASHP adoption, governments should aim to better reach the

LM with their communication and advertising of voluntary policies. More effective messaging to the LM will not only make voluntary policies more successful, but it may also indirectly provide public acceptability benefits to compulsory policies as the LM may be less resistant to these policies if they are more aware of heat pumps, including their real-world benefits and incentive programs.

To better influence the LM's home heating purchase decisions, governments should use customized communication and advertising strategies that account for this market segment's unique features. Unlike the PEM, which may respond well to environmental or technological innovativeness framings of heat pump adoption, the LM may require different approaches. Governments should look to address aspects of ASHPs that the LM appear to possess negative views about, including heating effectiveness and operating costs. To target LM individuals, governments should devise strategies to target harder to reach groups, namely less educated, less wealthy, and less politically engaged individuals. Messaging should also potentially be aimed at female homeowners, as this group is overrepresented in the LM.

While the LM are of special concern because they score higher in unwillingness to adopt ASHPs, the PEM may deserve their own unique attention as well. These individuals are already interested in ASHPs, but their heat pump perceptions are often significantly more negative than Pioneers'. Purchase and installation costs continue to be a considerable barrier as does confusion about the invasiveness of installations, the noise level of units, and heating and cooling ability in cold climates (Carlson, 2022). Governments should seek to help address these concerns though voluntary and/or compulsory policies so that PEM households can shift to becoming Pioneer households in the near future.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by Research Ethics BC - University of Victoria & Simon Fraser University. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

AP contributed the conceptualization, literature review, analysis, and first draft of the manuscript. ER and MJ contributed to the conceptualization and revision of the manuscript and project supervision. ER acquired funding. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2022.983454/full#supplementary-material

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