ASSESSING THE IMPACTS OF EDUCATIONAL INTERVENTIONS ON THE REPORTED PROBABILITY OF HEAT PUMP ADOPTION

by

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Authors Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

It is regarded that targeted energy efficiency improvements to residential, commercial, and industrial buildings are essential components of an effective climate action plan. While the energy performance of buildings in Ontario has improved, projected future emission totals are inconsistent with the commitments ratified at the Paris Accord. Over 60% of residential energy consumption is devoted to space heating in Ontario. Further, the mainstream usage of natural gas furnaces is delaying potential progress on achieving the Provincial and Federally ratified climate action goals. There is a pressing need to facilitate the residential adoption of low carbon and energy efficient alternatives to reduce the carbon emissions associated with seasonal space heating requirements.

Technical improvements have made the air source heat pump among the most efficient and reliable heating systems available on the market. Despite these improvements, many residential consumers in Ontario are not aware of the functional reliability and energy performance of cold-climate heat pumps. Consequently, provincial rates of heat pump adoption are low. Previous researchers have claimed that a sustained provision of focused awareness building campaigns is essential to stimulating residential interest in heat pump adoption. However, these conclusions have not been sufficiently tested in Ontario.

The present study's sample consisted of 158 homeowners and landlords in the Region of Waterloo. A between group pre-test post-test research design examined the direction and change to the reported probability of heat pump adoption after administering a focused educational intervention to two seminar cohorts and two online survey cohorts. Descriptive and inferential tests of significance demonstrated that the probability of heat pump adoption significantly increased in each experimental group when the existing heating system required replacement. The reported high probability of adoption on a five-point Likert scale increased from 40% to 73% in the seminar cohorts and from 33% to 51% in the survey cohorts when the existing system required replacement. The high probability of adoption in the seminar cohort's post-test scores increased from 17% within the year to 73% when the existing system

required replacement. The high probability of adoption in the survey cohort's post-test scores increased from 8% within the year to 51% when the existing system required replacement.

It is concluded that local environmental organizations may play a strategic role in facilitating interest in heat pump adoption by distributing positive and reliable information throughout their contact lists and by hosting awareness building seminars. This may increase the frequency in which homeowners discuss the technology, and raise public exposure to cold-climate heat pumps. The sustained diffusion of information should make important contributions to raising residential exposure and interest in high performance heat pump models.

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List of Abbreviations

Coefficient of Performance (COP)

Heating Degree Days (HDD)

Home Energy Loan Program (HELP)

International Energy Agency (IEA)

Independent Electricity System Operator (IESO)

Local Distribution Company (LDC)

Multi Unit Residential Building (MURB)

Chapter One: Introduction

The Potential to Improve Building Performance

Unsustainable patterns of economic growth and high global carbon emissions are acknowledged as principal drivers of human induced climate change (Climate Action Tracker, 2019; Environment and Climate Change Canada, 2016, 2018; Rockström et al., 2009; Steffen et al., 2018; Williams et al., 2014). Global climate zones are shifting, causing an increase to the frequency and intensity of extreme weather patterns and events (Rockström et al., 2009; Steffen et al., 2018). The effects on Earth's terrestrial systems are demonstrated through altered natural habits and species biodiversity. Abusing these already precarious ecosystem's threatens global food and water security, especially among vulnerable populations (Environment and Climate Change Canada, 2016, 2018; IPCC, 2018; Mckibben, 2012; Rockström et al., 2009; Williams et al., 2014).

The world's nations joined in Paris, in 2015, at the 21st Conference of the Parties to negotiate a framework to mitigate the increasingly observable rates of climate change in the Anthropocene. Eventual commitments were made to restrict the average global temperature increase to within 2 degrees Celsius. Ambitious goals were set to further limit the global temperature increase to within 1.5 degrees Celsius. The deeper targets were set to further respect the increased vulnerability to climate related disasters faced by small island states and coastal communities (Climate Action Tracker, 2019; Environment and Climate Change Canada, 2016, 2015; United Nations & FCCC, 2015). Canada ratified emission reductions of 30% relative to 2005 levels by 2030 as a national contribution to restricting the global temperature increase. A deeper reduction of 80% was pledged by 2050 (Climate Action Tracker, 2019, 2015). The International Panel on Climate Change (IPCC) has projected that global carbon emissions must decrease 25% by 2030, while net zero emissions are required by 2070 to respect the 2-degree threshold. Remaining within the 1.5-degree threshold requires deeper reductions of 45% relative to 2010 levels by 2030 and net zero emissions by 2050 (IPCC, 2018).

Progress towards the targeted 2 degrees temperature threshold has been critiqued as insufficient (Climate Action Tracker, 2019; IPCC, 2018; Steffen et al., 2018). The IPCC (2018) has projected that the national legislatures formed would result in global carbon emissions of 52-58 $GtCO_2eq$ per year by 2030. The projected emission totals will rapidly deplete humanity's remaining carbon budget, preventing the possibility of remaining within the 2-degrees threshold. If the average global temperature exceeds 2 degrees Celsius, irreversible feedback cycles will result. For example, droughts and wildfires will destroy precious carbon sinks, while pollutants will be released into the atmosphere with the melting of permafrost and ice sheets (Steffen et al., 2018). Catalyzing these feedback cycles will produce catastrophic and irreversible global impacts to food security, clean water, and species biodiversity (Rockström et al., 2009; Steffen et al., 2018).

Canada is currently failing to implement the required actions to achieve the ratified emission reductions. The Climate Action Tracker has projected that National emission totals are projected to increase to 794 MT CO_2e by 2030, a 30% increase relative to the emission levels recorded in 1990 (Climate Action Tracker, 2019). A reconsideration of current private and political support oriented at facilitating deep sectoral carbon reductions is essential to avoid the irreversible impacts of anthropogenic climate change (Environment and Climate Change Canada, 2016, 2018; IPCC, 2018; Rockström et al., 2009; Steffen et al., 2018; United Nations & FCCC, 2015; Williams et al., 2014).

Generating electricity through renewable and low carbon primary energy sources, facilitating the adoption of high efficiency technologies in commercial and residential buildings, and encouraging responsible residential energy management will all make important contributions to reducing global carbon emissions (Environment and Climate Change Canada, 2016, 2018; IESO, 2017; IPCC, 2018; Lovins, 2014; Ruokamo, 2016; Satnik, 2019; Williams et al., 2014; Wyse & McVey, 2018). Generating electrical and heat energy constitutes 25% of global GHG emissions (US EPA, 2016). Further, the residential sector was responsible for 27% of global energy consumption and 17% of recorded emission totals in 2015 (Nejat, Jomehzadeh, Taheri, Gohari, & Abd. Majid, 2015). The International Energy

Agency (IEA) project that just under 40% of the emission reductions required to stay within the 2 degree temperature threshold are obtainable through deep energy efficiency retrofits on industrial, commercial, and residential buildings (Baxter et al., 2013; OECD/IEA, 2011). These findings are supported by Lovins (2014), who concluded that deep energy efficiency retrofits could reduce the energy consumption of the United State's building sector by 75%.

While Canada's building sector is not the largest contributor to national emission totals, an opportunity exists to obtain carbon reductions through sustained commercial and residential efficiency improvements (Environment and Climate Change Canada, 2016; IESO, 2017; Leach, n.d.; NRCAN, 2017; Patel, Tran, McKenzie, & Sferrazza, 2015; Safa, 2012; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). Canada's building sector composed 14% of national emission totals in 2013 (NRCAN, 2013). Buildings contributed 19% of Ontario's emission totals the same year (Government of Ontario, 2013, 2016). The building sector was the third largest sectoral contributor to national emission totals in 2016, contributing 81.4 MT CO_2e of 704 MT CO_2e (Environment and Climate Change Canada, 2019). A growing population and economic expansion threatens to increase Ontario's residential and commercial carbon emissions, indicating a pressing need to obtain residential action on efficiency improvements (Government of Ontario, 2013, 2016; Satnik, 2019).

The Government of Ontario has formed partnerships with municipalities, the Independent Electricity System Operator (IESO), and local distribution companies (LDC) to provide the required support to actualize commercial and residential efficiency improvements. Further, the energy performance of buildings in Ontario has improved through provincial partnerships with the Federal Government to establish and enact stricter Building Codes and Green Building Standards (Environment and Climate Change Canada, 2016; NRCAN, 2013; Satnik, 2019). However, the rate of improvement is inconsistent with the deep decarbonization scenario that is necessary to mitigate the observable effects of anthropogenic climate change (Climate Action Tracker, 2019; Environment and Climate Change Canada, 2018).

There is an opportunity to obtain emission reductions in commercial and residential buildings by encouraging the adoption of low carbon and energy efficient heating systems given the high seasonal heating requirements in Canada (Canada & Office of Energy Efficiency, 2012; Government of Ontario, 2016; IESO, 2017; Leach, n.d.; NRCAN, 2013; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). Seasonal heating degree days (HDD) provide an estimate of a region's seasonal heating requirements by calculating the average difference between the daily temperature and 18 degrees Celsius (Canada & Office of Energy Efficiency, 2012). Canada is split into four heating degree zones, as shown in Figure 1. below.

Figure 1. National Seasonal Heating Degree Days

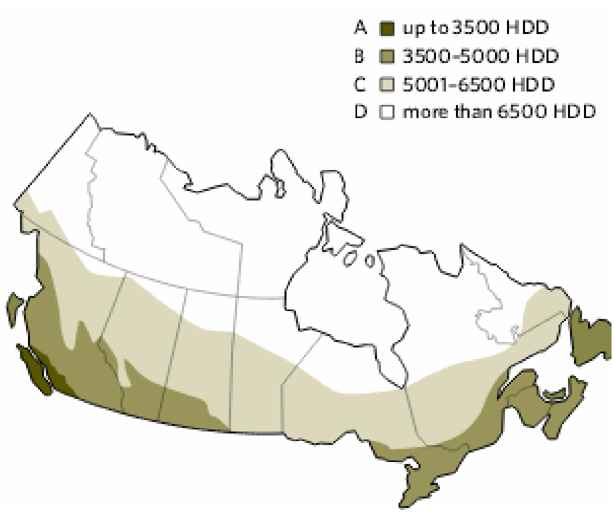


Image retrieved from Canada & Office of Energy Efficiency, 2012.

Most of the populated regions of Canada are within heating degree zones B, averaging 3500-5000 seasonal HDDs. Space heating constitutes 63% of national residential energy consumption as a result of the high heating requirements (NRCAN, 2013). Szekeres & Jeswiet (2016) observed that a consistent percentage of residential energy consumption is devoted to space heating in Ontario. Further, the usage of natural gas and other fossil fuel furnaces is delaying potential emission reductions that are achievable through facilitating the adoption of low carbon and energy efficiency market alternatives (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b).

The combustion of natural gas and fuel oil to satisfy provincial space heating requirements is a large contributor to Ontario's residential emission totals (Environment and Climate Change Canada, 2016, 2018; Szekeres & Jeswiet, 2016, 2018a, 2018b). The combustion of natural gas for electricity production and end use sources of energy was responsible for 48.6 MT CO_2e in 2016. The emissions from the combustion of natural gas have increased by 35.6 MT CO_2e since 1990 (Environment and Climate Change Canada, 2018). Currently, 60% of residential consumers in Ontario heat their home's with a natural gas furnace (IESO, 2017). The use of fossil fuels accounted for 90.6% of the province's residential GHG emissions in 2012 (Szekeres & Jeswiet, 2018a). Space heating contributed 50% of the City of Toronto's reported emission totals in 2015 (Patel et al., 2015). Further, the building sector is responsible for 24% of the air pollutants in Ontario (Government of Ontario, 2016). These emissions are projected to increase as population growth continues and provincial access to natural gas pipelines expands (Environment and Climate Change Canada, 2016, 2018; Government of Ontario, 2013, 2016).

Investments to expand natural gas pipelines are continuing to be pushed by utility regulators and are supported through provincial legislation (Wyse & McVey, 2018). These investments are sustained, even after 2 billion dollars was invested in expanding natural gas pipelines through 2015-2017 (Enbridge Gas, 2019a). Pipeline expansion typically targets rural regions of the province to increase natural gas access to homes that are heated with electricity or oil. However, these homes are already ideal candidates for residential heat pump adoption. These policies will only further encourage the residential usage of natural gas and overlook an opportunity to improve the energy performance of buildings in Ontario (IESO, 2017; Leach, n.d.; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

Encouraging residential adoption of high-performance cold-climate heat pump models is an ideal technical solution to achieve the required provincial energy savings and carbon reductions (Government of Ontario, 2016; IESO, 2017; Leach, n.d.; NRCAN, 2013; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). During the heating season, the heat pump uses a fan to draw ambient air into a coil located outside of the home. The air passes over a refrigerant fluid, which boils and expands into a vapour at a low temperature. The vapour enters the heat pump's compressor. The compressor reduces volume of the vapour, increasing its temperature. The heated vapour enters the indoor coil, which releases the energy into the home's heating circuits. The refrigerant condenses back into a liquid and passes back through the heat pump's expansion valve, lowering its pressure and temperature. The refrigerant returns to the evaporator in the outdoor coil, and the heating process is repeated as necessary. The same process is reversed during the cooling season to remove warm air from inside of the house (NRCAN, 2017).

Technical improvements have made cold-climate heat pumps among the most energy efficient heating system's currently available on the market (Bertsch & Groll, 2008; Chua, Chou, & Yang, 2010; Dentz, Podorson, Varshney, & Energy, 2014; IESO, 2017; Mitsubishi Electric, 2017a; Safa, 2012; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018). A heating system's coefficient of performance (COP) rating indicates the heat energy that a system produces relative to the energy that it consumes. Modern heat pumps display average COP ratings ranging between 2 and 4 during the heating season (NRCAN, 2017). Heat pumps typically operate at 300% energy efficiency in optimal temperatures, producing three units of heat energy for every kWh input into system (NRCAN, 2017). These efficiency ratings are possible because the air source heat pump moves heat energy using phase changes (liquid-gas). Fossil fuel furnaces can never exceed 100% energy efficiency because of the heat energy that is lost from the combustion of the fuel source.

The heat pump's COP decreases as temperatures decline. However, technical improvements are continuing to increase the heat pump's performance in cold-climates (Bertsch & Groll, 2008; Chua et al., 2010; Dentz et al., 2014; NEEP, 2014; Safa, 2012; Szekeres & Jeswiet, 2016, 2018a, 2018b). Feasibility studies have concluded that modern cold-climate air source heat pumps display high seasonal performance reliability when installed across Ontario (IESO, 2017; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018). The heat pump's COP relative to market alternatives will also provide notable carbon emission reductions, particularly if fossil fuel furnaces are replaced with high performance models (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018b, 2018a; Wyse & McVey, 2018).

The primary energy source that is used to generate the region's electricity determines the carbon emissions associated with electrical space heating (Baxter et al., 2013; OECD/IEA, 2011). Producing electricity through carbon intensive sources, such as oil and coal, will not provide lifecycle emission reductions that are obtainable in regions with low carbon electricity sources. Meaningful emission reductions are obtainable in Ontario because almost 90% of the electricity is produced from hydro, wind, and nuclear energy sources (Environment and Climate Change Canada, 2016, 2018; Government of Ontario, 2013a, 2016; IESO, 2017, 2019b; IPCC, 2018; NRCAN, 2017; Williams et al., 2014). Consuming electricity results in carbon emissions of 40 gCO_2e / kWh heat, relative to natural gas which produces 215 gCO_2e / kWh heat and furnace oil which produces 351 gCO_2e / kWh (Szekeres & Jeswiet, 2018a). Natural gas furnaces have been estimated to produce 15 times the CO_2e of a mini-split air source heat pump operated in Toronto (Nieboer, n.d). Szekeres & Jeswiet (2018a, 2018b) project that provincial energy savings and emission reductions of almost 9% are achievable if 10% of the homeowners using a fossil fuel furnace installed a cold-climate heat pump. Provincial feasibility studies conclude that increasing the residential adoption rate of the air source heat pump could make notable contributions to achieving provincial emission reductions of 37% by 2030 (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018b, 2018a; Wyse & McVey, 2018).

The Government of Ontario acknowledged the need to reduce sectoral emission totals in the provincial climate action plan released in 2016 (Government of Ontario, 2016). Ontario set emission reduction targets of 37% relative to 1990 by 2030. Ambitious reductions of 90% were set for 2050 (Government of Ontario, 2016). The plan specifically referenced the growing need to facilitate residential energy efficiency improvements and to encourage the residential adoption of low carbon heating systems. A crucial component of this goal was to ensure that the public was aware and educated on the availability of low carbon and energy efficient market technologies, including high-performing heat pump models (Government of Ontario, 2016).

Although commitments were made to facilitate residential heat pump adoption, provincial feasibility studies conducted by the Independent Electricity System Operator (IESO) (2017) and Wyse & McVey (2018) conclude that market barriers are delaying provincial heat pump adoption. It has been suggested that the current price differential between natural gas and electricity is the most substantial barrier to heat pump adoption. However, it is important to acknowledge that there has been an observed awareness gap pertaining the functional reliability and energy performance of modern cold-climate heat pumps. Further, it is concluded that there is insufficient regulatory support to facilitate local awareness building campaigns and financial assistance programs to stimulate the heat pump's provincial rate of adoption (IESO, 2017; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). The reviewed provincial feasibility studies conclude that focused awareness building campaigns are essential to increase residential exposure and interest in heat pump adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). However, there is a lack of experimental data to support these conclusions in Ontario.

1.1. Research Purpose, Questions, & Hypotheses

The purpose of this study was to address the provincial research gap by examining if focused awareness building campaigns can stimulate interest in residential heat pump adoption. Emphasis was placed on examining the role that local environmental organizations can have on increasing residential exposure and interest in cold-climate heat pumps. A second objective of the study was to determine if two seminar sessions hosted by a local environmental organization would be more effective at increasing interest in heat pump adoption than directly providing consumers with information through digital media.

A series of research questions and hypotheses were developed to test the claims of the theories of consumerism reviewed in the next chapter, arguing that consumers are slow to adopt innovative and unfamiliar technologies (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983, 2010). The research questions and hypotheses were also directed at providing deeper insight into the reviewed provincial barriers to heat pump adoption (IESO, 2017; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). Descriptive research questions were developed to determine the sample population's awareness of cold-climate heat pump models;

1) Are participants aware of the technical improvements in heat pumps?
2) Are participants aware of the availability of cold-climate heat pump models?
3) Are participants confident in the heat pump's performance reliability prior to receiving the educational intervention?

Inferential research questions were also developed to examine the effectiveness of educating the public on how the heat pump functions, and the benefits that are associated with using a heat pump including;

1) How will a reduced energy bill influence the probability of heat pump adoption?
2) How will a reduced residential carbon footprint influence the probability of heat pump adoption?
3) How will a reduced consumption of purchased energy influence the probability of heat pump adoption?

Three directional hypotheses were developed to test the reviewed theories of consumerism and the conclusions of the provincial feasibility studies regarding the effectiveness of focused awareness building campaigns (Ajzen, 1991; Bamberg & Möser, 2007; IESO, 2017 Klöckner, 2013; Patel et al., 2015; E. M. Rogers, 1983, 2010; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018);

H1: If participants are provided with positive reviews from early system adopters then the reported probability of heat pump adoption will increase.

H2: If participants are educated on the performance capacity and relative advantages to using a heat pump then the reported probability of adoption will increase.

H3: Interpersonal seminar sessions will be more effective at increasing the reported probability of heat pump adoption than providing information through digital media.

1.2. Research Context

The study took place throughout 2018-2019 in the Region of Waterloo, Southern Ontario. A sample of 158 homeowners and landlords were recruited from a population of approximately 550,000 residents (Region of Waterloo, 2017). Similar to other municipalities across Ontario, the Region of Waterloo released a climate action plan in 2013 to facilitate municipal emission reductions (ClimateActionWR, 2013). Residential emissions constituted 22% of the Region's emission totals (Brown et al., 2015; ClimateActionWR, 2013). It was reported that 60-80% of the region's residential energy consumption was devoted to space heating. Further, 80% of the Region's residential emission totals were caused by the combustion of natural gas to meet these heating requirements (Brown et al., 2015).

The Region of Waterloo set specific targets to facilitate residential carbon emission reductions by increasing residential awareness to low carbon and energy efficient alternative heating systems (ClimateActionWR, 2013). The Region of Waterloo celebrated a five percent reduction relative to 2010 levels by 2015. Municipal emissions would have increased by 4.4% in the absence of the phase out of coal from the provincial electrical grid (Brown et al., 2015). Residential heat pump adoption provides a strategic way to continue to reduce the Region's residential emission totals. The impacts that local awareness building campaign can have on simulating residential heat pump adoption warrants further investigation.

1.3. Research Strategy

There are insufficient studies in Ontario to support the conclusions that educational interventions will constitute effective market interventions to mitigate the reported barriers to heat pump adoption. However, the reviewed market literature was observed to consistently measure the direction and change to a sample population's perceptions and interest in heat pump adoption following an educational treatment (Caird & Roy, 2010; Caird, Roy, & Herring, 2008; Caird, Roy, & Potter, 2012; Ipsos MORI & Energy Saving Trust, 2013; Owen, Mitchell, & Unsworth, 2013; Snape, Boait, & Rylatt, 2015). The present study adopted the same research design to compare and contrast the results of the present sample with broader debates regarding the reported market barriers to heat pump adoption.

The researcher established partnerships with Reep Green Solutions and eMERGE Guelph to recruit the sample for each experimental cohort. A cross-sectional questionnaire was provided at two separate seminar sessions hosted by Reep. An online intervention was provided to two survey cohorts to compare the effectiveness of the two experimental treatments. A pre-test of the awareness to modern heat pump models, the perceived reliability, the impact of the relative advantages, and the reported probability of adoption was collected before each experimental group received the educational intervention. A post-test of the perceived reliability and reported interest in heat pump adoption was collected immediately after the intervention to measure the direction and change on the reported probability of adoption.

1.4 Contributions

The present study aimed to provide further evidence to explain the low rate of heat pump adoption in Ontario relative to other regions of Canada. Ensuring that heat pump adoption increases will make important contributions to achieving the provincial climate action goals, warranting research designed to provide a greater understanding to the market barriers to heat pump adoption. Identifying the factors that motivate a participant to install a particular heating system can provide insights to certain populations that may be more receptive to learning about the relative advantages to using a heat pump.

Further, the research aimed to provide further insights into the effectiveness of raising residential exposure to modern efficient technologies, including high-performance cold-climate heat pumps. Determining if awareness building campaigns will observably increase the reported interest in heat pump adoption will provide important contributions to future private and public efforts at improving the energy performance of Ontario's building sector.

1.5 Overview

A thorough review of the provincially reported market barriers to heat pump adoption provided by the IESO (2017) and Wyse & McVey (2018) is provided in the following Chapter. The identified market barriers are nestled into broader discussions of the psychological and sociological determinants to consumer behavior. Further, consistencies are drawn between the identified barriers and the conclusions presented within a larger body of reviewed market literature examining the feasibility for residential heat pump adoption. The chapter concludes with a discussion of the recommendations as proposed by the IESO (2017) and Wyse & McVey (2018) regarding the need to ensure that awareness building campaigns are sustained across Ontario and are reinforced by appropriate financial incentives.

A detailed description of the methodology and experimental procedures used to examine the research questions and hypotheses under investigation is presented in Chapter Three. The chapter concludes with a discussion of the descriptive and inferential tests of significance used to compare the direction and change of the outcome variable within and between experimental groups. The results of the experimental treatment are presented in Chapter Four and are elaborated in Chapter Five. Recommendations are provided based on the findings of the current study and the conclusions of the IESO (2017), Satnik (2019), and Wyse & McVey (2018) regarding the need to sustain provincial awareness building campaigns and strategically designed incentive models to stimulate interest in heat pump adoption.

Chapter Two: Literature review

Barriers to Residential Heat Pump Adoption: Understanding Consumer Behavior

Cold-climate heat pumps are among the most reliable and energy efficient heating system's currently available (Bertsch & Groll, 2008; NEEP, 2014; NRCAN, 2017; Safa, 2012; Szekeres & Jeswiet, 2018a). However, provincial rates of heat pump adoption are being delayed by several market barriers (IESO, 2017; Wyse & McVey, 2018). It is suggested that the heat pump's purchase, installation, and operational costs are discouraging homeowners from replacing an existing natural gas furnace with a cold-climate heat pump. However, it has also been argued that the public is not aware of the functional reliability and energy performance of cold-climate heat pumps (IESO, 2017; Leach, n.d.; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

Wyse & McVey (2018) have suggested a lack of robust regulatory assistance from private and public institutions is perpetuating the reported barriers to residential heat pump adoption. It is concluded that the provision of financial assistance to mitigate the reported economic barriers can increase residential action on efficiency improvements, including heat pump adoption (Caird et al., 2012; N. R. C. Government of Canada, 2018; Huijts, Molin, & Steg, 2012; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Klöckner, 2013; Lillemo, Alfnes, Halvorsen, & Wik, 2013; Satnik, 2019; Wyse & McVey, 2018). However, these incentive programs will likely fail to obtain action on residential efficiency improvements unless awareness to the advantages offered by cold-climate heat pumps is increased (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018).

It is important to reflect upon the motivating factors to a consumer's consumption patterns to effectively design future financial assistance programs and awareness building campaigns (Ajzen, 1991; Bamberg & Möser, 2007; Han & Stoel, 2017; Hecher, Hatzl, Knoeri, & Posch, 2017; Huijts et al., 2012; Klöckner, 2013; E. M. Rogers, 1983, 2010). Meta-analysis studies have concluded that perceived personal, social, and environmental consequences are psychological determinants to a consumer's consumption patterns (Bamberg & Möser, 2007; Han & Stoel, 2017; Hecher et al., 2017; Klöckner, 2013). Rational consumers are unlikely to a purchase a technology if they perceive the disadvantages to outweigh the advantages associated with adoption (Ajzen, 1991; Huijts et al., 2012; E. M. Rogers, 1983). However, a consumer who is unfamiliar with a technology's performance metrics cannot conduct a rational cost-benefit analysis (Aertsens, Verbeke, Mondelaers, & Huylenbroeck, 2009; Bamberg & Möser, 2007; Han & Stoel, 2017; Klöckner, 2013; E. M. Rogers, 1983). Therefore, unfamiliar and innovative technologies are slow to be perceived as attractive and reliable market alternatives, even when they are superior to market competitors (Ajzen, 1991; Bamberg & Möser, 2007; Howarth & Andersson, 1993; Klöckner, 2013; E. M. Rogers, 1983, 2010; Wyse & McVey, 2018).

It has been concluded that raising public exposure to a technology's performance metrics catalyzes adoption rates (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983). Rogers (1983) Diffusion of Innovations theory elaborates on the specific conditions that must be satisfied to increase an unfamiliar or innovative technology's rate of adoption;

(1) *Relative Advantage:* The consumer must perceive the technology to be superior in performance reliability and offer measurable benefits to the product that is being replaced,

(2) *Compatibility:* A consumer must be confident in the technology's suitability for their particular lifestyle requirements,

(3) *Complexity:* Consumers are attracted to technologies that are easy to understand and operate,

(4) *Observability & (5) Trialability:* Receiving reliable information from competent sources and through interactions between social networks often increases a consumer's interest in installing an unfamiliar technology. However, the public must be exposed to the technology for this information exchange to be possible. Frequent technological exposure reduces the perceived complexity, demonstrate performance reliability, and increases awareness to the advantages associated with system adoption. As the system's rate of adoption increases, the consumer is

exposed to technology more frequently during their daily encounters and social interactions. The technology's adoption rate is projected to show further increases if public exposure to reliable and positive information is sustained.

The provincial barriers identified by the IESO (2017) and Wyse & McVey (2018) demonstrate consistent violation with the variables that Rogers' affirms are necessary to increase technological adoption, as shown in Table 2.1 below. It should not be concluded that the price disparity between natural gas and electricity is the most significant provincial barrier to residential heat pump adoption without first examining the impacts of satisfying each of the conditions outlined in the Diffusion of Innovations theory. The results will provide crucial insights to the motivations to consumer behavior and can help to facilitate the success of future market interventions oriented at increasing provincial heat pump adoption.

Table 2.1: Provincially Identified Barriers and the Diffusions of Innovations Theory

Rogers' Variables (1983)	*Provincially Identified Barriers*
Trialability & Observability	There is insufficient residential awareness to the functional reliability and energy performance of cold-climate heat pumps in Ontario (IESO, 2017; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). Heat pumps constitute 0.0002% of provincially installed residential heating systems (IESO, 2017). Consequently, homeowners do not have sufficient exposure to cold-climate heat pumps to determine the system to be a reliable and attractive market alternative.
Relative Advantage & Compatibility	The provincial price disparity between natural gas and electricity is regarded as the most substantial barrier to residential heat pump adoption in Ontario. However, consumers are not aware of the energy savings available by replacing an oil furnace or electric baseboards with a cold-climate heat pump. Consumers are also skeptical of the heat pump's performance reliability during the winter. It is suggested that the lack of exposure and awareness to cold-climate heat pumps perpetuates negative public perceptions and inhibits residential system adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Wyse & McVey, 2018).

Complexity	Residents have reported that they do not know how to properly operate their air source heat pump. The heating and cooling industry is also reported to lack information on the proper installation and operational procedures for cold-climate heat pumps. This is resulting in faulty installations and the provision of inconsistent and inaccurate information to residential consumers. Consequently, performance deficiencies are being experienced, contributing to the negative consumer perceptions and the reported skepticism regarding the heat pump's seasonal heating performance (IESO, 2017; Wyse & McVey, 2018). Homeowners who experience performance deficiencies are unlikely to recommend the heat pump to other members of their social networks, perpetuating the misconceptions and lack of exposure to cold-climate heat pumps (Ajzen, 1991; Rogers, 1983).

The Diffusion of Innovations theory concludes that focused information exchange is required to raise exposure and interest in the adoption of unfamiliar and innovative technologies (Rogers, 1983). This information effectively reduces skepticism regarding a technology's performance reliability and raises exposure to the relative advantages associated with adoption. This ensures that consumers are able to conduct a rational cost-benefit analysis regarding system adoption (Ajzen, 1991; Huijts et al., 2012; E. M. Rogers, 1983). It is concluded that market barriers delaying an unfamiliar or innovative technology's rate of adoption will continue to be mitigated as public exposure to reliable information is increased (Ajzen, 1991; Bamberg & Möser, 2007; Han & Stoel, 2017; Hecher et al., 2017; Klöckner, 2013; E. M. Rogers, 1983, 2010). However, it is concluded that the required regulatory support to develop and implement awareness building campaigns and financial assistance programs is not being provided to property owners in Ontario (IESO, 2017; Patel et al., 2015; Wyse & McVey, 2018).

The IESO (2017) and Wyse & McVey (2018) have concluded that focused awareness building campaigns and the provision of financial assistance programs will make important contributions to increasing residential exposure and interest in heat pump adoption. These conclusions remain consistent with a wider body of reviewed market literature examining the impacts of raising residential awareness to modern energy efficient technologies, including cold-climate heat pumps (Braun, 2010; Caird & Roy, 2010; Caird et al., 2012; Thomas Decker & Menrad, 2015; Hecher et al., 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2016; Mills & Schleich, 2012; Ruokamo, 2016; Snape et al., 2015; Sopha, Klöckner, Skjevrak, & Hertwich, 2010; Zografakis, Menegaki, & Tsagarakis, 2008). However, to date these conclusions have been insufficiently tested in Ontario. Addressing this research gap will help to effectively align educational interventions into municipal and provincial climate action initiatives. Further, determining if there is a significant impact on the reported probability of adoption depending on how the public receives this information will provide future insights for the development of effective awareness building campaigns. Each of the identified barriers to heat pump adoption is discussed in greater detail throughout the following subsections.

2.1 Economic Barriers to Heat Pump Adoption

Market research has concluded that consumers are hesitant to replace a functional heating system, even after being educated on superior market alternatives (Bjørnstad, 2012; Caird & Roy, 2010; Caird et al., 2008, 2012; Howarth & Andersson, 1993; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo et al., 2013; Owen et al., 2013; Roy et al., 2010; Ruokamo, 2016; Snape et al., 2015; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018). Further, homeowners report being preferential to less expensive efficiency improvements (Caird & Roy, 2010; Ipsos MORI & Energy Saving Trust, 2013). Ipsos MORI & Energy Saving Trust (2013) observed that 81% of their sample would not replace their heating system unless it required expensive repairs. Further, a homeowner often selects a replacement model according to its purchase and operational costs (IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo, n.d.; Lillemo et al., 2013; Owen et al., 2013; Snape et al., 2015; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018).

Regional variations between fuel sources is a predictive factor of which heating system’s will be predominately used (Braun, 2010; Nesbakken, 2001; Vaage, 2000). A homeowner’s annual income can also restrict otherwise willing consumers from replacing an existing heating system, particularly if their energy bills will increase (Lillemo, n.d.; Lillemo et al., 2013). Caird et al. (2012) reported that a heating system's operational costs were the most significant factor influencing adoption. These findings have been consistently demonstrated across the reviewed market literature (Braun, 2010; Caird et al., 2012; Thomas Decker & Menrad, 2015; Hecher et al., 2017; Ipsos MORI & Energy Saving Trust, 2013; Michelsen & Madlener, 2016; Owen et al., 2013; Ruokamo, 2016; Snape et al., 2015; Szekeres & Jeswiet, 2016, 2018b, 2018a).

The importance of regional fuel costs on the heat pump's installation rate has been demonstrated in Newfoundland and Labrador. The Muskrat falls Hydro dam is set to come online at the end of 2020. It has been projected that residential electricity rates will increase by approximately 50% to pay for the dam. Heat pump adoption increased by 57% from 10,321 to 37,321 installed systems between 2014 to 2018 after the Province announced the increased electricity rates. The majority of the homeowners that were installing mini-split or ducted heat pump models were using electric baseboards rather than oil or gas furnaces. It has been concluded that the heat pumps adoption rate was a response to avoid increasing energy bills by reducing energy required to heat the home (Bird, 2019; Quinn, 2019). The response by homeowners has demonstrated that rates of technological adoption are likely to be influenced by changes to the regional costs of various fuels.

The price differential between natural gas and electricity in Ontario is concluded to be the most substantial market barrier to provincial heat pump adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). The IESO (2017) has observed that a heat pump's operational costs can be 120% higher than using a natural gas furnace. It is concluded that that the price/m^3 of consumed gas would have to increase by over 50% for the heat pump to become an economically competitive market alternative (IESO, 2017). The financial barriers delaying heat pump adoption are reflected by the provincial market share of natural gas furnaces (60%) relative to air source heat pumps (0.0002%) (IESO, 2017).

Consumer behavior is motivated by the presence of direct personal benefit (Ajzen, 1991; IESO, 2017; Klöckner, 2013; Wyse & McVey, 2018). Provincial feasibility studies have concluded that financial assistance programs and disincentive models such as the federal carbon tax are required to reduce the price disparity between the operational costs of a heat pump and a natural gas furnace (IESO, 2017; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Wyse & McVey, 2018). Projected rates of heat pump adoption are low in the absence of these conditions (IESO, 2017; Szekeres & Jeswiet, 2016, 2018a, 2018b; Wyse & McVey, 2018). However, it is suggested that early rates of heat pump adoption can be leveraged by strategically targeting properties that will receive financial benefits from the retrofit (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

2.2 Opportunities for Energy Savings

There is an existing business case in Ontario to replace an oil furnace or electric baseboard heaters with a high-performance heat pump (Calder, 2017; IESO, 2017; Leach, n.d.; Patel et al., 2015; Safa, 2012; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). The IESO (2017) compared the operational costs of an air source heat pump relative to an oil furnace when installed across the province. The installed heat pump model operated at 300% energy efficiency, while the oil furnace was 78% energy efficient. The oil furnace's annual operational costs averaged between $803-$1338 in Southern Ontario. The heat pump's annual operational costs averaged between $491-$801. The oil furnace's operational costs increased to $1072-$1764 in central and northern regions of the province. The heat pump's operational costs increased to $882-$1430 (IESO, 2017). It is important to note that the costs of operating an oil furnace will continue to increase under the current carbon tax scenario. The result has been projected to increase residential rates of heat pump adoption, provided that residents are aware of the available energy savings (Szekeres & Jeswiet, 2016, 2018a, 2018b).

There is also a strong business case for heat pump adoption in electrically heated homes (IESO, 2017; Wyse & McVey, 2018). Homeowners who replace electric baseboards with a high-performance heat pump can reduce their energy consumption by 60%. The associated reductions to the users energy bills can exceed 50% (IESO, 2017; NRCAN, 2017). Optimal financial savings will be observed in well insulated and efficient home designs (Canada & Office of Energy Efficiency, 2012).

The Toronto and Region Conservation Authority (2018) installed cold-climate heat pumps provided by Mitsubishi and Daiken in nine different electrically heated multi-unit residential buildings (MURBs) across Southern Ontario. The purpose of the study was to assess the heat pump's seasonal heating performance and the associated operational costs at each test site. Each property's average energy consumption decreased by 19% to 32%, producing energy savings of $868. Reported monthly energy savings averaged between $75-$150 (Toronto and Region Conservation Authority, 2018).

Despite the potential savings, landlords lack direct financial incentives to install modern heat pumps throughout their properties. The owner of a MURB is responsible to purchase and install new equipment in their buildings. However, tenants are usually responsible to pay the utility bills on rental properties. A split-incentive problem is produced in which the landlord pays to reduce their property's energy consumption. However, the tenants receive the financial benefits from the retrofit (Wyse & McVey, 2018). Further, Ontario's Provincial Rent Control Act prevents landlords from raising rental prices to compensate for the expenses of installing new equipment (Toronto and Region Conservation Authority, 2018).

Wyse & McVey (2018) and the Toronto and Region Conservation Authority (2018) suggest that landlords must be made aware of the indirect financial benefits associated with installing modern heat pumps in their properties. Advertising cheaper electricity bills relative to other buildings can help encourage current and prospective tenants to sign a lease. This effectively reduces vacant units and tenant turnover. The heat pump's performance reliability and comfortable distribution of heat is also worth advertising to potential tenants (Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

The Toronto and Region Conservation Authority concluded that 24% of Ontario's MURB and rowhouse units are heated with electric baseboards (approximately 405,000 units) (Toronto and Region Conservation Authority, 2018). Further, four percent of the homes in Ontario are heated with electric baseboards (approximately 200,000 homes) (IESO, 2017). It has been concluded that focused awareness building campaigns are required to ensure that these property owners are aware of the obtainable benefits associated with residential heat pump adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Wyse & McVey, 2018). The implementation of financial assistance programs can stimulate further interest in heat pump adoption, particularly when these homeowners are aware of the relative benefits to adoption.

2.3 Financial Assistance Programs

Direct influence is often required to change a consumer's previously entrenched habits, perspectives, and patterns of behavior (Ajzen, 1991; Huijts et al., 2012; Klöckner, 2013; E. M. Rogers, 1983; Shove, 1998). A report recently released by the research team at S2e Technologies concluded that strong partnerships are required between private and public institutions to raise residential awareness regarding the benefits of improving a home's energy performance, while providing financial assistance to actualize these efficiency improvements (Satnik, 2019). However, community consultation is also required to ensure that the particular needs of the community are respected. The consultation often is essential to achieve residential and commercial cooperation on efficiency improvements (Satnik, 2019).

The availability of financial assistance programs has been found to be among the most significant factors influencing a homeowner to install a particular heating system (Caird et al., 2012; Hecher et al., 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo, n.d.; Lillemo et al., 2013; Ruokamo, 2016). Ipsos MORI & Energy Saving Trust observed that 40% of the participants were waiting for financial assistance programs to offset the replacement costs of their existing heating system (Ipsos MORI & Energy Saving Trust, 2013). Provincial heat pump adoption has been projected to reach 30% of residential consumers in the presence of various robust financial assistance programs and focused awareness building campaigns (IESO, 2017).

The importance of regional fuel costs has been demonstrated in Newfoundland and Labrador after the province announced the slated increases to the provincial electricity rates to pay for Muskrat Falls. The province expanded the Home Energy Savings Loan program to provide $1-million dollars to facilitate residential heat pump adoption. The program will distribute $1000 to 1000 households to rebate the heat pump's purchase costs. Within one month, almost 700 residents had applied to the program (Bird, 2019; Quinn, 2019).

It is important that policy makers remain open to inspiration from the success that other awareness building campaigns and financial assistance programs have had in similar jurisdictions (Satnik, 2019). Numerous incentive programs are being offered from municipal and provincial governments across Canada to support residential energy efficiency improvements. Many of these programs were developed and supported in partnership with provincial electricity regulators and LDCs to help reduce the heat pump's initial purchase costs (N. R. C. Government of Canada, 2018; Satnik, 2019). Residents in British Columbia are offered Fortis BC's oil to heat pump program, which provides a $1700 cash rebate to residents who replace an oil furnace with a high-performance air source heat pump (BC Hydro, 2019; N. R. C. Government of Canada, 2018). On the east coast, Nova Scotia's Heat Pump Incentive Program rebates consumers based on the size and energy performance of the installed heat pump (N. R. C. Government of Canada, 2018; Satnik, 2019) These incentive models were previously available in Ontario and should be redesigned to help stimulate residential heat pump adoption (IESO, 2017).

There are incentive programs available to some residential consumers to support efficiency improvements in Ontario. The IESO provides free energy audits and efficiency upgrades to qualifying low income residents homeowners through the Save on Energy Home Assistance Program (N. R. C. Government of Canada, 2018; IESO, 2019a). Provincial support from the Government of Ontario is also available through the Affordability Fund. The Affordability Fund which also provides free energy audits and efficiency upgrades, including the installation of cold-climate heat pumps (N. R. C. Government of Canada, 2018; Ontario, 2019). The City of Toronto provides low interest loans for efficiency improvements through the Home Energy Loan Program (HELP). Interest rates of 4.4% over 20 years are charged to support various residential improvements, including the installation of air source heat pumps (City of Toronto, 2019b). These loans are repaid through an added lien on the recipients property tax bill (N. R. C. Government of Canada, 2018). Although these programs are currently available, there is insufficient access to similar province across Ontario, indicating a need to expand the existing financial incentive programs (IESO, 2017; Wyse & McVey 2018).

The IESO (2017) and Wyse and McVey (2018) have concluded that provincial rates of heat pump adoption will remain low until financial rebate programs are redesigned and made widely available to consumers currently heating their home's with oil and electricity. However, it will be crucial to look beyond incentive models that exclusively rebate purchase costs to increase residential rates of adoption. Financial rebates do not address the current provincial price disparity between natural gas and electricity. Consequently, these assistance programs are expected to have little effect on the majority of homeowners in Ontario given the mainstream usage of natural gas furnaces. It suggested that incentive models should be strategically designed to reduce the heat pump's operational costs to have the most significant effect on increasing provincial rates of adoption.

There are incentive models across Canada that provide energy credits for new constructions that obtain certified levels of green building standards or retrofit projects providing measurable energy savings (N. R. C. Government of Canada, 2018; Satnik, 2019). An example is presented by Langley BC's Green Building Rebate Program, which provides a $15 energy credit per GJ of reduced energy consumption up to an annual maximum of $750 (N. R. C. Government of Canada, 2018; Township of Langley, 2015). These incentives can be redesigned to provide energy credits to homeowners who install a cold-climate heat pump. These incentives will be particularly attractive to homeowners using electric baseboards given the available energy savings. Further, continuing to provide low-interest loans can encourage action on efficiency improvements if the loan is designed so that it is repaid through money previously allocated to a homeowner's energy bills (Satnik, 2019).

While financial incentive models will be important to increase provincial heat pump adoption, it is also essential to consider the impacts of disincentive programs, such as a price on carbon. A carbon price is used to recognize the external costs imposed on society by the combustion of fossil fuels. The result is that the external costs become incorporated in the price of carbon intensive products and directly influence purchase decisions.

The residential penalty associated with combusting natural gas has already started to increase under the federal carbon tax. The federal government imposed the provincial Carbon Tax on Ontario April 1st, 2019 after the province failed to submit their own detailed taxation plan. A charge of 3.91 cents/m^3 of consumed gas was enforced. The price per consumed cubic meter of gas will increase by 2.3 cents annually under the current framework (Enbridge Gas, 2019b, 2017; D. of F. Government of Canada, 2018; E. and C. C. Government of Canada, 2018). Carbon pricing could increase the operational costs of a natural gas furnace by 1.07 cents, total price 4.7 cents/kWh by 2022, which was projected to significantly increase rates of heat pump adoption (Szekeres & Jeswiet, 2018a).

Szekeres & Jeswiet (2018a) conducted a system dynamics analysis to project the heat pump's provincial adoption rate as provincial natural gas and electricity rates changed. It was concluded that the projected rates of heat pump adoption were significantly higher as the price disparity between the two fuel sources was reduced (Szekeres & Jeswiet, 2018a). These findings are supported by Ipsos MORI and Energy Saving Trust (2013), who observed that 34% of their sample would replace their heating system for a model with a lower operational cost. An additional 38% would replace their heating system if its operational costs continued to increase (Ipsos MORI & Energy Saving Trust, 2013). It has been concluded that incentives and disincentives facilitating competitive fuel pricing between natural gas furnaces and modern air source heat pumps can effectively increase interest in heat pump adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2016, 2018b, 2018a; Wyse & McVey, 2018).

Financial rebate programs were previously available in Ontario (IESO, 2017; Satnik, 2019). However, provincial heat pump adoption did not increase. Future incentive models may be more effective if strategically designed to reduce the heat pump's operational costs. However, it is crucial to recognize that financial considerations are only a single barrier to the adoption of innovative and unfamiliar technologies (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983). It is unlikely that a consumer will seek out financial assistance programs unless they are already aware of cold-climate heat pumps and the benefits associated with adoption.

A consumer weighs the full range of relative advantages and disadvantages associated with technological adoption (Ajzen, 1991; Bamberg & Möser, 2007; Bjørnstad, 2012; Caird et al., 2012; Han & Stoel, 2017; Hecher et al., 2017; Klöckner, 2013; Michelsen & Madlener, 2016; E. M. Rogers, 1983). Therefore, purchase decisions are rarely influenced solely on the financial implications (Bamberg & Möser, 2007; Han & Stoel, 2017; Hecher et al., 2017; Huijts et al., 2012; Klöckner, 2013; E. M. Rogers, 1983). Financial barriers cannot overshadow the importance of ensuring that the public is aware of the functional reliability and full range of relative advantages to installing a cold-climate heat pump, particularly the confidence in the heat pump's seasonal heating performance (Caird & Roy, 2010; Caird et al., 2008, 2012; Caird, Roy, Potter, & Herring, 2007; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Patel et al., 2015; E. M. Rogers, 1983; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

2.4 Public Awareness Gap

Market research has consistently identified that a heating system's perceived performance reliability is among the most influential factors to technological adoption (Caird & Roy, 2010; Caird et al., 2008, 2012, 2007; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Leach, n.d.; Lillemo, n.d.; Lillemo et al., 2013; Michelsen & Madlener, 2012, 2016; Owen et al., 2013; Patel et al., 2015; Snape et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). However, it is essential that the consumer has an accurate understanding of the technology's performance metrics to determine it to be a reliable market alternative (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983). It has been concluded that residents in Ontario lack reliable information on modern heat pump models and the advantages that are associated with adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Wyse & McVey, 2018). Further, they are exposed to inaccurate and contradictory claims from the heating and cooling industry and throughout their social networks (Wyse & McVey, 2018).

The reported awareness gap perpetuates public concern regarding the heat pump's seasonal performance reliability (Calder, 2017; IESO, 2017; Leach, n.d.; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). The IESO (2017) reported that 72% of provincially sampled homeowners were skeptical in the heat pump's functional reliability and energy performance. These provincial findings are consistent with a large body of market research examining the feasibility for residential heat pump adoption (Caird & Roy, 2010; Caird et al., 2008, 2012, 2007; Ipsos MORI & Energy Saving Trust, 2013; Lillemo, n.d.; Lillemo et al., 2013; Michelsen & Madlener, 2012, 2016; Owen et al., 2013; Snape et al., 2015; Sopha et al., 2010). Ipsos MORI and Energy Saving Trust (2013) observed that 40% of their sample reported negative perceptions of the air source heat pump. Further, 75% doubted that the heat pump would function reliably in temperatures beneath zero degrees Celsius. However, 68% had no previous knowledge of the technology (Ipsos MORI & Energy Saving Trust, 2013). Rectifying these misconceptions is understood to be a crucial precursor to stimulating residential interest in heat pump adoption (Ajzen, 1991; Bamberg & Möser, 2007; IESO, 2017; Klöckner, 2013; Leach, n.d.; Patel et al., 2015; E. M. Rogers, 1983, 2010; Wyse & McVey, 2018).

Public concerns regarding the functional reliability and energy performance of cold-climate heat pumps are not reflective of the performance demonstrated by modern models. Contrarily, public perceptions are often reflective of inefficient and outdated heat pumps, which failed to reliably function in temperatures below five degrees Celsius (Wyse & McVey, 2018). Field trials conducted in the North Eastern regions of the United States and Canada have demonstrated that cold-climate heat pumps are an extremely reliable alternative to fossil fuel furnaces (Abdelaziz & Shen, 2012; Dentz et al., 2014; Faesy, Grevatt, McCowan, & Champagne, 2014; Mitsubishi Electric, 2017b; Roy, Caird, & Potter, 2010; Safa, 2012; Toronto and Region Conservation Authority, 2018). Modern heat pumps remain fully functional until minus 15 degrees Celsius (Stevens, Craven, Marsik, & Hammer, 2015; Szekeres & Jeswiet, 2018b, 2018a). Electric resistance heaters are also preinstalled in most heat pumps to provide supplementary heating in extreme temperature lows (NRCAN, 2017; Szekeres & Jeswiet, 2018a). High performance cold-climate models are fully functional in temperatures as low as minus 20 degrees Celsius and remain operational until minus 30 degrees Celsius (Abdelaziz & Shen, 2012; Dentz et al., 2014; Faesy, Grevatt, McCowan, & Champagne, 2014; IESO, 2017; Mitsubishi Electric, 2017b; NEEP, 2014; Patel et al., 2015; Roy et al., 2010; Safa, 2012; Szekeres & Jeswiet, 2016, 2018a, 2018b; Wyse & McVey, 2018).

Cold-climate heat pumps installed throughout Ontario reported average COP ratings of 3.23 during the heating season and 5.27 during the cooling season (Safa, 2012). Seasonal COP averages are increasing with sustained technical advancements (IESO, 2017; Patel et al., 2015; Safa, 2012; Szekeres & Jeswiet, 2016, 2018b, 2018a). Szekeres & Jeswiet (2018b) demonstrated the heat pump's seasonal performance reliability and feasibility for residential adoption in seven case studies conducted across Ontario. The test sites included; Kingston, Ottawa, Sudbury, Thunder Bay, Timmins, Toronto, and Windsor. The research sites were selected to expose the technology to a range of different meteorological conditions. The coldest observed temperature during the study period was recorded in Timmins (-16.8 degrees Celsius). It was concluded that modern heat pumps were more than capable of providing reliable seasonal heating in each research site (Szekeres & Jeswiet, 2018b).

Cold-climate heat pumps are capable of providing 98% of Toronto's required seasonal heating hours, despite the concerns voiced amongst the public (Patel et al., 2015; Szekeres & Jeswiet, 2016). The previously discussed study conducted by The Toronto & Region Conservation Authority reported that none of the MURB units receiving a cold-climate heat pump required the usage of supplementary heating during the study period, even when temperatures reached minus 20 degrees Celsius (Toronto and Region Conservation Authority, 2018). Raising public awareness of the demonstrated performance of cold-climate heat pumps is suggested to be an essential component of mitigating the observed perception of risk and stimulating interest in residential heat pump adoption (IESO, 2017; Michelsen & Madlener, 2016; Snape et al., 2015; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b).

A consumer's perception of an unfamiliar technology is highly influenced by organizations responsible for developing and promoting the technology (Bamberg & Möser, 2007; Caird & Roy, 2010; Huijts et al., 2012; Klöckner, 2013; Michelsen & Madlener, 2012, 2016; Owen et al., 2013; E. M. Rogers, 1983, 1983). However, the provincial heating and cooling industry and local contractors across Ontario have been critiqued to be lacking sufficient training regarding the installation, maintenance, and operational procedures for both ducted and ductless heat pump models (IESO, 2017 Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). Specific installation procedures are not being followed, resulting in inconsistent and incorrect installations. A commonly observed error is that the heat pump will not be sized to provide the home's required heating load (Delta Energy & Environment, 2011; IESO, 2017; NRCAN, 2017; Owen et al., 2013; Patel et al., 2015; Wyse & McVey, 2018). In addition, the provincial heating and cooling industry and local contractors are suggested to be providing inaccurate, contradictory, or a complete lack of information regarding the proper operational procedures to residential consumers. The result is preventing optimal energy performance and is perpetuating negative consumer perceptions regarding the heat pump's functional reliability (IESO, 2017; Patel et al., 2015; Wyse & McVey, 2018).

Performance deficiencies are often the result of operational behavior or improperly installed technologies. Consumers who experience performance deficiencies are more likely to have negative perceptions regarding the heat pump's functional reliability and heating performance (Caird et al., 2012; Herring & Roy, 2007; Hirai, Morita, & Elokia, 2007; Roy et al., 2010; Sorrell, University of Sussex, & Sussex Energy Group, 2007; Wyse & McVey, 2018). Caird et al., (2012) observed that 50% of sampled heat pump users were experiencing performance deficiencies and regretted purchasing the heat pump. However, these participants reported that they had received no information on how to properly operate the heat pump (Caird et al., 2012). Consequently, improper user behavior was concluded to be preventing obtainable energy savings.

The importance of enforcing stricter regulations and guidelines targeted at the heating and cooling industry's awareness of cold-climate heat pumps and their proper installation procedures cannot be overlooked in future awareness building campaigns (Wyse & McVey, 2018). Efforts to increase residential heat pump adoption may backfire if the heat pump's adoption rate increases without ensuring that the knowledge and expertise of the heating and cooling industry is increased given the increased risk of a homeowner experiencing a performance deficiency. Increasing the capacity of the heating and cooling industry can help to reduce the instance of faulty installations and experienced performance deficiencies. The result should help to reduce negative perceptions regarding the heat pump's performance reliability (Wyse & McVey, 2018).

2.5 Awareness Building Campaigns

Awareness building campaigns have demonstrated effectiveness at encouraging sustainable consumption patterns and lifestyles, including the adoption of high efficiency technologies (Bamberg & Möser, 2007; Caird & Roy, 2010; Caird et al., 2012; Huijts et al., 2012; Klöckner, 2013; Michelsen & Madlener, 2012, 2016; E. M. Rogers, 1983; Zografakis et al., 2008). It has been concluded that these awareness building campaigns are among the most effective market interventions to stimulate residential interest in heat pump adoption (Caird & Roy, 2010; Caird et al., 2012; Thomas Decker & Menrad, 2015; Fawcett, 2011; Ipsos MORI & Energy Saving Trust, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2012, 2016; Mills & Schleich, 2012; Owen et al., 2013; Roy et al., 2010; Ruokamo, 2016; Satnik, 2019; Snape et al., 2015; Sopha et al., 2010). Continuing to develop and implement future awareness building programs is suggested to make important contributions to increasing residential heat pump adoption in Ontario (IESO, 2017; Patel et al., 2015; Wyse & McVey, 2018). However, this begs the questions as to the most effective way to provide the public with this information.

Rogers' (1983, 2010) argues that the communication channel that is used to disseminate information to the public is crucial to establishing a sustained opinion change. A consumer can independently access information through a one-way communication channel, such as the use of digital media. Contrarily, information can be transmitted through a two-way communication channel that connects two or more individuals in a social exchange of information (E. M. Rogers, 1983). There are reportable benefits to both communication channels. However, it is regarded that a social diffusion of information from a trusted source is more effective at producing a sustained opinion change (Hecher et al., 2017; Michelsen & Madlener, 2012, 2016; E. M. Rogers, 1983, 2010; Sopha et al., 2010).

There have been market studies to support that interpersonal educational seminars increase the reported perceptions and interest in heat pump adoption. Ipsos MORI & Energy Saving Trust (2013) observed that interest in heat pump adoption increased from 2% to 31% when the existing system required replacement after an educational treatment. Caird et. al., (2007, 2008, 2010, 2012) have observed consistent increases to consumer perceptions and the reported interest in heat pump adoption when consumers are educated on cold-climate heat pumps. Zografakis et al., (2008) concluded that focused educational interventions highlighting the importance of residential efficiency to youth can encourage sustainable consumption patterns later in life. It has been concluded that focused educational seminars are an effective way to establish information exchange from an individual who is perceived to be competent and well educated on the topic. The result can effectively stimulate lasting alterations to a consumer's consumption patterns (Hecher et al., 2017; Huijts et al., 2012; Jackson, 2003; Owen et al., 2013; E. M. Rogers, 1983; Snape et al., 2015; Staddon, Cycil, Goulden, Leygue, & Spence, 2016; Zografakis et al., 2008). Further, these seminars connect individuals within the same community, which can be used to facilitate an increased amount of information exchange through a residential consumer's local social networks.

Ensuring that residential consumers continue to exchange positive information on cold-climate heat pumps will make important contributions to increasing residential interest in technological adoption

(Han & Stoel, 2017; Hecher et al., 2017; Lillemo, n.d.; Lillemo et al., 2013; Owen et al., 2013; E. M. Rogers, 1983, 2010; Sopha et al., 2010). It has been determined that homeowners express high satisfaction with their heat pump's performance reliability, energy performance, and comfortable regulation of heat when the system is installed and operated correctly (Bjørnstad, 2012; Caird et al., 2012; Thomas Decker & Menrad, 2015; Lillemo, n.d.; Lillemo et al., 2013; Owen et al., 2013; Roy et al., 2010; Snape et al., 2015; Toronto and Region Conservation Authority, 2018). Caird et al., (2012) observed that 75% of the participants using a heat pump reported that it significantly outperformed their previous heating system. Homeowners have also expressed satisfaction in reducing their home's energy bills and residential carbon footprint (Bjørnstad, 2012; Caird et al., 2012; Owen et al., 2013; Snape et al., 2015). It has been concluded that sharing these positive experiences will further increase residential exposure and interest in technological adoption, particularly when they are distributed through trusted social networks (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; Michelsen & Madlener, 2016; E. M. Rogers, 1983; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b).

Homeowners frequently communicate and share experiences with modern technologies. This exchange of information can be highly influential to a homeowner's future purchase decisions (Lillemo, n.d.; Lillemo et al., 2013; Sopha et al., 2010). Information that is shared from a trusted source or a member of ones close social network is argued to have the most substantial influence on a consumer's perceptions of an unfamiliar technology because of the rapport shared between group members (Lillemo et al., 2013; Owen et al., 2013; E. M. Rogers, 1983; Szekeres & Jeswiet, 2016, 2018a, 2018b). It has been concluded that local seminars can leverage these existing group networks and strategically increase local interest in heat pump adoption. However, it is important to acknowledge that the impact of local educational seminars will likely be limited if they are not reinforced with other directed methods of information exchange.

The observed awareness gap pertaining to cold-climate heat pumps suggests that hosting local educational seminars may be insufficient to providing the exposure that is required to catalyze public rates of heat pump adoption. A consumer must take time out of their schedule and commit financial resources to attend a seminar session. If the consumer does not have prior information on the technology being discussed, potential rates of attendance will likely suffer. Further, the resources required to host the seminars suggest that the frequency of these events will be limited, restricting the amount of exposure that can be provided relative to using digital communication channels.

Digital media is an effective medium to rapidly increase exposure to an unfamiliar technology amongst a large population. Further, internet technologies have revolutionized an individuals capacity to acquire a wealth of information pertaining to the subject of inquiry (Biggs, 2012; Caird & Roy, 2010; Casey, 2008; Deloitte, 2014; Hawkins, 2002; Maloney, Storr, Paynter, Morgan, & Ilic, 2013; Mayer, 2003; Oliver & Herrington, 2001; E. M. Rogers, 2010; West, 2015). Internet access can connect a homeowner to industry experts, consultants, public agencies, and national databases to receive reliable information on unfamiliar and innovative technologies (Casey, 2008; Deloitte, 2014; Hawkins, 2002; E. M. Rogers, 2010; West, 2015). Homeowners can also read academic feasibility studies and other reports highlighting a technology's observed performance metrics. Information can also be transferred through social networks across vast geological distances in a short period of time, allowing residential consumers to share experiences they have had with certain technologies. The presence of this information can encourage further inquiry into cold-climate heat pumps and can effectively adjust observed consumption patterns (Biggs, 2012; Caird & Roy, 2010; Caird et al., 2012; Deloitte, 2014; Hawkins, 2002; Maloney et al., 2013; E. M. Rogers, 1983; Santer et al., 1995; West, 2015).

Market research has found that participants are more receptive to information about unfamiliar technologies when it is independently accessed through digital media (Caird & Roy, 2010; Caird et al., 2012; Hecher et al., 2017; Maloney et al., 2013). Caird & Roy (2010) explain that the public may perceive information that is disseminated from manufacturers or technological advocates to be subject to bias. Hecher et al., (2017) observed consistent findings as Caird & Roy (2010), supporting the use of digital media to increase residential exposure to cold-climate heat pumps. The resulting exposure amongst a large population can help to stimulate further inquiry into cold-climate heat pumps and attendance at future community seminar sessions. Ensuring that these awareness building campaigns are sustained is concluded to be a precursor to residential heat pump adoption.

2.6 Summary

The discussed market barriers to cold-climate heat pump adoption currently are stalling the heat pump's provincial rate of adoption. While it is concluded that the price disparity between natural gas and electricity is the most significant barrier to provincial adoption, this statement must be critically appraised. It has been determined that each of the conditions that Rogers' (1983) affirms is essential to raise a technology's rate of adoption currently is being violated in Ontario. It has been suggested that low rates of provincial awareness and concerns regarding the heat pump's performance reliability are preventing accurate cost-benefit analysis pertaining to heat pump adoption. Awareness building campaigns are concluded to be essential components to increasing residential exposure and interest in modern high-performance heat pump models (IESO, 2017; Leach, n.d.; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). However, these conclusions have not been sufficiently tested in Ontario. The current study has been designed and implemented to address the existing research gap and to contribute insights regarding the impacts that local awareness building campaigns will have on the reported probability of residential heat pump adoption. Comparing the effectiveness of directly providing residential consumers with information through digital media and hosting local educational seminars will also provide important insights for the development and implementation of future awareness building campaigns.

Chapter Three: Methodology

There has been a lack of experimental trials in Ontario to provide a research design for the current study to replicate. For that reason, inspiration was drawn from the wider body of reviewed market literature examining the effectiveness of educational interventions on consumer interest in energy efficient technologies (Caird & Roy, 2010; Caird et al., 2012; Thomas Decker & Menrad, 2015; Fawcett, 2011; Ipsos MORI & Energy Saving Trust, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2012, 2016; Mills & Schleich, 2012; Owen et al., 2013; Roy et al., 2010; Ruokamo, 2016; Satnik, 2019; Snape et al., 2015; Sopha et al., 2010; Zografakis et al., 2008). The research design used to address the research objectives, questions, and hypotheses proposed by the present study is elaborated in the following subsection. Information regarding the study's sample, including the recruitment procedures, has been included as section 3.2. The instrument and materials that were provided to each experimental cohort are described in section 3.3. The experimental procedures used to administer the instrument to each experimental group is discussed in section 3.4. The chapter concludes with a discussion of the threats to internal and external validity faced by the current study. The solutions and considerations used by the researcher to mitigate the impacts of these threats are also clearly identified.

3.1. Research Design

A between group pre-test post-test design was used to measure the direction and change to the reported probability of heat pump adoption following two different educational interventions. The study was quasi-experimental in nature because participants were not randomly assigned to each experimental condition. Two cohorts attended a local educational seminar. The remaining two cohorts received a detailed factsheet that was hosted online. The research design has been visually represented using the classic notation system provided by Campbell & Stanley (1963) and as recommended by Creswell (2014) in Figure 2. below. O1 has been set to represent the measure of the reported probability of heat pump adoption prior to receiving the treatment. X has been set to represent the educational intervention. O2 has been set to represent the measure of the reported probability of heat pump adoption after providing the educational treatment. The linear lay out of the variables has been set to represent the temporal procedures used during the experiment (Campbell & Stanley, 1963).

Figure 2. Research Design

	Pre-test	Treatment	Post-test
Seminar Cohorts:	O1	X	O2
Survey Cohorts:	O1	X	O2

Pre-test post-test research designs provide a clear indication of the direction and change to the outcome variables after an experimental treatment (Creswell, 2014). Further, the effects can be clearly compared between two or more experimental groups. This research design has been used in the reviewed market literature to test the measured change in the reported perspectives and interest in heat pump adoption after an educational treatment (Caird & Roy, 2010; Caird et al., 2008, 2012; Ipsos MORI & Energy Saving Trust, 2013; Owen et al., 2013). Therefore, the research design was determined to be appropriate for the current study's objectives.

3.2 Participants

Partnerships were established with local environmental organizations to recruit a sample and facilitate the awareness building campaigns. The main partnership was formed with Reep Green Solutions, a local environmental charity that improves residential energy literacy and energy performance. Reep played a pivotal role in the study by recruiting participants and hosting the two seminar sessions. Reep distributed information about each seminar through their social media accounts. A description of the event and the registration page was also posted on Reep's website. Reep sent a mass email providing information about the seminar and the opportunity to participate in the research study to approximately 3400 residents in the Region of Waterloo. Information about the second seminar was posted on the City of Kitchener's Community Calendar and the regional newspaper's Record Community Calendar.

A second partnership was formed with eMERGE Guelph, a local organization premised on facilitating 100% of the community's energy requirements from renewable sources by 2050. The partnership with eMERGE Guelph was established to recruit participants for the survey cohorts. A description of the study and an invitation to participate in the survey treatment was included in a newsletter that was distributed to eMERGE Guelph's 1500 residential subscribers. An invitation to participate in the survey was also extended to graduate students, alumni, faculty, and other staff at the University of Waterloo through the Environmental Faculty's community emailing list. The email also invited participants to register for the second seminar, however, participants were requested to not participate in both experimental groups to mitigate response bias.

Participation in the study was restricted to homeowners and landlords. Individuals who do not own their home are not responsible for the purchase and installation costs of replacing their heating system. The inclusion of these responses would introduce an internal bias to the dataset, as these participants might not consider the economic constraints faced by homeowners and landlords. No other exclusionary criteria were added to the methods of recruitment.

Participants voluntarily signed up for the seminar sessions or the online intervention. Therefore, it was not possible to randomly assign participants to each experimental treatment. The majority of the participants volunteered to participate in the online survey (survey cohort A n= 45, survey cohort B n= 78). The remaining thirty-five participants attended the seminar sessions (seminar cohort A n= 11, seminar cohort B n= 24). The purpose of the second seminar and survey treatment was to increase the study's sample size and to include demographic measures on age, level of education, and annual income. Fifty-five percent of the sample was under the age of 45 (n= 55). The majority of the sample (60%) earned an annual income above $75,000 (n= 61). Of these participants, 42% were earning an annual income exceeding $100,000 (n= 43). Eighty-eight percent of the participants had a university degree (n= 90). A detailed presentation of the sample's demographic composition has been included as Appendix A.

3.3. Instrument & Materials

A cross-sectional questionnaire was designed by the researcher to test the theoretical claims that raising awareness to the performance capacity and advantages offered by a technology are precursors to increasing the adoption of the technology (Ajzen, 1991; Bamberg & Möser, 2007; Han & Stoel, 2017; Hecher et al., 2017; Klöckner, 2013; E. M. Rogers, 1983, 2010). Further, the items were developed to provide further insight to the identified barriers to residential heat pump adoption as identified by the IESO (2017) and Wyse & WcVey (2018). The treatment variable was characterized by the educational seminar or the independently accessed online factsheet. Both treatments provided information on each mediating variable under investigation, including; the heat pump's functional reliability, the relative advantages associated with using a cold-climate heat pump, and the positive consumer satisfaction ratings. The outcome variable was characterized by the reported probability of adoption. Each variable under investigation in this study has been summarized in Table 3.1 below.

Table 3.1: Variables under Investigation

Treatment Variables	*Mediating Variables*	*Outcome Variables*
Educational Intervention	Raising Awareness of Cold-climate heat pumps	Probability of Adoption
Age	Awareness of Cold-climate heat pumps	
Education	1) Technical Improvements 2) Availability of Cold-Climate Models	
Income	Performance Reliability	
	Relative Advantages	
	1) Reduced Energy Bill	
	2) Reduced Carbon Footprint 3) Reduced Consumption of Purchased Energy	
	Positive Satisfaction Ratings	

The participant's awareness of the cold-climate heat pump was operationalized using multiple choice questions. A yes or no scale was used to determine if participants were aware of the technical improvements heat pumps models have made and the awareness of cold-climate models. The remainder of the instrument was measured on a 5-point Likert scale. The scale was operationalized with 1 representing low and 5 representing high. These instrument items measured; the participant's perceived reliability of the heat pump, the influence of each relative advantage, the reported probability of adoption, and the influence of the positive consumer satisfaction ratings. The post-test used the same Likert scale to measure the direction and change to the perceived reliability of the heat pump when installed in a cold-climate and the reported probability of adoption. The instrument that was administered to each experimental group has been included as Appendix B.

The instrument provided to each experimental group remained consistent. However, the materials that were used to provide the treatment variable varied between the two experimental groups. The seminar cohorts received an interpersonal seminar hosted by a representative of Reep Green Solutions. An industry representative from Waterloo Energy Products provided a guest lecture at the second seminar session. The educational intervention clearly explained how the heat pump heats and cools the home. The performance reliability of modern cold-climate heat pumps in Ontario was emphasized. Participants also learned about the relative advantages they would receive relative to the heating system that they replaced. A power-point presentation reinforced the content discussed during the lecture. A diagram visually represented how the heat pump's components interact to move and pressurize heat energy from the air outside of the home through phase changes (liquid-gas). Tables comparing the heat pump's performance metrics to market competitors were also provided. The performance metrics included; 300% energy efficiency, average seasonal COP values, the operational lifespan, projected operational costs, and potential energy and carbon savings.

The experimental treatment administered to the survey cohorts summarized the information that was presented during the seminars in an informative factsheet that was made available online on

Qualtrics. A diagram was included in the factsheet to visually represent the heat pump's heating and cooling process. The relative advantages associated with using a cold-climate heat pump and the performance metrics relative to market competitors were also listed for the participants reference. The information used to develop the independently accessed factsheet was retrieved from IESO (2017) and Natural Resources Canada (2017). The information factsheet provided to the survey cohorts has been provided as Appendix C.

3.4. Experimental Procedures

All experimental sessions were conducted individually throughout 2018-2019. The experimental procedures remained consistent at each seminar session. The experimental procedures also remained consistent between each online intervention. The experimental procedures are discussed in detail in the following subsections.

3.4.1. Seminar Cohorts

The first seminar was hosted September 22, 2018 at the Reep House for Sustainable Living. The second seminar was hosted March 2nd, 2019 at evolv1, Canada's first zero carbon design certified building, developed and managed by the CORA Group Inc. Both venues used ground source heat pumps as their primary source for space heating. Participants were greeted by the representative of Reep who briefly provided an overview of the seminar and referenced the benefits to improving a home's energy performance. The researcher was introduced and informed the participants that the purpose of the study was to examine residential awareness of modern cold-climate heat pump models and to investigate effective strategies to mitigate the identified market barriers associated with heat pump adoption. The pre-test of the mediating variables and the outcome variables was distributed. The participants were exposed to the experimental treatment after the completion of the pre-test. The magnitude of the direction and change to the outcome variable was measured immediately after the conclusion of the educational seminar. The participants were debriefed, and their time commitment was satisfied. The results were then analyzed using descriptive statistics and intergroup and between group tests of statistical significance.

3.4.2 Survey Cohorts

The first survey was launched in September 2018 and collected responses until February 2019. The second survey was launched in February 2019 and collected responses until June 2019. Each survey was hosted on Qualtrics using institutional access through the University of Waterloo. Participants took part in the study by using a personal or public internet connection. The methods of recruitment provided potential participants with a link to the instrument's cover letter. Participants were informed that the purpose of the study was to examine residential awareness of modern cold-climate heat pump models and to investigate effective strategies to mitigate the identified market barriers associated with heat pump adoption. Providing informed consent allowed the participants to navigate to the pre-test of the mediating and outcome variables. The participants were directed to the experimental treatment after completing the pre-test. The magnitude of the direction and change to the outcome variable was measured after the participants were satisfied with the provided information. Participants received a debriefing form and their time commitment was satisfied. The results were then analyzed using descriptive statistics and intergroup and between group tests of statistical significance.

3.5 Threats to validity

Although opportunistic, the methods of recruitment introduce a threat to the study's external validity. It is crucial to acknowledge that participants can be predisposed to certain perspectives and attitudes. These personal characteristics can affect the outcomes of the experimental treatment (Creswell, 2014). Creswell explains that an experimental sample that shares common characteristics prevents the researcher from generalizing the study's findings to populations that do not share the same personality traits (2014). The researcher must limit the study's conclusions to populations that share the same similar characteristics to overcome this threat to validity.

It can be reasonably expected that the current sample was predisposed to value environmental and residential sustainability given their personal connections to the local environmental organizations that assisted with recruitment. For that reason, the sample may have been predisposed to respond more favorably to the treatment variable. The conclusions presented in the current study have been restricted to the effectiveness that local environmental organizations can have on leveraging residential interest in heat pump adoption by spreading awareness through their contact lists and hosting local seminar sessions. Future research will be necessary to examine if consistent trends are observed among different sample populations.

It is important to indicate that triangulating a study's results to previously observed findings in different contexts can effectively identify observed consistencies and deviations (Altrichter, H., Feldman, A., Posch, P., & Somekh, B., 2008; Cohen, L. & Manion, L., 2000; O'Donoghue, T. & Punch, K., 2003). The consistencies and variations that are observed within a sample from the reviewed literature can often provide important insights for future research (Creswell, 2014). For that reason, the results of the current study were compared and contrasted the existing body of reviewed market literature examining the feasibility for residential heat pump adoption.

Chapter Four: Analysis & Results

The following chapter begins with a discussion of the procedures used to determine the reliability and consistency of the instrument administered to each experimental group. A discussion of the descriptive and inferential tests of statistical significance used to analyze the data is also provided. The chapter then transitions to provide the evidence to answer each research question and to support or reject each hypothesis under investigation.

Pearson's *r* coefficient provided insufficient evidence to suggest that each of the demographic variables were correlated to each of the other variables under investigation, as shown in Appendix D. Further, multivariate analysis determined that there was not a significant difference between the experimental groups pertaining to each demographic variable and the remaining variables under investigation. However, there were reportable correlations observed within the sample, which are identified in section 4.2 and highlighted in each of the relevant subsections.

Each cohort's observed awareness related to modern cold-climate heat pump models is presented in Section 4.3. Section 4.4 provides an overview of the impact that a reduced energy bill, residential carbon footprint, and consumption of purchased energy had on each experimental group's reported probability of adoption. Statistical evidence is presented in Section 4.5 to test H_1; if homeowners receive positive consumer satisfaction reports then the probability of adoption will increase, H_2; educational interventions highlighting the performance capacity and relative advantages to using a heat pump will increase the reported probability of adoption, and H_3; seminars will be more effective at increasing the reported probability of adoption than information that is accessed online.

4.1 Analysis

An a priori sample was estimated based on the standard type II error rate (p= 0.05), estimated power ($1 - \beta = 0.80$), and small effect size set at 0.10 as recommended by Cohen (1992). The result of the power analysis provided by Cohen (1992) indicated that the desired sample size for a small effect was

393 participants. A non-random opportunistic sampling method recruited 158 homeowners and landlords from the Waterloo Region in Southern Ontario after omitting the incomplete questionnaires. The sample size did not meet the requirements as indicated by Cohen (1992), meaning that effects of practical importance may not have been detected.

Cronbach's alpha was calculated to test the instrument's internal consistency. The level of acceptable consistency was set to be above 0.70 under the recommendations of BrckaLorenz et al., (2013). However, an alpha value closer to one was desired (BrckaLorenz, Chiang, & Laird, 2013). Inter-item correlations were also determined to assess if scores were accurately representing the instrument items and to reduce redundancies measuring the same construct (BrckaLorenz et al., 2013; Briggs & Cheek, 1986; Cohen, 1988). The mean inter-item correlation was set to be within 2 to 4 and the desired average inter-item correlations were set to be between 0.15 and 0.50 under the recommendations of Briggs & Cheek (1986). The instrument passed each established test of internal reliability, as shown in Table 4.1 below.

Table 4.1: Internal Consistency Analysis

	Cronbach's Alpha	*Cronbach's Alpha Based on Standardized Items*	*Item Means*	*Inter-Item Correlations*	*N of Items*
Full Dataset	.92	.91	2.95	.31	23
Demographic Dataset	.90	.89	3	.24	26

Descriptive statistics including frequency distributions, averages, and standard deviations were measured for each instrument item. The results were used to provide evidence to each research question under investigation by demonstrating the trends within and between experimental groups after administering the experimental treatment. Further, observable trends were provided to help support or reject each hypothesis under investigation. These descriptive statistics were supported by inferential tests of significance to determine if observed within and between group differences passed the established alpha level (p= 0.05). The statistical tests included; paired sample for means analysis, univariate analysis, and multivariate analysis. These inferential tests were selected based on the recommendations of Creswell (2014) for within group and between group pre-test post-test research designs.

Paired sample for means analysis was conducted on each experimental group to statistically test the within group differentials between the reported confidence in the heat pump's performance reliability when installed in a cold-climate, the impact of the consumer satisfaction ratings, and the differential to the reported probability of adoption after the experimental treatment. These tests were conducted to provide statistical evidence to support H1; If participants are provided with positive consumer satisfaction ratings then the reported probability of adoption will increase, and H2; If participants are educated on the performance capacity and relative advantages to using a heat pump then the reported probability of adoption will increase. Univariate analysis was conducted to determine if the observed differences between group means were significant to provide statistical evidence to support or reject H3; seminar sessions will be more effective at increasing the reported probability of adoption than information that is hosted online. Multivariate analysis was also conducted to examine if the direction and change to the outcome variable in each experimental group was significantly different after accounting for the participants age, level of education, and annual income.

Pearson's *r* correlation coefficients were calculated to assess the relationships between each variable under investigation. An inter-item correlation matrix was composed for the full dataset. A second correlation matrix was developed to determine if correlations were present between the demographic variables and each other item under investigation. Correlations were determined to be strong at $r = 0.50$ with established alpha levels of p= 0.05, as recommended by Cohen (1988). Emphasis was placed on determining if the awareness of cold-climate heat pumps was related to the perceived performance reliability. It was also examined if the participants perceived reliability or if the relative advantages were correlated to the reported probability of adoption. Statistical evidence was used to support the impact of the educational intervention by examining if correlations were present between the reported probability of adoption in the pre-test and post-test. Further, correlations were also examined to assess the impact of informing the participants on the positive consumer satisfaction ratings.

4.2 Pearson's r Correlation Coefficients: Key Results

The Pearson's *r* correlation matrix for the full dataset has been included in Table 4.2 below. It can be observed that there were strong positive correlations observed between the importance of reducing the home's environmental impacts while reducing measurable savings. There was also evidence to support that participants who were interested in heat pump adoption responded favorably to receiving the positive consumer satisfaction ratings. Evidence was provided to suggest that the participants who were interested in heat pump adoption also responded favorably to receiving the educational intervention. Further, relationships were present to suggest that interest in system adoption continued to increase as the system was approaching the end of its lifespan. The relevant correlations are highlighted and discussed in greater detail in each of the following subsections.

Table 4.2: Inter-Item Correlation Matrix - Full Dataset

	V1	*V2*	*V3*	*V4*	*V5*	*V6*	*V7.*	*V8.*	*V9.*	*V10.*	*V11.*	*V12.*	*V13.*	*V14.*	*V15.*	*V16.*	*V17.*	*V18.*	*V19.*	*V20.*	*V21.*	*V22.*	*V23.*
*V1.**	1.00	-.07	.00	.03	.12	-.08	-.05	.02	.00	-.03	.00	.03	.11	-.14	-.04	.03	.03	.03	.02	-.06	.03	.02	.06
V2.	-.07	1.00	.48	.28	.33	.00	.09	.04	.10	.11	.21	.18	.15	-.03	-.04	.07	.15	.14	-.02	-.02	.04	.11	.09
V3.	.00	.48	1.00	.25	.23	-.04	.08	-.02	.18	.15	.19	.24	.16	.02	.03	.09	.16	.09	.09	.02	.06	.08	.04
V4.	.03	.28	.25	1.00	.60*	.10	.16	.18	.23	.27	.35	.32	.45	.20	.18	.18	.25	.30	.13	.27	.22	.22	.27
V5.	.12	.33	.23	.60*	1.00	.13	.23	.15	.10	.14	.20	.22	.35	.11	.13	.16	.31	.32	.10	.16	.20	.18	.23
V6.	-.08	.00	-.04	.10	.13	1.00	.62*	.79*	.19	.26	.30	.22	.34	.19	.23	.20	.20	.12	.27	.28	.32	.30	.33
V7.	-.05	.09	.08	.16	.23	.62*	1.00	.56*	.18	.25	.26	.20	.33	.05	.17	.19	.17	.22	.16	.15	.19	.19	.34
V8.	.02	.04	-.02	.18	.15	.79*	.56*	1.00	.25	.28	.30	.24	.42	.14	.27	.18	.17	.21	.33	.32	.38	.34	.43
V9.	.00	.10	.18	.23	.10	.19	.18	.25	1.00	.87*	.64*	.44	.32	.53*	.52	.41	.33	.29	.68*	.62*	.45	.35	.20
V10.	-.03	.11	.15	.27	.14	.26	.25	.28	.87*	1.00	.76*	.50*	.36	.64*	.68*	.57*	.43	.37	.72*	.74*	.54*	.35	.22
V11.	.00	.21	.19	.35	.20	.30	.26	.30	.64*	.76*	1.00	.65*	.41	.57*	.62*	.68*	.51*	.33	.59*	.69*	.69*	.47	.23
V12.	.03	.18	.24	.32	.22	.22	.20	.24	.44	.50*	.65*	1.00	.52*	.34	.45	.55*	.71*	.40	.36	.41	.51*	.65*	.22
V13.	.11	.15	.16	.45	.35	.34	.33	.42	.32	.36	.41	.52*	1.00	.29	.38	.38	.42	.64*	.19	.25	.32	.22	.50*
V14.	-.14	-.03	.02	.20	.11	.19	.05	.14	.53*	.64*	.57*	.34	.29	1.00	.79*	.57*	.34	.25	.61*	.70*	.50*	.36	.22
V15.	-.04	-.04	.03	.18	.13	.23	.17	.27	.52*	.68*	.62*	.45	.38	.79*	1.00	.78*	.51*	.39	.56*	.72*	.63*	.41	.30
V16.	.03	.07	.09	.18	.16	.20	.19	.18	.41	.57	.68*	.55*	.38	.57*	.78*	1.00	.75*	.51*	.38	.53	.65*	.44	.29
V17.	.03	.15	.16	.25	.31	.20	.17	.17	.33	.43	.51*	.71*	.42	.34	.51*	.75*	1.00	.63*	.27	.33	.47	.58*	.30
V18.	.03	.14	.09	.30	.32	.12	.22	.21	.29	.37	.33	.40	.64*	.25	.39	.51*	.63*	1.00	.24	.32	.35	.38	.56*
V19.	.02	-.02	.09	.13	.10	.27	.16	.33	.68*	.72*	.59*	.36	.19	.61*	.56*	.38	.27	.24	1.00	.87*	.65*	.47	.32
V20.	-.06	-.02	.02	.27	.16	.28	.15	.32	.62*	.74*	.69*	.41	.25	.70*	.72*	.53*	.33	.32	.87*	1.00	.76*	.53*	.36
V21.	.03	.04	.06	.22	.20	.32	.19	.38	.45	.54*	.69*	.51*	.32	.50*	.63*	.65*	.47	.35	.65*	.76*	1.00	.69*	.50*
V22.	.02	.11	.08	.22	.18	.30	.19	.34	.35	.35	.47	.65*	.22	.36	.41	.44	.58*	.38	.47	.53*	.69*	1.00	.58*
V23.	.06	.09	.04	.27	.23	.33	.34	.43	.20	.22	.23	.22	.50*	.22	.30	.29	.30	.56*	.32	.36	.50*	.58*	1.00

*V1 = Installed heating system, V2 = Awareness of Technical Improvements, V3 = Awareness of CC-ASHPs, V4 = Perceived performance reliability (pre-test), V5 = Perceived performance reliability (post-test), V6 = Reduced energy bill, V7= Reduced carbon footprint, V8= Reduced consumption of purchased energy, V9= Probability of adoption – Within the year (pre), V10 = Within 1-2 years (pre), V11= Within 3-5 years (pre), V12= Within 6-10 years (pre), V13= End of Life (pre), V14 = Probability of adoption – Within the year (post), V15= Within 1-2 years (post), V16= Within 3-5 years (post), V17= Within 6-10 years (post), V18 = End of life (post), V19 = Impact of satisfaction ratings – Within the year, V20= Impact of Satisfaction ratings – Within 1-2 years, V21= Impact of Satisfaction Ratings – Within 3-5 years, V22= Impact of Satisfaction Ratings – Within 6-10 years, V23 = Impact of Satisfaction Ratings – End of Life

4.3 Awareness of Cold-Climate Heat Pumps

The first research question under investigation was to examine the reported awareness of cold-climate heat pumps in each experimental group. Each experimental group reported a low level of awareness to the technical advancements heat pumps have made; seminar cohorts (31%, n= 11), survey cohorts (20%, n= 25). The average awareness was comparable between the two cohorts with a similar variance, as shown in Table 4.2 below; seminar cohorts (M=1.31, SD .47), survey cohorts (M=1.20, SD .41). The awareness of the availability of cold-climate heat pumps was higher in the seminar cohorts (63%, n= 27), as highlighted in Table 4.3. The reported awareness was low in the survey cohorts and was consistent with the reported awareness of the system's technical improvements; survey cohorts (22%, n= 27).

Table 4.3. Awareness of Cold-Climate Heat Pumps

	Improvements	*CC-ASHP*	*Reliability (pre-test)*	*Reliability (post-test)*
Seminar Cohorts	M=1.31, SD .47, n=35	M=1.63, SD .49 n=35	M=3.77, SD .84 n=35	M=3.89, SD .87 n=35
Survey Cohorts	M= 1.20, SD .41 n=122	M=1.22, SD .42 n=122	M=3.67, SD 1.04 n=121	M= 3.90, SD .92 n=115

Descriptive statistics show that the majority of each experimental group was confident in the CC-ASHP's performance reliability prior to receiving the educational intervention; seminar cohorts (68%, n= 24), survey cohorts (57%, n= 70). There was not an observable differential to the frequency distributions observed in each experimental group following the education intervention, as highlighted in Appendix E. The perceived reliability was slightly higher with a lower observed variance from the mean in the seminar cohorts prior to the educational intervention, as highlighted in Table 4.3. However, the average confidence in the cold-climate heat pump's performance reliability was consistent with a similar calculated variance from the mean following the experimental treatment.

Pearson's r coefficient determined a moderate correlation between the perceived reliability in the pre-test and the perceived reliability in the post-test; $r = .60$, $p < 0.001$. The difference between the survey cohorts' pre-test and post-test mean scores was significant; (M1=3.67, M2=3.90), t= -2.76, p< 0.01. Univariate analysis provided insufficient evidence to suggest that the difference between group means was significant; F (1, 146) = 2.13, p= 0.15, η^2 = 0.01. No other significant effects were observed.

4.4 Impact of Relative Advantages Associated with using a Cold-Climate Heat Pump

It was observed that the high impact of each relative advantage on the reported probability of adoption was similar in each experimental group; reduced energy bill (seminar cohorts 48%, n= 17, survey cohorts 55%, n= 67), reduced carbon footprint (seminar cohorts 54%, n= 19, survey cohorts 57%, n= 70), reduced consumption of purchased energy (seminar cohorts 46%, n= 16, survey cohorts 43%, n= 53). The full frequency distributions for each condition of relative advantage have been included as Appendix F. It can be observed that the average scores were similar between each experimental group in the condition of a reduced energy bill, residential carbon footprint, and consumption of purchased energy in Table 4.4 below. It can also be seen that variance from the mean scores was also similar in each condition of relative advantage.

Table 4.4: Importance of Relative Advantages

	Reduced Energy Bill	*Reduced Residential Carbon Footprint*	*Reduced Consumption of Purchased Energy*
Seminar Cohorts	M= 4.26, SD .92 n= 35	M= 4.34, SD .91 n=35	M= 4.23, SD .88 n=35
Survey Cohorts	M= 4.30 SD .98 n= 118	M= 4.28 SD 1.03 n=120	M= 4.18, SD .93 n= 117

The consistent average scores observed among experimental groups were supported by univariate analysis, which showed that the difference between group means was not significant in the condition of each relative advantage;

i. *Energy bill; F* (1, 151) = 0.83, p= 0.83, η^2= 0.00

ii. *Residential carbon footprint; F* (1, 153) = 0.12, p= 0.73, η^2= 0.00

iii. *Consumption of purchased energy; F* (1, 150) = 0.08, p= 0.78, η^2= 0.00

Pearson's *r* coefficient indicated a strong correlation between the importance of a reduced energy bill and reducing the consumption of purchased energy; $r = .79$, $p < 0.001$. A strong positive correlation was also observed between the importance of a reduced energy bill and a reduction to the home's carbon footprint; $r = .62$, $p < 0.001$. A positive correlation was observed between the importance of a reduced consumption of purchased energy and a reduced residential carbon footprint; $r = .56$, $p < 0.001$. However, there was insufficient evidence to suggest that each relative advantage was correlated with an increased probability of adoption, as shown in Table 4.5 below.

Table 4.5: Pearsons' *r* Correlation Coefficients: Relative Advantages & Reported Probability of Adoption

	Pre-test					*Post-test*				
	Within the year pre	1-2 years	3-5 years	6-10 years	EOL	Within the year	1-2 years	3-5 years	6-10 years	EOL
Energy Bill	.19	.26	.30	.22	.34	.19	.23	.20	.20	.12
Carbon Emissions	.18	.25	.26	.20	.33	.05	.17	.19	.17	.22
Purchased Energy	.25	.28	.30	.24	.42	.14	.27	.18	.17	.21

4.5 Impact of Educational Interventions on Reported Probability of Adoption

Hypothesis 1: There was insufficient evidence to reject the null hypothesis that the reported probability of adoption would be unaffected by receiving positive consumer feedback in each experimental group. There was not an observable differential to the frequency distributions after informing the participants of the positive consumer satisfaction ratings, as shown in Appendix G. The average reported probability of adoption did not show an increase following the provision of the educational intervention, as shown in Tables 4.6 and 4.7 below. It can also be observed that there was not an observable difference in the variance that was observed from the mean scores.

Table 4.6: Paired Sample for Means Analysis – Impact of Satisfaction Ratings: Survey Cohorts

	Pre-test	*Post-satisfaction*	*t*	*p*
Within the year	M= 1.82 SD, 1.11 n=98	M= 2.10 SD 1.17 n=98	-2.94	P<.01
Within 1-2 years	M= 2.21 SD 1.38 n=99	M= 2.42 SD 1.39 n=99	-2.13	P<.05
Within 3-5 years	M= 2.93 SD 1.42 n=99	M= 2.88 SD 1.34 n=99	.51	P=.61
Within 6-10 years	M= 3.15 SD 1.42, n=98	M= 3.15 SD 1.42 n=98	.00	P=1.00
End of Life	M= 3.66 SD 1.22 n=104	M= 3.77 SD 1.27 n=104	-.90	P=.37

Table 4.7: Paired Sample for Means Analysis – Impact of Satisfaction Ratings: Seminar Cohorts

	Pre-test	*Post-satisfaction*	*t*	*p*
Within the year	M= 2.68, SD 1.19 n=31	M= 2.84, SD 1.49 n=31	-.82	P=.42
Within 1-2 years	M= 2.72 SD, 1.34 n=25	M=2.76, SD 1.42 n=25	-.19	P=.85
Within 3-5 years	M= 3.38, SD, 1.35 n=24	M= 3.00, SD 1.45 n=24	1.28	P=.21
Within 6-10 years	M= 3.50, SD 1.57 n=22	M= 3.32, SD 1.46 n=22	.50	P=.62
End of Life	M= 3.83, SD 1.34 n=24	M= 3.79, SD 1.44 n=24	.13	P=.90

Although informing the sample of the positive satisfaction ratings did not produce an observable increase to the average reported probability of adoption, Pearson's *r* coefficient indicated strong positive correlations between the probability of adoption in the pre-test and the reported probability of adoption after learning about the positive satisfaction ratings;

- Within the year & Within the year post-satisfaction ratings; r = .68, p< .001
- Within 1-2 years & Within 1-2 years post-satisfaction ratings; r =.74, p< .001
- Within 3-5 years and Within 3-5 years post-satisfaction ratings; r = .69, p< .001
- Within 6-10 years and Within 6-10 years post-satisfaction ratings; r = .65, p< .001
- End of Existing System's Operational Lifespan and E.o.L post-satisfaction ratings; r = .50, p< 0.001.

Strong positive correlations also were present between the positive satisfaction ratings and the reported probability of adoption in the post-test;

- Within the year & Within the year post-satisfaction ratings; r = .61, p< .001
- Within 1-2 years & Within 1-2 years post-satisfaction ratings; r =.72, p< .001
- Within 3-5 years and Within 3-5 years post-satisfaction ratings; r = .65, p< .001
- Within 6-10 years and Within 6-10 years post-satisfaction ratings; r = .58, p< .001
- End of Existing System's Operational Lifespan and E.o.L post-satisfaction ratings; r = .56, p< .001

Hypothesis 2: There was evidence to support that the educational intervention increased the reported probability of adoption as the existing system approached the end of its operational lifespan. It was observed that the percentage of participants indicating a high probability of adoption increased as their existing system was requiring replacement in each experimental group, as highlighted in Appendix H. The reported high probability of adoption increased from 40% (n= 10) to 73% (n= 19) at the end of the existing system's operational lifespan after providing the educational intervention to the seminar cohorts. A smaller increase was observed at the end of the existing system's operational lifespan in the survey cohorts from 33% (n= 37) to 51% (n= 51). The reported high probability of adoption increased from 17% (n= 5) within the year to 73% (n = 19) at the end of the existing system's operational lifespan in the seminar cohorts. The high probability increased from 8% within the year (n= 8) to 51% at the end of the existing system's operational lifespan in the survey cohorts (n= 51).

Paired sample for means analysis supported the descriptive statistics, as shown in Table 4.8 and 4.9 below. It can be observed that the average scores were highest and the observed variance from the mean was the lowest as the existing system required replacement. The difference between the mean scores was significant in the seminar cohorts within 6-10 years (M1=3.32, M2=4.18), t= -2.84, p= 0.01, and at end of the existing system's operational life; (M1= 3.81, M2= 4.67), t= -3.54, p= 0.01. The difference between the pre-test and the post-test scores in the survey cohorts was significant in each time interval except within 3-5 years, as highlighted in Table 4.8.

Table 4.8: Paired Sample for Means Analysis – pre-test versus post-test: Survey Cohorts

	Pre-test	*Post-test*	*T*	*p*
Within the year	M= 1.85 SD 1.17 n=95	M= 2.22 SD 1.39 n=95	t= -3.45	P<.001
Within 1-2 years	M= 2.18 SD 1.38 n=94	M= 2.53 SD1.49 n=94	t= -3.23	P< .01
Within 3-5 years	M= 2.91, SD 1.44 n=93	M= 3.02, SD 1.34 n=93	t= -1.13	P= .26
Within 6-10 years	M= 3.11 SD 1.46 n=91	M= 3.44 SD 1.42 N=91	t= -3.22	P< .01
End of Life	M=3.66 SD 1.23 N=99	M= 4.09 SD 1.20 N=99	t= -4.45	P< .001

Table 4.9 Paired Sample for Means Analysis – pre-test versus post-test: Seminar Cohorts

	Pre-test	*Post-test*	*T*	*p*
Within the year	M= 2.89, SD 1.12 n=27	M= 2.26, SD 1.14 n=27	t= 1.91	P= .07
Within 1-2 years	M= 2.91, SD 1.19 n=22	M=2.77, SD 1.51 n=22	t= .45	P= .66
Within 3-5 years	M= 3.45, SD 1.30 n=22	M= 3.73, SD 1.35 n=22	t= -.70	P= .49
Within 6-10 years	M= 3.32, SD 1.62, n=22	M= 4.18, SD 1.14 n=22	t= -2.84	P< .01
End of Life	M= 3.81, SD 1.21 n=21	M= 4.67, SD 0.58 n=21	t= -3.54	P< .01

It can be observed from the above tables that the reported differential to each group's average scores was not reportable until within 6-10 years to the end of the existing system's operational lifespan. The observed variance from the mean was also at its lowest as the existing system was approaching replacement in each experimental cohort. The reported probability of adoption was higher in each time period in the seminar cohorts, with less than half the variance observed from the mean at the end of the existing system's operational lifespan.

While the observed impact of the educational interventions was not significant until the end of the existing system's operational lifespan, there was strong positive correlations observed between the reported probability of adoption after administering the educational intervention;

- Within the year pre-test & within the year post-test; r = .53, p< .001,
- Within 1-2 years pre-test & within 1-2 years post-test; r = .68, p< .001,
- Within 3-5 years pre-test & within 3-5 years post-test; r = .68, p< .001,
- Within 6-10 years pre-test & within 6-10 years post-test; r = .71, p< .001,
- End of existing system's operational lifespan & E.o.L post-test; r = .64, p< .001.

There were also strong positive correlations observed between the reported probability of adoption ranging from within the year to the end of the existing system's operational lifespan after administering the educational intervention;

- Within the year & within 1-2 years; r = .79, p< .001,
- Within 1-2 years & within 3-5 years; r = .78, p< .001,
- Within 3-5 years & within 6-10 years; r = .75, p< .001,
- Within 6-10 years & End of Existing System's Operational Lifespan; r = .63, p< .001.

Hypothesis 3: Univariate analysis provided insufficient evidence to reject the null hypothesis that seminars will be equally effective at increasing the reported probability of adoption as information that is accessed using digital media;

i) Within year the year; F (1,127) = .474, p= .49, η^2 = .004,

ii) Within 1-2 years; F (1, 121) = .33, p= .57, η^2 = .03,

iii) Within 3-5 years F (1, 119) = 1.92, p= .17, η^2 = .02,

*iv) Within 6-10 years; F (*1, 116) = 2.34, p= .13, η^2 = .02,

v) End of Life; F (1, 125) = 3.66, p= .06, η^2 = .03.

Chapter Five: Discussion

Observable rates of anthropogenic climate change in the post-industrial era have been faulted on unsustainable global production and consumption patterns (Rockström et al., 2009; Steffen et al., 2018; United Nations & FCCC, 2015). Urgent intervention from public and private institutions is required to facilitate sectoral shifts towards a low carbon economy (Climate Action Tracker, 2019; Environment and Climate Change Canada, 2016, 2019; IPCC, 2018; Rockström et al., 2009; Steffen et al., 2018; United Nations & FCCC, 2015; Williams et al., 2014). This necessitates global transitions to support clean electricity production and a mass adoption of low carbon and energy efficient technologies within industrial, commercial, and residential buildings (Baxter et al., 2013; Environment and Climate Change Canada, 2016; IPCC, 2018; Lovins, 2014; OECD/IEA, 2011; Ruokamo, 2016; Satnik, 2019; Williams et al., 2014).

The energy performance of buildings in Ontario has improved through improvements to national and provincial building codes and the enforcement of more stringent building standards for new construction (Canada & Office of Energy Efficiency, 2012; Government of Canada, 2017; N. R. C. Government of Canada, 2017; Government of Ontario, 2016; NRCAN, 2013; Satnik, 2019). However, there is an opportunity to obtain deeper reductions by facilitating the adoption of low carbon and energy efficient heating systems. Space heating is responsible for 62% of provincial residential energy consumption (Szekeres & Jeswiet, 2016, 2018a, 2018b). Further, census data indicates that 60% of the homes in Ontario are heated with natural gas (IESO, 2017). This mainstream usage of natural gas is preventing potential improvement in Ontario's building sector (IESO, 2017; Leach, n.d.; Nieboer, n.d; Patel et al., 2015; Szekeres & Jeswiet, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). Facilitating the residential adoption of modern cold-climate heat pump models should be regarded as an ideal technical solution to achieving important energy savings and provincial emission reductions (IESO, 2017; Patel et al., 2015; Szekeres & Jeswiet, 2018b, 2018a; Wyse & McVey, 2018).

The Government of Ontario acknowledged the opportunity to obtain meaningful energy savings and carbon reductions by facilitating the residential adoption of high-performance cold-climate heat pump models (Government of Ontario, 2013, 2016). However, the regulatory support that is required to actualize these claims has been critiqued to be insufficient (IESO, 2017; Wyse & McVey, 2018). While it has been affirmed that the price differential between natural gas and electricity is the most significant barrier to residential heat pump adoption, each of the variables that Rogers' (1983) affirms is essential to increase an innovative or unfamiliar technology's rate of adoption is not being satisfied. It should not be concluded that the existing price differential is the most significant barrier to residential heat pump adoption without first increasing residential awareness to the functional reliability and energy performance of cold-climate heat pumps.

The reviewed provincial feasibility studies have concluded that focused awareness building campaigns are essential to rectifying the current misconceptions regarding the heat pump's seasonal heating performance and to stimulate increased adoption (IESO, 2017; Leach, n.d.; Patel et al., 2015; Satnik, 2019; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

The purpose of this study was to assess the impacts of providing two independent educational interventions on the reported probability of heat pump adoption. Significant increases were observed in each experimental group as the existing heating system was approaching the end of its operational lifespan. The current study has reinforced that future awareness building campaigns will be important to raise provincial exposure to cold-climate heat pumps. Local environmental organizations can adopt a strategic role in facilitating residential heat pump adoption by sustaining a diffusion of information throughout their contact lists and by hosting local awareness building seminars. However, the effectiveness of these programs will likely hinge on additional support from the IESO, the Government of Ontario, and LDCs across Ontario (IESO, 2017; Satnik, 2019; Wyse & McVey, 2018).

5.1 Awareness of Cold-Climate Heat Pumps

The first research question examined the sample's reported awareness of cold-climate heat pump models. The sample reported a low level of awareness to the technical improvements heat pumps have made and to the availability of cold-climate heat pumps. One out of three participants in the seminar cohorts were aware of the technical improvements. The reported awareness was lower in the survey cohorts, at one in five participants. The reported awareness of the availability of cold-climate heat pump models was consistent with the awareness of the technical improvements in the survey cohorts (22%, n= 27). It was found that 63% (n= 27) of the seminar cohort was aware of the availability of cold-climate heat pump models. However, these participants constituted a small percentage of the total sample (n= 158).

The findings suggest that attendance at an awareness building seminar is likely to be prompted by previous exposure to the technology. However, the reported provincial awareness gap was demonstrated in the current study's sample. The low reported rates of awareness to cold-climate heat pumps may prove to be a barrier to recruiting attendance for future seminar sessions. It is suggested that directly providing residential consumers with information through digital media and other mass media networks will help to provide the required exposure to stimulate further inquiry into cold-climate heat pumps.

The sample demonstrated that residential consumers are not being directly provided with sufficient information regarding cold-climate air source heat pumps and the technical improvements that have increased the cold-climate heat pump's functional reliability and energy performance (Calder, 2017; IESO, 2017; Leach, n.d.; Patel et al., 2015; Wyse & McVey, 2018). These findings reinforce that the commitments of the previous Government of Ontario to ensure a sustained provision of reliable information to residential consumers have not been upheld (Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). The observed awareness gap has been correlated to public concerns regarding the heat pump's seasonal heating performance (Calder, 2017; IESO, 2017; Patel et al., 2015; Wyse & McVey, 2018). The third research question investigated whether the sample was confident in the heat pump's seasonal heating performance prior to receiving the awareness building campaign. Although the sample demonstrated a low level of awareness to cold-climate heat pumps, there was no evidence presented to suggest that either experimental group was skeptical of the cold-climate heat pump's functional reliability.

The results show that each experimental cohort was highly confident in the cold-climate heat pump's performance reliability prior to receiving the educational intervention. The observed average scores and variance from the mean demonstrated that the reported confidence was similar between the experimental groups. Further, there was not a significant correlation between the awareness to the technical improvements and the reported confidence in the heat pump's seasonal heating performance. There was also not an observable relationship between the awareness of cold-climate heat pump models and the observed confidence in the seasonal heating performance. These findings are inconsistent with the reviewed literature that has correlated the existing awareness gap to consumer concern's regarding the heat pump's seasonal heating performance (IESO, 2017; Patel et al., 2015; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018).

The confidence in the heat pump's performance reliability observed in the seminar cohorts can be attributed to the reported awareness of cold-climate heat pumps. It can be reasonably expected that a homeowner who is aware of a heat pump designed to function in a cold-climate would expect it to perform reliably during the winter. However, it is interesting that the survey cohorts also reported a high degree of confidence in the cold-climate heat pump's performance reliability prior to the educational intervention. The demonstrated functional reliability and energy performance of cold-climate heat pumps has resulted from sustained technical improvements (Bertsch & Groll, 2008; Calder, 2017; Chua et al., 2010; IESO, 2017; NRCAN, 2017; Patel et al., 2015; Szekeres & Jeswiet, 2018b). Although the study did not provide evidence to support a relationship between the observed awareness gap and the public's perception of the heat pump's performance reliability, these findings warrant further investigation.

An extensive body of psychological and sociological research supports that a consumer must understand the implications of technological adoption to determine the technology to be an attractive and reliable market alternative (Ajzen, 1991; Bamberg & Möser, 2007; Caird et al., 2012; Ipsos MORI & Energy Saving Trust, 2013; Klöckner, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2016; Owen et al., 2013; E. M. Rogers, 1983, 2010; Snape et al., 2015; Zografakis et al., 2008). It is an unexpected finding that an experimental group with little to no prior exposure to the technology would report a high degree of confidence in the cold-climate heat pump's functional reliability. Participation in a study focused on highlighting the benefits offered by cold-climate heat pumps may have predisposed the survey cohort to report a higher perceived confidence. Therefore, these findings should not be used to suggest that the findings of the previously reviewed literature are inaccurate or exaggerated without rigorous future examination into this relationship.

5.2 Impact of Educational Intervention on Perceived Confidence

The reviewed market literature has concluded that focused awareness building campaigns are effective ways to target the previous misconceptions held by consumers and to reduce skepticism regarding the a technology's functional reliability (Ajzen, 1991; Bamberg & Möser, 2007; Caird & Roy, 2010; Caird et al., 2012; Fawcett, 2011; Hecher et al., 2017; Ipsos MORI & Energy Saving Trust, 2013; Klöckner, 2013; Owen et al., 2013; E. M. Rogers, 1983, 2010; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018). The present study measured the direction and change to the reported confidence in the heat pump's performance reliability when installed in a cold-climate. There was evidence presented to suggest that educational interventions can effectively increase the reported confidence in the heat pump's seasonal heating performance.

It was observed that there were small increases to the average confidence in each experimental group. Although the observed increases were small, it is important to indicate that the reported confidence was high in the pre-test. The average scores were consistent between the two experimental groups post-test scores (M= 3.90) with small variations from the mean observed in each dataset. The difference between the survey cohort's average scores increased from M=3.67 to M=3.90 at alpha 0.01, indicating that the effectiveness of the intervention was unlikely to be attributed to chance. Further, the reported confidence in the pre-test showed a strong linear relationship with the reported confidence in the post-test (r = .60, p= 0.001). These findings suggest with confidence that the participants who were confident in the performance reliability in the pre-test became more certain of their perspectives after the educational intervention.

The current sample provided evidence to support that focused awareness building campaigns can increase the reported confidence in the heat pump's seasonal heating performance (Caird & Roy, 2010; Caird et al., 2008, 2012, 2007; Ipsos MORI & Energy Saving Trust, 2013; Michelsen & Madlener, 2016; Owen et al., 2013). The reviewed market literature has concluded that increasing the reported confidence in a technology's performance reliability is among the most influential factors to adoption (Bamberg & Möser, 2007; Caird & Roy, 2010; Caird et al., 2012; Fawcett, 2011; Han & Stoel, 2017; Hecher et al., 2017; Ipsos MORI & Energy Saving Trust, 2013; Klöckner, 2013; Owen et al., 2013; E. M. Rogers, 1983, 2010; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018). However, there were no correlations observed between the perceived performance reliability and the reported probability of adoption in both the pre and post-test. These findings suggest that the high perceived performance reliability was not enough to encourage the replacement of a functional heating system.

5.3 Importance of Relative Advantages Associated with using a Cold-Climate Heat Pump

Market research has already determined that homeowners are highly motivated by an alternative heating system's purchase, installation and operational costs (Bjørnstad, 2012; Caird & Roy, 2010; Caird, Roy, & Herring, 2008; Caird, Roy, & Potter, 2012; Howarth & Andersson, 1993; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo, Alfnes, Halvorsen, & Wik, 2013; Owen, Mitchell, & Unsworth, 2013; Roy, Caird, & Potter, 2010; Ruokamo, 2016; Snape, Boait, & Rylatt, 2015; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018). However, trends are emerging to suggest that homeowners also consider their heating system's environmental performance (Bjørnstad, 2012; Caird et al., 2012; Owen et al., 2013; Snape et al., 2015). The heat pump's functional reliability and a comfortable regulation of heat have also been suggested to be attractive factors to potential adopters (Bjørnstad, 2012; Caird et al., 2012; Lillemo et al., 2013; Owen et al., 2013; E. M. Rogers, 1983; Roy et al., 2010; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018). Three research questions were designed to investigate if the probability of heat pump adoption would increase in the condition of a reduced; energy bill, residential carbon footprint, and consumption of purchased energy.

It was concluded that the sample was interested in the potential to improve their home's energy performance while obtaining measurable financial returns. Frequency distributions indicated that approximately 50% of each experimental group stated that their reported probability of adoption would highly increase in the condition of each relative advantage. The average scores and observed variations from the mean were also consistent between the experimental groups in each condition of relative advantage. The observed descriptive statistics suggest that each experimental group placed equal value in reducing their home's environmental performance and reducing their annual energy bills. These findings reinforce the reviewed market literature pertaining to the importance that environmental and economic benefits can have on a consumer's interest in a particular heating system (Bjørnstad, 2012; Caird & Roy, 2010; Caird, Roy, & Herring, 2008; Caird, Roy, & Potter, 2012; Howarth & Andersson, 1993; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo, Alfnes, Halvorsen, & Wik, 2013; Owen, Mitchell, & Unsworth, 2013; Roy, Caird, & Potter, 2010; Ruokamo, 2016; Snape, Boait, & Rylatt, 2015; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018).

The implications of these results are reinforced by the strong positive correlations observed between each condition of relative advantage at calculated alpha levels of .001. The relationships between each relative advantage demonstrate with confidence that the participants who were interested in improving their home's environmental performance were also motivated by reducing their annual energy bills. These findings are consistent with the conclusions that heat pump adoption is stimulated by a desire to obtain energy savings through energy efficiency improvements (Bjørnstad, 2012; Caird et al., 2008, 2012; T Decker, Zapilko, Menrad, &Center, 2010; Thomas Decker & Menrad, 2015; Lillemo et al., 2013; Mahapatra Krushna & Gustavsson Leif, 2007; Roy et al., 2010; Scarpa & Willis, 2010).

The reviewed market literature has concluded that emphasizing the relative advantages associated with technological adoption can stimulate a consumer's future consumption patterns (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983, 2010). However, the study provided no evidence to suggest that the condition of each relative advantage was correlated to an increased probability of adoption, even after administering the awareness building campaign. These findings demonstrate that while environmental and economic considerations are desirable, these advantages did not elicit interest in heat pump adoption until the existing system required replacement.

5.4 Examining Demographic Trends

There is a lack of market research in Ontario to suggest if interest in heat pump adoption demonstrates observable trends relative to a consumer's age, level of education, and annual income. However, previous studies have observed correlations between an increased annual income and an increased interest in heat pump adoption (Braun, 2010; Caird & Roy, 2010; Caird et al., 2012, 2007; Lillemo et al., 2013). Young adults have also been found to be more interested in adoption given that these individuals are often in the process of buying their first home and can receive a return on investment that senior citizens may not (Bird, 2019; Michelsen & Madlener, 2012, 2016; Quinn, 2019). The present study aimed to determine if there were observable impacts on each variable under investigation relative to each demographic variable. No significant effects were observed in the demographic dataset.

Pearson's *r* coefficient determined that there was not an observable relationship between each demographic variable and each other variable under investigation. Further, multivariate analysis provided insufficient evidence to suggest that the between group scores were impacted by the participants age, level of education, and annual income. It is suggested that future reports examining residential interest in heat pump adoption continue to investigate if potential demographic trends among various sample populations given the study's relatively small sample population and the participants homogeneity in shared connections to environmental organizations. Potential demographic trends can identify market trends suggesting higher rates of interest among certain population groups. Continuing to target these opportunistic market trends will make important contributions to increasing provincial heat pump adoption (IESO, 2017).

5.5 The Impacts of Educational Interventions on the Probability of Heat Pump Adoption

The current study has supported the provincially identified awareness gap pertaining to cold-climate heat pump models (IESO, 2017; Wyse & McVey, 2018). Further, the results have demonstrated that the sample was interested in the environmental and economic benefits that can be associated with installing a cold-climate heat pump. These findings have remained consistent with the provincially reviewed feasibility studies and a wider body of market literature (Bjørnstad, 2012; Thomas Decker & Menrad, 2015; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Klöckner, 2013; Leach, n.d.; Michelsen & Madlener, 2016; Owen et al., 2013; Patel et al., 2015; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b; Toronto and Region Conservation Authority, 2018; Wyse & McVey, 2018). It is concluded that providing focused educational interventions to raise public awareness about the advantages offered by modern energy efficient technologies, including heat pumps, can increase interest in system adoption (Ajzen, 1991; Bamberg & Möser, 2007; Caird & Roy, 2010; Caird et al., 2012, 2007; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Klöckner, 2013; Michelsen & Madlener, 2012, 2016; E. M. Rogers, 1983; Wyse & McVey, 2018; Zografakis et al., 2008). The same conclusions are proposed by the IESO (2017) and Wyse & McVey (2018) regarding the need to provide focused awareness building campaigns to residential consumers across Ontario, particularly to those that will receive relative advantages to installing the heat pump. To date, there was insufficient experimental data in Ontario to support these claims.

The objective of the current study was to address this gap in the reviewed provincial literature and to examine the impacts that focused educational interventions will have on the reported probability of heat pump adoption. The sample has provided evidence to support that focused educational interventions can increase interest in residential heat pump adoption at the end of the existing system's operational lifespan. The results of the hypotheses under investigation in the current study are elaborated in the following subsections. Section 5.5.1 discusses the effectiveness that educating consumers on the positive consumer satisfaction ratings can have on the reported probability of heat pump adoption. The effectiveness of the educational intervention is elaborated in section 5.5.2. The subsection concludes with a discussion of the impacts of hosting seminar sessions versus making information available through digital media.

5.5.1. $H_{1:}$ Impact of Learning about Positive Consumer Satisfaction Ratings

Surveyed heat pump users have reported high satisfaction ratings with their system's functional reliability, energy performance, and comfortable regulation of heat (Bjørnstad, 2012; Caird et al., 2012; Lillemo et al., 2013; Owen et al., 2013; Snape et al., 2015; Toronto and Region Conservation Authority, 2018). The reviewed market literature has concluded that a social exchange of these positive satisfaction ratings can encourage further interest in residential heat pump adoption (Thomas Decker & Menrad, 2015; Lillemo, n.d.; Michelsen & Madlener, 2016; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b). The first hypothesis proposed that if homeowners receive positive consumer feedback on cold-climate heat pumps then the probability of adoption will increase. There was insufficient evidence presented to suggest that sharing the positive consumer satisfaction ratings increased the reported probability of adoption prior to the end of the existing heating system's operational lifespan.

There was not an observable or significant difference to the average scores and the observed variance from the mean after informing the participants of the positive consumer experiences. The lack of an observable increase to the frequency distributions and reported average scores is inconsistent with the market literature suggesting that this information exchange is highly influential to a consumer's observed consumption patterns (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; Lillemo et al., 2013; Owen et al., 2013; E. M. Rogers, 1983, 2010; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b). However, the findings of the study should not be used to discount the claims of the existing market literature.

There was not a personal association between the informants who educated the sample to the high satisfaction ratings. It has been concluded that the effectiveness of information exchange is determined by the degree of trust and association between the informant and recipient of the information (Lillemo et al., 2013; Owen et al., 2013; E. M. Rogers, 1983, 2010; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b). The experimental procedures failed to replicate these conditions. Further, the individuals were not connected in a personal dialogue, preventing a reciprocal exchange of information and further inquiry from the informants regarding the positive experiences. It is plausible that the failure to accurately replicate these conditions could have attributed to the low increases to each experimental group's average scores.

Although there was not an observed increase to the reported probability of adoption, there was statistical evidence presented to suggest that the positive satisfaction ratings were related to an increased probability of adoption in both the pre-test and post-test. There were strong positive correlations observed between the reported probability of adoption within the year and the influence of the consumer satisfaction ratings within the year. The correlations were consistently observed ranging from within the year to the end of the existing system's operational lifespan. Further, each linear relationship was significant at alpha .001. These findings demonstrate with confidence that the participants who displayed an increased interest in heat pump adoption were also positively influenced by learning about the positive consumer satisfaction ratings.

There were also strong positive correlations observed between the impact of the consumer satisfaction ratings within the year and the reported probability of adoption within the year after administering the educational intervention. The trend was also consistently observed until the end of the existing system's operational lifespan at alpha levels of .001. These findings reinforce that participants who were positively influenced by the positive satisfaction ratings reported a higher probability of adoption after receiving the awareness building campaign.

The observed correlations suggest that sharing positive consumer satisfaction ratings may help to increase residential interest in heat pump adoption among consumers who already demonstrate interest in system adoption (Ajzen, 1991; Bamberg & Möser, 2007; Thomas Decker & Menrad, 2015; Klöckner, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2012, 2016; Owen et al., 2013; E. M. Rogers, 1983, 2010; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b). Ensuring that information regarding these positive experiences is included in future awareness building seminars may increase heat pump adoption. Future research is recommended to continue the effectiveness of this information exchange, particularly when specifically applied to local communities to maximize the information that is further distributed through a consumer's social networks. Replicating this research design can provide further insight into the effectiveness of sharing positive consumer satisfaction ratings when applied across different sample populations.

5.5.2. H_2: Impact of Educational Interventions on Reported Probability of Heat Pump Adoption

Consumption patterns are argued to be motivated by an assessment of the advantages versus the disadvantages associated with technological adoption (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983, 2010). Psychological and sociological theories suggest that awareness building campaigns are effective market interventions encouraging public interest in unfamiliar and innovative technology's (Ajzen, 1991; Bamberg & Möser, 2007; Klöckner, 2013; E. M. Rogers, 1983, 2010). The reviewed market literature has demonstrated the effectiveness of focused educational interventions on the reported perceptions and interest in heat pump adoption (Caird & Roy, 2010; Caird et al., 2008, 2012, 2007; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2012, 2016). However, there was a need to expand the available experimental data in Ontario to support these claims.

The second hypothesis proposed that if educational interventions on cold-climate heat pumps are provided to the public then the reported probability of adoption will increase. It was concluded that the educational intervention effectively increased each experimental group's average reported probability of adoption when the existing system required replacement. Notable increases were observed to the average scores between the pre-test and post-tests at the end of the existing system's operational lifespan. Large differentials were observed in each experimental group between the reported probability of adoption within the year and at the end of the existing system's operational lifespan after administering the experimental treatment. The reported differential to the average scores when the existing system required replacement was significant at alpha .01 in the seminar cohorts and alpha .001 in the survey cohorts. It can be stated with confidence that the educational intervention effectively increased interest in heat pump adoption when the user's existing system required replacement.

The effectiveness of the educational intervention is reinforced by the strong positive correlations observed between the reported probability of adoption within the year in the pre-test and the reported probability of adoption within the year after administering the experimental treatment. The correlations were consistently observed until the end of the existing system's operational lifespan at alpha levels between .01 and .001. These findings suggest that the participants who were interested in installing a heat pump became more confident in their decision after receiving the awareness building campaign. There were also strong linear correlations observed between the reported probability of adoption within the year and within 1-2 years after administering the experimental treatment. The trend was consistently observed until the end of the existing system's operational lifespan at alpha .001. These findings suggest with confidence that the participants who were interested in system adoption following the educational intervention became more confident in their decision as their existing heating system was approaching the end of its operational life.

The findings of the current study have remained consistent with a wide body of reviewed market literature advocating the success of similar awareness building campaigns (Caird & Roy, 2010; Caird et al., 2008, 2012, 2007; T Decker et al., 2010; Thomas Decker & Menrad, 2015; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Michelsen & Madlener, 2016; Owen et al., 2013; Roy et al., 2010; Ruokamo, 2016; Wyse & McVey, 2018). It is concluded that local environmental organizations can play strategic roles in facilitating interest in residential heat pump adoption by raising residential awareness to cold-climate heat pumps. It is recommended based on the findings of the current study and the reviewed market literature that future awareness building programs are provided across Southern Ontario. The effects of these programs should be clearly monitored to assess their continued effectiveness. However, it is suggested based on the findings of the current study and the context of the reviewed literature that assistance from public and private intervention will be required to sufficiently increase residential exposure and interest in cold-climate heat pumps.

5.5.3. H_3; Impact of Seminar Sessions versus Online Mediums

There is a debate pertaining to which educational mediums will be most effective at facilitating a sustained opinion change and alterations to a consumer's consumption patterns. It has been advocated that information exchange is more influential on the individual when disseminated from an expert (Caird & Roy, 2010; Caird et al., 2008, 2012, 2007; T Decker et al., 2010; Thomas Decker & Menrad, 2015; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Michelsen & Madlener, 2016; Owen et al., 2013; E. M. Rogers, 1983, 2010; Roy et al., 2010; Ruokamo, 2016; Wyse & McVey, 2018). However, other scholars have reported that this information can be perceived to be untrustworthy (Caird et al., 2008, 2012, 2007; Hecher et al., 2017; Maloney et al., 2013; Roy et al., 2010). Although the reviewed provincial feasibility studies conclude that focused awareness building campaigns are required to raise residential awareness to cold-climate heat pumps, few suggestions are provided on how to develop and implement these programs. The third hypothesis proposed that seminar sessions will be more effective at increasing the reported probability of adoption than information that is accessed through digital media. However, there was insufficient evidence from this study to support this hypothesis.

The seminar cohorts displayed a higher average reported probability of adoption ranging from within the year to the end of the existing heating system's operational lifespan. Further, it was observed that the variance from the mean at the end of the existing system's lifespan was 50% lower than the variance observed in the survey cohorts. However, univariate analysis determined that there was not a significant difference observed between the reported probability of adoption in each experimental group ranging from within the year until the end of the existing heating system's operational lifespan. The differences in the reported descriptive statistics can likely be attributed to the size differences between the two samples (seminar cohorts n= 35, survey cohorts n= 123). The significant increases to the average scores observed in each experimental group support that both of these communication channels can effectively increase residential exposure and interest in heat pump adoption.

There was also no evidence provided to suggest that hosting interpersonal seminar sessions hosted by perceived experts will be more effective at increasing the reported confidence in the heat pump's performance reliability. Univariate analysis demonstrated that there was not a significant difference between the reported confidence in the cold-climate heat pump's seasonal heating performance after administering the experimental treatment. Further, it was determined that the difference within the seminar cohort's mean scores did not pass the established alpha test of significance. Contrarily, the observed difference to the mean scores in the survey cohorts was significant at alpha .01. It can be stated with confidence that the observed increase within the survey cohorts was attributable to the educational intervention. The findings have supported that the effectiveness of local awareness building seminars can be optimized if residents are also directly provided with information through various forms of digital media.

5.6. Implications of Research

The study has reinforced the provincial awareness gap pertaining to the availability of modern cold-climate air source heat pump models and the impressive technical improvements the heat pump has made. The present study has demonstrated that local environmental organizations can play an important role in increasing future interest in heat pump adoption by disseminating information throughout their residential contact lists and by hosting future awareness building seminars. However, these local organizations will require the support from provincial awareness building programs and financial incentive models to overcome to the reported barriers to provincial heat pump adoption.

The results presented in the study have demonstrated that the participants were highly interested in reducing their home's environmental footprint while achieving financial returns. Further, it was clearly demonstrated that the participants were confident in the heat pump's seasonal performance reliability. However, there were no correlations present to suggest that these relative advantages were related to an increased probability of adoption prior to the existing system requiring replacement. These findings remain consistent with a wide body of reviewed market literature suggesting that consumers are hesitant to replace a functional heating system, even after receiving information on efficient market alternatives (Bjørnstad, 2012; Caird & Roy, 2010; Caird et al., 2008, 2012; Howarth & Andersson, 1993; IESO, 2017; Ipsos MORI & Energy Saving Trust, 2013; Lillemo et al., 2013; Owen et al., 2013; Roy et al., 2010; Ruokamo, 2016; Snape et al., 2015; Szekeres & Jeswiet, 2018a; Wyse & McVey, 2018).

The IESO (2017) and Wyse & McVey (2018) have concluded that awareness building campaigns can be paired with financial assistance programs to help encourage a homeowner to replace a functional heating system. Governmental agencies should accept the responsibility to implement concerted market interventions when the public is failing to adopt low risk, low energy technologies (Howarth & Andersson, 1993). The findings of the current study indicate that awareness building campaigns increase interest in future heat pump adoption. The impact of supplementing these awareness building campaigns with appropriately designed financial assistance programs is recommended to be a focal point for future research.

5.6.1. Stimulating Interest in Heat Pump Adoption: Financial Incentives

The reviewed provincial feasibility studies have concluded that the provision of financial assistance programs should help to increase interest in residential heat pump adoption (IESO, 2017; Wyse & McVey, 2018). Market research has determined that rates of technological adoption, including heat pump installation, are often catalyzed by the presence of financial assistance programs (IESO, 2017; Lillemo et al., 2013; Mills & Schleich, 2012; Satnik, 2019; Wyse & McVey, 2018). However, the resources that are available to municipalities and local organizations are often restricted, indicating a need for additional funding and grant money from provincial governments and electricity regulators (Satnik, 2019). These partnerships could provide crucial financial support to ensure that these awareness building campaigns are sustained. Further, residents may have access to programs that can directly increase the heat pump's market competitiveness if inclusive programs are designed.

Some financial assistance programs are available from targeted government programs and utility providers across Ontario to support residential efficiency improvements (N. R. C. Government of Canada, 2018; IESO, 2019a; Ontario, 2019; Satnik, 2019). However, the IESO (2017) and Wyse & McVey (2018) suggest that the provided funding to facilitate residential heat pump adoption needs to be expanded. It is suggested based on the recommendations of Satnik (2019) that provincial and municipal policy makers draw inspiration from incentive models that have already demonstrated success across Canada and within Ontario.

Financial rebates are being offered to stimulate residential heat pump adoption across Canada, ranging from Fortis BC's Oil to Heat Pump program to Nova Scotia's Heat Pump Incentive Program. These programs provide templates that can be used by Hydro One, the IESO, and the Government of Ontario to redesign and reimplement financial rebate programs (IESO, 2017). These financial incentives have effectively encouraged residential partnership on efficiency improvements, particularly when the homeowners are aware of the obtainable benefits (IESO, 2017; Lillemo et al., 2013; Mills & Schleich, 2012; Satnik, 2019; Wyse & McVey, 2018).

Financial incentive models that rebate the heat pump's purchase or installations costs do not address the heat pump's provincial operational costs relative to a natural gas furnace. The impact of financial rebate programs may be limited considering that 60% of the residents of Ontario heat their home with a gas furnace. Therefore, financial assistance programs that are strategically designed to reduce the heat pump's operational costs may be more effective at increasing provincial rates of heat pump adoption.

Provincial Governments and utility companies across Canada are currently providing financial rebates, tax reductions, and discounted building permits for new construction and deep retrofit projects that achieve certified green building standards or display measurable energy savings. Energy credits are also being provided that scale according to the property's reduced consumption of purchased energy, such as Langley BC's Green Building Rebate Program (N. R. C. Government of Canada, 2018; Satnik, 2019; Township of Langley, 2015). Further, Toronto's High Performance Building program previously provided rebates of $0.10/kWh of reduced energy consumption (City of Toronto, 2019a). However, the program stopped accepting applicants as of April 1, 2019.

These programs demonstrate that incentive models can encourage sustainable energy decisions by directly providing financial returns on the energy savings (Satnik, 2019). It is suggested that future incentive models adopt similar frameworks to provide energy credits to homeowners who install a cold-climate air source heat pump and can demonstrate a reduced consumption of purchased energy. Szekeres & Jeswiet (2018a) determined that provincial electricity rates significantly impacted the projected provincial rate of heat pump adoption. Further, rates of heat pump adoption were significantly increased as the price of natural gas continued to increase under the projected carbon tax scenario (Szekeres & Jeswiet, 2018a).

The provincial carbon tax will directly reduce the existing price differential between the operational costs of a natural gas furnace and a cold-climate heat pump model. The provision of energy credits to stimulate heat pump adoption will become increasingly competitive under the projected carbon tax scenario, which introduces further potential to catalyze public interest in heat pump adoption.

However, these incentive models will be particularly attractive to homeowners who are currently using electric heating system's given the available energy savings until the current price disparity is reduced (IESO, 2017; Patel et al., 2015; Wyse & McVey, 2018).

A strategic opportunity is available by providing energy credits to residential consumers who are not connected to provincial natural gas lines. These homeowners will receive direct energy savings, while the strain on rural energy grids will be reduced. The result will help to increase residential exposure to cold-climate heat pumps, while also demonstrating the importance of obtaining higher standards in new and existing building designs. While these programs will increase the heat pump's market competitiveness, it is suggested that reinforcing the provision of energy credits with low interest loans may offer the greatest potential to stimulate residential partnership on efficiency improvements (Satnik, 2019).

5.6.2 Determining Effective Financial Assistance Programs: Circular Incentive Models

It is important to carefully consider the effectiveness and financial implications associated with implementing a particular incentive model. The result ensures a rational and effective distribution of funding. It is suggested that incentive models will be most effective when they have a circular model designed to produce a full return on the distributed funding (Satnik, 2019). For example, municipalities often provide low interest loans to facilitate structural improvements on community and commercial properties. The improvements increase the property's value, which also increases the future property taxes collected by the municipality. The distributing party often collects a full return on the distributed funding if these circular incentive models are carefully designed (Satnik, 2019).

Circular incentive models have also been used to facilitate deep energy efficiency improvements to residential properties, such as Property Assessed Payments for Energy Reduction (PAPER) loans. Applicants receive a free energy audit conducted by a certified efficiency expert to determine if a series of efficiency improvements can reduce the home's energy bill by at least 50%. Qualifying homes will receive a low interest loan (typically $30,000) to cover the costs of deep residential energy efficiency improvements. The loan is repaid by adding an extra amount to the resident's property tax bill. The loan is gradually repaid with funds that the homeowner previously allocated to their electricity bills. Therefore, the homeowner avoids the initial capital costs of the efficiency upgrades and the loan is reimbursed in full (Satnik, 2019).

A key strength to PAPER loans are that they enable deep efficiency retrofits in circumstances that they would otherwise not be possible given financial restrictions (Satnik, 2019). Further, the presence of a certified energy efficiency expert can also help to disseminate reliable information about cold-climate heat pumps, providing increased technological exposure. The United States frequently provides PAPER loans to raise residential awareness to various available efficiency improvements and to provide financial support in actualizing these improvements. However, these loans are not commonly offered in Canada (Satnik, 2019).

While these programs are not common in Canada, Toronto's HELP Program currently facilitates residential efficiency improvements by providing low interest loans that are repaid through adding an extra lien on the property tax (City of Toronto, 2019a; N. R. C. Government of Canada, 2018). The program includes coverage for air source heat pumps, providing a clear demonstration that these models are feasible and possible across the province. Further success of these loan models is presented by Newfoundland and Labrador's Home Energy Savings Loans Program was expanded to provide a $1-million heat pump program designed to offer 1000 homeowners with $1000 towards the purchase of their heat pump. In one month the program had received 682 applicants, along with receiving thousands of inquiries (Bird, 2019; Quinn, 2019). It is concluded that the template of the HELP program should be used by the Government of Ontario and the IESO to ensure that homeowners across the province have access to similar low interest loans.

The present study concludes that the provision of energy credits and low interest loans may help to increase interest in heat pump adoption prior to the existing system requiring replacement. It is suggested that future research continue to examine residential interest and cooperation with these incentive models to provide direct evidence on their effectiveness. However, it is crucial to acknowledge that the reported awareness gap suggests that consumers do not have enough information about cold-climate heat pumps to determine the system to be a reliable market alternative. It should not be expected that consumers will independently seek financial assistance programs to install a technology that they have little to no previous exposure to. Therefore, these financial assistance programs will have little effect unless funding is also directed into developing provincial awareness building campaigns and supporting the efforts of community seminars hosted by local environmental organizations.

5.6.3 Developing & Launching Local Awareness Building Campaigns

The findings of the current study have reinforced that the Government of Ontario previously failed to sufficiently increase residential awareness to cold-climate heat pumps (IESO, 2017; Leach, n.d.; Patel et al., 2015; Szekeres & Jeswiet, 2018a, 2018b; Wyse & McVey, 2018). A clear case has been presented regarding the need to sustain future awareness building campaigns. The present study has concluded that local environmental organizations can play a pivotal role in facilitating early rates of residential heat pump adoption given the associations within group members and between other members of the broader community. These local organizations should continue to disseminate information regarding cold-climate heat pumps through their social media accounts, emailing lists, organizational websites, and monthly newsletters. The results can effectively expose residential consumers to reliable information and may promote further inquiry into the technology. However, it is suggested that provincial support from the IESO, Hydro One, LDC's, and the Government of Ontario is required to facilitate the effectiveness of these local campaigns.

The Government of Ontario should acknowledge a responsibility to ensure that their previous commitments to educate the public on modern efficient technologies, including cold-climate heat pumps, are fulfilled. The IESO can support the Ministry of Environment on developing mass media campaigns and public advertisements designed to highlight the performance capacity and benefits that cold-climate heat pumps offer residential consumers. Further, the IESO can encourage LDC's across the province to promote similar advertisements in local communities. These advertisements can reach a large consumer base if hosted on frequently visited multi-media platforms, such as YouTube, Facebook, and Instagram. The Government of Ontario has previously used these platforms as a medium to propagate public service announcements and their usage will contribute to increasing residential exposure to cold-climate heat pumps. Provincial forms of support such as local advertisements will ensure that information is also transmitted to members of the public that are not affiliated with these local organizations, helping to further mitigate the observed awareness gap.

It is suggested that the IESO, Hydro One, and the Government of Ontario can provide more effective support to local organizations by developing and supporting programs that directly provide information about cold-climate heat pumps to residential consumers. These directed approaches will ensure that the public processes and is attentive to the provided information about cold-climate heat pumps. An effective way to provide this direct exposure is to sustain the provision of programs supporting free residential efficiency audits with a certified energy advisor, such as the Affordability Fund.

The continued facilitation of these energy audits can be a strategic way to personally connect a residential consumer with a certified expert who can clearly translate the benefits associated with residential efficiency improvements (Satnik, 2019). These energy audits present an ideal opportunity to raise residential awareness to cold-climate heat pumps. Special consideration should highlight the available environmental and financial savings to homeowners using electric baseboards or an oil furnace. Further, energy advisors can inform residential consumers that areas of deficiency throughout the home's envelope will affect the energy performance of their heat pump to optimize the heat pump's functional reliability and energy performance (Canada & Office of Energy Efficiency, 2012). This directed information exchange provides a consumer with expert advice, which should increase public perceptions of cold-climate heat pumps and facilitate further information exchange throughout social networks

(Ajzen, 1991; Caird et al., 2012; Han & Stoel, 2017; Hecher et al., 2017; IESO, 2017; Klöckner, 2013; Lillemo et al., 2013; Owen et al., 2013; E. M. Rogers, 1983, 2010; Sopha et al., 2010; Wyse & McVey, 2018).

Provincial support should not be provided without developing programs and partnerships designed to work with local business, utilities, environmental groups, and residential consumers. This process involves deep consultation between various stakeholders and with local municipal organizations. While this process is time consuming, it is important to ensure that the public is are an active stakeholder in the transition to a low carbon building sector (Brown et al., 2015; Government of Ontario, 2013, 2016; IESO, 2017; Satnik, 2019; Szekeres & Jeswiet, 2018a, 2018b; Wyse & McVey, 2018). Therefore, awareness building programs such as energy audits that highlight cold-climate heat pumps should be encompassed into broader programs supported by a local environmental action team.

A strong example is provided by BC's Sustainable Communities Program. The Sustainable Communities Program was designed to reduce communal GHG reductions across British Columbia. Financial assistance is provided from BC Hydro and local community organizations to support a wide scope of local environmental services, financial assistance programs, and awareness building campaigns (BC Hydro, 2019; N. R. C. Government of Canada, 2018; Satnik, 2019). An Energy Manager is hired to develop a robust Community Energy and Emissions Plan through consultation with local organizations, municipal representatives, and residential consumers. Further, educational seminars are hosted in partnership with local community organizations to raise residential awareness and interest in modern efficient technologies, while providing financial assistance to help actualize these improvements. Data analysists are hired to track emission reductions and to project opportunities for further reductions through future energy saving projects. Finally, the success and failures of the implemented programs are used to provide recommendations to other policy makers (BC Hydro, 2019; Satnik, 2019).

The Sustainable Communities program provides a clear example of the regulatory assistance that can be provided to mitigate the reported barriers to provincial heat pump adoption. Developing local environmental action teams can provide financial assistance to local community organizations to help spearhead residential awareness building campaigns, including local community awareness building sessions. Further, funding can be provided to implement the previously discussed financial assistance programs to help increase the reported interest in replacing a functional heating system. Sustained provision of these programs will likely facilitate greater exposure to cold-climate heat pumps through a consumer's daily social interactions and make important contributions to future rates of heat pump adoption.

The reviewed market literature has concluded that a consumer's behavior can be highly motivated by the standards and group norms of their social networks (Jackson, 2003; Mills & Schleich, 2012; Owen et al., 2013; E. M. Rogers, 1983; Sopha et al., 2010). Further, consumers have been found to frequently share information about innovative or unfamiliar technologies and their personal experiences with the technology throughout their social networks (Lillemo et al., 2013; E. M. Rogers, 1983, 2010; J. C. Rogers, Simmons, Convery, & Weatherall, 2008; Sopha et al., 2010). Sopha et al., (2010) have found that early heat pump adoption is highly influenced by the recommendations and advice from friends and family members, reinforcing these findings. If these local awareness building campaigns are sustained by local environmental organizations and supported by the IESO and the Government of Ontario, then the amount of exposure that consumers receive through interacting with their social groups is expected to increase (IESO, 2019a; Szekeres & Jeswiet, 2016, 2018a, 2018b; Wyse & McVey, 2018).

These local awareness building campaigns can ensure a sustained facilitation of information throughout members of the community. A circular feedback cycle is established that perpetuates the likelihood that recipients of this information will continue to pass it to other consumers (IESO, 2017; Patel et al., 2015; E. M. Rogers, 1983, 2010; Szekeres & Jeswiet, 2016, 2018b, 2018a; Wyse & McVey, 2018). The trust and rapport that is shared amongst a social group can highly influence the behavior and consumption patterns displayed by group members (Thomas Decker & Menrad, 2015; Hecher et al., 2017; Jackson, 2003; Klöckner, 2013; Lillemo et al., 2013; Michelsen & Madlener, 2016; Mills &

Schleich, 2012; Newborough & Probert, 1994; Owen et al., 2013, 2013; E. M. Rogers, 1983; Sopha et al., 2010; Staddon et al., 2016; Szekeres & Jeswiet, 2016, 2018a, 2018b). Consequently, the perceived attractiveness in the technology is often increased, contributing to sustained rates of technological adoption (Ajzen, 1991; Bamberg & Möser, 2007; Han & Stoel, 2017; Hecher et al., 2017; IESO, 2017; Klöckner, 2013; E. M. Rogers, 1983; Sopha et al., 2010; Szekeres & Jeswiet, 2016, 2018a, 2018b; Wyse & McVey, 2018). The present study concludes that the sustained provision of these awareness building campaigns through local environmental networks provides a real opportunity to help increase residential exposure and interest in residential heat pump adoption.

5.7. Directions for future research

Specific personality characteristics can often elicit certain responses on an outcome variable that may not be observed within a different population (Creswell, 2014). The study's sample was recruited by leveraging Reep Green Solution's and eMERGE Guelph's contacts. It can be reasonably assumed that these participants already have demonstrated some degree of environmental awareness. For that reason, these participants may have responded more favorably to the treatment variable. Therefore, the conclusions presented in the current study have been limited to the impacts that local environmental organizations can have on increasing interest in heat pump adoption. The experimental procedures of the current study need to be replicated before stating the effectiveness on homeowners who are not affiliated with these organizations, particularly considering the effectiveness that these campaigns have had in previous contexts. The results will continue to provide important contributions to the existing body of market literature examining the effective market interventions to stimulate residential heat pump adoption.

5.7.1 Replicating the Research

The present market conditions in Ontario discourage consumers from replacing a natural gas furnace with a cold-climate heat pump. However, these market conditions will change as the federally enforced carbon tax continues to increase the residential penalty associated with the combustion of natural gas for heat energy. Previous research has suggested that rates of heat pump adoption will be highly influenced by these changing market conditions (Szekeres & Jeswiet, 2016, 2018a, 2018b). It is suggested that future research will be important to replicate the procedures of the current study as the difference between annual electricity and natural gas costs changes. The importance of replicating these results will become increasing important if financial incentive models, such as those discussed in this current study, are redesigned and provided to residential consumers across Ontario.

There is also a pressing need to continue to replicate these experimental procedures to continue to determine the impacts of local community awareness building sessions on increasing information exchange throughout residential consumers. There is currently insufficient market research in Ontario to make any generalizations to the general population that are not associated with environmental organizations. An extensive body of future research is required to continue examining the effectiveness that educational interventions can have on mitigating the reported barriers to residential heat pump adoption. If the effectiveness of future awareness campaigns can be demonstrated, and these campaigns actively connect more consumers in dialogues regarding modern heat pumps, than it is expected that the exposure to modern heat pumps will increase. The results will provide important contexts of effective local awareness building campaigns and can contribute important insights for the effective development and implementation of future programs.

5.7.2 Replicating the Research – Probability of Adoption versus Intention of Adoption

The current study assessed if focused educational interventions constitute effective market interventions to increase the reported probability of heat pump adoption. It is crucial to acknowledge that the reported probability of adoption does not determine whether a homeowner will actually install a heat pump in the future. Future longitudinal studies are warranted to determine the heat pump's observed adoption rate following an educational intervention. These results can provide market data to reinforce the observed effectiveness of future awareness building campaigns. These research objectives can also be strategically incorporated into future studies that examine the impacts on the probability and the actual installed frequency of heat pumps as the carbon tax or increased natural gas prices reduces the price disparity between natural gas and electric heating systems.

Conclusion

Facilitating residential adoption of cold-climate heat pumps in Ontario will provide important carbon reductions, helping to achieve the provincially stated climate action goals. The present study has provided contributions to the existing body of reviewed market literature pertaining to the need to develop and sustain local awareness building programs across Ontario. These programs will be important to increase residential exposure and interest in cold-climate heat pumps. It has been concluded that local environmental organizations can play an important role in spearheading these local campaigns. Novel insights have been provided to suggest that leveraging digital media and hosting future local seminar sessions can both effectively increase a homeowner's interest in future heat pump adoption.

The current study has concluded based on the suggestions of previous research that appropriate financial assistance programs are developed and implemented to incentivize the replacement of a functional heating system. Existing financial incentives for residential efficiency improvements should be expanded to include funding to support heat pump adoption, particularly through the provision of energy credits and low interest loans. The result of these programs may help to encourage a homeowner to replace their heating system for a cold-climate heat pump prior to the end of its operational lifespan. However, it is important to acknowledge that the effectiveness of these programs will be limited in the absence of the discussed awareness building campaigns.

While local environmental organizations should continue to spearhead effective awareness building campaigns, provincial support from the IESO and the Government of Ontario will be important to increase the availability of reliable information on cold-climate heat pumps. The existing educational programs offered by the IESO and the Government of Ontario should be expanded to include information about cold-climate heat pumps. For instance, free energy audits with certified efficiency experts provide an ideal opportunity to educate homeowners on the benefits to using a cold-climate heat pump. These partnerships will provide increased exposure to the technology, particularly among residents that do not have personal affiliations with local environmental organizations.

These educational programs should also be incorporated into the organizational goals of local environmental action teams or climate action teams that are developed to support regional emission reduction targets. These teams can help obtain action on residential efficiency improvements by supporting local awareness building campaigns and by providing financial incentives to local homeowners. These programs may effectively increase exposure and information exchange regarding cold-climate heat pumps, which should contribute to increasing future rates of residential adoption.

Concerted effort will be required to stimulate broad residential awareness of cold-climate heat pumps. This process will necessitate consultation between various stakeholders, including the residents of local communities who must be actively involved in a low carbon transition within the provincial building sector. However, the available carbon savings cannot be overlooked as population growth and economic development continues throughout the province. The results of forming these partnerships to support local awareness building campaigns presents an opportunity to facilitate residential partnership on efficiency improvements, including the installation of modern cold-climate heat pump models.

References

Abdelaziz, O., & Shen, B. (2012). Cold Climates Heat Pump Design Optimization. *ASHRAE Transactions; Atlanta*, *118*, 34–41.

Aertsens, J., Verbeke, W., Mondelaers, K., & Huylenbroeck, G. V. (2009). Personal determinants of organic food consumption: A review. *British Food Journal*, *111*(10), 1140–1167. https://doi.org/10.1108/00070700910992961

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, *50*, 179–211.

Altrichter, H., Feldman, A., Posch, P., & Somekh, B. (2008). *Teachers investigate their work; An introduction to action research across the professions* (2nd ed.). Routledge.

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, *27*(1), 14–25. https://doi.org/10.1016/j.jenvp.2006.12.002

Baxter, V., Groll, E., Abdelaziz, O., Shen, B., Groff, G., Sikes, K., & Khowailed, G. (2013). *IEA HPP ANNEX 41 – COLD CLIMATE HEAT PUMPS:* (p. 35). Retrieved from Oak Ridge National Laboratory, Herrick Labs, Purdue University, Groff Associates, SRA International, Inc.

BC Hydro. (2019). Sustainable communities. Retrieved October 31, 2019, from Sustinable Communities website: https://www.bchydro.com/powersmart/business/programs/sustainable-communities.html

Bertsch, S. S., & Groll, E. A. (2008). Two-stage air-source heat pump for residential heating and cooling applications in northern U.S. climates. *International Journal of Refrigeration*, *31*(7), 1282–1292. https://doi.org/10.1016/j.ijrefrig.2008.01.006

Biggs, J. (2012). What the student does: Teaching for enhanced learning. *Higher Education Research & Development*, *31*(1), 39–55. https://doi.org/10.1080/07294360.2012.642839

Bird, L. (2019). N.L. lags behind Canada in energy efficiency, but there's a silver lining to the stats | CBC News. Retrieved November 25, 2019, from CBC website: https://www.cbc.ca/news/canada/newfoundland-labrador/energy-efficiency-scorecard-newfoundland-labrador-1.5367900

Bjørnstad, E. (2012). Diffusion of renewable heating technologies in households. Experiences from the Norwegian Household Subsidy Programme. *Energy Policy*, *48*, 148–158. https://doi.org/10.1016/j.enpol.2012.04.078

Braun, F. G. (2010). Determinants of households' space heating type: A discrete choice analysis for German households. *Energy Policy*, *38*(10), 5493–5503. https://doi.org/10.1016/j.enpol.2010.04.002

BrckaLorenz, A., Chiang, Y., & Laird, N. (2013). *Internal Consistency Reliability*. Retrieved from http://fsse.indiana.edu/pdf/pp/2013/FSSE13_Internal_Consistency_Reliability.pdf

Briggs, S. R., & Cheek, J. M. (1986). The role of factor analysis in the development and evaluation of personality scales. *Journal of Personality*, *54*(1), 106–148. https://doi.org/10.1111/j.1467-6494.1986.tb00391.x

Brown, S., Cipriani, A. M., Davidson, T., Patterson, M. J., Roewade, D., & Willms, P. (2015). *Our Progress, Our Path: An Update on Waterloo Region's Community Carbon Footprint*. 20.

Caird, S., & Roy, R. (2010). Adoption and Use of Household Microgeneration Heat Technologies. *Low Carbon Economy*, *01*(02), 61–70. https://doi.org/10.4236/lce.2010.12008

Caird, S., Roy, R., & Herring, H. (2008). Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low- and zero carbon technologies. *Energy Efficiency*, *1*(2), 149–166.

Caird, S., Roy, R., & Potter, S. (2012). Domestic heat pumps in the UK: User behaviour, satisfaction and performance. *Energy Efficiency*, *5*(3), 283–301. https://doi.org/10.1007/s12053-012-9146-x

Caird, S., Roy, R., Potter, S., & Herring, H. (2007). *Consumer adoption of household renewable energy technologies*. Design Innovation Group.

Calder, D. (2017, March 8). Seven heat pumps perfect for Ontario homes. Retrieved April 7, 2018, from Seven Heat Pumps Perfect for Ontario homes website: http://taf.ca/seven-heat-pumps-perfect-ontario-homes/

Campbell, D., & Stanley, J. (1963). Experimental and Quasi-Experimental Designs for Research. Retrieved September 4, 2019, from The James Lind Library website: https://www.jameslindlibrary.org/campbell-dt-stanley-jc-1963/

Canada, & Office of Energy Efficiency. (2012). *Keeping the heat in*. Retrieved from http://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2013/internet/w13-03-U-E.html/collections/collection_2013/rncan-nrcan/M144-41-2012-eng.pdf

Casey, D. (2008). A Journey to Legitimacy: The Historical Development of Distance Education through Technology. *TechTrends*, *52*(2), 45. https://doi.org/10.1007/s11528-008-0135-z

Chua, K. J., Chou, S. K., & Yang, W. M. (2010). Advances in heat pump systems: A review. *Applied Energy*, *87*(12), 3611–3624. https://doi.org/10.1016/j.apenergy.2010.06.014

City of Toronto. (2019a). High Performance New Construction Program. Retrieved November 13, 2019, from City of Toronto website: https://www.toronto.ca/services-payments/water-environment/environmental-grants-incentives/energy-efficiency-incentives/

City of Toronto. (2019b). Home Energy Loan Program. Retrieved November 13, 2019, from City of Toronto website: https://www.toronto.ca/services-payments/water-environment/environmental-grants-incentives/home-energy-loan-program-help/

Climate Action Tracker. (2019). Canada | Climate Action Tracker. Retrieved August 13, 2018, from https://climateactiontracker.org/countries/canada/

ClimateActionWR. (2013). *A Climate Action Plan for the Waterloo Region: Living Smarter in 2020*.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.).* Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, L., & Manion, L. (2000). *Research methods in education.* (5th ed.). Routledge.

Creswell, J. (2014). *Research Design: Qualitative, Quantitative, and Mixed Method Approaches.* (4th ed.). Sage Publications.

Decker, T, Zapilko, M., Menrad, K., & Center, S. (2010). *PURCHASING BEHAVIOUR RELATED TO HEATING SYSTEMS IN GERMANY WITH SPECIAL CONSIDERATION OF CONSUMERS' ECOLOGICAL ATTITUDES*. 8.

Decker, Thomas, & Menrad, K. (2015). House owners' perceptions and factors influencing their choice of specific heating systems in Germany. *Energy Policy*, *85*, 150–161. https://doi.org/10.1016/j.enpol.2015.06.004

Deloitte. (2014). *Value of Connectivity: Economic and social benefits of expanding internet access* (p. 53). Retrieved from https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/TechnologyMediaCommunications/2014_uk_tmt_value_of_connectivity_deloitte_ireland.pdf

Delta Energy & Environment. (2011). *Heat Pumps in the UK: How Hot Can They Get?* (p. 8). Retrieved from http://www.green-alliance.org.uk/resources/01.01.11%20Delta%20-%20Heat%20Pumps%20in%20the%20UK%20How%20Hot%20Can%20They%20Get.pdf

Dentz, J., Podorson, D., Varshney, K., & Energy, A. R. I. (2014). *Mini-Split Heat Pumps Multifamily Retrofit Feasibility Study*. 45.

Enbridge Gas. (2019a). Our Projects—Union Gas. Retrieved November 12, 2019, from https://www.uniongas.com/projects

Enbridge Gas. (2019b). Southern Ontario Historical Residential Rates—Residential—Union Gas. Retrieved June 16, 2019, from https://www.uniongas.com/residential/rates/historical-rates/rate-historical-m1

Environment and Climate Change Canada. (2015, December 31). The Paris Agreement [Program descriptions;international treaties]. Retrieved September 24, 2019, from Aem website: https://www.canada.ca/en/environment-climate-change/services/climate-change/paris-agreement.html

Environment and Climate Change Canada. (2016). *Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy*. Retrieved from Government of Canada, Minister of Environment and Climate Change website: http://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf

Environment and Climate Change Canada. (2017, May 18). Pricing carbon pollution in Canada: How it will work [Backgrounders]. Retrieved June 16, 2019, from Gcnws website:

https://www.canada.ca/en/environment-climate-change/news/2017/05/pricing_carbon_pollutionincanadahowitwillwork.html

Environment and Climate Change Canada. (2018). *Canadian environmental sustainability indicators greenhouse gas emissions.* Retrieved from http://publications.gc.ca/collections/collection_2018/eccc/En4-144-18-2018-eng.pdf

Environment and Climate Change Canada. (2019). Temperature—Monthly data for Toronto. Retrieved February 11, 2019, from Amateur Weather Statistics for Toronto, Ontario website: https://toronto.weatherstats.ca/charts/temperature-monthly.html

Faesy, R., Grevatt, J., McCowan, B., & Champagne, K. (2014). *Ductless Heat Pump Meta Study* (p. 28). Retrieved from Northeast Energy Efficiency Partnerships website: http://www.neep.org/sites/default/files/products/NEEP-Ductless-Heat-Pump-Meta-Study-Report_11-13-14.pdf

Fawcett, T. (2011). The future role of heat pumps in the domestic sector. Retrieved November 12, 2018, from ResearchGate website: https://www.researchgate.net/publication/285980293_The_future_role_of_heat_pumps_in_the_domestic_sector

Government of Canada. (2017). Greenhouse gas emissions by Canadian economic sector [Research]. Retrieved April 10, 2018, from Aem website: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions/canadian-economic-sector.html

Government of Canada, D. of F. (2018, October 23). Backgrounder: Fuel Charge Rates in Listed Provinces and Territories [Fact sheet]. Retrieved June 16, 2019, from https://www.fin.gc.ca/n18/data/18-097_1-eng.asp

Government of Canada, E. and C. C. (2018, October 23). Ontario and pollution pricing [Program descriptions]. Retrieved June 16, 2019, from Aem website: https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/ontario.html

Government of Canada, N. R. C. (2017, December 12). Residential Sector Canada Table 2: Secondary Energy Use and GHG Emissions by End-Use. Retrieved August 13, 2018, from http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&rn=2&page=0

Government of Canada, N. R. C. (2018). Natural Resources Canada. ENERGY STAR Rebates and incentives directory. Retrieved January 31, 2019, from http://oee.nrcan.gc.ca/energy/products/energystar/why-buy/results.cfm?attr=0

Government of Ontario. (2013a). *Achieving Balance—Ontario's Long-Term Energy Plan*. 92.

Government of Ontario. (2016). *Ontario's Five Year Climate Change Action Plan 2016 – 2020* (p. 86). Retrieved from http://www.applications.ene.gov.on.ca/ccap/products/CCAP_ENGLISH.pdf

Han, T.-I., & Stoel, L. (2017). Explaining Socially Responsible Consumer Behavior: A Meta-Analytic Review of Theory of Planned Behavior. *Journal of International Consumer Marketing*, *29*(2), 91–103. https://doi.org/10.1080/08961530.2016.1251870

Hawkins, R. J. (2002). *Ten Lessons for ICT and Education in the Developing World*. 6.

Hecher, M., Hatzl, S., Knoeri, C., & Posch, A. (2017). The trigger matters: The decision-making process for heating systems in the residential building sector. *Energy Policy*, *102*, 288–306. https://doi.org/10.1016/j.enpol.2016.12.004

Herring, H., & Roy, R. (2007). Technological innovation, energy efficient design and the rebound effect. *Technovation*, *27*(4), 194–203. https://doi.org/10.1016/j.technovation.2006.11.004

Hirai, Y., Morita, Y., & Elokia, N. (2007, August 28). *Evaluation of Usability methodologies in the Universal Design Process*. Presented at the Proceedings International Conference on Engineering Design “Design for Society: Knowledge, Innovation, and Sustainability,” Paris.

Howarth, R. B., & Andersson, B. (1993). *Market barriers to energy efficiency*. 11.

Huijts, N. M. A., Molin, E. J. E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*, *16*(1), 525–531. https://doi.org/10.1016/j.rser.2011.08.018

IESO. (2017a). *An Examination of the Opportunity for Residential Heat Pumps in Ontario* (p. 41).

IESO. (2019a). Home Assistance Program—Home Energy Rebates | Save on Energy. Retrieved October 6, 2019, from https://saveonenergy.ca/en/For-Your-Home/Home-Assistance-Program

IESO. (2019b). *Reliability Outlook: An adequacy assessment of Ontario's electricity system from October 2019 to March 2021* (p. 37). Retrieved from file:///C:/Users/cmaca/Downloads/ReliabilityOutlook2019Sep%20(1).pdf

IPCC. (2018). *Summary for Policy Makers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global* *response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (pp. 1–32). World Meteorological Organization, Genva, Switzerland.

Ipsos MORI, & Energy Saving Trust. (2013). *Homeowner's Willingness To Take Up More Efficient Heating Systems* (pp. 1–124). Retrieved from Department of Energy & Climate Change website: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/191541/More_efficient_heating_report_2204.pdf

Jackson, T. (2003). *Policies for Sustainable Consumption*. 77. Sustainable Development Commission.

Klöckner, C. A. (2013). A comprehensive model of the psychology of environmental behaviour—A meta-analysis. *Global Environmental Change*, *23*(5), 1028–1038. https://doi.org/10.1016/j.gloenvcha.2013.05.014

Leach, J. (n.d.). Pumping Energy Savings. Retrieved April 7, 2018, from The Atmospheric Fund website: http://taf.ca/projects/pumping-energy-savings/

Lillemo, S. C. (n.d.). *Philosophiae Doctor (PhD) Thesis*. 147.

Lillemo, S. C., Alfnes, F., Halvorsen, B., & Wik, M. (2013). Households' heating investments: The effect of motives and attitudes on choice of equipment. *Biomass and Bioenergy*, *57*, 4–12. https://doi.org/10.1016/j.biombioe.2013.01.027

Lovins, A. (2014). *Reinventing Fire: Physics + Markets = Energy Solutions*. Rocky Mountain Institute.

Mahapatra Krushna, & Gustavsson Leif. (2007). Innovative approaches to domestic heating: Homeowners' perceptions and factors influencing their choice of heating system.

International Journal of Consumer Studies, *32*(1), 75–87. https://doi.org/10.1111/j.1470-6431.2007.00638.x

Maloney, S., Storr, M., Paynter, S., Morgan, P., & Ilic, D. (2013). Investigating the efficacy of practical skill teaching: A pilot-study comparing three educational methods. *Advances in Health Sciences Education*, *18*(1), 71–80. https://doi.org/10.1007/s10459-012-9355-2

Mayer, R. E. (2003). The promise of multimedia learning: Using the same instructional design methods across different media. *Learning and Instruction*, *13*(2), 125–139. https://doi.org/10.1016/S0959-4752(02)00016-6

Mckibben, B. (2012, July 19). Global Warming's Terrifying New Math. Retrieved April 11, 2018, from Rolling Stone website: https://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719

Michelsen, C. C., & Madlener, R. (2012). Homeowners' preferences for adopting innovative residential heating systems: A discrete choice analysis for Germany. *Energy Economics*, *34*(5), 1271–1283. https://doi.org/10.1016/j.eneco.2012.06.009

Michelsen, C. C., & Madlener, R. (2016). Switching from fossil fuel to renewables in residential heating systems: An empirical study of homeowners' decisions in Germany. *Energy Policy*, *89*, 95–105. https://doi.org/10.1016/j.enpol.2015.11.018

Mills, B., & Schleich, J. (2012). Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of European countries. *Energy Policy*, *49*, 616–628. https://doi.org/10.1016/j.enpol.2012.07.008

Mitsubishi Electric. (2017a). *The Hyper-Heat Advantage: Zuba-Central Zuba-Multi*. Retrieved from Mitsubishi website: https://cozycomfortplus.com/wp-content/uploads/2017/11/Brochure-Zuba-Central.pdf

Mitsubishi Electric. (2017b). *The Hyper-Heat Advantage: Zuba-Central Zuba-Multi*. Retrieved from Mitsubishi website: https://cozycomfortplus.com/wp-content/uploads/2017/11/Brochure-Zuba-Central.pdf

NEEP. (2014). *NortheastMid-Atlantic Air-Source Heat Pump Market Strategies Report*. Retrieved from https://neep.org/sites/default/files/resources/NortheastMid-Atlantic%20Air-Source%20Heat%20Pump%20Market%20Strategies%20Report_0.pdf

Nejat, P., Jomehzadeh, F., Taheri, M. M., Gohari, M., & Abd. Majid, M. Z. (2015). A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries). *Renewable and Sustainable Energy Reviews*, *43*, 843–862. https://doi.org/10.1016/j.rser.2014.11.066

Nesbakken, R. (2001). Energy Consumption for Space Heating: A Discrete-Continuous Approach. *The Scandinavian Journal of Economics*, *103*(1), 165–184.

Newborough, M., & Probert, D. (1994). Purposeful energy education in the UK. *Applied Energy*, *48*(3), 243–259. https://doi.org/10.1016/0306-2619(94)90013-2

Nieboer, S. (n.d). *Comparing ducted and mini-split air-source heat pumps to natural gas, propane, and fuel oil heating systems in a simulated Ontario residential home*. Waterloo-Laurier Graduate Program in Geography.

NRCAN. (2013). *Energy Efficiency Trends in Canada 1990 to 2013* (p. 51). Retrieved from Office of Energy Efficiency website: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/trends2013.pdf

NRCAN. (2017). Heating and Cooling With a Heat Pump. Retrieved April 10, 2018, from http://www.nrcan.gc.ca/energy/publications/efficiency/residential/heating-heat-pump/6817

O'Donoghue, T., & Punch, K. (2003). *Qualitative Educational Research in Action; Doing and Reflecting.* Rou.

OECD/IEA. (2011). *Energy-efficient Buildings: Heating and Cooling Equipment* (p. 56). International Energy Agency.

Oliver, R., & Herrington, J. (2001). *Teaching and learning online: A beginner's guide to e-learning and e-teaching in higher education*. Perth: Edith Cowan University, Centre for research in information technology and communications.

Ontario. (2019). AffordAbility Fund. Retrieved October 6, 2019, from AffordAbility Fund website: https://www.affordabilityfund.org/

Owen, A., Mitchell, G., & Unsworth, R. (2013). Reducing carbon, tackling fuel poverty: Adoption and performance of air-source heat pumps in East Yorkshire, UK. *Local Environment*, *18*(7), 817–833. https://doi.org/10.1080/13549839.2012.732050

Patel, M., Tran, J., McKenzie, A., & Sferrazza, T. (2015). *TAF-Heat-Pumps-Final-Report-2015.pdf*. Retrieved from http://taf.ca/wp-content/uploads/2015/06/TAF-Heat-Pumps-Final-Report-2015.pdf

Quinn, M. (2019). Can you guess what products are selling like hotcakes as Muskrat Falls looms? Heat pumps | CBC News. Retrieved November 25, 2019, from CBC website: https://www.cbc.ca/news/canada/newfoundland-labrador/heat-pump-sales-newfoundland-labrador-1.5321181

Region of Waterloo. (2017). About Waterloo Region. Retrieved September 3, 2019, from https://regionofwaterloo.icreate7.esolutionsgroup.ca/en/exploring-the-region/about-waterloo-region.aspx

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S. I., Lambin, E., … Foley, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, *14*(2). https://doi.org/10.5751/ES-03180-140232

Rogers, E. M. (1983). *Diffusion of innovations* (3rd ed). New York : London: Free Press ; Collier Macmillan.

Rogers, E. M. (2010). *Diffusion of Innovations, 4th Edition*. Simon and Schuster.

Rogers, J. C., Simmons, E. A., Convery, I., & Weatherall, A. (2008). Public perceptions of opportunities for community-based renewable energy projects. *Energy Policy*, *36*(11), 4217–4226. https://doi.org/10.1016/j.enpol.2008.07.028

Roy, R., Caird, S., & Potter, S. (2010). *Getting Warmer: A field trial of heat pumps* (p. 22). Retrieved from The Energy Saving Trust website: http://oro.open.ac.uk/31647/1/Getting_warmer_a_field_trial_of_heat_pumps_report.pdf

Ruokamo, E. (2016). Household preferences of hybrid home heating systems – A choice experiment application. *Energy Policy*, *95*, 224–237. https://doi.org/10.1016/j.enpol.2016.04.017

Safa, A. A. (2012). *Performance analysis of a two-stage variable capacity air source heat pump and a horizontal loop coupled ground source heat pump system* (Theses and dissertations). Ryerson University.

Santer, D. M., Michaelsen, V. E., Erkonen, W. E., Winter, R. J., Woodhead, J. C., Gilmer, J. S., … Galvin, J. R. (1995). A Comparison of Educational Interventions: Multimedia Textbook, Standard Lecture, and Printed Textbook. *Archives of Pediatrics & Adolescent Medicine*, *149*(3), 297–302. https://doi.org/10.1001/archpedi.1995.02170150077014

Satnik, D. (2019). *FCM/GMF FEASIBILITY STUDY: MUNICIPAL TOOLS FOR CATALYZING NET-ZERO ENERGY DEVELOPMENT*. The Corporation of the City of London.

Scarpa, R., & Willis, K. (2010). Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies. *Energy Economics*, *32*(1), 129–136. https://doi.org/10.1016/j.eneco.2009.06.004

Shove, E. (1998). Gaps, barriers and conceptual chasms: Theories of technology transfer and energy in buildings. *Energy Policy*, *26*(15), 1105–1112. https://doi.org/10.1016/S0301-4215(98)00065-2

Snape, J. R., Boait, P. J., & Rylatt, R. M. (2015). Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling. *Energy Policy*, *85*, 32–38. https://doi.org/10.1016/j.enpol.2015.05.008

Sopha, B. M., Klöckner, C. A., Skjevrak, G., & Hertwich, E. G. (2010). Norwegian households' perception of wood pellet stove compared to air-to-air heat pump and electric heating. *Energy Policy*, *38*(7), 3744–3754. https://doi.org/10.1016/j.enpol.2010.02.052

Sorrell, S., University of Sussex, & Sussex Energy Group. (2007). *The Rebound effect: An assessment of the evidence for economy-wide energy savings from improved energy efficiency*. Sussex: UK Energy Research Centre.

Staddon, S. C., Cycil, C., Goulden, M., Leygue, C., & Spence, A. (2016). Intervening to change behaviour and save energy in the workplace: A systematic review of available evidence. *Energy Research & Social Science*, *17*, 30–51. https://doi.org/10.1016/j.erss.2016.03.027

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., … Schellnhuber, H. J. (2018). *Trajectories of the Earth System in the Anthropocene*. 8.

Stevens, V., Craven, C., Marsik, T., & Hammer, C. (2015). *Air Source Heat Pump Potential in Alaska*. Retrieved from Cold Climate Housing Research Center website: http://www.cchrc.org/sites/default/files/docs/EETFRound2_ASHP_Potential_in_AK_12.31.2015.pdf

Szekeres, A., & Jeswiet, J. (2016). Impact of Technological Advancement on Adoption and Use of Residential Heat Pumps. *Procedia CIRP*, *48*, 394–400. https://doi.org/10.1016/j.procir.2016.03.160

Szekeres, A., & Jeswiet, J. (2018a). Effects of technological development and electricity price reductions on adoption of residential heat pumps in Ontario, Canada. *International Journal of Energy and Environmental Engineering*. https://doi.org/10.1007/s40095-018-0263-y

Szekeres, A., & Jeswiet, J. (2018b). Heat pumps in Ontario. *International Journal of Energy and Environmental Engineering*. https://doi.org/10.1007/s40095-018-0292-6

Toronto and Region Conservation Authority. (2018). *Assessment of Multi-Split Ductless Air-source Heat Pump Retrofits in an Ontario Rowhouse: Heating and Cooling.* Toronto and Region Conservation Authority, Vaughan, Ontario.

Township of Langley. (2015). Using Cash Incentives to Encourage High Performance New Homes: An Overview of the Township of Langley’s Green Building Permit Rebate Program. Retrieved November 12, 2019, from http://neia.org/wp-content/uploads/2015/02/Using_Cash_Incentives_to_Encourage_High_Performance_New_Homes_Township_of_Langley_EN.pdf

United Nations, & FCCC. (2015). *Adoption of the Paris Agreement: Proposal by the President, draft decision*. Retrieved from Framework Convention on Climate Change website: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

US EPA, O. (2016, January 12). Global Greenhouse Gas Emissions Data [Overviews and Factsheets]. Retrieved April 10, 2018, from US EPA website: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

Vaage, K. (2000). Heating technology and energy use: A discrete/continuous choice approach to Norwegian household energy demand. *Energy Economics*, *22*(6), 649–666. https://doi.org/10.1016/S0140-9883(00)00053-0

West, D. M. (2015). *Digital divide: Improving Internet access in the developing world through affordable services and diverse content*. 30.

Williams, J. H., Haley, B., Kahrl, F., Moore, J., Jones, A. D., Torn, M. S., & McJeon, H. (2014). *Pathways to Deep Decarbonization in the United States. The U.S. report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations.* 100.

Wyse, S. M., & McVey, I. (2018). *Barrier Assessment: Uptake of Heat Pump technologies in Ontario's Multi-Unit Residential Sector.* Ontario CLimate Consortium White Paper 2018001.

Zografakis, N., Menegaki, A. N., & Tsagarakis, K. P. (2008). Effective education for energy efficiency. *Energy Policy*, *36*(8), 3226–3232. https://doi.org/10.1016/j.enpol.2008.04.021

APPENDIX A

Demographic Composition of the Sample

A.1 Age

	Frequency	Percent
18-25	17	17%
26-35	21	21%
36-45	17	17%
46-55	19	19%
56-65	20	20%
65+	8	8%

A.2 Education

	Frequency	Percent
High School	4	4%
Trade School	8	8%
Bachelors	48	47%
Masters	30	29%
Doctorate	12	12%

A.3 Income

	Frequency	Percent
Under $20,000	4	4%
$20,000 - $34,999	5	5%
$35,000-$49,999	6	6%
$50,000-$74,999	24	24%
$75,000-$99,999	18	18%
Over $100,000	43	43%

APPENDIX B

Instrument

B.1 Multiple Choice Questions

Are you aware of the performance improvements that modern ASHP models have received?	*NO*	*YES*
Are you aware of the availability of system models designed to function in a cold-climate?	NO	YES

B.2 PRE-TEST

	Low	2 / 5	3 / 5	4 / 5	High
On a scale of 1 – 5, with 1 being low and 5 being high, how confident are you in the ASHP's performance reliability when installed in a cold-climate?					
On a scale of 1 – 5, with 1 being low and 5 being high, what is the probability that you would install an ASHP; *within the year*					
within 1-2 years					
within 3-5 years					
within 6-10 years					
End of Existing System's Operational Life					
On a scale of 1 – 5, with 1 being low and 5 being high, would your probability of adoption increase if the system reduced; *your energy bills?*					
your residential carbon footprint?					
your consumption of purchased energy?					
A 2012 study conducted by Caird, Roy, & Potter (2012) determined that early heat pump adopters reported high satisfaction ratings. On a scale from 1 – 5, with 1 being low and 5 being high, does this information increase your probability of adoption; *within the year*					
Within 1-2 years					
Within 3-5 years					
Within 6-10 years					
End of Existing System's Operational Lifespan					

B.3 POST-TEST

	Low	*2 / 5*	*3 / 5*	*4 / 5*	*High*
On a scale of 1 – 5, with 1 being low and 5 being high, how confident are you in the ASHP's performance reliability when installed in a cold-climate?					
On a scale of 1 – 5, with 1 being low and 5 being high, what is the probability that you would install an ASHP; *within the year*					
within 1-2 years					
within 3-5 years					
within 6-10 years					
End of Existing System's Operational Life					

APPENDIX C

Online Factsheet

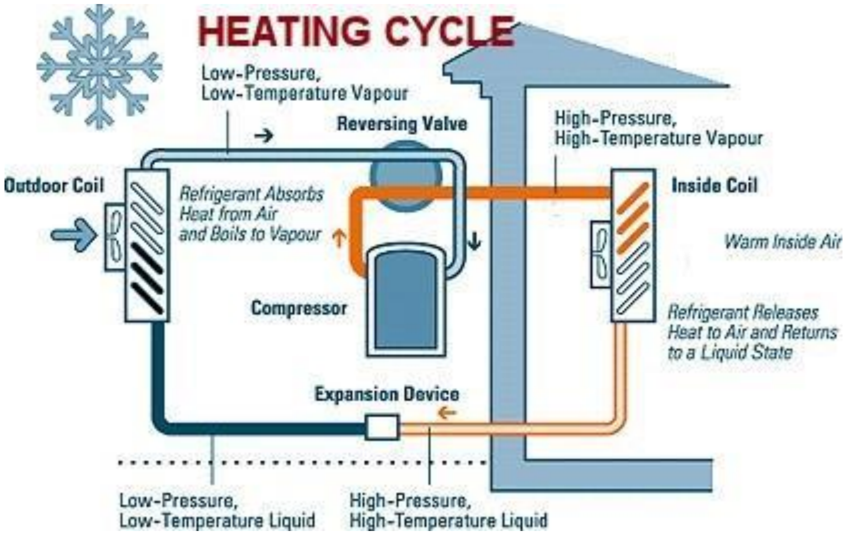
How a Heat Pump Works

Air source heat pumps are among the most energy efficient heating systems available on the market. This is because the system transfers heat from one area to another, which is a more efficient use of energy than generating heat. In the cold months, the ASHP heats the home using the heat energy in the air outside of the house. This is possible even when the temperature is below zero degrees Celsius because heat energy is present in the air until absolute zero (-273 degrees Celsius). The heating process begins in the outdoor coil as a fan draws air into the system. There is refrigerant fluid inside of the outdoor coil, which boils at a low temperature. As the fan draws air into the system, the heat boils the refrigerant, expanding it into a vapour. The vapour enters the system's compressor, which reduces the volume, while increasing the temperature, of the vaporized refrigerant. The heated vapour then enters the indoor coil, where the heat energy is released into the home's heating circuits, effectively warming the house to the desired temperature. The refrigerant is condensed back into a liquid and when it passes through the expansion valve its pressure and temperature decreases. The cold refrigerant is then returned to the evaporator in the outdoor coil, and the heating process is repeated. For the purposes of cooling the home during the summer months, the same process is reversed to transfer the heat in the air from inside of the home to the external environment. When heating or cooling the home, the ASHP provides a slow, steady provision of heat or cool air. Therefore, it is important to not interrupt the cycle by switching the system on and off to try and save money. It is important to allow its cycles to progress as required to ensure optimal system performance (NRCAN, 2017).

Benefits of installing an ASHP

- The ASHP has a 300% energy efficiency rating at temperatures around 10 degrees Celsius, compared to the 96% energy efficiency rating of a high efficiency natural gas furnace. This will reduce your home's consumption of purchased energy and save you money on your annual energy bills if you are currently using electric baseboard heating.
- An ASHP is powered by electricity, which will lower your home's carbon emissions relative to using a fossil fuel furnace
- A study conducted by the Independent Electricity System Operator (IESO) found Ontario residents who installed an ASHP reported up to 50% reductions in their energy bill (IESO, 2017)*
- The typical payback period is 2-7 years
- An ASHP's lifespan is 15-20 years
- An ASHP requires less space inside of the home relative to a fossil fuel furnace
- An ASHP requires less maintenance than a fossil fuel furnace
- Technical advancements have improved an ASHP's performance efficiency
- ASHP models designed for colder climates can heat homes in temperatures as low as minus 25-30 degree Celsius

• There have been high satisfaction ratings among early adopters



Retrieved from http://btw.build/learn/heating-and-cooling/air-source-heat-pumps/

* *For additional information on how an ASHP functions and the benefits that they provide post installation, please refer to the following resources;*

- *IESO. (2017). An Examination of the Opportunity for Residential Heat Pumps in Ontario. file:///C:/Users/cmaca/Downloads/An-Examination-of-Opportunity-for-Residential-Heat-Pumps-in-Ontario.pdf%20 NRCAN. (2017). Heating and Cooling with a Heat Pump. Retrieved April 10, 2018, from http://www.nrcan.gc.ca/energy/publications/efficiency/residential/heating-heat-pump/6817*

APPENDIX D

Pearsons' *r* coefficient – Demographic Dataset

	Age	*Education*	*Income*
Age	1.00	-.15	.22
Education	-.15	1.00	-.01
Income	.22	-.01	1.00
Installed Heating System	.18	.05	.19
Awareness of performance improvements	-.02	.04	.14
Awareness of Cold-Climate System Models	.11	.01	.08
Perceived Reliability: Pre-test	.04	-.09	-.05
Perceived Reliability: Post-test	.10	-.02	.02
Impact of Reduced Energy Bill	-.21	-.17	-.20
Impact of Reduced Carbon Footprint	-.01	-.03	-.11
Impact of Reduced Consumption of purchased energy	-.13	-.18	-.05
Probability of adoption: Within the Year	-.11	-.18	.08
Probability of adoption: Within 1-2 years	-.16	-.14	-.09
Probability of adoption: Within 3-5 years	-.14	-.19	-.05
Probability of adoption: Within 6-10 years	-.35	-.06	-.14
Probability of adoption: End of Existing System's Operational Lifespan	-.04	-.03	.03
Probability of adoption: Within the year – post-test	-.16	-.22	.05
Probability of adoption: Within 1-2 years – post-test	-.11	-.12	-.03
Probability of adoption: Within 3-5 years – post-test	-.09	-.21	-.14
Probability of adoption: Within 6-10 years – post-test	-.10	-.15	-.14
Probability of adoption: End of Existing System's Operational Lifespan – post-test	.10	-.11	-.09
Probability of adoption: Within the year – post-satisfaction	.07	-.18	-.18
Probability of adoption: Within 1-2 years – post-satisfaction	-.14	-.22	-.18
Probability of adoption: Within 3-5 years – post-satisfaction	-.21	-.15	-.25
Probability of adoption: Within 6-10 years – post-satisfaction	-.30	-.23	-.34
Probability of adoption: End of Life – post-satisfaction	.01	-.11	-.32

APPENDIX E

Frequency Distributions: Perceived Reliability

E.1 SEMINAR COHORTS

	Low Confidence	2/5	3/5	4/5	High Confidence
Pre-test	0%, n= 0	9%, n= 3	23%, n= 8	51%, n= 18	17%, n= 6
Post-test	0%, n= 0	9%, n= 3	17%, n= 6	51%, n= 18	23%, n= 8

E.2 Survey Cohorts

	Low Confidence	2/5	3/5	4/5	High Confidence
Pre-test	4%, n= 5	7%, n= 8	31%, n= 38	34%, n= 41	24%, n= 29
Post-test	2%, n= 2	4%, n= 5	23%, n= 26	45%, n= 52	46%, n= 30

APPENDIX F

Frequency Distributions: Relative Advantages

F.1 Seminar Cohorts

	Low Influence	2/5	3/5	4/5	High Influence
Reduced Energy Bill	0%, n= 0	9%, n= 3	6%, n= 2	37%, n= 13	49%, n= 17
Reduced Carbon Emissions	3%, n= 1	0%, n= 0	11%, n= 4	31%, n= 11	54%, n= 19
Reduced Purchased Energy	0%, n= 0	6%, n= 2	11%, n= 4	37%, n= 13	46%, n= 16

F.2 Survey Cohorts

	Low Influence	2/5	3/5	4/5	High Influence
Reduced Energy Bill	1%, n= 1	8%, n= 9	9%, n= 11	25%, n= 30	57%, n= 67
Reduced Carbon Emissions	2%, n= 2	7%, n= 8	13%, n= 15	21%, n= 25	58%, n= 70
Reduced Purchased Energy	1%, n= 1	6%, n= 7	13%, n= 15	35%, n= 41	45%, n= 53

APPENDIX G

Frequency Distributions: Impact of Positive Satisfaction Ratings

G.1 – Seminar Cohorts: Pre-test

	Low	2/5	3/5	4/5	High
Within the year	26%, n= 8	10%, n= 3	39%, n= 12	23%, n= 7	3%, n= 1
Within 1-2 years	31%, n= 8	4%, n= 1	27%, n= 7	35%, n= 9	4%, n= 1
Within 3-5 years	8%, n= 2	24%, n= 6	12%, n= 3	32%, n= 8	24%, n= 6
Within 6-10 years	21%, n= 5	8%, n= 2	17%, n= 4	17%, n= 4	38% n= 9
End of Life	12%, n= 3	0%, n= 0	20%, n= 5	28%, n= 7	40%, n= 10

G.2- Seminar Cohorts: Post-Satisfaction Ratings

	Low	2/5	3/5	4/5	High
Within the year	31%, n= 10	9%, n= 3	9%, n= 3	38%, n= 12	13%, n= 4
Within 1-2 years	30%, n= 8	7%, n= 2	22%, n= 6	30%, n= 8	11%, n= 3
Within 3-5 years	27%, n= 7	8%, n= 2	27%, n= 7	23%, n= 6	15%, n= 4
Within 6-10 years	20%, n= 5	8%, n= 2	28%, n= 7	20%, n= 5	24%, n= 6
End of Life	15%, n= 4	0%, n= 0	19%, n= 5	26%, n= 7	41%, n= 11

G.3 Survey Pre-test

	Low	2/5	3/5	4/5	High
Within the year	55%, n= 56	18%, n= 18	16%, n= 16	6%, n= 6	6%, n= 6
Within 1-2 years	44%, n= 46	18%, n= 19	13%, n= 13	16%, n= 17	9%, n= 9
Within 3-5 years	23%, n= 24	14%, n= 14	23%, n= 24	20%, n= 21	19%, n =2-
Within 6-10 years	21%, n= 21	7%, n= 7	28%, n= 28	20%, n= 20	25%, n= 25
End of Life	6%, n= 7	9%, n= 11	27%, n= 30	23%, n= 26	33%, n= 37

G.4 Survey Post-Satisfaction

	Low	2/5	3/5	4/5	High
Within the year	44%, n= 46	20%, n=21	24%, n= 25	8%, n= 8	4%, n= 4
Within 1-2 years	37%, n= 38	18%, n= 19	23%, n= 24	8%, n= 8	14%, n= 14
Within 3-5 years	24%, n= 24	11%, n= 11	35%, n= 36	17%, n= 17	14%, n= 14
Within 6-10 years	21%, n= 21	8%, n= 8	25%, n= 25	26%, n= 26	21%, n= 21
End of Life	10%, n= 11	3%, n= 3	23%, n= 24	28%, n= 30	36%, n= 38

APPENDIX H

Frequency Distributions: Reported Probability of adoption

H.1 Seminar Cohorts: Pre-test

	Low	2/5	3/5	4/5	High
Within the year	26%, n= 8	10%, n= 3	39%, n= 12	23%, n= 7	3%, n= 1
Within 1-2 years	31%, n= 8	4%, n= 1	27%, n= 7	35%, n= 9	4%, n= 1
Within 3-5 years	8%, n= 2	24%, n= 6	12%, n= 3	32%, n= 8	24%, n= 6
Within 6-10 years	21%, n= 5	8%, n= 2	17%, n= 4	17%, n= 4	38% n= 9
End of Life	12%, n= 3	0%, n= 0	20%, n= 5	28%, n= 7	40%, n= 10

H.2 Seminar Cohorts: Post-Test

	Low	2/5	3/5	4/5	High
Within the year	41%, n= 12	17%, n= 5	14%, n= 4	10%, n= 3	17%, n =5
Within 1-2 years	30%, n= 8	15%, n= 4	22%, n= 6	22%, n= 6	11%, n= 3
Within 3-5 years	15%, n= 4	8%, n= 2	27%, n= 7	15%, n= 4	35%, n= 9
Within 6-10 years	12%, n= 3	4%, n= 1	12%, n= 3	27%, n= 7	46%, n= 12
End of Life	4%, n= 1	0%, n= 0	4%, n= 1	20%, n= 5	73%, n= 19

H.3 Survey Cohorts: Pre-test

	Low	2/5	3/5	4/5	High
Within the year	55%, n= 56	18%, n= 18	16%, n= 16	6%, n= 6	6%, n= 6
Within 1-2 years	44%, n= 46	18%, n= 19	13%, n= 13	16%, n= 17	9%, n= 9
Within 3-5 years	23%, n= 24	14%, n= 14	23%, n= 24	20%, n= 21	19%, n =2-
Within 6-10 years	21%, n= 21	7%, n= 7	28%, n= 28	20%, n= 20	25%, n= 25
End of Life	6%, n= 7	9%, n= 11	27%, n= 30	23%, n= 26	33%, n= 37

H.4 Survey Cohorts: Post-Test

	Low	2/5	3/5	4/5	High
Within the year	48%, n= 48	12%, n= 12	16%, n= 16	16%, n= 16	8%, n= 8
Within 1-2 years	39%, n= 38	12%, n= 11	21%, n= 20	14%, n= 13	15%, n= 14
Within 3-5 years	20%, n= 19	17%, n= 16	20%, n= 19	26%, n= 25	17%, n= 16
Within 6-10 years	16%, n= 15	9%, n= 8	17%, n= 16	29%, n= 27	28%, n= 26
End of Life	7%, n= 7	4%, n= 4	12%, n= 12	27%, n= 27	51%, n= 51