Household Decision-Making Dynamics Associated with the Adoption of High-Involvement Renewable Energy Technologies: A Case Study of Consumer Experiences in the Adoption of Residential Ground Source Heat Pump Systems in Rural Southwestern Ontario (Canada)

by

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Author 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 revision, as accepted by my examiners.

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Abstract

In the province of Ontario, 88 percent of residential energy demand is for space heating, cooling and water heating, accounting for 99 percent of the residential sector's greenhouse gas (GHG) emissions (data are for 2011 and are taken from Natural Resources Canada, 2014a). Amongst the current and viable residential renewable energy technologies (RETs), ground source heat pump (GSHP) systems offer the potential to meet a substantial share of these energy requirements, but current levels of adoption are minimal. Ontario's existing and planned rural housing stock that does not have access to natural gas and relies on oil, propane or electric-based systems for heating and cooling demands, offers an immediate opportunity to achieve large scale reductions in GHG emissions and reduce pressure on the existing electricity infrastructure, while simultaneously reducing home heating and cooling costs.

The purpose of this thesis is to describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. To act on this purpose, 17 face-to-face interviews were conducted with householders that have retrofitted their house with a GSHP system in rural southwestern Ontario areas that do not have access to natural gas. This thesis utilizes Rogers' (2003) Innovation-Decision Process model as a theoretical framework to guide the collection of empirical data on household adoption experiences to achieve this research purpose.

The findings from this study indicate that the residential adoption of GSHP systems in rural southwestern is influenced by five determinants of adoption: (1) prior conditions; (2) characteristics of the decision-making unit; (3) perceived characteristics of the innovation; (4) change agent programs; and (5) communication channels; however, the influence of each determinant of adoption varied across households. Cost savings and the government grant(s) were the most significant drivers for adoption followed by factors related to sustainability and the GSHP system's ability to provide space cooling. The high initial capital cost of the system was identified as the most significant barrier to adoption. By developing a comprehensive understanding of the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario, findings may contribute to a better design of policy instruments and marketing strategies aimed at stimulating the adoption of these systems in rural areas.

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Dedication

This thesis is dedicated to my parents (co-advisor's in life) who always believe in me and stand by my side. I would not be where I am today without your love, support and guidance.

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Chapter 1: Introduction

1.1 Background

Climate change is arguably the most pressing environmental concern of today's global challenges. The Intergovernmental Panel on Climate Change (IPCC, 2011) states that greenhouse gas (GHG) emissions associated with the provision of energy services required for basic human needs (e.g. space heating and cooling, lighting, cooking, transportation, communication) are a major cause of anthropogenic climate change. One particular strategy to mitigate climate change and its adverse impacts is the development and deployment of renewable energy sources. According to the IPCC (2011), renewable energy sources and their associated technologies can provide a number of opportunities in addition to mitigating climate change, such as addressing sustainable and equitable development, energy access, secure energy supply and local environmental and health impacts. While the share of renewable energy sources in the global energy mix is still relatively small, deployment of renewable energy technologies (RETs) has been increasing rapidly in recent years (IPCC, 2011), due to the rising concerns about GHG emissions, increasing energy prices, limited fossil fuel reserves, and energy security issues (Mills & Schleich, 2009; Rao & Kishore, 2010; Thorsteinsson & Tester, 2010).

In 2011, Canada's residential sector accounted for 14 percent of the country's total secondary energy consumption and 16 percent of total GHG emissions (National Energy Board, 2013). In the same year, in the province of Ontario, 88 percent of residential energy demand was for space heating (64 percent), space cooling (3 percent) and water heating (21 percent), accounting for 20 megatonnes of CO_2e or 99 percent of the residential sector's GHG emissions (Natural Resources Canada [NRCan], 2014a). The main sources of energy used to satisfy these end-use demands are predominantly fossil fuels, such as natural gas, heating oil, and propane, which directly produce GHG emissions and contribute to climate change, and electricity - which although is largely (approximately 70 percent[1]) carbon-free in Ontario - still produces GHG emissions from natural gas generation, which has increased in recent years with the phase out of coal-fired generation plants, making up the remaining 30 percent of installed capacity (Independent Electricity System Operator [IESO], 2014).

[1] nuclear (39.4%); hydroelectric (24.4%); and wind (5.6%), according to June 2014 numbers (IESO, 2014).

Although the residential sector has made significant energy efficiency improvements in recent years, as highlighted in Ontario's Long-Term Energy Plan (LTEP) (Government of Ontario, 2013), the continued reliance on fossil fuels and electricity from the grid to supply households with their space heating, cooling and hot water needs, will hinder Ontario's transition towards a more sustainable and affordable energy future. In order for Ontario to make significant improvements in reducing its energy consumption and GHG emissions associated with the residential sector, the adoption and wide scale deployment of residential RETs is important. Likewise, Reddy and Painuly (2004), argue that transitioning from non-renewable to RETs at the household level should be the top priority in moving towards a sustainable energy future.

According to Randolph and Masters (2008), societies interested in pursuing a sustainable energy future must aim to accomplish three goals: 1) improve energy efficiency to reduce growth in demand; 2) displace oil (and other fossil fuels); and 3) increase the use of renewable energy sources. Although no single action can address all three goals, renewable energy sources and their associated technologies present a solution that is able to address the latter two (Adachi, 2009). Residential households present an immediate opportunity to achieve both of these goals, while simultaneously reducing GHG emissions cost-effectively (David Suzuki Foundation, 2004). According to the carbon abatement cost curve in a study by McKinsey and Company (2007), reducing the consumption of energy in buildings, such as residential dwellings, is one of the least costly ways to achieve large scale reductions in GHG emissions.

Amongst the current and viable residential RETs, ground source heat pump (GSHP) systems[2] - an application of geothermal energy - offer the potential to meet a substantial share of residential energy requirements, as they are capable of providing space heating, cooling and a portion of water heating needs, which collectively account for the majority of household energy demands in Ontario. According to the David Suzuki Foundation (2004), GSHP systems are the most cost-effective and environmentally friendly technology for residential space heating and cooling in Ontario; however, are one of the least understood and underdeveloped renewable energy options. GSHP systems are the focus of this thesis and will be examined in the following section, in terms of how they work, their associated benefits, and their current residential market status in Ontario.

[2] Also known as geothermal heat pumps, earth energy systems, or geoexchange systems.

1.2 Ground Source Heat Pump Systems

The U.S. Environmental Protection Agency (1993) has labelled GSHP systems as the most energy-efficient, cost-effective and environmentally benign space heating and cooling technology available. The David Suzuki Foundation (2004) asserts that GSHP systems are a proven technology and represent the most cost-effective GHG mitigation strategy available for the residential sector. This does not suggest, however, that GSHP systems are the sole solution; instead, they are one of a portfolio of technologies required to help achieve a sustainable residential energy future in Ontario. In this thesis, capital intensive residential RETs, such as GSHP systems, are regarded as *high-involvement* RETs, because of the significant amount of time and cognitive effort that is required for potential adopters to invest in their decision-making process, due to higher perceived financial and social risk (Michelsen & Madlener, 2011).

1.2.1 Making the Case for GSHP Systems

As cited by the David Suzuki Foundation (2004), NASA estimates that out of all the solar radiation that reaches the Earth, more than half is absorbed into the near surface land and water. This stored energy keeps the Earth's temperature approximately 10°C at only six feet below the surface across most of southern Ontario, even in the coldest months of winter (NextEnergy, 2012). This moderate temperature variation keeps the ground warmer than the air in the winter and cooler in the summer. GSHP systems take advantage of this temperature differential, using the free and abundant solar energy stored in the ground as a heat source in the winter and a heat sink in the summer (Self, Reddy & Rosen, 2013).

A typical residential GSHP system has five major components: 1) a series of underground pipes that transfer heat out of the Earth for space heating, or back into the Earth for space cooling via an energy absorbing anti-freeze solution; 2) a circulating pump; 3) a central heat exchange unit; 4) a compressor; and 5) a heat distribution system (i.e. standard ductwork or in-floor heating pipes) (NextEnergy, 2012). The most common type of distribution system is the standard ductwork; therefore, the majority of installations are water-to-forced air systems instead of water-to-water systems that use in-floor heating pipes (NextEnergy, 2012). GSHP systems can be installed in one of two configurations: open or closed-loop and the underground piping can be installed horizontally or vertically, which is usually dependent on the availability of land. For the purpose of understanding how GSHP systems function, horizontal closed-loop, water-to-forced air systems will be considered.

In the winter, the anti-freeze solution is circulated through the underground pipes absorbing low temperature thermal heat from the ground and is transferred into the central heat exchanger that contains a refrigerant that acts as a heat transfer fluid (Self et al., 2013). When the solution enters the heat exchanger, the energy absorbed from the ground is transferred into the refrigerant, which begins to boil and converts into vapour. The vapour is then upgraded to a higher temperature by the compressor before it is distributed as warm air throughout the house (Self et al., 2013). In the summer, the heat transfer process is reversed; high temperature thermal heat is captured from the indoor air and is transferred into the antifreeze solution and is circulated back underground, where the pipes exchange the heat with the cooler Earth, resulting in the solution returning to the house in a cooler state for space cooling (Next Energy, 2012).

GSHP systems can also provide a portion of residential hot water needs for domestic use through a device called the "desuperheater" (CanmetENERGY, 2005). The desuperheater is a small auxiliary heat exchanger that transfers excess heat from the compressed vapour to preheat water that circulates to the hot water tank (Self et al., 2013). This device is capable of reducing the energy required for water heating by 25 to 50 percent in the heating season and almost entirely in the cooling season (CanmetENERGY, 2005). However, not all GSHP systems contain a desuperheater; in many cases, the device is an "add on" and is usually the choice of the homeowners to have it installed (Self et al., 2013).

GSHP systems require electricity to power the circulating pump for the fluid in the loop, the heat exchanger and compressor to execute the heat transfer process, and the heat distribution system however, the amount is minimal (Kikuchi, Bristow & Kennedy, 2009). The ratio of supplied heat to the electricity consumed by the GSHP system is called the co-efficient of performance (COP), which is a measurement of energy efficiency (energy output by system divided by energy input) (CanmetENERGY, 2005). Contemporary GSHP systems are commonly assigned a heating COP of 4, meaning that for every 1kW of electricity consumed to operate the system, 4 units of thermal heat are absorbed from the soil for space heating, resulting in an efficiency level of 400 percent (Bayer et al., 2012). The COP for cooling is always one less than for heating, resulting in a COP of 3, meaning that 3 units of thermal heat are removed from the air for every 1 kWh of input energy (CanmetENERGY, 2005). The COP has a direct influence on energy consumption, GHG emissions and economic savings associated with GSHP systems.

CanmetENERGY (2005) estimates that GSHP systems can achieve reductions in energy consumption of 30 to 70 percent in the heating mode, and 20 to 50 percent in the cooling mode, compared to conventional fossil fuel and electric-based systems. According to the U.S. Department of Energy (2012), compared to a conventional electric-based heating system with a standard air conditioning unit, GSHP systems use 25 to 50 percent less electricity, which benefits local utilities by increasing their base load and reducing summer peak load demand (CanmetENERGY, 2005). While GSHP systems do not produce electricity to feed-in to the grid, they nevertheless contribute to reduce the pressure on Ontario's electricity infrastructure, by significantly reducing energy demand; hence, they are a powerful technology for energy conservation and peak load management in Ontario, which is a reoccurring issue identified in the LTEP (Government of Ontario, 2013).

GSHP systems do not directly emit GHGs; rather, the emissions originate from the power plants that produce the electricity that is required to power the system's components. Therefore, in provinces such as Alberta and Nova Scotia where over 80 percent of the electricity is produced from fossil fuels, including coal and natural gas plants, emissions associated with GSHP systems are correspondingly high (Self et al., 2013). Conversely, in areas such as Ontario, where approximately 70 percent of the electricity is generated from carbon-free sources, including nuclear, hydro and wind (IESO, 2014), the application of GSHP systems can be environmentally advantageous (Self et al., 2013).

Several studies have identified significant GHG emissions savings from the operation of GSHP systems compared to conventional fossil fuel-based heating and cooling systems (Hanova & Dowlatabadi, 2007; Hughes & Chaudhry, 2011; Kikuchi et al., 2013). However, the calculated savings vary substantially by geographic location and depend on the type of fuel being displaced and the emissions factor of the electricity mix that is required to run the system's components (Bayer et al., 2012). For example, Kikuchi et al. (2009) found in their evaluation of region-specific residential energy systems for GHG reductions in Canada, that GSHP systems can achieve total GHG emission savings of approximately 40 to 50 percent, when displacing natural gas systems, in locations where the emissions factor for electricity is small. Moreover, according to a study performed by the Canadian GeoExchange Coalition (CGC, 2010a) on the comparative analysis of GHG emissions of various residential heating systems in the Canadian provinces, by retrofitting 2 percent of Ontario's single detached houses with a GSHP system that currently heat with electric baseboards, natural gas, oil and propane, a total of 185,718 tons of CO_2e can be achieved, which is the equivalent of removing 55,273 cars from the road.

GSHP systems require a high initial capital cost; however, in the long term, this can be compensated by significantly lower household operation and maintenance costs (Kikuchi et al., 2009). In 2011, the average price for a horizontal installation was $24,464 and $31,544 for a vertical installation (CGC, 2012a). The economic feasibility of a GSHP system depends strongly on geographic location, the type of system and fuel being displaced, the present and future price of alternative energy sources, the size of the system being installed and its COP rating (NRCan, 2014b). According to Bakirci (2010), annual operating costs of GSHP systems are significantly lower than conventional fossil fuel and electric-based heating systems, especially in colder climates, resulting in cost savings of up to 70 percent. For locations also requiring space cooling, GSHP systems offer an increased economic advantage, as they can provide this service using 30 to 50 percent less electricity, compared to a conventional air conditioning system (Omer, 2007). Simple payback periods for GSHP systems are difficult to calculate due to fluctuating energy prices and climatic conditions, however, they are typically between 6 and 13 years with a COP of 4, for Ontario households, excluding financial incentives (Hanova & Dowlatabadi, 2007).

GSHP systems offer a number of other benefits, such as increased property value (Hanova & Dowlatabadi, 2007; Self et al., 2013) and longer life expectancy compared to conventional systems (Bakirci, 2010), with warranties of 20-25 years, with some systems operating in excess of 30 years (Self et al, 2013). Households that have adopted a GSHP system have experienced additional benefits, such as improved safety and reliability, lower maintenance costs, improved comfort and indoor air quality and a general pleasure from using a low-carbon energy system for home heating, cooling and water heating, as identified in a study on household satisfaction with GSHP systems in the United Kingdom (Caird, Roy & Potter, 2012).

In summary, the implementation of GSHP systems in existing and planned houses is a key strategy to displace fossil fuels and reduce electricity currently used for space heating, cooling and water heating in Ontario's residential sector, while providing households with additional economic, technological and social benefits.

1.2.2 Ontario Residential Market Status for GSHP Systems

Despite the wide range of benefits that GSHP systems offer, the current level of adoption is extremely low. The CGC (2012b) estimates that there are approximately 100,000 GSHP systems installed across Canada and two-third of these, or 66,667 systems, are installed in Ontario. The sectoral breakdown is estimated at 56 percent, or 37,334 systems installed in the residential sector and 44 percent, or 29,333 systems installed in the industrial, commercial and institutional (ICI) sectors. From these figures, the CGC (2012b) estimates that the market penetration for GSHP systems in the Ontario residential sector is approximately half a percent, suggesting that a number of barriers are inhibiting adoption.

Within current literature and industry publications, little is known about the barriers that are present to the residential adoption of GSHP systems in an Ontario context, however, it has been hypothesized that perceived high upfront costs and long payback periods are preventing greater market penetration (Nguyen, Law, Avaly, Walsh, Leong & Dworkin, 2014). In the United States, the Oak Ridge National Laboratory (2010) identified the three most significant barriers to adoption, in order of significance, as: high initial capital cost, lack of consumer knowledge of and trust in GSHP system benefits, and lack of policymaker and regulatory knowledge of and trust in the same benefits.

To help address the "traditional" barrier of the high initial capital cost and encourage the adoption of GSHP systems, the federal government, through Natural Resource Canada's ecoENERGY retrofit program, provided a $4,375 grant for homeowners that retrofitted their house with said system between April 2007 and March 2012. During the first three years of the program, the Ontario government matched the $4,375 grant, doubling the value of the grant to $8,750. Remarkably, the Ontario market for GSHP systems grew by more than 60 percent annually in 2007 and by 75 percent annually in 2008 as a probable result of the program, until it stabilized at a 5 percent increase in 2009 (CGC, 2010). The market then declined in 2010, presumably because the grant decreased from $8,750 to $4,375 when the Ontario government eliminated its contribution in March 2010 and also potentially due to the onset of harsh economic conditions (CGC, 2011). Since March 2012, there has been no financial incentive or policy instrument in place for stimulating the demand for GSHP systems in Ontario.

According to Hatherton (2009), one of the pioneers of the GSHP industry in North America, the greatest potential for GSHP systems is the existing and planned rural housing stock that does not have access to the natural gas grid and relies on oil, propane or electric-based systems for heating and cooling demands. Natural gas is North America's cheapest and most widely *distributed* energy source, however, less than 20 percent of Ontario's rural households have access to it (Ontario Federation of Agriculture, 2013). The rural housing stock is also, generally, more suitable for horizontal installations - which are approximately 30 percent cheaper than vertical installations (CGC, 2012a) - where property sizes are often larger than the required 1-1.5 acres needed for the horizontal ground loop (NextEnergy, 2012). GSHP systems are, therefore, very attractive for rural households that lack access to the natural gas grid and have adequate land available for a horizontal installation, thus reducing the initial capital cost and respective payback period.

Indeed, the CGC (2012a) estimates that approximately 90 percent of all Ontario residential installations are in rural areas without access to natural gas, and 67 percent are retrofits wherein the previous space heating system was displaced. The CGC (2012a) calculated that in Ontario from 2008 through 2011, oil (including oil combined with either electricity or wood), propane and electric-based systems, accounted for approximately 92 percent of the space heating systems that were displaced by a GSHP system. In comparison, natural gas furnaces accounted for just less than 6 percent[3] of displaced space heating systems, which is not surprising, however, due to the relatively low price of natural gas in recent years (CGC, 2012a). Perhaps the most interesting observation between these years was the increased proportion of electric-based systems that were displaced with a GSHP system. In Ontario, this proportion more than doubled from 20 percent in 2008 to 48 percent in 2010, potentially reflecting recent electricity price increases and/or announced/planned increases (CGC, 2012a).

[3] Wood (1.5%) and wood pellet (0.5%) systems accounted for the remaining 2 percent of displaced space heating systems.

1.3 Identifying the Research Problem and Need

While the environmental, economic, and technological potential of GSHP systems has been commonly acknowledged within the literature, the widespread adoption within the residential sector ultimately depends on households' decisions to purchase them (Kaenzig & Wϋstenhagen, 2008). GSHP systems remain one of the least understood and adopted residential RETs despite their range of benefits. In order to help achieve a sustainable residential energy future in Ontario, a better understanding of how GSHP aspirations can be translated into realities is crucial. According to Sovacool (2009), technology itself is only part of any solution; understanding and dealing with household attitudes and behaviours is the other important and often more difficult component.

A survey of the literature illustrates a growing call for more research to be directed towards renewable *heat*, alongside the far more loudly trumpeted renewable *electricity*. This research need is consistent with the Environmental Commissioner of Ontario's *Top Ten List for Energy Planning in Ontario*, wherein support for renewable heat, such as GSHP and solar thermal hot water systems, was the third most important recommendation on the list (Environmental Commissioner of Ontario, 2014). Indeed, GSHP systems were not even referenced in Ontario's LTEP (Government of Ontario, 2013), demonstrating little recognition and support for the technology, specifically, and a lack of political foresight for renewable heat, in general.

To date, as the literature review in chapter 2 highlights, minimal research has been conducted on the household adoption of GSHP systems in general, and more specifically, in Ontario. As a result, little is known about the households who adopt GSHP systems, what factors influence their decision, and how the adoption process transpires. Therefore, a research problem exists, which if understood, could help contribute to a better design of policy instruments and marketing strategies, for targeting households that do not have access to natural gas and continue to heat and cool with fossil fuel or electric-based systems in rural Ontario. In turn, this may help increase the rate of adoption of GSHP systems in rural Ontario, which will contribute to the reduction of energy consumption, GHG emissions, peak demand on the electricity grid and help transition Ontario's residential sector towards a more sustainable and affordable energy future.

1.4 Thesis Statement and Rationale

The purpose of this thesis, therefore, is to describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. This thesis utilizes Rogers' (2003) Diffusion of Innovations (DoI) theory, namely the innovation-decision process (IDP) model, as a theoretical framework to guide the collection of empirical data on household adoption experiences to help achieve this research purpose. As identified in the literature review in chapter 2, the IDP is influenced by five determinants of adoption, which are: 1) prior conditions; 2) characteristics of the decision-making unit; 3) perceived characteristics of an innovation; 4) change agent programs; and 5) communication channels (Rogers, 2003). Accordingly, a research objective has been set against each determinant of adoption, to explicate their influence on a household's decision to adopt a GSHP system. Specifically, objectives aim to:

1) Identify how households perceived a need for the GSHP system.
2) Identify characteristics of household decision-making units to discover commonalities that may have influenced adoption behaviour.
3) Identify the perceived characteristics of the GSHP system that promoted and hindered adoption and their respective significance.
4) Identify the influence of change agent programs on adoption behaviour.
5) Identify the communication channels that household decision-making units used in their adoption process and what information sources were regarded as the most useful in helping them make an informed decision to adopt a GSHP system.

To achieve these objectives, a sample of households that have retrofitted their house with a GSHP system in rural southwestern Ontario that do not have access to natural gas were selected for study. By focusing on the most experienced households - the adopters - research findings will be able to:

1) Describe and explain the factors that influence the residential adoption of GSHP systems, including the drivers for and barriers to adoption, in rural southwestern Ontario.
2) Identify and explain any correlations present within such data and experiences.
3) Contribute to a better design of policy instruments and marketing strategies.

This thesis addresses both theoretical and practical issues associated with the household adoption of GSHP systems in rural southwestern Ontario. Given the lack of empirical research to date on the household adoption of GSHP systems and the factors that influence it, this research seeks to build upon the consumer behaviour literature on the adoption of high-involvement residential RETs. In particular, this thesis will evaluate the utility of Rogers' (2003) IDP model for describing and explaining the factors that influence the residential adoption of GSHP systems, and more broadly, for understanding household decision-making dynamics associated with the adoption of high-involvement residential RETs. This thesis may serve as a starting point for empirical research on the household adoption of GSHP systems in general, and more specifically, in Ontario.

From a practical perspective, studying the underlying determinants of a household's adoption decision with respect to a specific residential RET is a prerequisite for understanding how to motivate adoption behaviour (Michelsen & Madlener, 2010). With the perceived high initial capital cost hypothesized as the chief barrier to the residential adoption of GSHP systems, it is important to understand what enables some households to overcome this factor. From an industry standpoint, understanding the key determinants of adoption can provide two key benefits. First, perceived strengths and weaknesses of GSHP systems can be identified and managed effectively. Second, more control can be imposed on the marketing strategy in order that these systems are made attractive to the most receptive audiences (Faiers & Neame, 2006). Moreover, understanding the key determinants of adoption can help GSHP companies identify target markets, position their products accurately and design more effective marketing strategies (Wang, Dou & Zhou, 2008).

From a political standpoint, this research has implications for the design of policy instruments aimed at targeting residential demand for renewable space heating and cooling technologies, such as the GSHP system, by providing empirical evidence of the factors that influence adoption. Considering there is currently no policy instrument in place in Ontario to encourage household adoption of GSHP systems - such as financial incentives (e.g. government grants) or regulations (e.g. building codes) - insights from this study may be of importance for policy intervention aimed at stimulating voluntary adoption or mandatory implementation of said systems.

1.5 Structure of Thesis

In this chapter, pertinent information regarding the background to this thesis was presented. The research problem and need were identified, followed by the thesis statement and rationale for the present study.

In chapter 2, a review of the literature is conducted on the consumer adoption of high-involvement residential RETs and draws together salient aspects of Diffusion of Innovation (DOI) theory, namely the IDP model and five determinants of adoption. As a result of the review, the IDP model was selected as a theoretical framework, later applied to guide the collection of primary data and to provide a foundation for interpreting research findings.

Chapter 3 describes the methodology employed in this thesis for data collection and analysis, providing justification for the choice of methods where appropriate. The overarching research purpose and case design is outlined, as well as the method used for data collection, the interview. This chapter also describes the research location and population, and the associated sampling strategy that was employed.

In chapter 4, results of the primary interviews are presented in a summarized format, organized with respect to the IDP model and five determinants of adoption.

Chapter 5 addresses the prominent findings that have emerged from the results with respect to the five objectives that were established for primary research. It also evaluates the utility of the IDP model for describing and explaining the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario, and more broadly, for understanding the adoption of high-involvement residential RETs. Research findings will be compared and contrasted to the literature where appropriate.

Chapter 6 concludes this thesis by summarizing the main empirical findings and the extent to which the five objectives of this study have been achieved. It will also discuss the policy and industry implications of these findings and will make recommendations for future research.

Chapter 2: Literature Review

2.1 Introduction

The goal of this literature review was to identify a theoretical framework on which to base further research, namely to help describe and explain the factors that influence the residential adoption of ground source heat pump (GSHP) systems in rural southwestern Ontario.

Specifically, this review examines the consumer adoption of high-involvement residential renewable energy technologies (RETs) and draws together salient aspects of Diffusion of Innovations (DoI) theory, namely the Innovation-Decision Process (IDP) model and five determinants of adoption. A search of the literature indicated that the IDP is a leading decision-making model associated with the adoption of high-involvement technological innovations (e.g. GSHP system) and has been favourably reviewed in various contexts, including the household adoption of high-involvement residential RETs (e.g. Faiers, Cook & Neame, 2007; Kaplan, 1999, Parthasarathy, Rittenburg & Ball; Wilson & Dowlatabadi, 2007). Thus, the IDP model, including the five determinants of adoption, will be examined in this chapter to determine its utility as a theoretical framework to guide the collection of empirical data necessary to help achieve the research objectives of this thesis.

First, section 2.2 will provide a brief overview of DoI theory, highlighting its wide use in academia and applicability for studying the adoption and diffusion of high-involvement residential RETs. Second, section 2.3 will review prior empirical research on the consumer adoption of high-involvement residential RETs in general, while identifying gaps in research approaches. Third, section 2.4 will examine the IDP model and five determinants of adoption, drawing upon empirical findings in the context of the consumer adoption of high-involvement residential RETs. Fourth, section 2.5 will identify the strengths and weaknesses of the IDP model, while acknowledging alternative technology adoption theories that were considered. Section 2.6 will conclude the review by providing a summary of the IDP model and five determinants of adoption, and rationale for using it as a theoretical framework on which to base further research and to provide a foundation for interpreting research findings.

2.2 Diffusion of Innovations Theory

DoI is a theory that seeks to explain how, why, and at what rate innovations are adopted and spread through a population (Rogers, 2003). DoI was popularized by Everett Rogers, a professor of rural sociology, in his 1962 book *Diffusion of Innovations.* Rogers (1962) defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (p. 11). An innovation is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 2003, p.12). Straub (2009) argues that it does not matter whether the innovation is objectively new, but rather its perceived novelty. If something is perceived as new by an individual, then it is considered an innovation. An innovation is not necessarily superior to the idea, practice or object that it supersedes. In the present study, the GSHP system is the innovation of interest, while single-family detached households in rural Ontario make up the social system.

Although the theory was not developed until 1962, research on the diffusion of innovations originated in a series of investigations during the 1940s; the most notable of these was the research carried out by Bryce Ryan and Neal Gross on the diffusion of hybrid seed corn in two Iowa communities in 1943 (Rogers, 1962). Academic interest in DoI theory has since flourished, spanning nine major research traditions: anthropology, early sociology, general sociology, rural sociology, education, public health, communication, marketing and management, and geography. Diffusion research traditionally aims to determine what influences the rate and direction of innovation adoption (Rogers, 2003).

DoI is often described as a single theory, however, it is more a set of interrelated hypotheses or sub-theories developed by studying the adoption and diffusion of innovations in many contexts (Harmancioglu, Droge & Calantone, 2009; Rogers, 2003). At the macro-level is diffusion theory, which describes how an innovation spreads through a *population*. At the micro-level is adoption theory (i.e. IDP model), which examines the process an individual goes through from recognition of a need, to learning about and forming an attitude towards an innovation, to making a decision to make full use of the innovation as the best course of action available (Straub, 2009). Thus, diffusion theory takes a macro-perspective on the spread of an innovation across time within a population and adoption theory takes a micro-perspective on individual behaviour change, focusing not on the whole but rather the pieces that make up the whole (Straub, 2009). Diffusion in essence, is more closely related to economics and mathematical modeling at the aggregate level than individual behaviour at the consumer level (Jansson, 2009). It is individual adoption that is the area of primary interest in this research, but as cumulative individual adoption leads to wider diffusion, both elements are considered. Figure 2-1 provides a visual representation of how diffusion over time is composed of individuals collectively adopting the innovation.

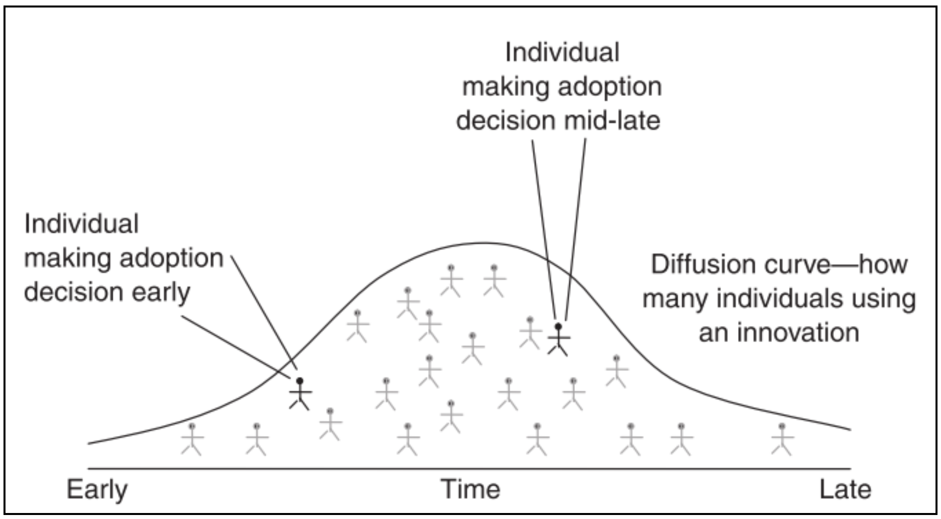

Figure 2-1 How Individual Adoption Collectively Composes Diffusion Across Time (Straub, 2009)

Not all individuals who adopt an innovation do so at the same time. To reflect this, Rogers (2003) has identified five adopter categories as the diffusion sequence unfolds. The criterion for adopter categorization is innovativeness, which is the degree to which an individual or other unit of adoption is relatively earlier in adopting an innovation generally in relation to other members in a given social system (Rogers, 2003, p.280). Thus, innovativeness is an objective measurement of when individual adoption occurs.

Figure 2-2 delineates the five adopter categories across time (x-axis), as innovators (2.5% of adopters), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16%). DOI theory suggests that the distribution of these categories follows a normal distribution curve (blue curve), with the first 50 percent of eventual adopters being in the first three categories (Rogers, 1995). The yellow curve represents the cumulative market share, which will eventually reach the saturation level. The categories range from most innovative on the left to least innovative on the right, therefore, individuals who adopt earlier have a higher degree of innovativeness compared to later adopters. However, this is not to say that an individual's adoption behaviour is consistent across different innovations (Pederson, 2000). For example, an individual will not necessarily favour energy efficient technologies just because they purchase organic food and verbally state that they favour environmental products (Faiers & Neame, 2006). This is also supported by Sultan and Winer (1993) who argued that an "innovator" for one product might be a "laggard" for another, suggesting that innovativeness is a relative phenomenon (Rogers, 2003).

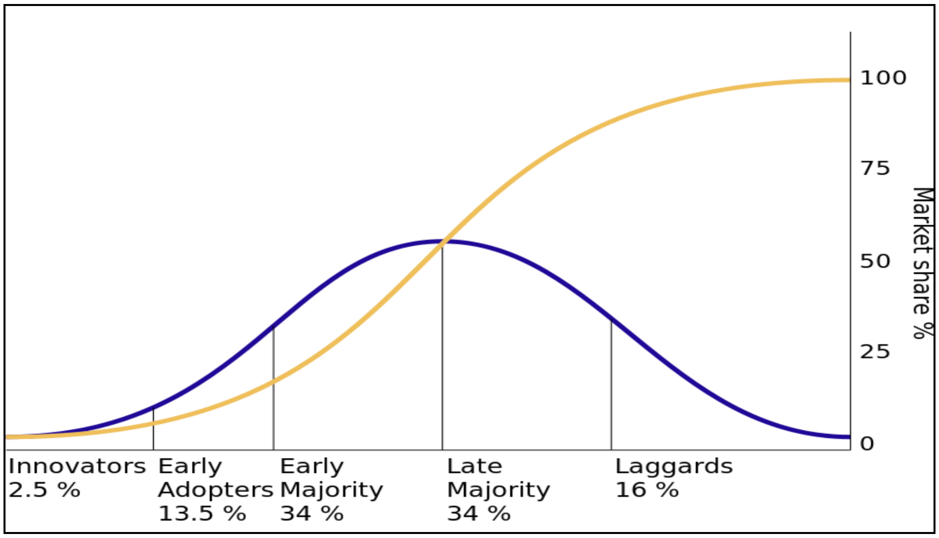

Figure 2-2 Diffusion of Innovations Curve (Rogers, 1962)

One issue with the above fivefold classification scheme is incomplete adoption, which occurs when an innovation has not reached 100 percent adoption. Such incomplete adoption means that the fivefold classification scheme is not exhaustive (Rogers, 2003, p.281). The Canadian GeoExchange Coalition (CGC) (2012b) estimates that market penetration for GSHP systems in Ontario's residential sector is approximately half of a percent, situating the market within the "innovator" stage. All GSHP system adopters (i.e. household participants) in this study are, therefore, regarded as "innovators." Indeed, according to this conceptualization, the next approximate two percent of households that adopt a residential GSHP system in Ontario would be categorized as "innovators" as well. In the future, when diffusion increases and more sales data are available on Ontario's GSHP industry, it may be possible to divide household adopters into more distinct groups.

In light of classifying household participants in this study as "innovators" it is appropriate to provide a brief overview of the main characteristics and values of this adopter category, as hypothesized by Rogers (2003):

> Venturesome is almost an obsession with innovators. Their interest in new ideas leads them out of a local circle of peer networks and into more cosmopolite social relationships... Being an innovator has several prerequisites. Control of substantial financial resources is helpful in absorbing the possible losses from an unprofitable innovation. The ability to understand and apply complex technical knowledge is also needed. The innovator must be able to cope with a high degree of uncertainty about an innovation at the time he or she adopts. The salient value of the innovator is venturesome, due to a desire for the rash, the daring, and the risky... The innovator plays a gatekeeping role in the flow of new ideas into a social system. (pp.282-283)

2.3 Prior Research on Consumer Adoption of Renewable Energy Technologies

As identified in section 1.2 of chapter 1, capital intensive residential RETs, such as GSHP systems, are regarded as *high-involvement* RETs in this thesis, because of the significant amount of time and cognitive effort that is required for potential adopters to invest in their decision-making process, due to higher perceived financial and social risk (Michelsen & Madlener, 2011). The adoption of high-involvement residential RETs typically means an extended decision-making period and more extensive search for information (Laurent & Kapferer, 1985). Some examples of high-involvement residential RETs include solar photovoltaic (PV) systems, solar thermal hot water systems, electric, hybrid-electric and alternative fuel vehicles, and GSHP systems. Other examples of high-involvement purchases include real estate, personal computers and cell phones. Conversely, for low-involvement decisions, such as buying a sandwich or chocolate bar, consumers are not required to use significant cognitive effort and use simple strategies, such as heuristics, when the outcomes of the decision are less important (Jager, 2006). Involvement, therefore, closely correlates with cost.

Over the years, a number of studies have investigated consumer behaviour in the adoption of high-involvement residential RETs. For example, researchers have investigated the consumer adoption of *solar PV and solar thermal hot water systems* (i.e. Adachi & Rowlands, 2010; Faiers & Neame, 2006; Faiers, Neame & Cook, 2007; Guagnano, Hawkes, Acredolo & White, 1986; Jager, 2006; Keirstead, 2007; Labay & Kinnear, 1981; Mills & Schleich, 2009), *hybrid-electric and alternative fuel vehicles* (i.e. Diamond, 2009; Jansson, 2011; Ozaki & Sevastyanova, 2011; Potoglou & Kanaroglou, 2007), as well as other low and zero-carbon microgeneration technologies, including *micro-wind turbines, biomass boilers*, and *combined heat and power generation systems* (i.e. Caird & Roy, 2010; Caird, Roy & Herring, 2008; Claudy, Michelsen, O'Driscoll & Mullen, 2010) and *wood-pellet heating systems* (i.e. Mahapatra & Gustavsson, 2008a, 2008b; Michelsen & Madlener, 2013; Skjevrak & Sopha, 2012; Tapaninen, Seppänen, & Mäkinen, 2009).

Conversely, upon an academic literature search, limited research has focused on the consumer (or household) adoption of GSHP systems, with the exception of the studies completed by Caird and Roy (2010) in the United Kingdom, who investigated the adoption and use of household microgeneration heat technologies, and Mahapatra & Gustavsson in Sweden who examined homeowners' perceptions and factors influencing their choice of an innovative low-carbon heating system[4] (2008a) and also the residential diffusion patterns of innovative low-carbon heating systems using an adopter-centric approach (2008b). However, in each of these studies, the GSHP system was one of a suite of heating technologies (i.e. solar thermal hot water systems, pellet systems, wood-fuelled boilers and biomass boilers) that was examined; therefore the insights were for this amalgam of various technologies together, rather than for GSHP exclusively. This illustrates that little, if any, research has focused solely on the household adoption of GSHP systems and the factors that influence it. This is especially true in Ontario, where no academic research has been found that investigates the adoption of GSHP systems at the household level. Therefore, it is evident that little is understood about the households who adopt GSHP systems and what factors influence their decision, due to a lack of nuanced research approaches or sheer lack of research.

Moreover, the literature search illustrated that out of the studies that have targeted consumer adoption of high-involvement RETs, researchers have often only examined a single determinant of adoption (e.g. sociodemographic characteristics), thus providing a limited perspective of consumer decision-making and the range of factors that influence adoption. For

[4] In this literature review, innovative low-carbon heating systems refer to heating systems such as ground source heat pumps, solar thermal hot water systems, wood pellet boilers, and biomass boilers that replace electric, oil and propane-based systems.

example, many studies have focused on the common characteristics of adopters, such as household characteristics (e.g. Mills & Schleich, 2009) and on how different consumers perceive the innovation in relation to the time of adoption (Martinez, Polo & Flavián, 1998; Wang et al., 2008). Another major focus of research on the consumer adoption of high-involvement RETs has been on understanding how specific adopter groups perceive the characteristics of an innovation (e.g. Faiers & Neame, 2006; Labay & Kinnear; 1981). Moreover, Faiers et al. (2007a) have studied whether consumers assess innovation characteristics in a stepwise process in the adoption of domestic solar PV systems.

Single determinant studies may show that a particular theoretical generalization has explanatory power, but these same studies contribute minimally to a comprehensive understanding of the suite of factors that influence the adoption of high-involvement residential RETs (Jansson, 2009). Nevertheless, the many studies on the consumer adoption of high-involvement residential RETs offer fruitful insights that are of utility for the design and implementation of primary research methods (i.e. interview guide) in the present study.

2.4 Innovation-Decision Process Model and Five Determinants of Adoption

The IDP model describes "the process through which an individual passes from gaining initial knowledge of an innovation, to forming an attitude towards the innovation, to making a decision to adopt or reject (not adopt), to implementation of the new idea (innovation) and to confirmation of this decision" (Rogers, 2003, p.168). The IDP consists of five sequential stages, which are: (1) knowledge; (2) persuasion; (3) decision; (4) implementation; and (5) decision. It is influenced by five determinants of adoption, which are: (1) prior conditions; (2) sociodemographic characteristics of the household decision-making unit; (3) perceived characteristics of the innovation; (4) change agent programs; and (5) communication channels, as portrayed in Figure 2-3 (Rogers, 2003, p.170).

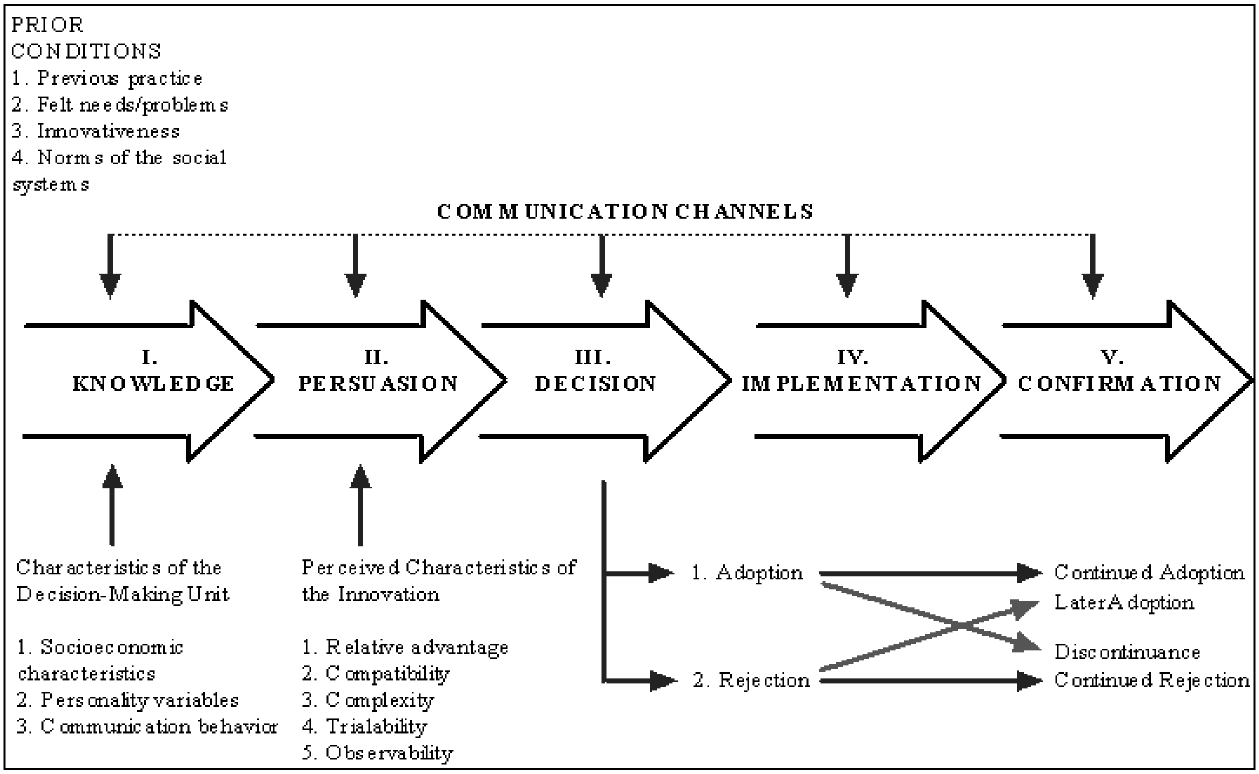

Figure 2-3 Innovation-Decision Process Model (Rogers, 2003)

Although not explicitly included as being part of the IDP model (Figure 2-3), Rogers' (2003) argues that *change agents* have a strong influence on consumer decision-making in the adoption of innovations, such as high-involvement residential RETs. For example, Mahapatra & Gustavsson (2008b) found that the Swedish government's investment subsidy created a need to adopt an innovative low-carbon heating system among homeowners who previously had not considered the idea. Rogers (2003) describes a change agent as an individual or group that influences consumer decision-making in favour of adoption, such as a salesperson, marketing organization, or government. Consequently, change agent programs have been included as a determinant of adoption worthy of investigation in the present study. Given the amount of published studies on the adoption of high-involvement residential RETs, the selection of determinants is necessary for any study.

This IDP consists of a series of choices and actions over time through which the individual evaluates the innovation and decides whether or not to incorporate it into ongoing practice based on their present or anticipated future situation. This behaviour involves dealing with the uncertainty and risk that is inherently associated with adopting something perceived as new. Thus, the IDP is an "information-seeking and information-processing activity in which an individual obtains information in order to gradually decrease uncertainty about the innovation" (Rogers, 2003, p.20-21). Consumer behaviour scholars have long recognized that an individual's decision to adopt an innovation is not an instantaneous act, but rather a process that occurs over time with identifiable stages moving from a change in knowledge to a change in behaviour (Wilson & Dowlatabadi, 2007).

The IDP model follows the paradigm of rational choice (as reviewed by Lovett, 2006), in that individuals are predisposed to learn about an innovation, and through a process that analyzes the costs and benefits of the innovation, and ultimately reach a decision whether to adopt, which is "the decision to make full use of an innovation as the best course of action available" or reject, which is "the decision not to adopt an innovation" (Rogers, 2003, p.177). The IDP can just as easily lead to rejection at any of the stages in the process, including after having previously adopted the innovation. This is known as discontinuance (Rogers, 2003) and is not within the scope of this investigation, therefore the two arrows below and to the right of the "decision" stage in Figure 2-3 are omitted from the present study. Nevertheless, it is acknowledged that discontinuance could have occurred in a number of different cases in Ontario.

The first two stages in the IDP, knowledge and persuasion, are essential in understanding adoption behaviour since they entail the cognitive process of thinking and learning about the innovation and affective process of forming a favourable and/or unfavourable attitude towards the innovation (Faiers, 2009; Jansson, 2009; Rogers, 2003). It has been found that both of these stages are influenced largely by the first two determinants of adoption, prior conditions and characteristics of the decision-making unit, including how the characteristics of the innovation are perceived (Faiers & Neame, 2006; Michelsen & Madlener, 2010; Peter, Dickie & Peter, 2005; Ozaki & Sevastyanova, 2011). During these stages, the individual typically asks questions such as "What is the innovation?", "How does it work?", "Why does it work?", "What are the innovation's consequences?", and "What will its advantages and disadvantages be in my situation?" (Rogers, 2003, p.172).

This section will examine each of the five stages in the IDP and the five determinants of adoption, drawing upon empirical findings from studies on the consumer adoption of high-involvement RETs. The first two determinants of adoption that will be investigated are prior conditions and characteristics of the decision-making unit, which are both posited as antecedents to the IDP and have the most influence on the two primary stages, knowledge and persuasion (Kaplan, 1999). The knowledge stage will then be explored, followed by the persuasion stage, which will highlight the five perceived characteristics of an innovation and change agent programs, the third and four determinants of adoption, respectively. This section will then briefly examine the latter three stages, decision, implementation and confirmation, respectively, before exploring the fifth and final determinant of adoption, communication channels, and how they can influence behavioural change throughout the entire IDP.

2.4.1 Prior Conditions

The first determinant of adoption, *prior conditions*, consists of an individual's or other unit of adoption's previous practice, felt needs or problems, innovativeness and norms of the social system. This section will briefly describe how each of these prior conditions influences the knowledge and persuasion stages in the IDP.

Previous Practice

Previous practice refers to the idea, practice, product or technology that an innovation would displace, if adopted. An innovation presents an individual with a new alternative and new means of solving problems. If an innovation is perceived as being superior to the previous practice, it is more likely to be adopted (Rogers, 1983). However, the probability of an innovation being superior to the previous practice is not exactly known by the individual (Rogers, 1983). Thus he or she becomes motivated to seek further information about the innovation in order to cope with the uncertainty that it creates. Previous practice is a familiar standard against which the innovation can be interpreted and measured, thus decreasing uncertainty. According to Rogers (1983), "old ideas are the main tools with which new ideas are assessed" (p. 224). An innovation that is more compatible with existing values, beliefs, past experiences and needs, is less uncertain to the individual and is more likely to be adopted (Rogers, 2003). Kaplan (1999) claims that the previous practice is the root of experience and that it has the potential to be a very important contributor not just to knowledge of the innovation, but to behavioural intentions and actual adoption decisions (p.471).

Felt Needs or Problems

Felt needs or problems are inherently connected to an individual's previous practice. A need is defined as "a state of dissatisfaction or frustration that occurs when an individual's desires outweigh the individual's actualities" (Rogers, 2003, p.172). An individual may develop a need when he or she experiences problems with their previous practice (i.e. high operating costs, unsatisfactory performance, unreliability, etc.) or by learning about an innovation and gaining an understanding of how it functions. According to Rogers (2003, p.171), many researchers have sought to determine what comes first, needs or awareness of an innovation. The answer to this question remains unclear due to contradicting empirical findings (Rogers, 2003). For example, in a study by Kaenzig and Wüstenhagen (2008) on household adoption of micropower systems, focus group participants stated that problem recognition was the first step towards adoption, and information search came afterwards, indicating that needs preceded awareness in this particular study. Conversely, Vishwanath and Chen (2011) found that certain individuals, such as early adopters, have greater awareness and knowledge of innovations even if a need is nonexistent. Hence, in cases where individuals are more innovative, awareness of an innovation can precede needs. For example, results from a study conducted by Mahapatra & Gustavsson (2008b) indicated that an investment subsidy and marketing campaign created a need among homeowners to adopt an innovative low-carbon heating system. In this case, a need was not perceived by homeowners until they became aware of the innovation and the perceived relative advantage it had over their previous heating system. Thus, awareness of the innovation via the investment subsidy and marketing campaign created a need for adoption.

Some individuals may become aware of an innovation through behaviour that they initiate due to a perceived problem or need, whereas others individuals could become aware of an innovation by accident or before actively looking for information, thus playing a relatively passive role (Rogers, 2003). However, perceived needs or problems are not a very complete explanation of why individuals begin the IDP. Individuals do not always recognize when a problem exists and may not agree with what experts think they need (Rogers, 2003).

Innovativeness

As defined in section 2.2, innovativeness is the degree to which an individual or other unit of adoption is relatively earlier in adopting an innovation generally in relation to other members in a given social system (Rogers, 2003, p.280). Innovativeness indicates overt behavioural change and is central in order to understand consumer adoption behaviour (Jansson, 2011; Labay & Kinnear, 1981; Pickett-Baker, 2011; Rogers, 2003). Innovativeness has been operationalized and measured in several ways using different scales (e.g. Roehrich, 2004) but there is still no consensus in the measurement of the construct (Tellis, Yin & Bell, 2009). According to Roehrich (2004), the innovativeness construct has become understood more as a psychological personality feature with higher generalizability across product categories. Innovativeness has since been redefined by several authors including Tellis et al., (2009) who define it "as a consumer's propensity to adopt new products" (p. 1). Therefore, consumers with higher degrees of innovativeness will take chances and spend greater time seeking out new products and technologies, regardless of the need (Jansson, 2009). This novelty seeking action has positively led to the early adoption of innovations in several settings (Dabholkar & Bagozzi, 2002). Individuals that are more innovative tend to look positively at new technologies, have greater intrinsic motivation to try such technologies, and enjoy the stimulation of trying new ways to solve old problems (Faiers & Neame, 2006; Jansson, 2011; Rogers, 2003).

Garling and Thorgorsen (2001) suggest that earlier adopters are persuaded to purchase an innovation based on what it is worth to them as individuals, regardless of the cost. Also, earlier adopters who are committed to the concept of the innovation will put up with inconvenience factors to do with product complexity or lack of performance because they are focused on the long-term benefits the innovation may have (Faiers et al., 2007a, p.3419). According to Rogers (2003, p.267-278), more is known about innovativeness than about any other concept in DOI research.

Norms of the Social System

Norms of the social system refer to the established behavioural patterns of the members of a social system (Rogers, 2003, p.26). Norms of the social system can dictate individual behaviour and thus promote or hinder the adoption of an innovation. For example, if there are strong social norms regarding a particular innovation, an individual may not have the motivation to defy the norm. Put differently, the norms of a social system may take precedence over an individual's values and attitudes in determining whether an innovation is adopted or not (Parthasarathy et al., 1995). Thus, it is possible for a person to symbolically accept an innovation, but decide not to adopt based on strong normative influences against doing so. For example, a household may want to install solar panels on their rooftop, but chooses not to, because the neighbouring households consider them an eyesore and oppose their implementation.

In contrast, normative influence may dictate which innovations *are* adopted (Parthasarathy et al., 1995). According to Ozaki and Sevastyanova (2011) it has been established that individuals are strongly influenced by social norms and social pressures. This finding corroborates the results of a United Kingdom study involving the adoption of green electricity where households were positively influenced to adopt based on community norms (Ozaki, 2011). Thus, it is illustrated that social norms can be a powerful force capable of both inhibiting and encouraging pro-environmental behaviour (Jackson, 2005).

2.4.2 Characteristics of the Decision-Making Unit

The second determinant of adoption, *characteristics of the decision-making unit*, consists of sociodemographic characteristics, personality variables and communication behaviour. This section will briefly describe how each of these characteristics can influence the knowledge and persuasion stages in the IDP. As identified in section 2.2, an individual or other unit of adoption is classified into one of five adopter categories based on the time when they adopt an innovation in relation to other members in a given social system. Although Rogers (2003) divides adopters into five separate categories, he has only presented hypotheses of adopter characteristics for *earlier* adopters (innovators and early adopters) and *later* adopters (early majority, late majority, and laggards). This is consistent with Moore (2006) who argues that there is a chasm between the early adopters and early majority (Figure 2-2, p.4), emphasizing the difference between innovators and early adopters to the latter three categories. Against this background, and considering that the focus of this thesis is on studying the GSHP system during the time households (innovators) have adopted it, the distinction of individuals into earlier and later adopters is satisfactory. Thus, the five adopter categories together are not of interest in the present study; namely just *earlier* adopters, with a specific focus on the innovators, including the overview of the main characteristics and values of this category, as presented in section 2.2.

Sociodemographic Characteristics

Sociodemographics factors have received the most research attention within the five determinants of adoption. This research interest is likely due to the relative ease of obtaining and measuring these factors, but also because consumer research and marketing has long used sociodemographic factors for consumer profiling and segmentation (Jansson, 2009). Moreover, it has been found that sociodemographics can be useful in profiling environmentally conscious consumers, however, results are contradictory (Diamantopoulos, Schlegelmilch, Sinkovics, & Bohlen, 2003). In spite of the widespread use, it is important to caution that sociodemographic characteristics, alone, do not always demonstrate high explanatory power on the adoption of innovations (Rogers, 2003).

The following is a set of hypotheses developed by Rogers (2003, p.288) based on voluminous research on sociodemographic characteristics of earlier and later adopters which are appropriate for consideration for further research in the present study:

- Earlier adopters are no different from later adopters in age.
- Earlier adopters have more years of formal education than do later adopters.
- Earlier adopters have higher social status than do later adopters. Social status is comprised by variables such as income, possession of wealth, occupational prestige and in some studies, education level is grouped under social status.
- Earlier adopters have larger-sized units (e.g. houses, farms, schools, companies, etc.) than do later adopters.

After reviewing several studies on the adoption of high-involvement residential RETs in relation to sociodemographic characteristics, there is inconsistent evidence about the above hypotheses, confirming Rogers (2003) assertion that the explanatory strength of sociodemographic characteristics is not always high.

For example, in terms of age, one study found that earlier adopters of solar energy systems are younger in general than later adopters, which is partly understood in terms of increasing risk aversion with higher age (Labay & Kinnear, 1981). However, a different study illustrated that adopters of solar PV systems were mainly in the middle-aged group, rather than in the younger group (Jager, 2006). In the context of residential heating systems, Mahapatra and

Gustavsson (2008a, 2008b) found that individuals in the age group of 36-45 years old were most likely to install an innovative low-carbon heating system, compared to younger and older age groups. Mahapatra and Gustavsson (2008b) stated that younger individuals who have recently moved into a new detached home may not be as motivated to make energy-related investment decisions as they are more likely to have less financial resources available. Conversely, older individuals are less likely to invest in an innovative low-carbon heating system due to less income post-retirement and/or they do not expect to obtain a return on their investment during their occupancy of the house (Mahapatra & Gustavsson, 2008a). This finding is consistent with a study conducted by Potoglou and Kanaroglou (2007), who found that respondents over the age of 45 years were more hesitant in adopting a hybrid vehicle, compared to younger respondents due to the perceived length of payback and risks associated with the technology.

Moreover, several studies have investigated social status, namely education and household income levels, as a determinant of adoption; however, the results of these efforts are often either inconclusive or inconsistent with each other. In separate studies over a 20 year period, examining the impact of education levels and household income on the adoption of solar energy systems, Guagnano et al. (1986) and Jager (2006) both concluded that households with more education and higher income levels were more likely to adopt. This finding is consistent with what Mahapatra and Gustavsson (2008a, 2008b) found in both of their studies, where the proportion of households planning to install an innovative low-carbon heating system increases as household income increases, however, the relationship was statistically insignificant. Conversely, Potoglou and Kanaroglou (2007) found that the probability of people selecting a hybrid vehicle was higher in the middle-income group, because they place a higher importance on fuel costs, compared to the low and high-income groups.

Regarding gender, Jansson (2009) stated that many studies have found that males are more likely to be earlier adopters compared to females, likely because the majority of research has been focused on *technological* innovations, which are usually of more interest to males than females (Rogers, 2003) and because males have traditionally been more likely to participate in research on the household adoption of high-involvement RETs. For example, in Kaplan's (1999) study on the residential adoption process of solar PV systems, the respondents were almost exclusively male, while studies carried out by Jager (2006) on consumer motives for adopting solar PV systems and Ozaki and Sevastyanova (2011) on consumer adoption of hybrid cars, both yielded a respondent gender breakdown of approximately 75 percent male to 25 percent female. Conversely, Martinez et al. (1998) found that older females were more likely to adopt innovative energy-efficient appliances than any other gender and age group. Thus, not all high-involvement energy-related innovations are adopted faster by males, which should be taken into consideration when forming target groups for marketing and the communication messages used (Faiers & Neame, 2006).

Personality Variables

Personality variables have received minimal research attention, due to the difficulties of accurately measuring personality dimensions associated with innovation adoption in survey research (Rogers, 2003). Personality variables include five broad dimensions of personality, which are: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (Gosling, Rentfrow & Swann Jr., 2003). Nonetheless, Rogers (2003, pp.289-290) has developed a set of hypotheses related to personality variables for earlier and later adopters. The following is a set of his hypotheses that are appropriate for consideration for further research in the present study:

- Earlier adopters may be less dogmatic than are later adopters. Dogmatism is the degree to which an individual holds a closed belief system and does not welcome new ideas. An individual with a high degree of dogmatism would not welcome new ideas.
- Earlier adopters have a more favourable attitude toward change than do later adopters.
- Earlier adopters are better able to cope with uncertainty and risk than are later adopters.
- Earlier adopters have a more favourable attitude towards science than do later adopters.
- Earlier adopters are less fatalistic than are later adopters. Fatalism is the degree to which an individual perceives a lack of ability to control his or her future and instead believes that the future is determined by fate.

Upon a review of the literature on the consumer adoption of high-involvement residential RETs, no empirical studies appeared to consider the above personality variables, thus the degree in which these hypotheses are supported is unknown.

Communication Behaviour

Rogers (2003, p.290) has also developed a set of hypotheses geared towards earlier and later adopters' communication behaviour. The following is a set of his hypotheses that are appropriate for consideration for further research in the present study:

- Earlier adopters have more social participation than do later adopters.
- Earlier adopters are more highly interconnected through interpersonal networks in their social system than are later adopters. Connectedness is the degree to which an individual is linked to other people (Rogers, 2003, p.290).
- Earlier adopters are more cosmopolite than are later adopters. Cosmopoliteness is the degree to which an individual is connected to people outside of their social system (Rogers, 2003, p.290).

An individual's communication behaviour is inherently linked to the communication channels he or she is exposed to, and thus engages in their adoption process. Due to this interrelated relationship, communication behaviour will be examined in section 2.4.8 in connection with communication channels and information sources, drawing upon empirical studies on the consumer adoption of high-involvement residential RETs.

The focus of this review will now shift to the first two stages in the IDP, knowledge and persuasion, respectively, before arriving at the third and fourth determinants of adoption, perceived characteristics of an innovation and change agent programs, respectively.

2.4.3 Knowledge Stage

The first stage in the IDP is *knowledge*, which commences when the individual or other unit of adoption becomes aware of the innovation's existence and gains an understanding of how it functions (Rogers, 2003, p.171). Research has found that the knowledge stage is the optimal point at which the individual should gain a full understanding of the innovation attributes and how they function, so that persuasion can then take place (Moreau, Lehmann & Markman, 2006). Kaplan (1999) argued that an early need for knowledge is critical, as it is a precursor to adoption interest and will help transition the individual to the persuasion stage. At the knowledge stage, the individual engages in information-seeking and information-processing activities to learn about and reduce uncertainty about the advantages and disadvantages of the innovation (Rogers, 2003).

Rogers (2003) claims that how-to knowledge, which refers to understanding how the innovation works, how to use it and how it relates or performs to similar products, is important at this stage. In the case of innovations that are perceived as relatively complex, the amount of how-to knowledge needed for adoption is much greater than in the case of less complex innovations (Rogers, 2003). In a study carried out by Keirstead (2007), results showed that both awareness and how-to knowledge, were prerequisites for the household adoption of micro-generated electricity systems. This finding is consistent with Caird et al. (2008) in their review of empirical studies in the United Kingdom on the household adoption of low and zero-carbon technologies, where they reported the importance of strong technical knowledge as a precursor for adoption. Furthermore, Kaenzig and Wüstenhagen (2008) claimed that "pro-environmental behaviours are rarely motivated by purely altruistic concerns, and that awareness in itself is not enough to foster pro-environmental behaviour" (p.13). This finding is echoed by Jansson (2009) who found that there is a gap between the awareness of environmental problems and the actual consumer behaviours carried out. This gap indicates the importance of understanding consumer behaviour beyond the mere influence of awareness. When an adequate level of how-to knowledge is not obtained before the decision stage, rejection of the innovation is likely to result (Rogers, 2003).

Rogers (2003) states that an individual must be able to think counterfactually and be able to mentally apply the innovation to their present or anticipated future situation to move beyond the knowledge stage. Consideration of an innovation does not go beyond the knowledge stage if the individual does not define the information as relevant or sufficient knowledge is not obtained to become adequately informed (Rogers, 2003, p.174). Thus, having the ability to understand and apply technical knowledge is a prerequisite to move to the persuasion stage. Knowledge attainment and retention are, therefore, regarded as a fundamental component of an individual's IDP. However, according to Jansson (2009), although a certain degree of knowledge can be viewed as a prerequisite for adoption, the fundamental value and attitudinal composition of the individual can be argued to be of greater importance for adoption behaviour.

2.4.4 Persuasion Stage

The second stage in the IDP is *persuasion,* where the individual or other unit of adoption forms a favourable or unfavourable attitude towards the innovation. Rogers (2003, p.174) defines attitude as a "relatively enduring organizing of an individual's beliefs about an object that predisposes his or her actions." Whereas the knowledge stage was mainly a mental activity of cognitive learning, the persuasion stage is affective, or feeling. Rogers (2003) refers to persuasion as "attitude formation and change on the part of the individual" (p. 175). At this stage, the individual becomes more psychologically involved with the innovation and continues to seek information to reduce uncertainty about its potential consequences for his or her present or anticipated future situation. Ultimately, an individual develops a general perception of the innovation at this stage. This section will examine the persuasion stage in greater detail, in terms of how the perceived characteristics of an innovation and change agent programs, the third and fourth determinants of adoption, respectively, influence attitude formation at this stage.

2.4.4.1 Perceived Characteristics of an Innovation

The five perceived characteristics of an innovation that help form an individual's attitude are: relative advantage, compatibility, complexity, trialability, and observability and are described in Table 2-1 (Rogers, 2003). The five *perceived characteristics of an innovation* form the third determinant of adoption in this study.

Table 2-1 Description of Five Perceived Characteristics of an Innovation (Rogers, 2003)

Characteristic	Description	Outcome
Relative Advantage	The degree to which an innovation is perceived as being better than the existing practise it displaces, typically measured via technical, economic, environmental and social factors.	A greater degree of relative advantage is positively related to adoption.
Compatibility	The degree to which an innovation is perceived as consistent with existing values, beliefs, past experiences and needs of adopters.	A greater degree of compatibility is positively related to adoption.
Complexity	The degree to which an innovation is perceived as relatively difficult to understand and use.	A greater degree of perceived complexity is negatively related to adoption.
Trialability	The degree to which an innovation may be experimented with on a limited basis.	A greater degree of trialability is positively related to adoption.
Observability	The degree to which the results of an innovation are visible to others.	A greater degree of observability is positively related to adoption.

According to Rogers (1995, p. 206), 49 to 87 percent of the variance in the rate of adoption is explained by these five characteristics. Empirical studies have also confirmed that individual perceptions of innovation characteristics in general are better predictors of adoption than sociodemographic characteristics, such as education and income levels (Faiers & Neame, 2006; Labay & Kinnear, 1981).

Relative advantage is considered to be the most influential of the five characteristics (Rogers, 2003), and together with compatibility and complexity has been shown to hold the most influence over the decision of whether or not to adopt the innovation (Faiers & Neame, 2006; Martinez et al, 1998; Rogers, 2003). The relative advantage characteristic describes the marginal advantage the innovation has over the existing practice it supersedes (Faiers et al., 2007a), in terms that matter to the individual, such as economic advantage, social prestige, convenience or satisfaction (Rogers, 2003). The perception of relative advantage can be observed in terms of its technical, economic, environmental or social benefits or some other advantage-producing perspective (Tapaninen et al., 2009). Instead of objective advantage, more important is the perception of relative advantage (Straub, 2009). Several studies have cited that individuals rate RETs as greater in relative advantage over conventional systems, namely due to economic constructs, such as lower operational costs, and emotional constructs, such as comfort and environmental considerations (i.e. Caird & Roy, 2010; Labay & Kinnear, 1981; Michelsen &

Madlener, 2010; Pickett-Baker, 2011). In the context of innovative low-carbon residential heating systems, the characteristics that are perceived as having relative advantage over incumbent technologies include annual heating costs, investment costs, reliability, indoor air quality, security in fuel supply, system automation, environmental friendliness, increased property value, lower greenhouse gas (GHG) emissions and time required to gather information (Caird & Roy, 2010; Mahapatra & Gustavsson, 2008a, 2008b; Michelsen & Madlener, 2013).

Compatibility is what Rogers (2003) labels the second most important characteristic of an innovation and is positively related to the rate of adoption. The premise is that an innovation that is incompatible with personal values, beliefs, past experiences and needs (or social norms), will not be adopted as rapidly as an innovation that is perceived as being compatible. However, if the innovation is completely compatible with the existing practice there would be no perceived relative advantage (Jansson, 2009). Tapaninen et al. (2009) state that compatibility is a measure of the suitability of the innovation in both a technical and social sense. In the context of high-involvement residential RETs, adopters perceived solar energy systems as having greater compatibility with personal values, beliefs and needs, than did knowledgeable non-adopters (Labay & Kinnear, 1981). However, this is inconsistent with Guagnano et al. (1986) where they found that non-adopters perceived higher compatibility for solar thermal hot water systems in terms of social norms, than did adopters. Some researchers, however, have only operationalized compatibility against personal values (Guagnano et al., 1986). This means, for example, that an individual's attitude towards a certain RET can be explained with the compatibility of his or her values regarding environmental issues or existing infrastructure (i.e. the possibility to connect to the natural gas grid, or sufficient roof space which is exposed to the sun) and not by their felt needs or problems (Michelsen & Madlener, 2010).

Complexity is typically negatively related to the rate of adoption. The more difficult an innovation is to understand and use (see section 2.4.3 - i.e. individual is unable to comprehend how-to knowledge) the less likely it is to be adopted (Rogers, 2003). Thus, for many high-involvement residential RETs, perceived complexity is an important barrier to adoption. For example, complexity was perceived as a barrier in the adoption of solar energy systems (Faiers & Neame, 2006; Labay & Kinnear, 1981) and other microgeneration heating systems, including the GSHP, due to performance and reliability uncertainties (Caird & Roy, 2008). Given the relative complexity of certain residential RETs, such as the GSHP, compared to conventional technologies, strong technical support and advice is especially important (Caird et al., 2012). In the case of high-involvement RETs, specifically low-carbon residential heating systems, complexity includes perceptions about the effort to adopt the technology, the required skills and capacity, the system automation, technicality, and maintenance intervals and effort (Michelsen & Madlener, 2010). Perceived risk and uncertainty have also been identified as critical elements of the complexity characteristic (Faiers et al., 2007b; Rogers, 2003). For example, when individuals possess minimal how-to knowledge and financial resources, they are more likely to be influenced by the degree of risk and uncertainty arising from the innovation, rather than by its positive benefits (Martinez et al., 1998). Consumers will perceive risk based on issues of cost, performance, or perceptions of the innovation based on personal or vicarious experiences (Faiers et al., 2007b).

Trialability refers to the chance an individual has to test an innovation prior to adopting it. According to Rogers (2003), innovations that can be tried beforehand will be adopted more rapidly than innovations that are not easily tried. Trialability increases how-to knowledge and reduces risk perception. In the case of high-involvement RETs, certain technologies are easily tried, such as an electric vehicle, whereas others are impossible to try on a limited basis, such as a solar energy system or GSHP system, where the installation is too difficult to remove or in some cases irreversible. Research has found that earlier adopters perceive trialability as more important than later adopters, since later adopters are able to try the innovation vicariously through their peers, whose subjective evaluation (based on their personal experience) is more accessible and convincing to them (Rogers, 2003). Consequently, the more people that have already adopted an innovation, the less important trialability becomes, since the experiences (i.e. pros and cons) of earlier adopters can more readily be communicated to potential adopters (Janssen & Jager, 2002).

Observability refers to the extent to which an innovation or the consequences of using the innovation are visible to others. According to Rogers (2003), the easier it is for individuals to see the results of an innovation, the more likely they are to adopt it - that is, if the results are positive. Lack of observability can be seen as a barrier to adoption, as it reduces awareness, knowledge and stimulation for such technologies (Jager, 2006). Moreover, Faiers & Neame

(2006) also cited observability as a potential barrier, where they found that men were more sceptical towards adopting solar power systems due to their negatively perceived visual appearance. Observability also relates to the degree to which the benefits can be communicated to potential adopters and thus can help increase the rate of adoption of the innovation. According to Jager (2006), the more households who adopt a solar PV system, the greater the degree of observability will be, which is positively related to adoption. However, where minimal households have adopted a solar PV system, observability may be low, making it difficult to communicate the associated benefits to potential adopters.

The five perceived characteristics of an innovation have been studied by many scholars in the analysis of different technological innovations, including high-involvement residential RETs, but scantily in regards to the GSHP system, especially within an Ontario context. After evaluating the five perceived characteristics of an innovation, an individual or other unit of adoption will have formed a favourable or unfavourable attitude towards the innovation. It is assumed that with a favourable attitude, the individual will adopt the innovation in the decision stage, however, this is not always the case. In many cases, attitudes and actions are divergent (Rogers, 2003), which has led to the development of the attitude-behaviour gap, or sometimes called value-action gap, which is when the attitudes or values of an individual do not correlate with their behavioural change (Jackson, 2005). Change agent programs, such as financial incentives are one way to mitigate the attitude-behaviour gap and play a significant role at the persuasion stage (Rogers, 2003), and will be discussed in the following section.

2.4.4.2 Change Agent Programs

The fourth determinant of adoption, *change agent programs*, can also have a significant influence on an individual's perception of an innovation. As defined earlier, a change agent is an individual or group that influences consumer decision-making in favour of adoption, such as a salesperson, marketing organization, or government. Although not visually conceptualized in Figure 2-3, change agents have been found to be present throughout the entire IDP and vary stage by stage (e.g. Morris, Mills & Crawford, 2000); however, they are most influential at the persuasion stage (Rogers, 2003).

The main role of change agent programs is to facilitate the flow of innovations to potential adopters (Rogers, 2003). Thus, change agent programs are used to provide an external communication link between the source of the innovation (i.e. company) and a population of potential adopters. To do this, change agents instigate interventions to bring about behavioural change in order to produce identifiable outcomes, such as to increase the rate of adoption of the innovation (Rogers, 2003). For high-involvement RETs, many change agents award financial incentives or subsidies to consumers to reduce the high initial capital cost, and thus increase the degree of relative advantage (Rogers, 2003, p.236) while decreasing elements of risk and uncertainty (Faiers et al., 2007b, p.4388).

Although it is the goal of incentive programs to help lower the financial barrier that is often attached to high-involvement RETs, the results of such programs have been mixed. For example, in 2002, the United Kingdom government implemented a marketing and grant scheme to increase the uptake of residential solar PV and thermal systems, but despite reducing the initial capital cost by up to 50 percent, very few households purchased a system (Faiers & Neame, 2006). In this particular case, the grant scheme was not as effective as anticipated for increasing the adoption of residential solar energy systems. Similarly, Velayudhan (2003) found that offering financial incentives, such as a grant, in promotional programs, can shift attention away from the advantageous attributes of the innovation, onto its high initial capital cost and payback period, thus negatively altering consumers' perceptions. According to Jager (2006), grants are expected to function as a necessary but not sufficient condition for the adoption of high-involvement residential RETs. Obviously, financial motives are expected to be important, but aspects like environmental problem awareness have also had a significant influence on the decision to adopt RETs (Jager, 2006). Therefore, it is important to consider additional, non-monetary factors, in the design and implementation of change agent programs.

In Ontario, the majority of the federal and provincial incentives are aimed at the development and diffusion of renewable *electricity* systems, such as wind and solar technologies (Jagoda, Lonseth, Lonseth & Jackman, 2011) through programs such as tax incentives, rebates, and microgeneration programs. One particular program that has generated Ontario-wide participation is the Ontario Power Authority's microFIT program, which is a renewable energy microgeneration program (less than 10 kW), that pays landowners to generate electricity via wind, solar and hydroelectric systems and sell it back to the electrical grid. The most popular system - rooftop solar PV - pays homeowners $0.396 per kWh (Ontario Power Authority, 2014).

Lastly, Rogers (2003) hypothesizes that "incentives lead to adoption of an innovation by individuals different from those who would otherwise adopt" (p.238). For example, if a relatively large financial incentive is present, individuals of the lowest socio-economic status may be more inclined to adopt the innovation, however, this is not always the case. In a study by Diamond (2009) on the impact of government incentives on the adoption of hybrid-electric vehicles, results indicated that financial incentives may disproportionately benefit individuals with higher incomes who are more likely to adopt in the first place (i.e. free-riders). Thus, monetary incentives may be rewarding those who need the incentive the least for a purchase they would have made anyways (Diamond, 2009). This has important implications for socio-economic equality in the diffusion process, which deserves further research attention.

2.4.5 Decision Stage

At the decision stage, an individual either adopts or rejects the innovation. Rogers (2003) defines adoption as "a decision to make full use of an innovation as the best course of action available" and rejection as "a decision not to adopt an innovation" (p. 177). It is at the decision stage where individuals are most likely to try the innovation on a probationary basis, of course, if feasible, to determine its usefulness for their own situation. This small-scale trial is often an important part of an individual's decision to adopt (Rogers, 2003). However, as discussed above, the degree of trialability varies across innovations, and in certain circumstances, is not practical (i.e. installing and using a GSHP system on a limited basis). To combat this issue, individuals can 'try' the innovation vicariously through others, such as a peer or demonstration project (Rogers, 2003).

2.4.6 Implementation Stage

Implementation usually follows the decision stage rather directly (Rogers, 2003). At the implementation stage, the innovation has been adopted and is put into practice. Until this stage, the IDP has been strictly a mental exercise of thinking and deciding. However, a certain degree of uncertainty about the expected consequences of the innovation still exists at this stage for many individuals, even though the decision to adopt has already been made (Rogers, 2003).

Eventually, this level of uncertainty disappears and the innovation becomes a regular part of the adopter's daily operations (Rogers, 2003). Implementation involves overt behaviour change when the individual displaces the previous practice and puts the innovation to use and begins evaluating its usefulness. According to Pickett-Baker (2011), the implementation stage for residential RETs is an extended process requiring a great amount of time and effort, such as having the innovation installed, signing documents, and in some cases, such as for receiving the government grant for installing a GSHP system in Ontario, having a post-installation energy audit performed (CGC, 2010b).

2.4.7 Confirmation Stage

At the confirmation stage, the individual seeks reinforcement for the adoption decision already made, and may reverse this decision if exposed to conflicting messages about the innovation (Rogers, 2003, p.189). At this stage, the individual seeks to avoid a state of dissonance (discomfort) or to reduce it if it occurs. According to Jackson (2005), internal feelings of dissonance motivate people to reduce inconsistencies in the cognitive information they hold about themselves, their behaviour, or their environment. When individuals experience inconsistency, a state of dissonance is created which drives individual desire to return to consistency. Therefore, if an individual adopted an innovation but is unsatisfied with its performance, he or she may discontinue its use to avoid dissonance. Conversely, if an individual originally rejected the innovation, but then is exposed to pro-innovation messages, he or she can then choose to adopt the innovation to reduce dissonance (Rogers, 2003). The confirmation stage may continue over a considerable period of time indefinite, thus making it impractical to measure the length of time required for an individual or other unit of adoption to pass through the IDP (Rogers, 2003, p.213).

2.4.8 Communication Channels

The fifth determinant of adoption, *communication channels*, is directly linked to individuals' communication behaviour and is present throughout all stages of the IDP. A communication channel is the means by which messages are transmitted from one individual to another (Rogers, 2003). In adoption and diffusion research, there are two main communication channels: mass media channels, such as the internet, radio, television, newspapers, magazines, etc., and interpersonal channels, such as face-to-face exchange of information between two or more individuals. Different communication channels play different roles at each stage of the IDP and differ for earlier and later adopters (Rogers, 2003, p. 204).

Rogers (2003, p. 205) claims that mass media channels can help reach a large audience quickly, generate awareness and spread information, and change weakly held attitudes. Conversely, interpersonal channels are effective in forming and changing strongly held attitudes via face-to-face exchange of information between two or more individuals, preferably including an earlier adopter. The use of interpersonal channels is especially important for two main reasons. First, they can help overcome barriers to adoption, as one individual can secure clarification or additional information about an innovation from another individual, thus reducing uncertainty (Rogers, 2003). Second, they increase motivation for adoption, by persuading individuals to form or change strongly held attitudes in favour of the innovation. In the context of the consumer adoption of residential RETs, interpersonal channels have been found to be more important in the persuasion and decision stages, whereas mass communication channels play their most important role at the knowledge stage (e.g. Michelson & Madlener, 2013; Pickett-Baker, 2011; Tapaninen et al., 2009).

This finding is consistent with Mahapatra and Gustavsson's (2008a, 2008b, 2009) studies in the residential heating context, whereby homeowners planning to install an innovative low-carbon heating system gather information from mass media channels at the knowledge stage and from interpersonal channels at the persuasion and decision stages. In these studies, interpersonal networks were regarded as the most important source of information, namely system installers and vendors, followed by recommendations from friends, relatives, neighbours and colleagues (Mahapatra & Gustavsson, 2008a, 2008b, 2009). Moreover, survey results in a study on the adoption of microgeneration heat systems indicated that households usually sought impartial information on the internet, from manufacturers, as well as advice from installers, family and friends, with each of these information sources reportedly playing an equal role in their adoption process (Caird & Roy, 2010). Furthermore, of the 546 households that proceeded to purchase a microgeneration heat system, most organized two to three installer visits and typically chose the installer that was perceived as the most knowledgeable, trustworthy, reliable, and preferably, from a personal recommendation (Caird & Roy, 2010).

Furthermore, Rogers (2003) states that "mass media channels are relatively more important than interpersonal channels for earlier adopters than for later adopters" (p. 211). This generalization is made because when earlier adopters adopt an innovation, there is usually no one else in their system who is experienced with the innovation to offer their personal evaluation. Later adopters do not need to rely on mass media channels as much because "an ample storehouse of interpersonal, local experience has accumulated in their system by the time they decide to adopt" (Rogers, 2003, p.211-212). This is supported by McDonald and Alpert (2007) who assert that earlier adopters are more comfortable making decisions on the basis of mass communication channels alone, whereas the vast majority wait for interpersonal communication, such as word-of-mouth recommendations or demonstrations, before they decide to adopt. McDonald and Albert (2007) go on to define true innovators as those who adopt an innovation both early and independent of interpersonal communication, whereas later adopters rely on word-of-mouth and other people's experiences. Consequently, earlier adopters themselves reduce barriers to adoption for later adopters, as they become sources of interpersonal communication over time. However, this contradicts findings from Wang et al. (2008) who found that word-of-mouth from family members and friends remains an important source of information for innovators and non-innovators alike. Considering this, marketers need to understand that these two different segments are both promising target audiences for RET adoption, but they will be not be reached through the same communication channels (Kaenzig & Wüstenhagen, 2008).

As a determinant of adoption, communication channels, and particularly interpersonal channels, have been labelled as strong drivers for the adoption of microgeneration heat technologies (Caird et al., 2008) but of minor importance for other innovative residential technologies, such as water-use technologies (Schwarz & Ernst, 2009). Although communication channels are studied in many different contexts, little is known about the sources that originate the messages. Further research is needed to investigate what type of sources are employed, during what stages, and what sources are regarded as the most credible for helping individuals make informed adoption decisions, especially in the context of GSHP systems in Ontario.

2.5 Strengths and Weaknesses of the Innovation-Decision Process Model

Upon a review of the literature, it is evident that the IDP model can be of utility for describing and explaining the factors that influence the adoption of GSHP systems, by providing an empirically established foundation to understand human behaviour change. In the context of investigating the adoption of high-involvement RETs, the IDP model has been favourably reviewed within the literature (e.g. Faiers et al., 2007b; Kaplan, 1999; Wilson & Dowlatabadi, 2007). The literature search yielded minimal critiques directing disputing the IDP model, which was also the consensus reached by Straub (2009) in his review of different adoption theories, including the IDP model. Nevertheless, it is not without some concerns, which are discussed below.

According to Morris et al. (2000), the IDP model can be "criticized for being prescriptive, static and deterministic, suggesting an orderly, predictable and linear progression from awareness through to adoption, whereas in reality, the process is unpredictable, uncertain and very diverse" (p.234). This critique is consistent with Wilson and Dowlatabadi (2007) who stated that the principal weakness of the IDP model is its linear representation of knowledge, awareness, intention, and behaviour, in their review of decision-making models in the context of residential RET adoption and energy use. Furthermore, Morris et al. (2000) argue that the IDP model emphasizes individual decision behaviour, but inadequately accounts for the influence of external factors, such as change agents, on the adoption decision. To address this potential shortcoming, the present study explicitly includes change agent programs as a determinant of adoption influencing the IDP.

Another, and perhaps most concerning limitation regarding DOI research is what Rogers (2003) calls the *recall problem*. In most adoption research, respondents are asked to look back in time in order to reconstruct their experience in adopting an innovation. But hindsight is not completely accurate, with the degree of accuracy varying on the basis of the innovation's importance to the individual, the length of time over which the recall is requested, and on the basis of the individual's memory (Rogers, 2003). This is a serious limitation that may reduce the validity of results and is found across most DOI studies (Jansson, 2009). However, due to the high-involvement effort of adopting RETs, individuals are more likely to remember the adoption process and the factors that influenced it, due to the financial and social significance of the investment (Lambert-Pandraud, Laurent & Lapersonne, 2005).

There are of course alternative models to the IDP, such as the Hierarchy-of-Effects model and Porchaska's Stage-of-Changes model (see Rogers, 2003, p.198-202 for a review of both models), and Klonglan and Coward's symbolic adoption process model (see Parthasarathy et al., 1998, p.40) that seek to explain how the adoption of innovations occur. Each of these models is based on traditional learning-oriented, high-involvement, "think-feel-do" behaviour (Parthasarathy et al., 1995; Rogers, 2003) and generally mimic the stages in the IDP, giving different emphasis to various elements of the decision process. This emphasizes the basic similarity of these theories, and implies that further conceptualizations of the stages, in different empirical studies, might be fruitful.

Based on Rogers' IDP model, Kaplan (1999) has generated a conceptual model that emphasized the importance of early need for knowledge, as it is a pre-cursor to adoption interest. Kaplan (1999) amended the IDP model by incorporating "interest" as an additional stage, placed between knowledge and persuasion. However, this modification has not gained popular support (Faiers, 2009). In addition, Mahapatra and Gustavsson (2008a, 2008b, 2009) have adapted Rogers' (2003) IDP model by replacing his five stages with four stages of decision-making involved in homeowners' adoption of an innovative low-carbon heating system. The four stages include: (1) need for a new system, (2) plan for a new system, (3) collection of information, and (4) selection of a system, and are influenced by three factors - rather than Rogers' (2003) five determinants of adoption - which are: socioeconomic characteristics, mass media and interpersonal communications and the perceived relative advantage of the system, including technical, comfort, economic and environmental aspects (Mahapatra & Gustavsson, 2008a). Thus, the stages are still consistent with a focus on the need, information and decision, but are simplified and do not contain stages after the decision to adopt or reject the innovation has already been made, such as the implementation and confirmation stages in the IDP. Nevertheless, this modified version has not yet received sufficient attention from other researchers, perhaps due to its singular focus on the adoption of low-carbon heating systems and rather identical composition to Rogers' (2003) highly regarded IDP model. Moreover, Caird et al. (2008) have developed a model to help understand the adoption and use of renewable energy systems;

however, it is more directly related to energy efficiency than the adoption of high-involvement RETs. For this reason and because it has not received adequate research attention, it was deemed premature to consider whether it is of utility for the present study.

In spite of its criticisms, the IDP model can provide a flexible and accessible foundation for investigating the household adoption of high-involvement residential innovations (Wilson & Dowlatabadi, 2007) such as the GSHP system. In summary, the IDP model has been studied in many contexts and has, for the most part, received very positive reviews for its effectiveness in helping researchers understand how, why, and what individuals adopt (or reject) innovations and the factors that influence their decision. In light of this, the IDP model, including the five determinants of adoption, has been selected as a theoretical framework to guide the collection of empirical data on household adoption experiences to achieve the research objectives of this thesis.

2.6 Summary and Rationale for Primary Research

This section summarizes the literature review and identifies opportunities for further research. This review demonstrated that the IDP model and five determinants of adoption can provide a theoretical framework on which to base further research, namely to describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. The IDP model was selected because it has gained widespread approval among consumer behaviour scholars, despite the few criticisms that it has attracted. The IDP model is being used as a theoretical framework to explore experiences rather than to test its application. Employing the IDP model and five determinants of adoption as a theoretical framework for the present study serves three purposes. The first is to describe and explain behaviour and to identify important behaviour drivers behind households' decisions to adopt a GSHP system. The second is to guide the collection of empirical data on a relatively underdeveloped area of research, i.e. household adoption of GSHP systems in Ontario. The third is to provide a foundation for interpreting research findings.

This review highlighted that in order to build a more comprehensive and nuanced understanding of the consumer adoption of high-involvement RETs, it is essential to investigate a suite of factors and how they influence consumer decision-making together. In the context of the adoption of residential GSHP systems in Ontario, little is known about the decision-making process in which households engage and the factors that influence it. As a result, a research objective is set against each of the five determinants of adoption, for primary research:

Objective 1 - Prior Conditions

To identify how households perceived a need for the GSHP system.

Objective 2 - Characteristics of the Decision-Making Unit

To identify characteristics of household decision-making units to discover commonalities that may have influenced adoption behaviour.

Objective 3: Perceived Characteristics of an Innovation

To identify the perceived characteristics of the GSHP system that promoted and hindered adoption and their respective significance.

Objective 4: Change Agent Programs

To identify the influence of change agent programs on adoption behaviour.

Objective 5 - Communication Channels

To identify the communication channels that household decision-making units used in their adoption process and what information sources were regarded as the most useful in helping them make an informed decision to adopt a GSHP system.

By accomplishing each of these objectives, a comprehensive understanding of the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario can be achieved. In turn, this may contribute to a better design of policy instruments and communication and marketing strategies, for targeting households that continue to heat and cool with fossil fuel and electric-based systems in rural Ontario. In turn, this can help increase the rate of adoption of GSHP systems which will contribute to a reduction in GHG emissions, peak demand on the electricity grid and help facilitate Ontario's transition to a more sustainable and affordable energy future.

Chapter 3: Methodology

3.1 Introduction

The goal of this thesis is to describe and explain the factors that influence the residential adoption of ground source heat pump (GSHP) systems in rural southwestern Ontario. This chapter presents the research design and methods that were deemed appropriate to achieve this research goal. Prior to presenting the specific methods of data collection, section 3.2 describes the overarching research purpose and design of this study. Next, section 3.3 outlines the research location and population of this study. Section 3.4 provides an in-depth discussion of the primary method used for data collection, the interview. Following this, section 3.5 describes the sampling strategy that was employed to select research participants and outlines the interview design and methods that were used for data collection. Section 3.6 presents the strategy taken for data analysis, while section 3.7 summarizes the chapter and highlights noteworthy limitations.

3.2 Research Purpose and Design

The research orientation of this study is qualitative and utilizes mainly words, with minimal use of numerical data, other than, for example, annual household income level and age of decision-making unit at time of adoption. Qualitative researchers often seek a rich description of a phenomenon that is relatively underdeveloped, by "seeing through the eyes of the people being studied" (Bryman, Teevan & Bell, 2009, p.134).

This thesis performs each of the exploratory, descriptive and explanatory purposes of research. First, the factors that influence the residential adoption of GSHP systems are largely unknown, generally, and in Ontario, specifically. In light of this gap in knowledge, this thesis can be considered to be exploratory in nature, wherein a study is designed to probe a situation previously unexplored or about which little is known (Babbie, 2007, p.88). Second, this thesis also seeks to understand and describe "what" factors influence the residential adoption, what Babbie (2007) refers to as the descriptive purpose of research. Third, upon identification, these factors will be used to explain why a subset of households decided to adopt a GSHP system. This final objective qualifies this research as being part explanatory, as it seeks to explain the "why" of the topic (Babbie, 2007; Yin, 2003). Thus, the overall research purpose of this thesis is mixed, comprising of exploratory, descriptive and explanatory elements. By identifying and describing the factors that influence adoption, research results will help provide a detailed explanation of why a subset of households adopted a GSHP system in rural southwestern Ontario.

Robson (2002) argues that certain research designs support certain research purposes. In the social sciences, a case study design is appropriate for an exploratory, descriptive or explanatory analysis of a person, group or event (Yin, 2003). Since the overall purpose of this thesis comprises elements of exploratory, descriptive and explanatory research, it was considered logical to adopt a case study research design. Babbie (2007) describes a case study as the process of research in which a detailed examination is given to a single individual, family, group or phenomenon. The rationale for using a case study typically is the availability of a special case that seems to merit intensive investigation (Babbie, 2007). For this thesis, the case study design is justified, as primary research seeks to develop a detailed understanding of the factors that influence the residential adoption of GSHP systems, by performing an in-depth, qualitative analysis of a sample of the most experienced individuals - the adopters. With a case study, the case is an object of interest in its own right and the researcher aims to provide an in-depth elucidation of it (Bryman et al., 2009).

The case study research design employed in this thesis is deductive, using Rogers' (2003) IDP model to guide the collection of empirical data to help describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. The IDP model was selected because it has gained popular approval among consumer behaviour scholars, despite the few criticisms that it has attracted. The IDP model, including the five determinants of adoption, is being used as a theoretical framework to explore experiences rather than to test its application. Nevertheless, this thesis is still influenced by inductive methods, in that it allows for new concepts and ideas to emerge because of its exploratory nature.

3.3 Research Location and Population

The research location of this case study is rural southwestern Ontario. Specifically, data were collected from households that reside within a subset of rural southwestern Ontario, as delineated by the red circle in Figure 3-1, extending north to south from Mount Forest to St. George, and east to west from Campbellville to Stratford. This subset of rural southwestern

Ontario was selected as the research location for this study due to the proximity and convenience to the researcher's location (red star) for primary data collection.

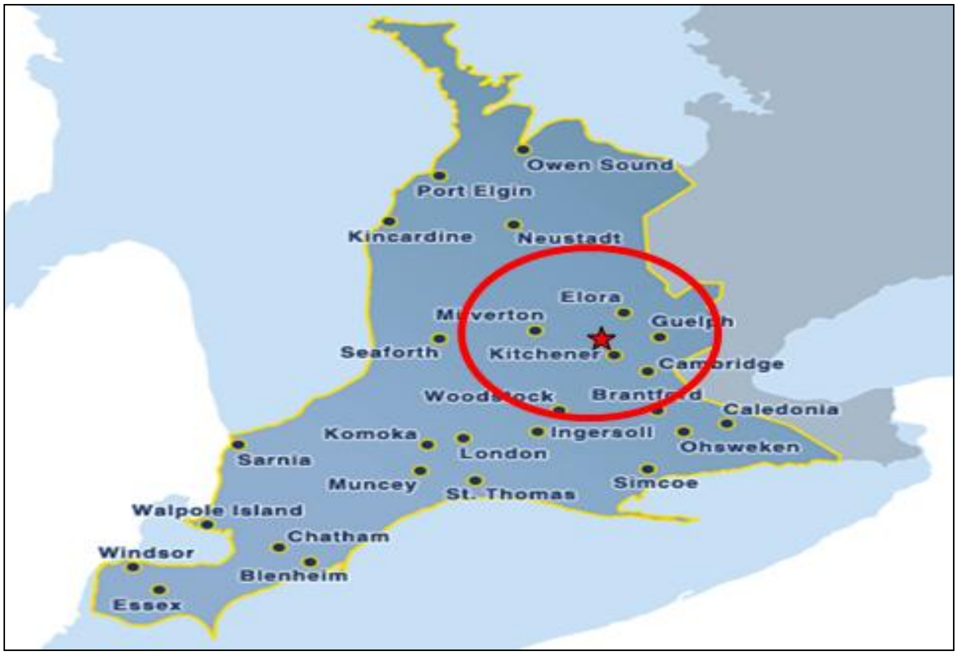

Figure 3-1 Map of Southwestern Ontario (Adapted from Southwestern Economic Alliance, 2014)

The research population of this case study was households that have adopted a GSHP system who met the criteria outlined in Table 3-1.

Table 3-1 Research Population Criteria

Criterion	**Details**
Location	Live in rural southwestern Ontario (within red circle portrayed in Figure 3-1) and did not have access to natural gas when GSHP system was installed.
Time	System must have been installed in the last 10 years (i.e. between 2004 and 2014).
Displaced Heating System	Household must have previously used an oil, propane or electric-based heating system - or a wood/corn/pellet stove if combined with any of the three aforementioned systems.
Type of Installation	System configuration can be open or closed loop that is installed horizontally or vertically.
Current Setting	System must still be in operation - at the time of interview (i.e. February-March, 2014) - by the same household that originally adopted the system.
Type of Home	System must be installed in a single-family detached house.

As identified in section 1.2.2 of chapter 1, the Canadian GeoExchange Coalition (CGC, 2012b) estimates that there are approximately 100,000 GSHP systems installed across Canada and two-third of these, or 66,667 systems, are installed in Ontario, accounting for. The sectoral breakdown in Ontario is estimated at 56 percent, or 37,334 systems installed in the residential sector and 44 percent, or 29,333 systems installed in the industrial, commercial and institutional (ICI) sectors. Furthermore, the CGC (2012a) estimates that approximately 90 percent of all Ontario residential installations are in rural areas without access to natural gas, and 67 percent are retrofits wherein the previous space heating system was displaced. From these estimates, approximately 22,512 (37,334*0.90*0.67) houses in rural Ontario that do not have access to natural gas have been retrofitted with a GSHP system, while displacing their previous space heating system.

However, it is unknown exactly how many of these systems have been installed in rural *southwestern* Ontario, as the CGC (2012a) is not in a position to provide full statistics broken down by region. Based on the above figures, the CGC (2012b) estimates that the market penetration for GSHP systems in the Ontario residential sector is approximately half a percent. Unfortunately, this is the most accurate estimate of the GSHP industry for the residential sector currently available, as there is no systematic reporting system in place, enabling a more comprehensive understanding of the industry. It must be reminded that the above data are estimates and considered anecdotal only. Thus, all conclusions drawn from this thesis are with respect to the given sample, and one should be cautious not to generalize findings to the broader population.

3.4 Selection of a Qualitative Research Method

Having determined the overarching research purpose, design, and population, it is now necessary to select an appropriate method for data collection. The main goal of qualitative researchers is to "see through the eyes of the people being studied" (Bryman et al., 2009, p.134). It was determined that to fully understand the factors that influence the residential adoption of GSHP systems, one must engage the decision-making unit involved in the adoption process. This is supported in the specific case of RETs by Painuly (2001) who argues that stakeholder perspectives are important because stakeholders are directly involved with the studied system, and may be better able to help identify and elucidate intricacies. This type of interactive research generally takes place through one of two popular methods - surveys or interviews (Palys, 2003, p.149). Both of these methods are considered to be useful means for achieving the present study's objectives because they can obtain information directly from the particular sample rather than from documents, archival records, physical artifacts, and they do not require the phenomena being studied to be directly observed (Babbie, 2007). There are several advantages and disadvantages of both the survey and interview as method which are discussed below.

Babbie (2001) argues that "[s]urvey research is probably the best method available to the social researcher who is interested in collecting original data for describing a population too large to observe directly" (p.238). Although it can certainly be argued that this study's objective to collect data on a large population, namely GSHP adopters in southwestern Ontario, would be best served by using a survey from which findings can be more readily generalized, it is necessary to emphasize that the use of a more structured approach prior to the completion of exploratory research on the subject would have been premature. The development and distribution of a survey without the advantage of an exploratory study preceding it could potentially question the validity of the survey's findings, as it is unknown to what extent prior research on the adoption of analogous RETs can be applied to the GSHP system. Without this knowledge, there is little foundation from which a survey's questions can be developed. Thus, without first developing a more precise understanding of what the potential answers could be, it would be difficult to know whether the "right" questions are being asked, to achieve the objectives of the study, thereby, calling its validity into question.

Another possible validity challenge faced by a survey that is conducted prior to an exploratory study is a potentially low response rate. Although a low response rate is a methodological challenge faced by most research, it may have been even greater for this specific study because in order to test the multitude of potential factors that were discussed throughout the literature, the survey would have needed to be both lengthy and complex - two factors that may decrease the likelihood of a respondent filling out the survey (Babbie, 2007). If the instructions are unclear, questions may be inadvertently omitted or answered improperly. Thus, for survey questionnaires, "it is always important to ensure that the questions asked are clear and unambiguous, since there is no interviewer to help respondents with questions they cannot understand" (Bryman et al., 2009, p. 71). Additionally, without the presence of an interviewer, there is no opportunity to probe respondents to elaborate an answer or seek clarification on responses. According to Bryman et al. (2009), "[q]uestionnaire respondents are more likely than interview participants to become tired of answering questions that are not fully salient to them, and to abandon the project entirely" (p.72). Due to these limitations, there is a greater risk of missing data. One last noteworthy issue with survey questionnaires which may impact the validity of the study, is that one can never be sure whether the intended respondent or someone else answered the questions.

Therefore, due to research limitations of the survey questionnaire and the lack of existing information regarding the factors that influence the residential adoption of GSHP systems, specifically in Ontario, it was not prudent from a research perspective to conduct survey research prior to the completion of an extensive exploratory study. Given the position that no such exploratory study currently exists, this research was designed to fill this foundational gap in understanding - a scenario that lends itself well to interviewing (Gorden, 1987). This is supported by Babbie (2007) who argues that the interview as method is most appropriate for collecting data for exploratory research.

Three arguments presented by Dunn (2000) further support the selection of the interview method for data collection specific to this type of research. First, Dunn (2000) argues that the interview is to be used to "fill a gap in knowledge which other methods, such as observation or the use of census data, are unable to bridge efficaciously" (p.52). The second reason to employ the interview as method is to "investigate complex behaviours and motivations" (Dunn, 2000, p.52). Thirdly, the interview is used to "collect a diversity of opinion and experiences" (Dunn, 2000, p.52). While a questionnaire or focus group could satisfy the first and third reasons presented here, it is the second reason, the complexity of behaviour and motivation, that deems the interview as the most appropriate method of data collection as it allows for the interviewees themselves to interpret, make sense, and describe in their own words how and why certain phenomena unfolded (Bryman et al., 2009). Babbie (2007) adds that interviews are more effective for studying complicated processes, such as the adoption of a high-involvement RET.

Given the above arguments and the overall research aim of this study, it is clear that the interview as method for data collection is most appropriate. Nevertheless, it is important to be made aware of methodological challenges faced by the interview. Within methodological literature, three limitations of the interview method are commonly presented: question bias, poor recall, and reflexivity (Babbie, 2007; Singleton & Straits, 2005). It is important to address these weaknesses prior to and during the data collection phase, and to develop strategies to reduce their presence and impact.

First, the validity of interviewee responses is threatened by bias due to the poor construction of questions (Yin, 2003). Questions may bias answers if their wording leads a respondent towards a certain answer. In the case of social science research, almost any survey method is subject to this problem. Strategies to overcome this challenge include pretesting of questions, as well as the proactive refinement of questions within and across the interviews themselves (Babbie, 2007). Pretesting is a useful method to help ensure that the interview questions being asked are clear, easy to understand, unambiguous and valid, to obtain the "right" data to help achieve the study's research objectives (Babbie, 2007). To address this issue of validity, the interview questions of this study were pre-tested and refined prior to commencing primary data collection. The pre-testing exercise that took place will be discussed in detail in section 3.6.1.

The second challenge of the interview as method is inaccuracy due to poor recall on the part of the participant (Yin, 2003). According to Singleton and Straits (2005), survey questionnaires and interviews "rely almost exclusively on reports of behaviour rather than observation of behaviour" (p.227). Relating to most innovation adoption research specifically, respondents are asked to look back in time in order to reconstruct their adoption experiences including all of the associated details and intricacies. However, hindsight is not completely accurate, with the degree of accuracy varying on the basis of the innovation's importance to the individual, the length of time over which the recall is requested, and on the basis of the individual's memory (Rogers, 2003). Conversely, due to the high level of time and effort invested by an individual during the innovation adoption process, one might presumably remember more about the adoption process and the factors that influenced it, due to the financial and social importance of the investment (Lambert-Pandraud et al., 2005). To address recall failures, interviews should be performed as close in time to the phenomenon being studied as it is more likely that respondents will be able to accurately recall their experiences (Singleton & Straits, 2005). To reduce this potential issue, it was decided that a criterion for the research population was households that had installed a GSHP system in the last ten years. To adjust for inaccuracies due to memory distortion, prospective participants will be contacted prior to their interview and will be given details pertaining to the study and what their involvement as an interview participant will entail. This strategy will allow participants to prepare themselves before meeting with the researcher, allowing them to re-familiarize themselves with their adoption experience, by recalling different phenomena or checking their files. Other techniques utilized to minimize recall inaccuracy include giving respondents more time to search their memories for a response, having them check their personal records and the use of prompts throughout the interview process (Singleton & Straits, 2005).

The third and final major challenge of the interview as method is that reflexivity may arise. This occurs when respondents produce "socially desirable answers to sensitive questions" (Singleton & Straits, 2005, p.227). In other words, respondents may formulate their answer(s) to particular questions "that are not sincere or genuine, but which nonetheless make them appear to be respectable or likeable people" (Bryman et al., 2009, p.77). Respondents may also produce answers that they feel the interviewer wants to hear, rather than the actual truth. For example, a respondent may indicate that their main motivation for purchasing a RET was for environmental reasons, whereas their actual motivation was based on long-term monetary savings. Strategies used to deal with these challenges include the use of indirect questions, the careful placement of wording of sensitive questions, assurances of anonymity and scientific importance, and the building of rapport between interviewer and respondent (Singleton & Straits, 2005).

3.5 Sampling Strategy

Two non-probabilistic sampling techniques were used to select households for primary interviewing - convenience sampling and snowball sampling. First, a convenience sample is defined as "a sample that is selected because of its availability to the researcher" (Bryman et al., 2009, p.343). In this study, convenience sampling was operationalized via gatekeeper recruitment, which is discussed in detail in section 3.5.1. Second, a snowball sample is defined as "a non-probability sample in which the researcher makes initial contact with a small group of people who are relevant to the research topic and then uses them to establish contacts with others" (Bryman et al., 2009, p.347). Snowball sampling was dependant on the convenience sample; it could only be employed once initial contact had been made with interview participants via gatekeeper recruitment. The snowball sampling method is discussed in detail in section 3.5.2.

Non-probability sampling does not involve random selection and implies that some units of the population are more likely than others to be selected (Bryman et al., 2009). With non-probability sampling, results cannot be used to infer from the sample to the general population. Any generalizations obtained from a non-probability sample must be filtered through one's knowledge of the topic being studied. It was determined that non-probability sampling was the most appropriate for this research, as the alternative, probability sampling, would not be feasible as there is no way of knowing the probability of each unit in the research population being selected for interviewing (Bryman et al., 2009) and because the population as a whole is unknown. This is because the total number of households that meet the research population criteria of this study is unknown. Furthermore, Bryman et al. (2009) note that for a research population where there is no accessible sampling frame from which the sample is to be taken, a non-probability approach is the only feasible one.

3.5.1 Convenience Sampling

Convenience sampling, operationalized via gatekeeper recruitment, was the chief method employed in this study for recruiting interview participants. Bryman et al. (2009) define a gatekeeper as "a non-researcher who controls researcher access to a research setting" (p.344). The gatekeepers that were used in this research, to connect the researcher with the interview participants, were (1) Waterloo Energy Products Inc. and (2) Bostech Mechanical Ltd. - both of which are industry leading renewable energy companies that specialize in the design, installation and servicing of GSHP systems across southwestern Ontario and beyond. The unit of analysis, for the convenience sampling method, is therefore, households who have adopted a GSHP system that meet the research population criteria outlined in Table 3-1 and who are customers of Waterloo Energy Products or Bostech Mechanical.

Waterloo Energy Products' office is located just outside of Waterloo, Ontario in Maryhill, and Bostech Mechanical's office is located in Listowel, Ontario, about 45 minutes away from Waterloo; thus, both are in close proximity to the researcher and the University of Waterloo. For this reason, and because of a pre-established relationship with the researcher, Waterloo Energy Products was recruited to assist in gatekeeper recruitment. Bostech Mechanical was also recruited to assist in gatekeeper recruitment, to ensure that an adequate sample size could be achieved within a specific timeframe. Also, Waterloo Energy Products and Bostech Mechanical have been installing GSHP systems for 12 and 21 years respectively, meaning their ability to match the researcher with households that meet the research population criteria of the study is heightened, compared to a company that has only been in the industry for less than five years, for example. Finally, both companies were also recruited to assist in gatekeeper recruitment because of market territory, meaning that prospective interview participants would be located within a reasonable distance to the researcher. The total number of companies that install GSHP systems in southwestern Ontario (i.e. gatekeeper recruitment candidates) is not publicly listed, however, based on an informal survey using Google search, there are approximately 35. Unfortunately, the market share for any of these companies, such as Waterloo Energy Products and Bostech Mechanical, is not publicly available.

In January 2014, a gatekeeper recruitment letter (Appendix A) was e-mailed to both of these companies requesting their assistance with the recruitment of participants for primary interviewing. Both companies responded within 2-3 days agreeing to assist the researcher and subsequent face-to-face meetings were arranged to discuss the research project in more detail and what their role as a gatekeeper would entail. Each company filled out, signed and returned the gatekeeper recruitment letter to the researcher during their respective meeting.

Prospective interview participants were recruited by respective company employees via a recruitment e-mail (Appendix B), prepared by the researcher for the company, to ensure that customer privacy was not breached. The recruitment e-mail was designed to be e-mailed to all households for which the companies had e-mail addresses, who met the research population criteria of this study. Attached to the recruitment e-mail was an information letter and consent form (Appendix C) containing information about the study and what the participant(s) involvement would entail, if they decided to take part in an interview. The researcher's contact information was provided in the information letter so that if prospective participants wanted additional information to assist them in reaching a decision about participating in an interview, or were willing to participate in the study and wanted to arrange a date and location for the interview, they were able to contact the researcher directly by e-mail or phone. Participants were given the option to have the interview conducted either face-to-face or by telephone or Skype at a time and location of their convenience. Ultimately, all interviews were conducted face-to-face.

Between both companies, a total of 42 recruitment e-mails were sent to households matching the research population criteria: 30 by Bostech Mechanical and 12 by Waterloo Energy Products, making up the sampling frame of this study. It must be noted that not all households that met the research population criteria were contacted by both companies, for reasons discussed below. A total of 17 households responded directly to the researcher, willing to participate in an interview; three who did not meet the research population criteria were excluded from the study (for reasons discussed in the following paragraph), and 14 were ultimately interviewed. Bostech Mechanical's and Waterloo Energy Products' recruitment e-mails yielded four and 10 household participants, respectively. This indicates that the households recruited by Waterloo Energy Products were much more receptive to participating in the study, with an interview response rate of 83.3 percent, compared to only 13.3 percent for households recruited by Bostech Mechanical. Rounding out the study sample size to 17 households were three participants who were recruited via snowball sampling and subsequently interviewed; they will be further discussed in section 3.5.2.

Of the three households that did not meet the research population criteria, two were excluded when the researcher was arranging a time and place for the interview and became aware that the household installed their system in a new residential build (not a retrofit). In the third case, the researcher was not made known that the household did not meet the research population criteria until the interview had already begun. Once made aware that the household installed their system in a new residential development, the researcher promptly continued through the interview process and thanked the participant for their time, and ultimately omitted the audio recording from the study. Two of the households (including the one that still participated in the interview) that were ultimately excluded from the study were recruited by Bostech Mechanical, while the third household was recruited by Waterloo Energy Products.

Therefore, on three occasions, the gatekeepers of this study accidentally recruited households that did not meet the research population criteria that was previously defined to them by the researcher. Of the 25 households who did not contact the researcher, it is unknown how many received and reviewed the information letter and considered participating in the study.

A noteworthy limitation to the gatekeeper recruitment method used in this study is sampling bias, which occurs when a sample is collected in such a way that some members of the intended research population are less likely to be included than others (Babbie, 2007). As mentioned above, not all households that met the research population criteria were identified and recruited by Waterloo Energy Products or Bostech Mechanical. As "gatekeepers", both companies were able to control what households were recruited, and therefore, ultimately interviewed by the researcher. For instance, both companies may have only recruited households who they believed would "speak positively" about their experience in adopting a GSHP system. Moreover, the companies may have excluded households that they believed would not be interested in participating in an interview, that otherwise perhaps would be. Thus, the data collected from the 14 household participants recruited via gatekeeper may be disproportionately represented in relation to the larger research population, resulting in a biased sample. To minimize sampling biases, both companies were informed during their initial respective meeting and again via e-mail dialogue, that the research results would be more fruitful if participants were not recruited in a preferential manner. Nonetheless, in the context of this study, it was reasonable to use non-probability convenience sampling, operationalized via gatekeeper recruitment, as the researcher previously had no access to the research population, and other sampling techniques were not feasible.

3.5.2 Snowball Sampling

Snowball sampling was employed as a secondary recruitment method in this study which yielded three of the 17 household participants, as identified above. With this approach, the researcher makes initial contact with an individual(s) who is relevant to the research topic and then uses them to establish contacts with others (Bryman et al., 2009). In this study, snowball sampling was dependant on the convenience sample; it could only be employed once initial contact had been made with interview participants via gatekeeper recruitment. At the end of each of the convenience sample interviews, participants were asked verbally if they knew of anyone who has adopted a GSHP system who meets the research population criteria of this study. If yes, the researcher asked the participant(s) to forward a copy of the information letter and consent form to the household(s) via e-mail or in-person, and if they were interested in participating in an interview, they could then contact the researcher. Once contacted had been established, the researcher followed the same protocol as with the convenience sample, for arranging an interview time and location. All three of the snowball sample interviews took place face-to-face; two at the place of residence of the participant(s), and one at a public place of convenience to the participant. The first participant from snowball sampling was a neighbour of a household that was recruited by Bostech Mechanical and interviewed by the researcher. The second participant was a friend of a household that was recruited by Waterloo Energy Products who was interviewed as well. The third and final participant was recruited by the second household that was selected by snowball sampling. On two occasions, the interview participant(s) stated that they were going to forward a copy of the information letter and consent form to a household that met the research population criteria, however, there was not subsequent contact made with the researcher - either the initial household failed to forward the information, or the receiving household did not wish to participate in an interview, and therefore, did not make contact with the researcher.

Snowball sampling was employed for two main reasons. First, it helped increase the sample size of this study, and second, it helped reduce the sampling bias of participants from gatekeeper recruitment. Snowball sampling made it possible for the researcher to include participants in the study that the researcher previously would not have known. The chief problem with snowball sampling is that it is very unlikely to be representative of the research population, which is a main concern of convenience sampling as well. However, by and large, snowball sampling is not used within a quantitative research strategy, but within a qualitative one (Bryman et al., 2009); it thus lends itself well to this kind of research. Bryman et al. (2009) also suggest that snowball sampling can be a better approach than conventional probability sampling when researching a statistically small group, which is the case in this research - namely, interviewing a sample of households that have adopted a GSHP system that meet a specific set of criteria as outlined in Table 3-1.

3.6 Primary Interviews

Primary interviews were conducted with households that have adopted a GSHP system in rural southwestern Ontario that satisfied the research population criteria outlined in Table 3-1. Interviews were arranged so that the key household decision-maker(s) involved in the GSHP adoption process would be the one(s) being interviewed. In cases where more than one household decision-making unit was self-reportedly involved in the adoption process, it was requested that all individuals were present for the interview; they would be interviewed as a collective decision-making unit, instead of separately. A total of 17 face-to-face interviews were conducted between February 13, 2014 and March 25, 2014. Interview lengths ranged from 32 minutes to 83 minutes, with an average length of 58 minutes. Twelve interviews took place at the residence of the participant(s); three at a public location of convenience to the participant(s); and two at the place of employment of the participant(s). All 17 participant consent forms were signed and received prior to beginning the interview; four were received via e-mail and the remaining 13 were received in-person at the place of the interview. Section 3.6.2 will describe the interview design and the particular methods that were employed during primary data collection.

3.6.1 Interview Design and Methods

To acquire data from the 17 households, in-depth, face-to-face interviews were employed in a mostly open-ended, semi-structured design, for many of the same reasons previously discussed in section 3.4. Semi-structured interviewing is designed to bring out how the interviewees themselves interpret and make sense of the issues and events that occurred (Bryman et al., 2009). A semi-structured approach allowed questions to be targeted towards the purposes of the research, while allowing the interviewee leeway to explore other relevant topics that emerged. There are, however, 10 questions (A11 to A20) in the interview guide (Appendix D) that are of closed-ended nature, either having a set of pre-fixed answers from which the participant(s) can choose or using a rating scale. After answering each of the closed-ended questions, the researcher asked the participant(s) "why" they chose that particular answer. This allowed the participant(s) to elaborate on their answer, which enabled the researcher to more accurately interpret the meaning of their answer.

The use of mostly open-ended questions allowed participants to respond freely with greater depth and insight into their adoption experience. It was presumed that because of the complexity involved in one's decision-making process, a survey questionnaire in a closed-ended format, would not be able to yield results of adequate depth and richness. Open-ended questions allow "the participant's knowledge and understanding of issues to be tapped" (Bryman et al., 2009, p.80), enabling the researcher to provide a thick description of the phenomenon being studied. Thick description is a rich, detailed account of people's experiences (Bryman et al., 2009, p.133), which explains not just the behaviour, but its context as well, so that the behaviour becomes meaningful to the researcher. Furthermore, open-ended questions allow for unusual responses - replies that the researcher may not have contemplated, and therefore did not ask about, thus relating to the exploratory element of this research. The main disadvantage with open-ended questions is that they generally produce lengthier responses, as interviewees are likely to talk longer, compared with closed-ended questions (Bryman et al., 2009). This makes transcribing interviews and the analysis of transcripts, including coding, a time-consuming process.

Face-to-face interviews were used in order to take advantage of both verbal and visual communication techniques. For example, with telephone interviews, the interviewer cannot see the participants, preventing them from responding to signs of puzzlement or unease on their faces or in physical movements (Bryman et al., 2009). In face-to-face interviews, the interviewer is able to respond to such signs by restating the question or attempting to clarify the meaning of the question. Moreover, face-to-face interviews were used to establish a more personal rapport with the participant(s) than would likely be developed via a telephone interview (Babbie, 2007). In the latter situation, "the interviewer is unable to offer the visual cues of friendliness, like smiling and maintaining good eye contact, which are conducive to gaining and maintaining rapport" (Bryman et al., 2009, p.68). Establishing rapport with the interviewee(s) not only eases the person into the interview setting, but opens the door for meaningful dialogue that deeply captures how participants interpret their experiences (Babbie, 2007). According to Bryman et al. (2009), there is evidence that the quality of data derived from telephone interviews are inferior to those of comparable face-to-face interviews, as telephone participants tend to be less engaged in the interview process.

Moreover, considering that each interview was estimated to take approximately 45 to 60 minutes, it was decided that face-to-face interviews would be more suitable and effective. This decision is supported by Frey (2004) who stated that a telephone interview is unlikely to be sustainable beyond 20 to 25 minutes, whereas face-to-face interviews can be conducted for longer periods of time. The cost and time of travelling to and from each interview was not a significant enough deterrent to select telephone interviews instead, because all 17 interviews were arranged in a location within an 80 kilometre radius of the researcher's location, as illustrated in Figure 3-1.

An interview guide was employed to direct conversation and ask questions on fairly specific topics, in order to obtain valid data to accurately achieve the objectives of this research. The interview guide consisted of a list of questions that were designed based on the study's literature review, namely via consulting Rogers' (2003) IDP model and empirical studies on the adoption of high-involvement residential RETs that investigated one or more of the five determinants of adoption, which were examined in chapter 2. Questions regarding sociodemographic and household characteristics were asked at the end of the interview in a two-page questionnaire that was handed to, and filled out by, the participants and returned to the researcher at the interview.

A number of techniques were followed to increase the utility of the interview guide as the method for data collection during its construction. Bryman et al. (2009) suggest that the researcher should begin the interview process with a question that is congruent with the interviewee's expectations, based on what they have been told by the interviewer about the study. It is also important that the first question asked is a more general, open-ended question that is relatively easy to answer. This allows the participant to respond freely, easing them into the interview process. The interview guide was developed to include questions and topics that address the objectives of the research study, ordered so that the questions flow reasonably well, but still allows for flexibility, for the interviewee to respond to what is important to them. The interview guide was developed for factual questions to come first, then attitudes, and finally questions of process and summing up, an order that Bryman et al. (2009) suggest will enhance the flow of the interview. Question order was also considered in the design of the interview guide so that the interview participant's adoption experience was probed in a chronological order.

For example, participants were asked about the most significant factors that promoted or hindered their decision to purchase a GSHP system, prior to asking about their overall experience in learning about and purchasing said system. Also, placing questions in the wrong chronological order can have an impact on participant responses. For example, asking a question prematurely may "put the answer in the participant's mouth" for a separate question that is asked later on, thus biasing the results. The proper ordering of questions is, therefore, important in the development of the interview guide.

Question sensitivity was also considered. According to Bryman et al. (2009), some people are not keen to divulge personal details such as their age and income. One way of reducing the impact of such questioning is to present participants with age or income ranges. Questions that were considered to be of a sensitive nature, such as the participant's age, income, or education level were, therefore, asked at the end of the interview process in a two-page questionnaire, with pre-defined ranges. Placing sensitive questions at the end of the interview is an effective strategy to increase the likelihood that the participant(s) will provide an answer, where the interviewer has already established interest, trust and rapport with them (Bryman et al., 2009). Placing sensitive questions at the beginning of the interview may make the interviewee(s) feel uncomfortable and less keen to respond. This technique also prevents participants from having to say sensitive things out loud. The questionnaire itself was relatively short, containing 12 easy-to-answer questions, to reduce the risk of "participant fatigue" (Bryman et al., 2009), considering they had just participated in an interview of, on average, 58 minutes in length. In the end, all interview participants answered each of the questions in the questionnaire without hesitation.

A number of prompts were used throughout the interview process, and are positioned in the interview guide (Appendix D), to prompt categories yet to be discussed. The use of prompts is important when the researcher is motivated to learn about certain topics, events or processes, yet to be explored by the participant(s) (Bryman et al., 2009). For example, in question B1, if a participant suggested that the most significant factor promoting their decision to purchase a GSHP system was environmental, and that was all they could think of, or remember, they would then be probed by a series of prompts, that cover different factors that may have influenced their decision. These prompts were developed based on the study's literature review, and proved to be effective in helping participants recall their decision-making process and the factors that influenced it. The frequency and significance of participant(s) responses, based on the use of prompts, is discussed in chapter 4.

Prior to beginning primary data collection, the interview guide was pre-tested on an Associate Professor at the University of Waterloo who had adopted a residential GSHP system and satisfied the research population criteria of this study, outlined in Table 3-1. The pre-test was conducted in two stages. First, the researcher conducted a face-to-face interview using the interview guide to facilitate the conversation. Concluding each section of the interview guide, and again at the end of the interview, the participant was asked to provide feedback on the questions being asked and the overall design and flow of the interview. Second, after completion of the interview, the participant was asked if there was anything else that the researcher should have asked about, regarding the adoption of a GSHP system that was not discussed during the interview that should have been. This gave the participant the opportunity to inform the researcher of other intricacies about purchasing a GSHP system of which the researcher was previously unaware. Changes were then made to the interview guide based on the pretest results, namely the ordering and wording of questions and the addition of questions A2, A12, A19, A20, D6, E10, E11 and E12. Overall, pretesting proved to be a valuable exercise, allowing the researcher to refine the interview guide, based on recommendations from an individual who has direct experience in the adoption of a residential GSHP system, in rural southwestern Ontario. This process helped to reveal a more in-depth and accurate understanding of the factors that influenced the residential adoption of GSHP systems. The interview guide was also reviewed by Waterloo Energy Products and Bostech Mechanical to confirm its legitimacy and acceptability, for both the consideration of their customers and the purposes of the study. Both companies commented that the interview guide was "comprehensive" and "precise" in that all factors that they believed would influence a household's adoption decision were covered. The only alteration to the interview guide from the companies, was the addition of question D4, requested by Waterloo Energy Products.

To collect the data, interviews were audio recorded, and later transcribed, with the consent of every participant. Palys and Atchison (2008) note that audio recording frees the interviewer to pay attention to the interviewee which helps the interviewer retain the flow of the interview. The use of an audio recorder also allowed the researcher to be highly alert to what was being said - following up interesting points that were made, probing where necessary, drawing inconsistencies in the interviewee's answers - which would not be feasible when having to concentrate on writing down everything that was said as well (Bryman et al., 2009). Audio recording was performed utilizing the researcher's Samsung Galaxy S5 mobile "voice recorder" application software. After completion of each interview, the researcher uploaded the audio recording to Google Drive, a free password protected online file storage service, to ensure the safe storage of data, to which only the researcher would have access. The influence of audio recording the interviews on the response of participants was not considered to be significant.

Following each interview, the researcher e-mailed a feedback letter (Appendix E) to the participant(s), thanking them for their participation in the study. Each feedback letter was e-mailed within 4-5 days of conducting the interview. In the feedback letter, participants were asked to respond via e-mail if they were interested in receiving information regarding the results of the study, or would like a summary of the results, once the study was completed.

3.7 Data Analysis

Each of the 17 audio recorded interviews was transcribed for data analysis, taking five times the length of each interview to transcribe. For example, a 60 minute interview would take five hours to transcribe, thus it was a time consuming process. To assist the transcription of audio recordings, Express Scribe software was used. The data from the two-page questionnaire were inserted at the end of each transcript.

Transcripts were then read a minimum of two times each, while editing, formatting, and deleting data that were deemed irrelevant to the research task. Data from the transcripts were condensed and extracted to an Excel spreadsheet "matrix", into one of the five topics in the interview guide: (1) prior conditions, (2) perceived characteristics of the innovation, (3) communication channels, (4) overall adoption experience, and (5) sociodemographic and household characteristics. The matrix was organized by having the interview questions listed down the first column (y-axis), in the same order as they appear in the interview guide, and the 17 household participants listed across the top row (x-axis), with the respective responses for each question placed in the appropriate rows below. This allowed for the data to be coded and analyzed in a manageable form, while retaining as much information as practical (Singleton & Straits, 2005). The data used in the matrix included codes, exemplary quotations and summaries of more complex and insightful data. The matrix was then printed into five separate poster-like matrices (36 x 36 inches each), per topic in the interview guide, for subsequent analysis.

For closed-ended questions, the coding of responses was simple; it required data to fit into preconceived standardized codes (Bryman et al., 2009). For questions that had a set of pre-fixed answers from which the participant had to choose from, the researcher assigned a different code to each category. For example, questions A11 and A13 of the interview guide prompted participants to pick one of the three pre-fixed answers that best suited them, and were thus coded. For questions that used the rating scale of 1 to 5, each response was simply listed in the matrix to identify the frequency of responses for interpretation in the Discussion chapter.

For open-ended questions, the researcher's interpretations of the data shape the emergent codes (Bryman et al., 2009). First, the researcher developed a coding scheme that adequately reflected the full range of responses, versus assigning a separate code for every respondent (Singleton & Straits, 2005). Bryan et al. (2009) state that it is critical at this stage to be open-minded and to generate as many codes as necessary to organize the data. According to Bryman et al. (2009, p.253), developing coding categories is a "process of breaking down, examining, comparing, conceptualizing, and categorizing data." Coding categories were formed by grouping together responses that appeared to share a similar theme. The researcher began the initial coding process using numerous categories, as suggested by Singleton and Straits (2005), and then progressed to more refined categories that encompassed responses that shared similar ideas and themes. For example, during the coding process a number of specific responses were categorized under "sustainability." Factors related to sustainability yielded the most diverse responses within its categorization. Responses that fell under one of the following five subcategories of sustainability were ultimately grouped together under the same core category: environment in general, renewable/clean form of energy, reduction of greenhouse gas (GHG) emission, reduced demand on fossil fuels, and energy self-sufficiency. This method allowed responses that shared a similar theme to be categorized together, for more useful interpretation and conceptualization of the phenomenon of interest.

The coding scheme that was used to identify the factors that promoted or hindered the adoption of GSHP systems and the presentation of the respective tables and figures (section 4.4.2.1), was adapted from Adachi (2009). This includes the method employed for identifying factors as "drivers", "barriers", or "neutral" to the adoption decision (Appendix F); the method for organizing and displaying data in Table 4-12; and the method for identifying the frequency and significance of each factor in the participant's adoption decision, as shown in Table 4-13 and Figure 4-13, respectively. The coding scheme was adapted for two reasons. First, it provided the researcher with an established tool for effectively coding responses and categorizing factors as drivers, barriers or neutral to the adoption decision. Second, it allowed for the development of tables and figures that effectively organize and communicate the data in a clear manner, for both the reader and for subsequent analysis by the researcher.

3.8 Summary

This chapter described the methodology employed in this study. Specifically, this chapter described the case study research design that was employed in this thesis and the specific methods that were deemed appropriate for achieving the research goal of describing and explaining the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. Fourteen households were ultimately interviewed from convenience sampling via the gatekeeper recruitment technique, while three households were interviewed from snowball sampling, rounding out the study sample size to 17 households.

In addition to the challenges already discussed, the chief limitation of this study pertains to the gatekeeper recruitment method that was used, as it controlled what households made up the sampling frame of the study. To mitigate this potential impact, both companies were informed by the researcher that recruiting a random sample of households that met the research population criteria of this study would yield more insightful results. Snowball sampling was also employed in the recruitment of interview participants to reduce sampling bias, however, this only yielded three of the 17 interview participants. Thus, all conclusions drawn from this thesis are with respect to the given sample, and one should be cautious not to generalize findings to the broader population, due to potential biases.

Moreover, a sample of 17 households is insufficient to extrapolate representativeness to a much larger research population that could quite easily number in the thousands, based on the statistics provided by the CGC (2011). However, despite the lack of statistical representativeness, it is expected that this case study will be applicable and useful to a wider audience for its insight into the household adoption of a GSHP system and the factors that influenced it. The applicability of the results from this study to households that meet the research population criteria, that have not already adopted a GSHP system, is expected to depend on the extent to which that population shares similar characteristics, conditions and attitudes, to the participants of this study.

Chapter 4: Results

4.1 Introduction

This chapter will present the results from the 17 primary interviews over approximately 16 and a half hours in a summarized format, including data collected from the interview guide and two-page questionnaire (Appendix D).

As a reminder, the goal of this thesis is to describe and explain the factors that influence the residential adoption of ground source heat pump (GSHP) systems in rural southwestern Ontario. Rogers' (2003) innovation-decision process (IDP) model was selected as a theoretical framework to guide the collection of primary data to help achieve this goal. The IDP consists of five stages, which are: (1) knowledge; (2) persuasion; (3) decision; (4) implementation; (5) decision, and is influenced by five determinants of adoption, which are: (1) characteristics of the household decision-making unit; (2) prior conditions; (3) perceived characteristics of the innovation; (4) change agent programs and, (5) communication channels. This chapter will present the results of household experiences at each of the five stages of the IDP, including the influence that each of the five determinants of adoption had on their decision to adopt a GSHP system.

First, section 4.2 will present results related to households' prior conditions, in terms of their previous practice (space heating system), felt needs or problems associated with their previous system, and innovativeness regarding the adoption of other energy efficient technologies. Second, section 4.3 will describe the characteristics of the 17 household decision-making units in the study sample, including sociodemographic and household characteristics, personality variables, and communication behaviour patterns. Third, section 4.4 will describe the ways in which household decision-making units passed through each of the five stages in the IDP in the adoption of their GSHP system, with a particular focus on the second stage, persuasion, where the decision-making unit forms a favourable or unfavourable attitude towards the innovation. This section will present the data for household decision-making units' perceived characteristics of the GSHP system, including the factors that promoted (drivers) and hindered (barriers) their decision to adopt a GSHP system. It will also describe the role of a financial incentive in the adoption of said system. Lastly, section 4.5 will describe the communication channels and information sources that household decision-making units used to inform their decision to adopt a GSHP system, and which sources were perceived as the most and least useful and credible throughout the process.

Interview participants have been coded with the abbreviation "H" to denote household decision-making unit, and have been assigned a number at random so as to retain the specific identification of respondents without sacrificing anonymity. Interview participants are referred to as either: "households", "household decision-making units" or "decision-making units." As identified in section 3.6 of the methodology chapter, interviews were arranged so that the key household decision-maker(s) involved in the GSHP adoption process would be the one(s) being interviewed. In cases where there was more than one household decision-maker involved in the adoption process, it was required that all individuals were present for the interview; they would be interviewed as a collective decision-making unit, instead of separately. A total of 17 household decision-making units were ultimately interviewed, comprising of 24 participants. Data in this chapter represent the collective decision-making units that were interviewed (n=17), except for Figure 4-3, which will represent all 24 participants (n=24). All data are indicative of the household decision-making units at their respective *time of adoption*, unless otherwise noted.

4.2 Prior Conditions

Results pertinent to the first determinant of adoption, prior conditions, are presented in this section. The three prior conditions that were investigated during primary interviews were the households' (1) previous practice (space heating and cooling systems); (2) perceived needs and problems associated with their previous system; and (3) innovativeness, measured by additional energy-efficient technologies that the household has adopted in the last 10 years and whether or not they would ever consider buying a hybrid and/or electric vehicle and why.

Figure 4-1 provides a breakdown of the space heating systems that were fully displaced by the adoption of a GSHP system.

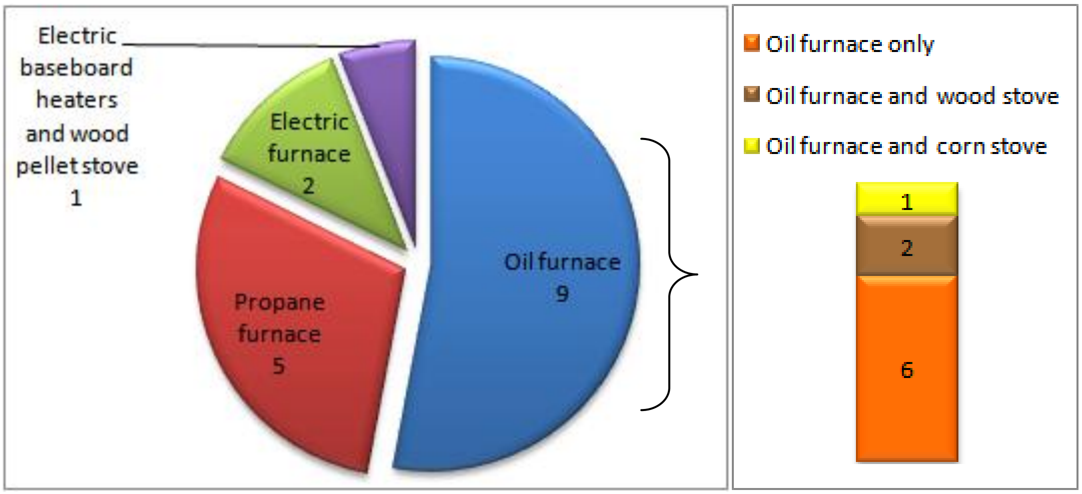

Figure 4-1 Type of Space Heating System that was Displaced (n=17)

The most frequently displaced space heating system was an oil furnace; either solely an oil furnace (6), or an oil furnace combined with a wood stove (2) or corn stove (1). The age of the space heating systems at the time of displacement ranged from five years to over 30 years old. Twelve of the 17 systems were less than 20 years old, including four systems that were between 5-10 years old, while the other five systems ranged between 20-35 years old, at the time of displacement.

All 17 household decision-making units perceived a range of problems with their previous space heating system, frequently identifying more than one problem in their response. A total of 48 problems were identified and were coded and categorized into eight different problem types, which are displayed in Table 4-1, including sample quotations and frequencies in parentheses.

Table 4-1 Perceived Problems Associated with Previous Space Heating System

Problem and Frequency (max=17)	Sample Quotation
Cost to operate (16)	"It was horribly expensive. It was cost prohibitive to keep the house warm universally, and therefore we started to compromise our home comfort because of cost. My heating bills would be over $1,000 a month." (H17).
Old/needed replaced (8)	"It was getting old and the efficiency of it was going down... we knew that we would have to replace it in the near future." (H8)
Inconsistent heating/comfort (6)	"It didn't provide us with even heating throughout the house... some rooms were colder than others." (H1)
Unsanitary/dirty/smelly (6)	"The [oil] guy would come here and fill up our tanks and they would overflow and he would spill some by the truck and we could always smell it after he left. One time, he forgot to shut off the hose, and it overflowed on our basement floor and it stunk like oil for months... it was dirty, nasty stuff." (H13)
Unsafe (5)	"We didn't like that the oil furnace had an open flame... we didn't want a flame burning in our house or even to store oil, we didn't find it safe." (H15)
Inconvenient/time consuming (3)	"We're getting older and I was getting tired of splitting and stacking wood... so we decided that maybe we had done enough of that and wanted something that was easier and less of a hassle." (H12)
Unreliable (2)	"More than once, the wood pellet stove had quit in the middle of the day when we were working and we would come home and it would be 8 degrees inside, and we had a 3 year old daughter at the time, so we couldn't have that... we needed something that was more reliable because we couldn't afford to keep the baseboard heaters turned up all day." (H14)
Tanks are an eyesore (2)	"...with the new regulations, we weren't allowed to store our oil tank underground anymore. We had to store it right outside our front window in an ugly looking tank. We even built a lattice affair around it to try and hide it a bit." (H8)

As shown in Table 4-1, cost was the most frequently reported problem with previous space heating systems, with all but one (16 of 17) of the household decision-making units stating that their previous system was expensive to operate. Approximately half (8 of 17) of the household decision-making units asserted that their previous system was old and in need - or soon in need - of being replaced. Oil systems in particular were frequently cited as being unsanitary, dirty, smelly and unsafe. The three household decision-making units who reported that their previous heating system was inconvenient and time consuming to operate, used two separate systems in conjunction with one another to reduce operating costs (oil furnace and wood stove, oil furnace and corn stove and electric baseboard heaters and wood pellet stove). For example, household 12 stated "...that's why we used the wood, to offset the cost of oil... if we heated predominantly with oil, it would have been too expensive." Moreover, household 14 stated that they "...used the pellet stove to supplement heating, as using just the electric baseboards would be far too expensive."

Eleven of the 17 households also displaced some form of an electric space cooling system, such as a central air conditioning system (7) or a window air conditioner (4). Six of the 11 households did not report any problems with their previous cooling system, while the other five households identified four problem types. The problems, including frequencies in parentheses, were: cost to operate (4); old/needed replaced (2); noisy (2); and, poor performance (1). For example, household 11 stated that their previous air conditioning system was "expensive to run... did a lousy job cooling the house... and was about 30 years old, so was very inefficient and needed replace", which speaks to three of the above problem types, cost to operate, poor performance, and old/needed replaced, respectively. Also, household 4 stated that there air conditioner was "noisy and sucked hydro like crazy, making it costly to run", which addresses the noisy and cost to operate problem types, respectively.

To develop a potentially more insightful profile of household decision-making units' innovativeness prior to the adoption of their GSHP system, households were asked to list - in the two-page questionnaire - any other energy-efficient products or technologies they have adopted in the last 10 years. The self-reported list with frequency of adoption is provided in Table 4-2.

Table 4-2 Household Adoption of Additional Energy Efficient Products/Technologies in the Last 10 Years

Energy-Efficient Product/Technology (n=15)	**Frequency of Adoption (max=17)**
High efficiency clothes washer	**11**
High efficiency clothes dryer	**10**
High efficiency dishwasher	**3**
High efficiency refrigerator	**5**
High efficiency windows	**2**
High efficiency doors	**1**
LED lighting retrofit	**4**
Improved insulation	**4**
Mechanical water treatment system	**1**
On/off timers for lights	**1**
Solar lights for garden	**1**
Cell phone/tablet solar charger	**1**
Toyota Prius Hybrid-Electric Vehicle (2014 model)	**1**
Solar photovoltaic system	**4**
Invested in solar trackers and wind farm in Ontario	**1**

A total of 15 different energy-efficient products or technologies were reported to be adopted by household decision-making units in the last 10 years. The number of different energy-efficient products or technologies adopted by each household ranged between one and five, with a median of three. Of the four solar photovoltaic (PV) systems that were adopted, one 10kW system is installed on a shed roof (H4); one 8kW system is installed on a barn roof (H8); one 8kW system is installed on a garage roof (H11); and one 10kW standalone system is installed in a field (H2). Household 11 also has money invested in solar trackers and a wind farm in Ontario. In addition, three households (H3, H7 and H16) reported that they were in the process of assessing the feasibility of having solar panels installed on their respective properties.

To further measure innovativeness, household decision-making units were also asked if they would ever consider buying a hybrid and/or electric vehicle and to list 2-3 reasons why or why not. Hybrid and electric vehicles are similar to GSHP systems, as they are considered a type of high-involvement RET, due to their perceived innovativeness and higher upfront capital cost, compared to traditional internal combustion engine vehicles. Therefore, it was determined to be of utility to examine household decision-making units' willingness to purchase an analogous high-involvement eco-innovation. The range of responses were coded and categorized by factor - promoting or hindering adoption - and are displayed in Table 4-3, including frequencies in parentheses.

Table 4-3 Perceived Factors Influencing Hybrid and/or Electric Vehicle Adoption

Responses (n=17)	**Factors Influencing Adoption (Frequency)**
Yes (9)	Cost savings (8)
	Environmentally friendly (7)
	Reduced fossil fuel consumption (2)
	Clean (2)
	Quiet (1)
	To support an innovative automaker (1)
Maybe (5)	Environmentally friendly (5)
	Cost savings (2)
	Reduced fossil fuel consumption (2)
	Clean (1)
	Quiet (1)
No (3)	Poor reliability (2)
	Too expensive to purchase (1)
	Short range (1)
	Have never considered (1)

As mentioned above, one household in the study sample has already purchased a hybrid-electric vehicle (Toyota Prius). The three most significant factors that influenced the adoption of their vehicle were: (1) environmentally friendliness; (2) cost savings; and (3) to support an innovative automaker.

4.3 Characteristics of Household Decision-Making Units

The second determinant of adoption, characteristics of the household decision-making unit, will be explored in this section. Data about sociodemographic and household characteristics, personality variables and communication behaviour patterns were collected.

4.3.1 Sociodemographic and Household Characteristics

Of the 17 household decision-making units that were interviewed, eight were male; two were female; and seven were two-person, each involving a male and female participant. Results of the seven household decision-making units that involved two people are presented collectively; there is no distinguishing between the responses from the male or female participant.

Figure 4-2 provides a breakdown of the age groups of the 17 household decision-making units, using the average age group for the seven two-person decision-making units, to prevent double counting. The age of the decision-making units ranged between 18-29 to over 70 years old at the time of adoption, with a median age group of 40-49.

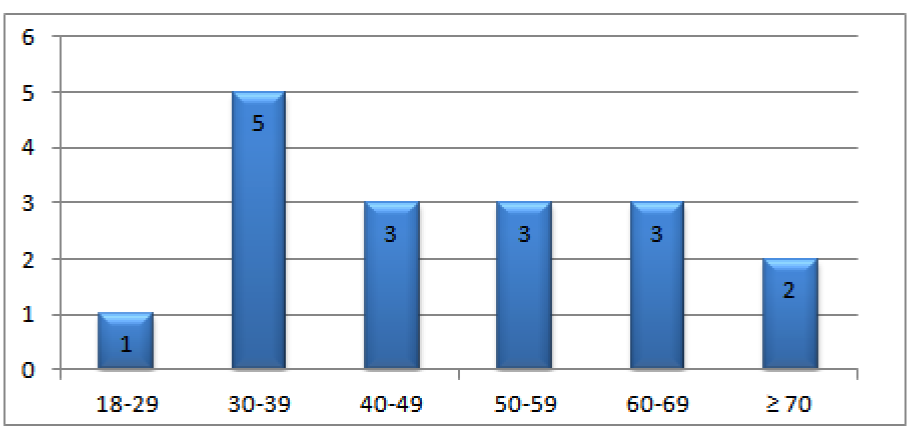

Figure 4-2 Age of Household Decision-Making Units in Years (n=17)

Figure 4-3 delineates the highest level of education obtained by each household decision-making unit at the time of adoption. For the seven two-person decision-making units, the highest level of education obtained between both individuals was selected. An individual in 10 of the 17 households had attained at least a bachelor degree, including four individuals who had received a graduate degree (two PhDs in Science and two MBAs) and two individuals who had received a professional degree (Doctor of Veterinary Medicine and Professional Engineer Designation). Out of the other seven household decision-making units, four individuals had received an apprenticeship or trades certificate, and three had completed their high school diploma, including one individual who took some university courses.

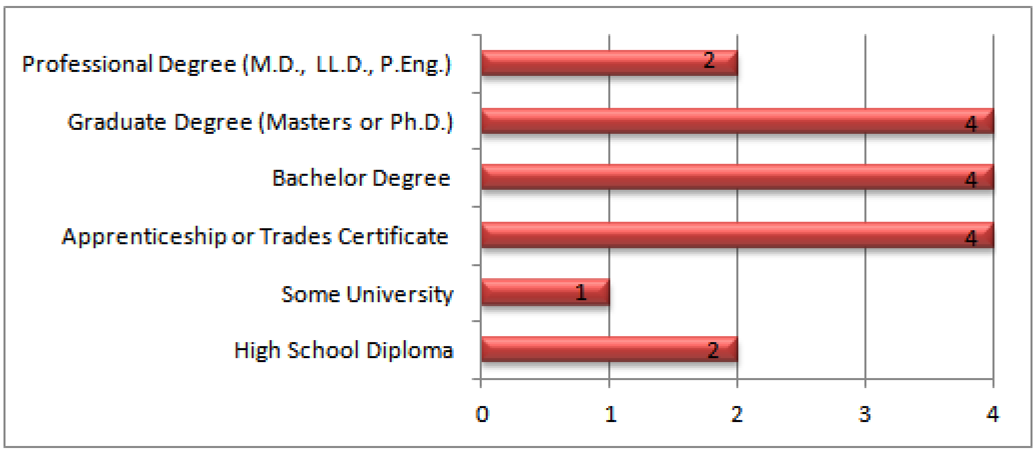

Figure 4-3 Highest Level of Education Obtained by an Individual in Each Decision-Making Unit (n=17)

Figure 4-4 summarizes household participants' occupation by classification at the time of adoption - or if retired when adoption occurred, at the time of retirement, classified according to the National Occupational Structure by Skill Type (Human Resources and Skills Development Canada, 2011). A range of different occupations were held among the 24 participants at the time of adoption, spanning eight classifications.

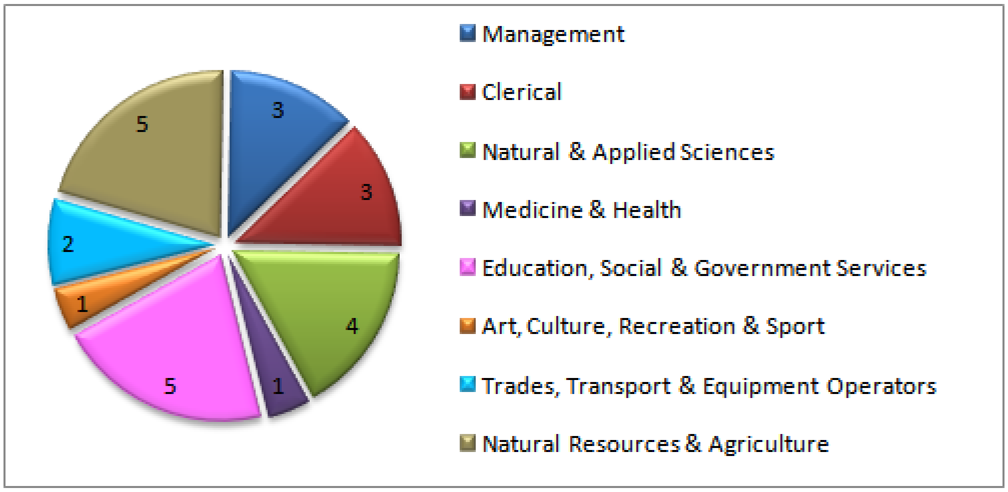

Figure 4-4 Occupation Classification of Household Participants (n=24)

As shown in Figure 4-5, pre-tax annual household income levels ranged between $50,000 to over $250,000 at the time of adoption or retirement. The median pre-tax household income level was between $100,000 - $149,999. Only four households had a pre-tax household income level of less than $100,000. Assuming an average Ontario tax rate of 29% for an income level of $100,000, and an average Ontario tax rate of 34.1% for an income level of $149,999, the median after-tax household income levels would be approximately $70,994 - $98,877[5], or $84,935. The median after-tax household income for Ontario is $73,290 (data are for 2011 and are taken from Statistics Canada, 2013a), indicating that households in the study sample, on average, may have been more wealthy than the median Ontario household.

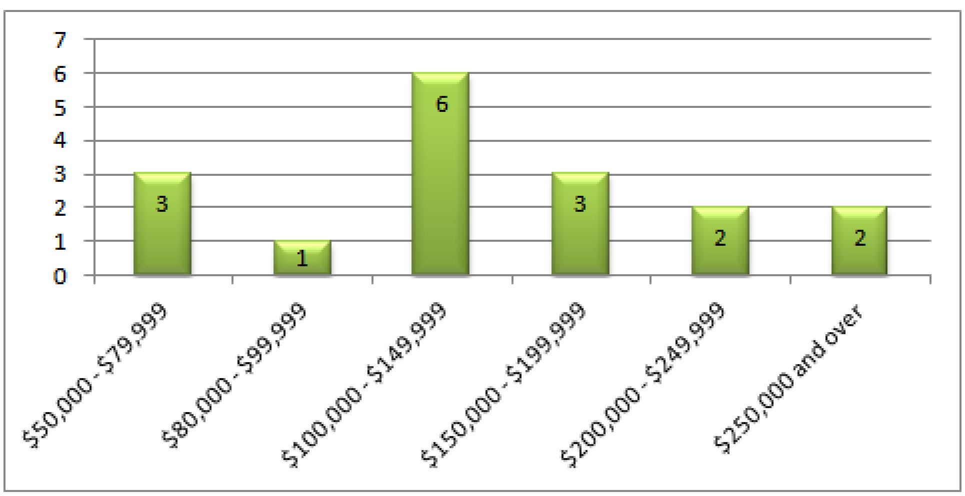

Figure 4-5 Pre-Tax Annual Household Income Levels at Time of Adoption/Retirement (n=17)

[5] Calculated from tax rates provided by Canada Revenue Agency (2014): http://www.cra-arc.gc.ca/tx/ndvdls/fq/txrts-eng.html

Data for house size were categorized into ranges, by square footage (not including basement), and are displayed in Figure 4-6. The median house size in the study sample at the time of adoption was 2,400 square feet, which is 60 percent larger than the average single-detached house in Ontario of approximately 1,500 square feet (Statistics Canada, 2007). Eight of the 17 houses were equal to, or larger than, 2,500 square feet, including three houses greater than 4,000 square feet. Only two houses in the study sample were smaller than the Ontario average.

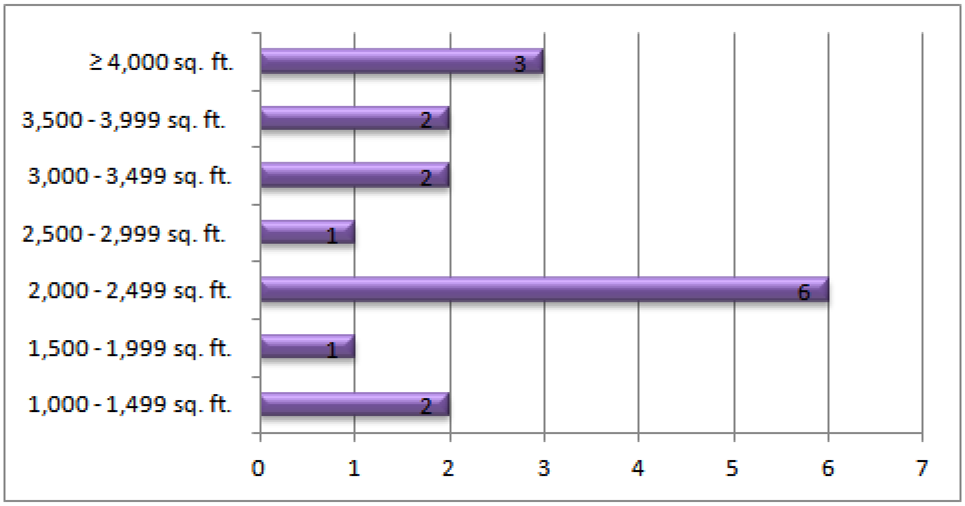

Figure 4-6 House Size by Square Footage Not Including Basement (n=17)

The median year that houses in the study sample were constructed in was 1983 (Figure 4-7). The three newest houses were built in or after year 2000, while the three oldest houses were built between 1850-1899; one of these houses had major renovations completed in 1990 and one had an addition to their house built in 2000.

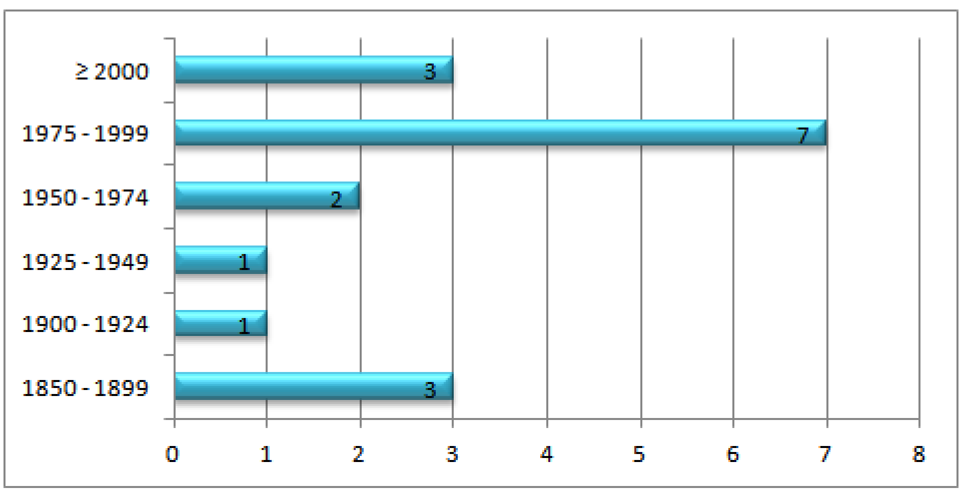

Figure 4-7 Year House was Constructed (n=17)

The median number of occupants living in each house in the study sample at the time of adoption was 3 (Figure 4-8), which is consistent with the Ontario average of 2.9 for single-family detached households (data are for 2009 and are taken from Statistics Canada, 2013b). Ten of the 17 households had three or less occupants, while the remaining seven households had four or more.

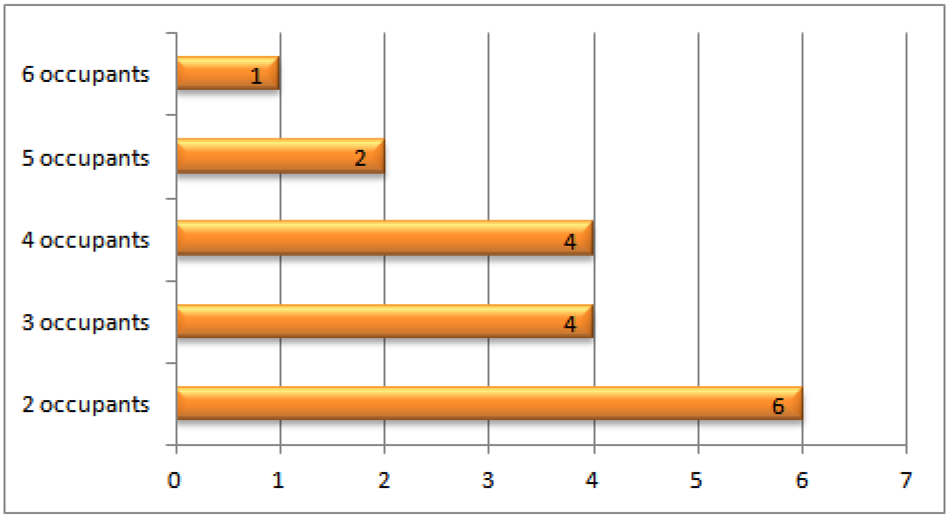

Figure 4-8 Household Size by Number of Occupants (n=17)

The median number of years each decision-making unit has been living in their current house for (where GSHP system was installed) is 10-14 years (Figure 4-9). Four decision-making units have been residing in their house for less than 5 years.

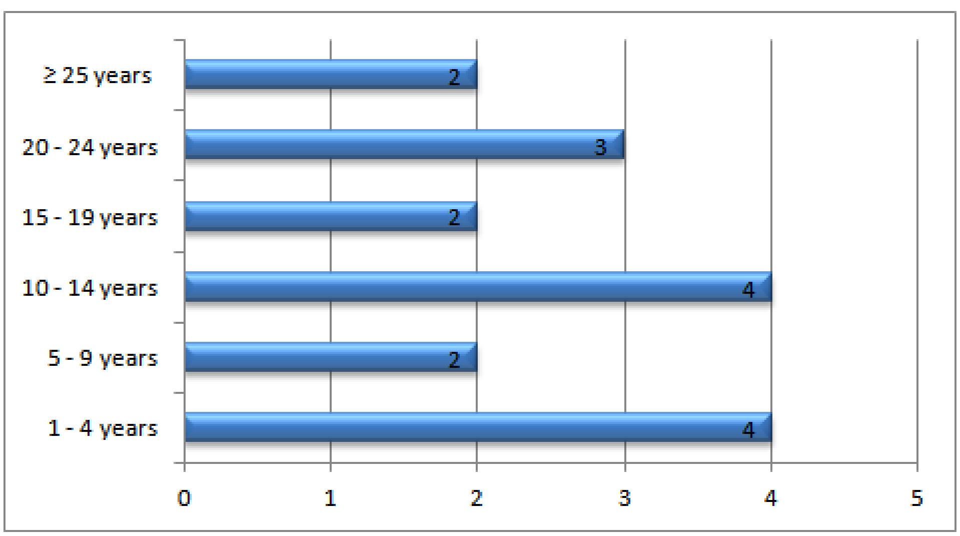

Figure 4-9 Number of Years Living in Current House (n=17)

The median number of additional years householders were planning to live in the same house is 15-19 years (Figure 4-10). Five decision-making units are planning to live in the same house for an additional 25 years or longer, while only one plans to move within the next 10 years (H14).

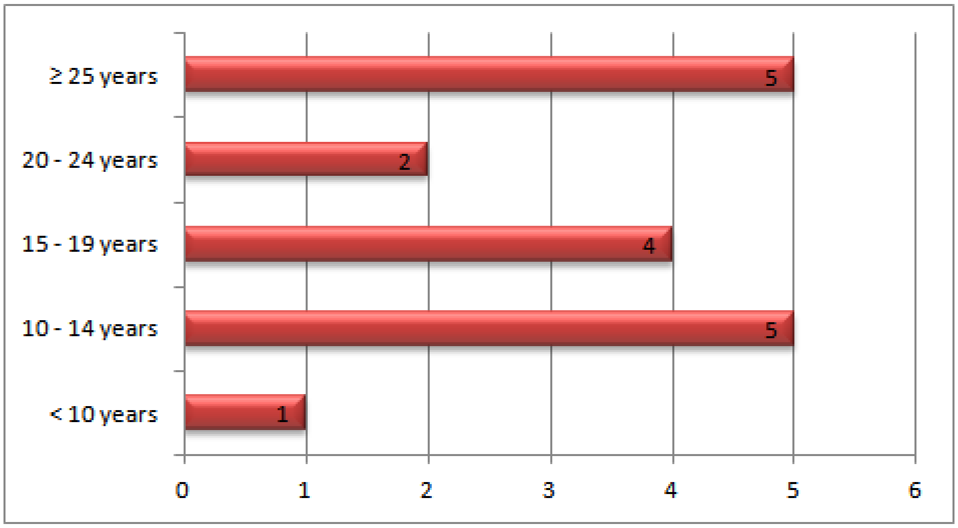

Figure 4-10 Number of Additional Years Planning to Live in Same House (n=17)

4.3.2 Personality Variables

The data for the six questions that were asked to measure personality variables are presented in the following tables and text in a summarized format, including sample quotations. Table 4-4 presents the data for household decision-making units' self-reported attitudes towards trying new things or new ways of doing things, which indicates that the majority (12 of 17) of household attitudes were "very favourable" (4), or closer to "very favourable" than "not at all" (8).

Table 4-4 How *favourable* is your attitude towards *trying new things or new ways of doing things*?

Scale	1	2	3	4	5
	Not at all ⟵			⟶	Very
Number of Responses (n=17)	**0**	**1**	**4**	**8**	**4**
Sample Quotation					
2	"I like to stick to what I'm familiar with..." (H14)				
3	"I like to see things proven before I jump into them... when a new idea comes along, I will research it thoroughly before I jump into it." (H7)				
4	"I wouldn't qualify myself as an early adopter... but I do enjoy trying new things..." (H11)				
5	"We will try or do anything. My next project is to build a Dutch windmill that has to pump water." (H2)				

Table 4-5 presents the data for household decision-making units' self-reported willingness to take risks, which indicates that just over half (9 of 17) of household attitudes were "very willing" (5), or closer to "very willing" than "not at all" (4).

Table 4-5 How *willing* are you to *take risks*?

Scale	1	2	3	4	5
	Not at all ⟵			⟶	Very
Number of Responses (n=17)	**0**	**3**	**5**	**4**	**5**
Sample Quotation					
2	"Pretty low..." (H8)				
3	"I am the safe kind of type." (H1)				
4	"We take risks quite often..." (H12)				
5	"I take risks, but I evaluate the risks first, so there's less chance of failure. I'd say it would be evaluating and taking prudent risk. I think taking no risk is a bigger risk..." (H17)				

Table 4-6 presents the data for household decision-making units' self-reported attitudes towards science, which indicates that the majority (16 of 17) of household attitudes were "very favourable" (12), or closer to "very favourable" than "not at all" (4).

Table 4-6 How *favourable* is your attitude towards *science*?

Scale	1	2	3	4	5
	Not at all ←			→	Very
Number of Responses (n=17)	0	0	1	4	12
Sample Quotation					
3	"I don't believe a lot of the things we are told... I think a lot of things are more political." (H2)				
4	"Pretty favourable, but I don't think that everything we read is necessarily true." (H7)				
5	"I believe because of science, there is an answer for everything." (H14)				

Two closed-ended questions from which two statements were read and the decision-making units had to select which statement they *most* agreed with, are presented below with the respective responses.

Question A19: Which of the following two statements do you *most* agree with?
1) Human beings can *solve* environmental problems through the use of technology.
2) Human beings *create* environmental problems through the use of technology.

The majority (10 of 17) of household decision-making units agreed more that human beings can *solve* environmental problems through the use of technology, as opposed to *creating* environmental problems with the use of technology.

Question A20: Which of the following two statements do you *most* agree with?
1) Human beings *have the power* to control the future.
2) Human beings are *powerless* and the future is determined by *fate*.

All but one (16 of 17) of the household decision-making units agreed more that human beings have the power to control the future and rejected the notion that the future is determined by fate and all events are predetermined and therefore inevitable.

The final question on the two-page questionnaire (E12) asked participants to choose which statement best describes their *willingness* to try new products (Table 4-7). The majority (11 of 17) of household decision-making units self-proclaimed that they are willing to try new products, but generally wait until someone they know has first to see how they like them. Four households claimed that they are excited about new products and are usually one of the first people to try them, while the remaining two stated that they are less willing to try new products.

Table 4-7 Self-Reported Willingness to Try New Products

Pre-Fixed Statements in Questionnaire	Number of Responses (n=17)
1) I am excited about new products and am usually one of the first people to try them out.	**4**
2) I am willing to try new products, but generally wait until someone I know has first to see how they like them.	**11**
3) I tend to hold off on new products until a majority of the people I know have purchased and are using them.	**1**
4) I am generally one of the last people to buy new products or try out something new.	**1**
5) I do not welcome new products and instead prefer to use or do what I have done in the past.	**0**

4.3.3 Communication Behaviour

The data for the three questions that were asked to examine communication behaviour patterns of household decision-making units that may have influenced adoption behaviour are presented in the following tables and text in a summarized format, including sample quotations. The majority (15 of 17) of household decision-making units self-reported that they have an average or high degree of social participation, while just two households claimed that they have a low, or below average, degree of social participation (Table 4-8).

Table 4-8 Degree of Social Participation

Scale	Low	Average	High
Number of Responses (n=17)	**2**	**5**	**10**
Sample Quotation			
Low	"We are not really social people. We moved out here in the middle of nowhere for a reason... for the most part, we like to keep to ourselves." (H14)		
Average	"I'm getting older, so I am less social than I used to be... I don't get out and about as much." (H5)		
High	"Running a company and doing what I do, I tend to be more social just by nature... and I think your awareness is heightened because of that. I travel the world for a living... I'm always in new places, meeting new people and thus have a wide range of social participation." (H15)		

Just over half (9 of 17) of the decision-making units self-reported that they are interconnected or very interconnected to other people living within their rural region (Table 4-9).

Table 4-9 Degree of Interconnectedness to People Living *Within* Rural Region

Scale	**1**	**2**	**3**	**4**	**5**
	Not at all ←			→	**Very**
Number of Responses (n=17)	**1**	**3**	**4**	**6**	**3**
Sample Quotation					
1	"We've only been living in this area for two years and since our house is in the country, our neighbours aren't as close by as they would be in a city... so we don't know many people in this rural region as a result of that." (H3)				
2	"My house in the country is more of a rural escape. We are not connected to our neighbours like people are in the city." (H15)				
3	"We do know all of our neighbours within walking distance, and my wife does some volunteering and other things within the area, but our overall network of friends and family is almost entirely outside of this rural region" (H6)				
4	"I have a strong connection to the people within this community through the volunteering work that I do." (H9)				
5	"There aren't too many places we go that we don't run into people that we know. We are very active in this community and because of that, we are highly connected to the local population. I would say we are almost fully connected to everyone to be honest." (H12)				

Moreover, the majority (10 of 17) of the decision-making units self-reported that they are interconnected or very interconnected to people living outside of the rural region in which they reside in (Table 4-10).

Table 4-10 Degree of Interconnectedness to People Living *Outside* of Rural Region

Scale	**1**	**2**	**3**	**4**	**5**
	Not at all ←			→	**Very**
Number of Responses (n=17)	**0**	**4**	**3**	**7**	**3**
Sample Quotation					
2	"I primarily work on the farm here, so I don't get to leave the area that often." (H7)				
3	"We are more connected to people in the local rural area, but we do have family and friends all across Ontario. It's easier to stay in touch with people outside of this area nowadays, with phones, texting and e-mailing." (H2)				
4	"I am on quite a few different committees for work, so I am often working outside of the Waterloo Region, so I am quite connected outside this rural area..." (H17)				
5	"Because of my business, I travel fairly extensively... so down to Michigan [U.S.] at least once a month for training and then all around the world too." (H4)				

As the above data illustrate, the majority of the decision-making units in the study sample have an average or high level of social participation and are interconnected or very interconnected to people living *within* and *outside* of the rural region in which they reside.

4.4 Innovation-Decision Process

This section describes the ways in which household decision-making units passed through each of five stages in the process in the adoption of their GSHP system, with a particular focus on the second stage, persuasion, where the decision-making unit forms a favourable or unfavourable attitude towards the innovation. This section will present the data for household decision-making units perceived characteristics of the GSHP system, the third determinant of adoption, including the factors that promoted (drivers) and hindered (barriers) their decision to adopt a GSHP system.

4.4.1 Knowledge Stage

This section describes how and when household decision-making units in the study sample became aware of GSHP systems and gained an understanding of how they functioned. In particular, this section will describe whether (1) household decision-making units became aware of GSHP systems *before* actively looking to replace their previous system, and if such awareness created a need or desire to purchase the system, or (2) household decision-making units became aware of GSHP systems because they were *actively* looking to replace their previous system, and whether such awareness created a need or desire to purchase the system. This section will conclude by examining household decision-making units' self-reported ability to understand and apply technical knowledge and whether they think that GSHP systems are a *simple* or *complex* technology.

Household decision-making units in the study sample became aware of GSHP systems through a variety of communication sources over different periods of time. The range of responses were coded and categorized into seven different communication sources, which are presented in Figure 4-11. Sixteen household decision-making units became aware of GSHP systems through some form of interpersonal communication (word of mouth), while only one became aware of GSHP systems via a mass media communication channel - more specifically, a billboard on a country road advertising GSHP systems and the government grant.

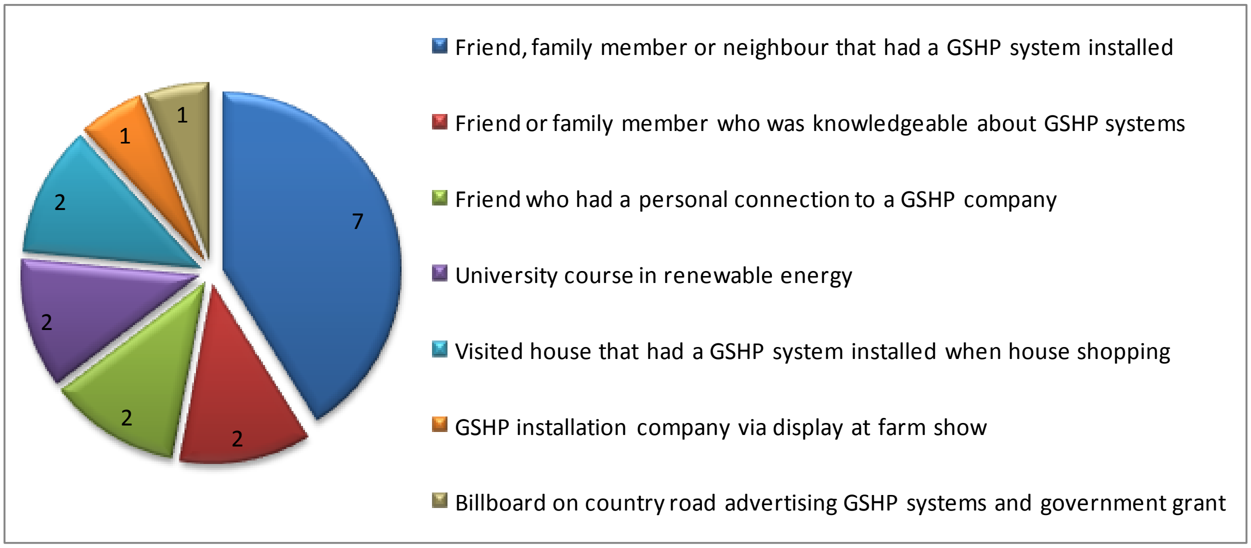

Figure 4-11 Communication Sources that Created Awareness of GSHP Systems for Households (n=17)

Of the 17 household decision-making units, 14 became aware of GSHP systems and gained an understanding of how they functioned *before* actively looking to replace their previous system. Such awareness of the GSHP system created a need to purchase the system for three of these 14 households, with two subsequently adopting a system approximately three years later, and one adopting a system a year and a half later. The other 11 households were satisfied with their previous system or were not in a position or motivated to adopt at the point of awareness for different contextual reasons (e.g. financial constraints or participant(s) did not own and live in their own house yet) and ultimately waited between five to more than 34 years later to adopt a system. The three remaining household decision-making units became aware of GSHP systems because they were *actively* looking to replace their previous system. When they became aware of the GSHP system as an option for them and developed an understanding of how it functioned, a need to purchase the system developed, and adoption subsequently followed, with all three households adopting a system within one year. Therefore, six of the 17 households developed a need to purchase a GSHP system once they became aware of the technology and gained an understanding of how it functioned, regardless of whether they were actively seeking to replace their previous system or not, with all six of these households adopting said system within four years of the point of awareness (Figure 4-12). The following example quotations illuminate the range of responses:

- "I became aware through a friend who had a system in his house, about 35 years before we installed ours, but they were cost prohibitive [to install] back then... really expensive." (H7)
- "It was through a friend who had another friend in the geothermal business and said that it might be something I would be interested in... knowing that I live in the country and have the available land to install it, and that I'm an environmental buff... so that's how I became aware and got into it... but prior to that, I was not actively looking to replace my propane system." (H4)
- "We became aware of geothermal energy as an option for us from my brother, as we were interested in replacing the previous oil furnace... we then did some internet research and learned more about how it works and what it would cost to buy and operate, and ultimately installed it [two months later]." (H3)

Figure 4-12 presents the number of years household decision-making units were aware of GSHP systems prior to adoption. Section 4.4.3 will discuss more on households' adoption decision-making periods, including a timeframe for when GSHP systems were adopted, and subsequently installed, in the study sample.

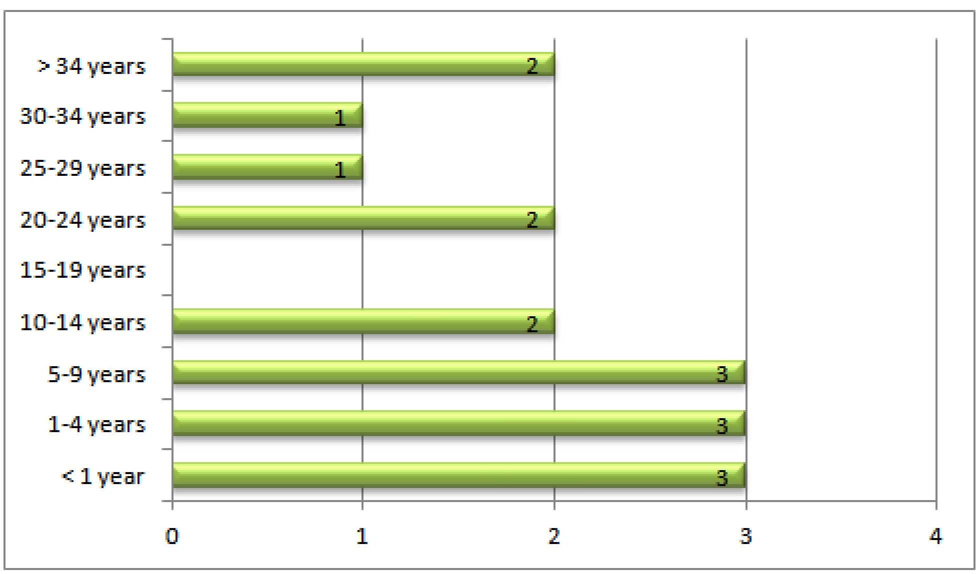

Figure 4-12 Number of Years Between Awareness and Adoption (n=17)

Table 4-11 presents the data on household decision-making units' ability to understand and apply technical knowledge in a summarized format, including sample quotations. Each household decision-making unit self-reported that they have an average or strong ability to understand and apply technical knowledge, with the majority (11 of 17) of households stating the latter.

Table 4-11 Ability to Understand and Apply Technical Knowledge

Scale	Weak	Average	Strong
Number of Responses (n=17)	**0**	**6**	**11**
Sample Quotation			
Average	"I'm not an engineer by any means. I can understand how my geothermal system functions, but I don't understand the science behind it..." (H3)		
Strong	"I am definitely above average and that's because of the industry I work in.. I do a lot of refrigeration work... I understand the way different heating and cooling systems work. [Our] geothermal system is fairly basic to me... it's similar to what I do every day." (H14)		

Moreover, household decision-making units were also asked whether they think that GSHP systems are a *simple* or *complex* technology (A12). Out of the 17 household decision-making units, 14 reported that they think GSHP systems are a simple technology, while only three felt that they are a complex technology, indicating that the majority of the study sample believed they were competent in understanding how the technology functions. The following examples illuminate such responses:

Perceive GSHP systems as a simple technology:

- "I think it's a very simple technology, it's just a simple heat exchange." (H2)
- "I would say they're a fairly simple technology... basically, it runs a lot like a refrigerator." (H10)
- "For the average person, I would lean more towards complex. But for me, because of the industry I work in, it's fairly simple. I install and troubleshoot these types of systems for a living." (H14)

Perceive GSHP systems as a complex technology:

- "I think they are more complex. There is simplicity to a burning flame that people are used to. If you have an open flame controlled in a unit and it forces out warm air, it is pretty straight forward. Whereas with geothermal, you are capturing thermal energy from underground and converting it to warm air... so it's much more complex, more science involved. (H11).

4.4.2 Persuasion Stage

This section will first identify and describe the factors, or perceived characteristics of the GSHP, that were influential to household decision-making units in their adoption process. Second, it will describe the role that the government grant(s) (i.e. change agent program) played in the adoption of said systems, if applicable. Third, it will identify the alternative space heating systems that the household decision-making units considered in their decision-making process, but ultimately rejected, in favour of the GSHP system. It will conclude by identifying and describing what perceived barriers the household decision-making units in the study sample suspect to be present for other rural households who have not adopted a GSHP system who continue to heat with oil, propane or electricity.

4.4.2.1 Perceived Characteristics of the GSHP System Influential to Adoption

To gain a better understanding of household decision-making units' perceived characteristics of the GSHP system that influenced adoption, they were asked during the primary interviews: "What were the most significant factors promoting or hindering your decision to purchase a GSHP system?" (B1). The range of factors considered by household decision-making units in the adoption of a GSHP system is presented in Table 4-12, including sample quotations, while Table 4-13 identifies the frequency in which each factor was considered, including their prompted nature. Factors that promoted or enabled adoption were coded as "drivers" and factors that hindered or delayed adoption were coded as "barriers." Factors that did not promote or hinder adoption, but were considered by the household decision-making unit, were coded as "neutral." In this chapter, results are presented in a summarized format, though further detail can be found in Appendix F.

Table 4-12 Factors Considered by Household Decision-Making Units in the Adoption of a GSHP System

	Factor (n=27)	Sample Quotation
Financial	Initial cost of system	"I would say the biggest barrier was the initial cost... it was a bit of a shock." (H7)
	Cost savings	"Our decision was really motivated by reducing costs... it wasn't trying to save the atmosphere or anything...." (H2)
	Length of payback	"We calculated that with the government grant, it would only be a 3 year payback period for us. So that made it a no brainer, since we [would be] saving $4,500 a year in heating costs." (H16)
	Government grant	"The grants were highly influential. I don't think without the grants that I would have had the courage to spend the full capital outlay on a heating and cooling system... I would have probably chosen the short-term solution, being a new high efficiency electric furnace... the grants were a huge catalyst." (H17)
	Inheritance of money	"A friend of my parents died and he left me some money, so my [partner] and I wanted to do something positive with the money, so we decided to look at geothermal energy for the house." (H13)
	Investment	"We looked at it as a smart investment at the time. We plan to stay in the house for a reasonable period of time, so we would see the payback and then if we did decide to move, it would still likely be reflected in the sale price of the house." (H10)
	Increase property value	"The other factor that I considered was whether it would increase the appraisal value of the property, which I found out that it would, so we felt that it made sense to go with geothermal, as a long-term investment." (H15)
Environmental	Sustainability	"Our main motivator was for environmental reasons. There is not an unlimited supply of fossil fuels, so I wanted us to get away from that to something that is more sustainable." (H4)
	Demonstrate environmental commitment	"The visibility or recognition component of it is important... it is important to me personally, that people know I am committed to the environment." (H3)
	Pleasure of using a RET	"...we feel good about it. We wanted to invest in something positive. We enjoy knowing that we heat this house with an environmentally friendly technology and are no longer burning oil. We feel less guilty. We just feel better that we are not hurting the environment as much... our environment footprint feels smaller." (H13)
Technological	Technological nature of system	"...the fact that you are taking energy out of the ground, which is free, for both heating and cooling, really intrigued me. I thought it was really neat how you could tap into a free renewable source of energy right in your backyard... that's pretty neat!" (H12)
	Cutting-edge technology	"Having something cutting-edge definitely was part of [my] buying decision, there's no question. I wouldn't consider myself an early adopter however. I just liked the idea of having something that was innovative... it's part of your overall psyche or persona, that you enjoy being leading edge." (H17)
	Reliability	"We liked that the systems were supposed to be reliable... we know [the technology] has been around for 30 years or so, and that the systems last for a long time." (H6)

	Ability to provide space cooling	"We would have had to replace our air conditioner if our propane system didn't break down, so getting both systems together was a bonus. This was a big factor for us, it made the capital cost seem cheaper, because you were getting two services out of the same system." (H11)
	Quality of heating	"We were sold on the [temperature] being very uniform throughout the house. Before, the bedrooms were a little cold with our propane system. Now, with geothermal, it is beautiful inside." (H2)
	No delivery of oil/propane	"We were really happy to cut our ties with the propane company and not have to count on the propane truck showing up here every month in the winter, or even paying a gas bill at all." (H6)
	Clean (sanitary)	"We really wanted something that was cleaner... with our [oil furnace and wood stove], it was always dusty and ashy in the house." (H12)
	Safe	"...we didn't like having a stinking oil tank down in our basement, because something could happen, health and safety wise... like a spill, or a fire or carbon monoxide... but you don't get that with geothermal, it is way safer." (H1)
	Maintenance free	"I liked that it is maintenance free. You take out the filter and wash it every three months... you don't need any checkups, because you don't have a boiler or burner. You don't have to worry about the heat exchanger burning out every three to four years." (H3)
Social	More convenient	"We wanted to get off the wood pellet stove as it required a lot of time and work each winter. Convenience was probably one of the biggest motivating factors." (H15)
	Opinion of others	"My cousin who works in the building industry was a very trusted source. He not only is aware of the technology because of his work, he has it in his house and really enjoys it. He was a very trusted source and a motivating reason why we went with geothermal." (H11)
	Lead by example	"I hope that given our experience and sharing our experience with friends and family, that if they are able to, whether by property or finances, that they will consider geothermal." (H3)
	Financial risk	"The main risk for us is how much the cost of electricity is going to increase by, relative to what we were paying for propane" (H11).
	Technological risk	"I think the only real risk is not having the system properly sized and installed and therefore does not perform optimally." (H14)
	Household disagreements	"My wife thought it was a lot of money [to spend] and we just moved into the house. It wasn't that she wanted to spend the money elsewhere, like on a kitchen upgrade... it was just that we moved and [she] didn't feel comfortable spending that money right away and that we should maybe try the oil furnace for a year." (H16)
Visual	Risk to lawn aesthetics	"Due to the nature of the system, you are taking a risk in regards to the aesthetics of your property, so land remediation would be a risk." (H8)
	Installed underground (not visible)	"I'm glad it's not intrusive... you don't want an eyesore." (H13)

Driver
Barrier
Driver/Neutral
Driver/Barrier

As Table 4-12 illustrates, the range of factors that influenced adoption were wide ranging. A total of 27 different factors that influenced adoption were identified across all 17 household decision-making units and are divided into five categories: financial, environmental, technological, social, and visual. Every factor was considered solely as either a driver or barrier across all household decision-making units, except for *quality of heating*, while primarily seen as a driver, was considered a barrier by one household. Household 12 stated that they were "a little concerned that it wasn't going to be as warm in [the house]... we didn't know whether geothermal was able to provide enough heating for the entire house." Two factors, *length of payback* and the system's *ability to provide space cooling*, were predominantly considered a driver by households, however in four of 10 cases and five of 14 cases, respectively, they were coded as neutral, as they were considered by the household, but ultimately did not influence their adoption decision. For example, for length of payback, household 12 claimed that "when hydro costs increase, so does the length of our payback, as we are paying more for hydro to operate our system... but length of payback [wasn't] a concern for us because we really just wanted to get off of oil and wood." Moreover, for the system's ability to provide space cooling, household 2 stated that "[they] wanted to buy geothermal for the heating part, to get rid of [their] oil system, so the cooling aspect was essentially free... it was more of a side benefit."

During the coding process, a number of specific responses were categorized under "sustainability." Factors related to sustainability yielded the most diverse responses within its categorization. Coded responses fell under one of the following five subcategories of sustainability, including frequencies in parentheses. The following sample quotations will illuminate such responses:

1) **Environment in general** (9): "Another strong influencing factor was that it was environmentally friendly." (H11)
2) **Renewable/clean form of energy** (4): "I also like that it's clean... being a farmer, I buy thousands of dollars of diesel every year, so I figured that I should look at an alternative heating supply for my house... something that is cleaner and makes more sense for the environment." (H7)
3) **Reduction of greenhouse gas (GHG) emissions** (6): "Reducing our carbon footprint was important for us." (H4)

4) **Reduced demand on fossil fuels** (6): "We really wanted to get off of fossil fuels as we thought there were more environmentally friendly ways to heat our house... and the price of fossil fuels is only going to go up." (H12)
5) **Energy self-sufficiency** (3): "For us also, a key thing is that we truly believe that in the future, it will be important to be energy self-sufficient." (H13)

Household decision-making units often identified more than one of the five subcategories of sustainability in their response. For example, household 12 reported that environmental considerations influenced their decision to adopt a GSHP system as "[they are] clean for the environment... you're not burning or emitting anything, so getting off of fossil fuels and reducing carbon dioxide emissions..." This response addressed the second, third, and fourth subcategory of sustainability outlined above, therefore, it was categorized under each respective subcategory.

While Table 4-12 identified the range of factors considered by household decision-making units in their decision to adopt a GSHP system, the significance of each factor varied among households. As question B1 in the interview guide (Appendix D) illustrates, household decision-making units were first asked the open-ended question: "what were the most significant factors promoting or hindering your decision to purchase a GSHP system?" When the decision-making units' responses failed to address any of the factors listed under each of the five categories (financial, environmental, technological, social, and visual), a prompt was used to explore other potential factors influencing adoption. All prompts were eventually revealed when household decision-making units failed to mention them in their response. The frequency of factors influencing adoption, including their prompted nature, is presented in Table 4-13. The median number of factors that influenced adoption for all decision-making units was 10, while the maximum was 16 and minimum was five, including both unprompted and prompted responses. For responses that were unprompted, the number of factors influencing adoption significantly declined; the median was five, while the maximum was nine and the minimum was two. See Appendix F for full list of factors identified by each household decision-making unit influencing adoption, including their prompted nature.

The factors have also been coded and categorized against Rogers (2003) five perceived characteristics of an innovation, plus an additional characteristic - relative *disadvantage*. Note that the factors are not mutually exclusive within each of the five perceived characteristics. The factors mainly related to the characteristic of relative advantage (17 factors) and compatibility (13), with only three factors relating to the characteristic of complexity, and two relating to observability. Three factors were also related to the characteristic of relative disadvantage - the initial cost of the system, quality of heating and risk to lawn aesthetics. None of the factors relate to trialability, which is to be expected, due to the nature of the system. However, factor 21, opinion of others, may be related to trialability, as households may 'try' the innovation vicariously through their peers, whose subjective opinions of the innovation (based on their personal experience) are more accessible and convincing to them.

Table 4-13 Presence of Drivers and Barriers Influencing Adoption by Household Decision-Making Units

Factor (n=27)	Innovation Characteristic [6]	Driver Unprompted	Driver Prompted	Driver Totals	Neutral Unprompted	Neutral Prompted	Neutral Totals	Barrier Unprompted	Barrier Prompted	Barrier Totals
Financial:										
1. Initial cost of system	RD							11	1	**12**
2. Cost savings	RA	16	1	**17**						
3. Length of payback	RA	3	3	**6**	1	3	**4**			
4. Government grant(s)	RA	10	3	**13**						
5. Inheritance of money	C1	1		**1**						
6. Investment	RA	3	2	**5**						
7. Increase property value	RA	4	1	**5**						
Environmental:										
8. Sustainability	RA/C1	11	1	**12**						
9. Demonstrate environmental commitment	C1		5	**5**						
10. Pleasure of using a RET	C1		8	**8**						
Technological:										
11. Technological nature of system	RA		5	**5**						
12. Cutting-edge technology	RA		3	**3**						
13. Reliability	RA/C1	3	4	**7**						
14. Ability to provide space cooling	RA/C1	5	4	**9**	1	4	**5**			
15. Quality of heating	RA/RD		6	**6**					1	**1**
16. No delivery of oil/propane	RA/C1	2	2	**4**						
17. Maintenance free	RA/C1		2	**2**						
18. Clean (sanitary)	RA/C1	2	3	**5**						
19. Safe	RA/C1	4	3	**7**						
Social:										
20. More convenient	RA/C1	2	1	**3**						
21. Opinion of others	C1	1	7	**8**						
22. Lead by example	C1		7	**7**						
23. Financial risk	C2								4	**4**
24. Technological risk	C2								6	**6**
25. Household disagreements	C2								1	**1**
Visual:										
26. Risk to lawn aesthetics	RD/O								3	**3**
27. Installed underground (not visible)	RA/O		7	**7**						

[6] RA: Relative advantage; RD: Relative disadvantage; C1: Compatibility; C2: Complexity; O: Observability; T: Trialability.

As Table 4-13 indicates, a wide range of factors have been identified as being influential to the households' decision to adopt a GSHP system. By large, the most frequently identified driver for adoption (i.e. factor that promoted or enabled adoption) was cost savings, followed closely by the government grant(s) and factors related to sustainability. All 17 decision-making units in the study sample identified cost savings as a driver for adoption, including 16 unprompted responses. All 13 households that received a government grant identified it as a driver for adoption, including 10 unprompted responses. Twelve of the 17 household decision-making units identified factors related to sustainability as a driver for adoption, including 11 unprompted responses that fit in one or more of the five subcategories of sustainability.

The most frequently identified barrier to adoption (i.e. factor that hindered or delayed adoption) was the initial capital cost of the GSHP system, identified by 12 of the 17 household decision-making units, including 11 unprompted responses, distantly followed by technological and financial risks.

While the purpose of Table 4-13 was to identify the frequency and manner in which each of the factors was perceived and identified, it is important to note that unprompted responses did not always imply that it was of primary significance. For example, although 10 household decision-making units stated, unprompted, that the government grants were a driving factor for adoption, two of these stated that they would still have purchased a GSHP system without the presence of the financial incentive, indicating that it was not a determining force behind their adoption decision. For this reason, factors were coded as being of either *primary* or *secondary* significance to the household decision-making unit's decision to adopt a GSHP system.

Factors that were coded as secondary significance yielded expressions such as "... it wasn't a primary determining factor, but I did consider it important" or "it played a small role in our decision-making process, but was not at the forefront." These factors were also neither identified as being the most or least significant. Factors that were coded as primary significance were identified without prompt and as being the most significant in promoting or hindering their decision. The following examples warranted such coding:

- "Our decision was really motivated by..."
- "The biggest motivator for us was..."

- "[Blank] played a huge role in our decision..."
- "[Blank] was the biggest motivator."
- "The biggest barrier was definitely..."

Figure 4-13 presents the results on the identified significance of factors influential to the household decision-making unit's decision to adopt a GSHP system.

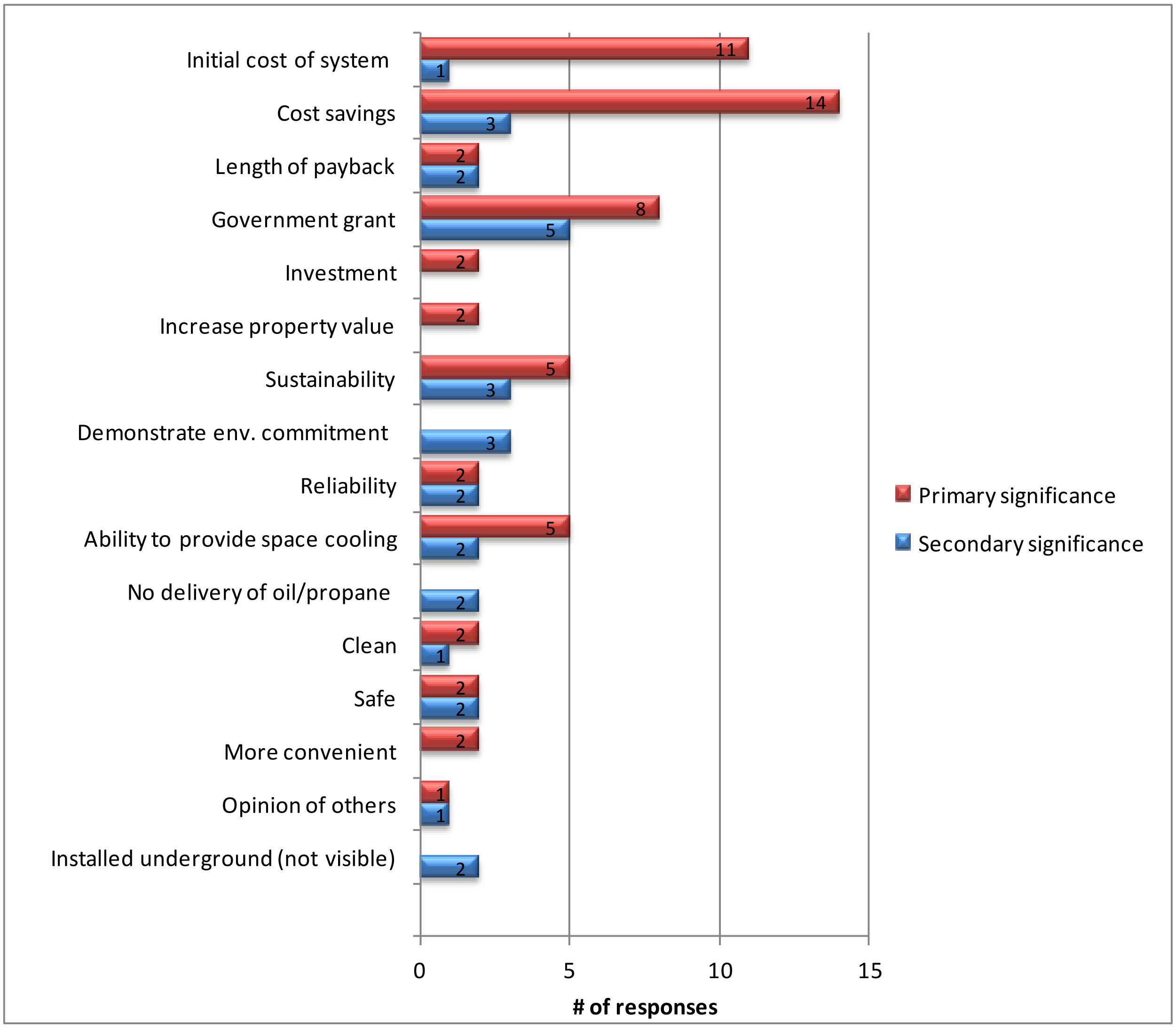

Figure 4-13 Identified Significance of Factors Influencing Adoption for Households

When examining significance, the range of factors influential to adoption, is greatly reduced; however, cost savings, the government grant(s) and sustainability remain the most significant drivers for adoption, followed closely by the system's ability to provide space cooling. While the initial cost of the system remains a significant barrier hindering the adoption of a GSHP system, it must be noted that household decision-making units in the study sample were able to overcome this barrier, as ultimately everyone adopted said system. In summary, it is evident that the perceived relative advantage of the GSHP system over previous systems most significantly influenced adoption, followed closely by the system's compatibility to household decision-making units' existing values, beliefs, past experiences and needs.

4.4.2.2 The Role of a Financial Incentive in the Adoption of GSHP Systems

The fourth determinant of adoption, change agents programs, will be explored in this section; namely, the role of the government grant(s) in the adoption of GSHP systems. As identified in the previous section, the government grant(s) were a significant driver for adoption among households in the study sample. A total of 13 household decision-making units adopted a GSHP system in the presence of a financial incentive. Seven households received a federal grant through Natural Resources Canada's ecoENERGY retrofit program (a federal government program), valued at $4,375, and a matching provincial grant from the Ontario Government, for a total of $8,750. Both of these grants were available together to homeowners for retrofitting their house with a GSHP system from April 2007 to March 31, 2010, when the Ontario Government eliminated their matching grant. Five households received just the federal grant through the ecoENERGY retrofit program, valued at $4,375, from April 2010 until the program closed on March 31, 2012. The final household that received a grant, installed their system in July 2006 and received $1,500 from a source that they could not remember. The four household decision-making units in the study sample that did not receive a government grant, installed their system after March 31, 2012.

Only five of the 13 household decision-making units that received the government grant(s) reported that they would still have purchased a GSHP system without the presence of a financial incentive. Three of these households received just the federal grant, while one household received both the federal and matching provincial grant and the final household received $1,500 from a source that could not be recalled. Household 3, who received the federal grant, claimed that they would still have purchased their GSHP system without the grant, as "...getting $4,375 back on a $25,000 investment was nice, but it was not enough to make or break our decision... we would still have made the purchase as it would result in cost savings in the long-term." Household 13, who received both the federal and matching provincial grant, had also recently inherited money from a family friend, so the government grants were of less significance to them, as they wanted to do something positive with the money. When asked if they would still have purchased a GSHP system without the presence of the government grant(s), they stated "...yes, we would have. It would have made the payback period a little longer, but it still made so much sense for us. Plus, we just received a bunch of money and wanted to invest it into something positive."

The remaining eight household decision-making units that received the government grant(s) stated that they would not have purchased a GSHP system without the presence of a financial incentive. Of this eight, seven households received both the federal and matching provincial grants, while one household received just the federal grant. Household 17, who received both grants, claimed that "The grants were highly influential. I don't think without the grants that I would have had the courage to spend the full capital outlay on a heating and cooling system... I would have probably chosen the short-term solution, being a new high efficiency electric furnace... the grants were a huge catalyst." Moreover, household 6, who received just the federal grant, claimed that they would not have purchased a GSHP system without the financial incentive. When asked if they would have purchased a GSHP system without the presence of the government grant, household 6 claimed "No, and I can pretty safely say that... it would have increased the payback period by four or five years, and we would have just kept with the propane system as it was still running fine."

Household decision-making units were also asked if they thought that the government should always have some form of a financial incentive available to homeowners for installing a GSHP system. Fifteen household decision making-units responded with a "yes," while the remaining two stated that they were "unsure." A range of different responses was collected, including different suggestions and viewpoints regarding what form of a financial incentive the government should have available. The following examples will help elucidate the different perspectives:

- Household 6 asserted that they "...think a smart government should put in policy to help move away from fossil fuel dependency, and a rebate program is a good way to do this because people feel good about getting money back for doing something that is environmentally friendly."
- Household 4 stated that "...the government could make an incentive at the other end, such as reducing the upfront cost of the actual system, by making the equipment more affordable."
- Household 15 stated that they "...would really like to see the government introduce tax breaks for people who install a geothermal system."
- Household 9 felt that before reintroducing some form of a financial incentive available to homeowners for installing a GSHP system, "...the government should massage the numbers and find out how much money they should devote to this type of program, based on an environmental cost-benefit analysis... maybe a grant of $1,000 would be a better use of taxpayers' dollars."

The above range of responses illustrates the diversity of opinions and viewpoints regarding the form of a financial incentive that the government should have available for installing GSHP systems.

4.4.2.3 Consideration of Alternative Space Heating Systems

This section will identify the alternative heating systems that the household decision-making units considered at the persuasion stage, but ultimately rejected, in favour of the GSHP system. Eight of the 17 households did consider one or more alternative heating systems in their decision-making process, while nine stated that they only considered a GSHP system for the various reasons outlined in section 4.4.2.1. Also, six of these households did not consider any alternative heating system because they were not actively looking to replace their previous system, until they became aware of the GSHP system and developed a need for it (see section 4.4.1). Of the households that considered an alternative heating system, five considered a high-efficiency propane furnace, two considered a high-efficiency oil furnace, and one considered a high-efficiency electric furnace.

A significant factor driving household decision-making units' decisions in favour of the GSHP system over alternative systems, was the availability of the government grant(s). Six of the eight households who considered an alternative heating system reported that they ultimately adopted a GSHP system largely because the government grant(s) made the initial cost of the system more comparable to alternative systems. For example, household 13 stated the following: "We asked for a quote on a new oil furnace and that was for about $10,000 and our geothermal system was quoted for $23,000, but we could get both [government] grants, valued at almost $9,000, making the difference in cost only $4,000, meaning that we were looking at a payback period of just two to three years to pay off that extra $4,000." Moreover, household 14 stated that they "...priced out a propane furnace, the ductwork, the tank, and an air conditioner, and it would have [cost] around $11,000, whereas our quote for geothermal was $20,000 and we could get about $4,500 back from the government, so then we were talking a $4,500 difference and that would be paid off within a couple of years." Both of these examples illustrate that with the government grant(s), the initial capital cost of the GSHP system becomes much more competitive with alternative heating systems.

Moreover, two household decision-making units stated that they ultimately adopted a GSHP system because it could also provide space cooling, as they previously did not have any form of air conditioning. For example, household 1 stated that "[they] really wanted air conditioning, so the fact that a geothermal system could provide both heating and cooling was a main reason for purchasing it." The perceived relative advantage and compatibility with the household decision-making unit's existing values, beliefs, past experiences and needs, were identified as the most influential perceived characteristics of the GSHP system that influenced adoption over alternative heating systems.

4.4.2.4 Perceived Barriers to Adoption for Other Rural Households

During primary interviews, household decision-making units were asked what they perceived were the three biggest reasons or barriers preventing other rural Ontario households that heat with oil, propane or electricity from converting to a GSHP system (D4). The range of responses were coded and categorized into seven different types of barriers, which are displayed in Table 4-14, including frequencies in parentheses and sample quotations.

Table 4-14 Perceived Barriers Preventing Other Rural Ontario Households from Adopting a GSHP

Barrier (max=17)	**Sample Quotation**
High initial capital cost (16)	"I think that the initial cost is a big barrier. Not many people have $20,000 to put out... if they can get a new furnace for $5-10,000, they are going to do that. I think people are only concerned with the short-term and don't look at the long-term potential savings, like my [partner] and I did." (H3)
Lack of consumer awareness and/or knowledge of GSHP systems (14)	"Lack of awareness... I think that's one of the biggest issues. There is a lack of understanding that there is an alternative to oil and propane... people aren't aware of geothermal as an option for them" (H6)
Lack of trust or confidence in the perceived benefits of GSHP systems (7)	"Lack of trust in the economic benefits... I think there's a cynicism with the benefits of geothermal. I think that it maybe sounds too good to be true for many people." (H17)
Inadequate land space (6)	"The last barrier I would say is that many people don't have the land to install the system horizontally and they don't want to go vertical because people are afraid of that." (H3)
Not motivated to replace existing system if still working fine (5)	"If their current system is working fine, I don't think people are going to rip it out to put in a geothermal system. I don't see the economic value of putting in a geothermal system when your existing oil or propane system is working fine. I [don't] think retrofitting your house when your existing system is still working fine makes sense." (H14)
Skepticism towards the functionality of GSHP systems (2)	"Lack of trust in the technology, that it would be capable of heating an entire house, such as a large farmhouse. Some people probably think that geothermal can't keep up with cold Canadian winters. Everyone is so used to heating with fuel, such as oil and gas, or even wood, so when they don't have that, and they are using this perceived newer technology, they are skeptical that it can't provide adequate heating or that it isn't reliable." (H12)
Length of payback (1)	"Length of payback... some people might not know how long they will be living in that house for and if they will see their [return on investment]... or if somebody is young or elderly and are thinking of moving away... I would say that the ROI is too long for anyone who doesn't think they will be living in the same house for at least 5-10 years." (H7)

As displayed in Table 4-14, the high initial capital cost associated with the adoption of GSHP systems was the most frequently identified perceived barrier preventing other rural Ontario households that heat with oil, propane or electricity from converting to a GSHP system. This finding is consistent with what the households reported was the biggest factor hindering *their* decision to adopt a GSHP system as well. Lack of consumer awareness and/or knowledge of GSHP systems and lack of trust or confidence in the perceived benefits of the technology, were the second and third most frequently identified suspected barriers to adoption, respectively.

The majority of household decision-making units stated that they believe there is a general lack of awareness of GSHP systems and trust or confidence in the associated benefits. Household 4, in particular, believes there is a major lack of awareness and that the technology. They argued that it "...needs to be advertised more... there needs to be an overarching geothermal authority that does the advertising, or the government. Standalone companies don't want to advertise when it will cost them the money, but will reward other installers in the area as well." Moreover, household 9 argued that "...there is a lack of awareness of the technology and the associated benefits because everyone hears about the initial cost and that's all they know, just that it's expensive. I think that's what stops people from learning more about it, as they don't see the point if they can't afford it."

4.4.3 Decision-Implementation Stage

The decision stage in the IDP takes place when the decision-making unit engages in activities that lead to a choice to adopt or reject the innovation. The implementation stage occurs when the decision-making unit puts the innovation to use. As implementation usually follows the decision stage rather directly (Rogers, 2003), both stages will be discussed together in this section. In particular, this section will examine the number of quotes household decision-making units received before selecting a company and having the system installed. It will then provide a breakdown for when each of the GSHP systems was installed, including pre-installation levels of uncertainty and/or confidence in the perceived performance of the technology. Finally, it will describe households' opinions of the installation process, such as the level of disruption to their property (i.e. lawn).

Eight household decision-making units received just one quote, while six received three quotes, and the remaining three received, two, four and six quotes, respectively. Each of the systems in the study sample was installed between July 2006 and May 2013, a seven year span. As mentioned in section 4.4.2.2., 13 systems were installed between July 2006 and March 31, 2012, when some form of a financial incentive was available. The other four households installed their system between March 31, 2012 and May 2013. The innovation-decision period, which is the length of time required for a decision-making unit to pass through the IDP, which is usually measured from first knowledge to the decision to adopt or reject the innovation (Rogers, 2003), varied substantially within the study sample. As Figure 4-12 in section 4.4.1 illustrates, the number of years between awareness to the decision to adopt the GSHP system ranges from less than a year to over 34 years. Just over half (nine of 17) of the decision-making units installed their system within nine years of awareness (including six within four years), while the remaining eight waited between 10 years to more than 34 years to adopt a system. However, in some cases, decision-making units were not in a position to adopt the technology at the point of awareness for different contextual reasons. For example, household 15 stated the following: "I always knew about geothermal growing up in the country, from friends who had a system in their house. I knew of geothermal long before I even owned my own house."

At the time of installation, three household decision-making units asserted that they still experienced a degree of uncertainty towards the performance of the technology. For example, household 6 stated that "...the only thing that we worried about was whether or not it could keep up with cold Ontario winters... we just worried if we would be able to keep the temperature up to what we were comfortable with." Similarly, household 17 stated that they "...were a little worried that the system wouldn't be able to keep the entire house warm enough, as it is a rather large house." Household 12 claimed they experienced a degree of uncertainty prior to installation, stated that "... we were a little worried whether the geothermal could heat the entire house alone, with no secondary source... we were just a little skeptical because we've always been used to having a backup heating source."

The other 14 household decision-making units claimed that they did not experience any degree of uncertainty towards the performance of the technology at the time of installation and that they were confident that the system would result in positive consequences. For example, household 10 stated that they "knew that it would be more cost-effective and that it would be reliable... there was never any skepticism." Moreover, household 7 claimed that they did not face any degree of uncertainty because they "...had done quite a bit of research and was fairly familiar with how the technology worked." They asserted that "...you just have to do your due diligence, that's what I would recommend... do the research, talk to different people that have installed the system, talk to the installers themselves... there's all kinds of sources out there, you just have to spend some time and research it." Likewise, household 17 claimed that they were "without a doubt" that the system would result in positive consequences. Specifically, they stated that they "...did [their] research and spoke to different households that had a system installed." In general, the majority of household-decision making units were confident from their research efforts that the GSHP system would result in positive consequences.

Household decision-making units were asked what their opinion was of the installation process of their GSHP system. Opinions ranged from positive to negative and have been categorized as positive, negative or mixed. A positive opinion corresponded with solely positive statements, while a negative opinion corresponded with solely negative statements. In the middle of these two categories is the mixed category, which includes opinions that contained both positive and negative statements towards the installation process. Sample quotations for each type of opinion are provided below, including frequencies in parentheses (n=17).

Positive Opinion (11): "Oh my gosh, it was amazing. It was really good. They came in Wednesday morning and by Friday afternoon we were all hooked up. You couldn't even see where the trenches were dug two weeks later. Gosh, they were in, they were out, they were clean... they were really, really nice people and great at what they did." (H13)

Mixed Opinion (3): "We were impressed with the company. It only took them about two days... they were very efficient. However, it did leave a lot of repair work for me to do the following spring... more than what I had hoped for, but it wasn't the end of the world." (H9)

Negative Opinion (3): "Oh, it was a mess. I did not expect the landscaping repair work that I would personally have to do after. It probably took two to three springs and summers after to actually get the landscaping blended in, looking like it did before the installation took place." (H17)

Household decision-making units were also asked if there was any disruption to their property and if so, was it less than, equal to, or more than what they had anticipated, due to the nature of the installation process. Twelve households stated that the level of disruption was equal to what they had anticipated. For example, household 1 said "I remember they installed it when it was very muddy out, so it was a little disruptive to our lawn, but no more disruptive than what we thought it would be." Four households stated that the level of disruption was more than what they had expected. For example, household 15 stated that "...some things were unexpected, such as the amount of stones that were excavated... after backfilling everything, [the] lawn was like a stone field... I know my [partner] was very upset with having our lawn dug up to install the system." Only one household (H13) stated that the installation process was less disruptive than what they had anticipated, and are quoted above saying "You couldn't even see where the trenches were dug two weeks later.... maybe that's just [my partner] and I and that we don't let little things like that bother us... we never really had a fully landscaped backyard anyways."

As the above examples illustrate, household decision-making units had a range of experiences with the installation process of their GSHP systems; however, the majority of these were positive and what households anticipated.

4.4.4 Confirmation Stage

The confirmation stage is the fifth and final stage in the IDP and is where the decision-making unit seeks reinforcement for their decision to adopt the innovation. At this stage, the decision-making unit seeks to avoid cognitive dissonance or reduce it, if it does arise (Rogers, 2003). Household decision-making units were asked to describe their overall experience in learning about and purchasing a GSHP system as positive, negative or mixed. Experiences ranged from "fairly positive" to "really, really positive," while no single household stated that there experience was less than positive. The following examples illuminate the range of responses from most to least positive:

- "It was really, really positive. It was a 10 out of 10 experience." (H13)
- "I would say it was a very positive experience. All of the information that I was getting answered all of the concerns that I had, especially when it came down to the numbers... the overall experience was enjoyable, very informative... everything went really smooth." (H4)
- "It was fun. I really enjoyed learning about and working with that kind of technology. I enjoyed researching it and learning more about it. It was enjoyable and informative. It was a very positive experience." (H15)
- "Positive... I can't think of a negative. Well, the whole process took a lot of time and parts of it were a hassle, because there was a lot of drop ins... three appointments for three different quotes, then the pre-audit, then the post-audit... there was just a lot of people in

the house, then you have to take time of work to be here... it was just time consuming. But again, if I am spending that kind of money, it should be a rigorous process..." (H6)

- "Overall, it was a fairly positive experience. I think it's no different than going out to purchase a new car, or upgrade your kitchen... you have to do your homework." (H16)

Household decision-making units were then open-endedly asked if they were currently satisfied with their decision to adopt a GSHP system. All households reported that they were satisfied, with responses ranging from "Yes, I am satisfied" to "Yes, very satisfied," with the majority (13 of 17) of households using expressions such as "absolutely" or "more than ever", or "highly," satisfied. The following examples elucidate the level of enthusiasm household decision-making units have with their decision to adopt a GSHP system and why:

- "More than ever, that propane prices unexpectedly went up so much [this past winter], resulting in us getting the ROI on the system before we expected." (H6)
- "Absolutely! The comfort in our home has improved so much that the quality of life has increased. Second, it is much more cost-effective, and third, it has increased the value of our home." (H17)
- "Yes, very satisfied. It gives us more even heating and cooling throughout the house. So we're getting a better product or system than we had before. We are now approaching year three, so the system will soon be completely paid for and then we will be seeing financial savings. We've also had no issues with the system yet... no complaints." (H9)
- "Yes, I am. I think we switched at a good time too, because the price of oil has only gone up since, so we would have been paying a lot more now for oil, if we didn't switch." (H8)
- "Yes, I am satisfied, because it is saving me money, it's clean, we [now] have air conditioning and don't have to worry about storing an oil tank in our basement for health and safety reasons." (H7)

Lastly, household decision-making units were asked if they have recommended purchasing a GSHP system to anyone yet, and if not, would they recommend this purchase to someone in the future. Based on the high level of satisfaction that household decision-making units have with their decision to adopt a GSHP system, every household has recommended purchasing a GSHP system to either family, friends, neighbours, work colleagues, or clients. Just over half (nine of 17) of the decision-making units claimed, in one way or another, that they are "advocates" or "endorsers" for geothermal and "promote it whenever [they] can." For example, household 13 stated that "...if there is anyone who ever wants to learn more about geothermal, bring them to us... we are happy to talk about it... we always say the best thing we have ever done for our house is put in a geothermal system." Conversely, the other half stated that they "are not pushy" or they are not "trying to sell it to anybody" or "out beating a drum," but will "speak positively about it" and recommend it to people if it is brought up in conversation.

This section demonstrated that the household decision-making units in the study sample are satisfied with their decision to purchase a GSHP system, share mostly positive experiences throughout their IDP, and have since recommended purchasing a GSHP system to potential adopters.

4.5 Communication Channels

Communications channels are the fifth and final determinant of adoption that this study examines; it will be discussed in this section. This section describes what communication channels and information sources household decision-making units used to inform their decision to purchase a GSHP system. It will conclude by describing what information sources were identified as the most and least useful and credible in helping them make the decision to purchase a system.

Household decision-making units in the study sample used both mass media and interpersonal communication channels to inform their decision to purchase a GSHP system. During the primary interviews, participants were asked to list the information sources that they used to inform their adoption decision. The range of responses were coded and categorized into 10 different information sources, which are presented in Table 4-15, including the frequency that each source was used across household decision-making units.

Table 4-15 Communication Sources Used by Household Decision-Making Units to Inform Adoption Decision

Information Source (n=58)	Number of Responses (max=17)
GSHP installation companies	17
Internet	15
Friend/family member/neighbour/work colleague who had a GSHP system installed	11
REEP House & Elora Environmental Centre	4
Billboard/signs on country road advertising GSHP systems and government grant	3
Magazines & newspapers	2
GSHP equipment manufacturer/supplier	2
GSHP company client testimonials	2
Television advertisement	1
University course in renewable energy	1

As Table 4-15 illustrates, household decision-making units in the study sample used a variety of different information sources through both mass media and interpersonal communication channels. The median number of different information sources household decision-making units used to inform their decision was three, while the maximum was five and the minimum was one. Household 8 became aware of the technology via a GSHP company display at a farm show and received the company's contact information and subsequently arranged a meeting; they had the system installed three years later (once finances were aligned), using only the GSHP installation company to inform their decision.

Five types of information sources were obtained from mass media communication channels (i.e. internet, billboard/signs, magazines/newspaper), while five were obtained from interpersonal communication channels (i.e. households that have had a GSHP system installed, GSHP equipment manufacturer/supplier, university course in renewable energy). The frequency in which both types of communication channels was employed is greater for interpersonal communication channels. All decision-making units obtained information from GSHP installation companies, via different pamphlets/brochures, PowerPoint presentations, videos, and face-to-face exchange of information. Fifteen households obtained information from the internet, including home renovation blogs, GSHP manufacturer/supplier and installer websites and the Canadian GeoExchange Coalition, an industry association. Thirteen households sought and obtained advice and/or information from other households that have previously adopted a GSHP system, either from GSHP installation company client testimonials or from family, friends, neighbours or work colleagues who have had installed a system.

Table 4-16 identifies what information sources household decision-making units regarded as the most useful and credible in informing their decision to adopt a GSHP system (participants could list more than one information source in their response). The majority (11 of 17) of household decision-making units stated that GSHP installation companies, including salespeople, installers and technicians, were the most useful and credible source of information helping to inform their decision to purchase a system. For example, household 3 stated that "The dialogue with the geothermal companies was really helpful. They were all very knowledgeable and were able to answer any questions that I had. They explained everything to me about how the system worked and what I could expect from it, in terms of how it would be installed and what our cost savings would be. They were the best source of information in my opinion." The next most highly regarded source of information was obtaining feedback and reassurance from households that have previously installed a GSHP system. For example, household 17 stated that "The most reliable source was probably the local [households]... so from speaking with the three different homeowners that had previously installed a system in my area. The empirical evidence and feedback from these homeowners is what really sold me on geothermal." Moreover, household 11 stated that "...word-of-mouth from a trusted source is the most reliable source of information." The internet was the third most highly endorsed source of information, but only by three households and "should be used with caution and for high level information only" according to household 9.

Table 4-16 Most Useful and Credible Information Sources Helping Inform Adoption Decision

Most Useful and Credible Information Sources	**Number of Responses (max=17)**
GSHP installation company	11
Friend/family member/neighbour/work colleague who had a GSHP system installed	9
Internet	3
GSHP equipment manufacturer/supplier	2
GSHP company client testimonials	2
REEP House & Elora Environmental Centre	1
University course in renewable energy	1
Magazines & newspaper	1

In terms of information sources that were least useful, the majority (14 of 17) of households stated that no information sources were regarded as being not useful or credible, and that each source of information played its role in the IDP. For example, household 10 claimed that "each source played [its] part in moving the process forward... I couldn't pick one source over the other, they were all useful and needed." Moreover, household 7 stated that they "wouldn't put one against the other... they all had their pros and cons... you have to use each source for what it's worth and with a grain of salt." The other three households each mentioned a single source of information that was regarded as being the least useful and credible. Household 10 asserted that the least useful sources were "the sales[people] as they weren't as technically inclined, so they couldn't answer some of the specific technical questions I had." This was echoed by household 15 who stated that they "personally didn't put much emphasis on what the dealer was telling me, so that was probably the source that I least relied on." Lastly, household 13 claimed that they "found the internet to be the least useful source." Overall, it is clear that professional advice from GSHP installation companies and word-of-mouth from other households that have previously adopted said system, are the most useful and credible sources of information in helping household decision-making units inform their decision to adopt a system.

4.6 Summary

Results of the primary interviews served two purposes. The first was to describe and explain the series of actions and behaviours over time through which the decision-making units evaluated the GSHP system and decided to adopt it. This purpose was fulfilled by describing and explaining the five stages of the IDP that each household decision-making unit passed through, from first awareness of the innovation, to the decision to adopt the innovation, to confirmation of that decision. The second purpose was to examine the influence that each of the five determinants of adoption had on the decision-making units, to determine the most significant catalysts for adoption. As the chapter indicated, each of the five determinants of adoption influenced the decision-making units' IDP and ultimate adoption decision. The 17 in-depth interviews yielded 16 and a half hours worth of data, illustrating the level of rich material that can be analyzed in detail to help describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. These data will be analyzed and interpreted in chapter 5, with respect to the five research objectives of this study.

Chapter 5: Discussion

5.1 Introduction

The purpose of this chapter is to analyze and interpret the research findings that have emerged from the results in order to describe and explain the factors that influence the residential adoption of ground source heat pump (GSHP) systems in rural southwestern Ontario. Specifically, this chapter will reflect upon the findings of this research with respect to the five objectives that were established at the end of the literature review in chapter 2, while comparing and contrasting findings to the literature on consumer adoption of high-involvement residential RETs. It will also evaluate the utility of the innovation-decision process (IDP) model as a theoretical framework for investigating the factors that influence the residential adoption of GSHP systems, and more broadly, for understanding the adoption of high-involvement residential RETs. Research findings have been drawn from the results presented in the preceding chapter, as well as other data collected from the 17 primary interviews, introduced here as appropriate.

Section 5.2 will address the first objective of this research - that is, identify how households perceived a need for the GSHP system. Section 5.3 will examine the second objective, that is, to identify characteristics of household decision-making units to discover commonalities that may have influenced adoption behaviour. Section 5.4 will address the third objective - that is, to identify the perceived characteristics of the GSHP system that promoted (drivers) and hindered (barriers) adoption and their respective significance. Section 5.5 will examine the fourth objective - that is, to identify the influence of change agent programs (e.g. government grant(s) program) on adoption behaviour. Section 5.6 will address the fifth and final objective of this research - that is, to identify the communication channels that household decision-making units used in their adoption process and what information sources were regarded as the most useful in helping them make an informed decision to adopt a GSHP system. Section 5.7 will evaluate the utility of the IDP model as a theoretical framework for the present study, and more broadly, for understanding the adoption of high-involvement residential RETs, while section 5.8 will conclude the chapter by providing a brief summary.

5.2 How Households Perceived a Need for the GSHP System

The first objective of this research is to identify how households perceived a need for the GSHP system (i.e. what motivated household decision-making units to begin looking at replacing their previous practice, or space heating system, in the first place). Specifically, this section will examine what came first: *needs* or *awareness* of the GSHP system.

As identified in section 4.4.1 of the results chapter, three household decision-making units became aware of the GSHP system and gained an understanding of how it functioned because they were actively looking to replace their previous system due to perceived problems, such as those identified in Table 4-1; thus a perceived need created awareness of the GSHP system for these three households and the IDP subsequently followed. The remaining 14 households were not actively looking to replace their previous system due to perceived problems when they perceived a need for the GSHP system, thus their perceived need played a relatively passive role. Figure 5-1 provides an illustration of how the 17 household decision-making units became aware of, and perceived a need for, the GSHP system.

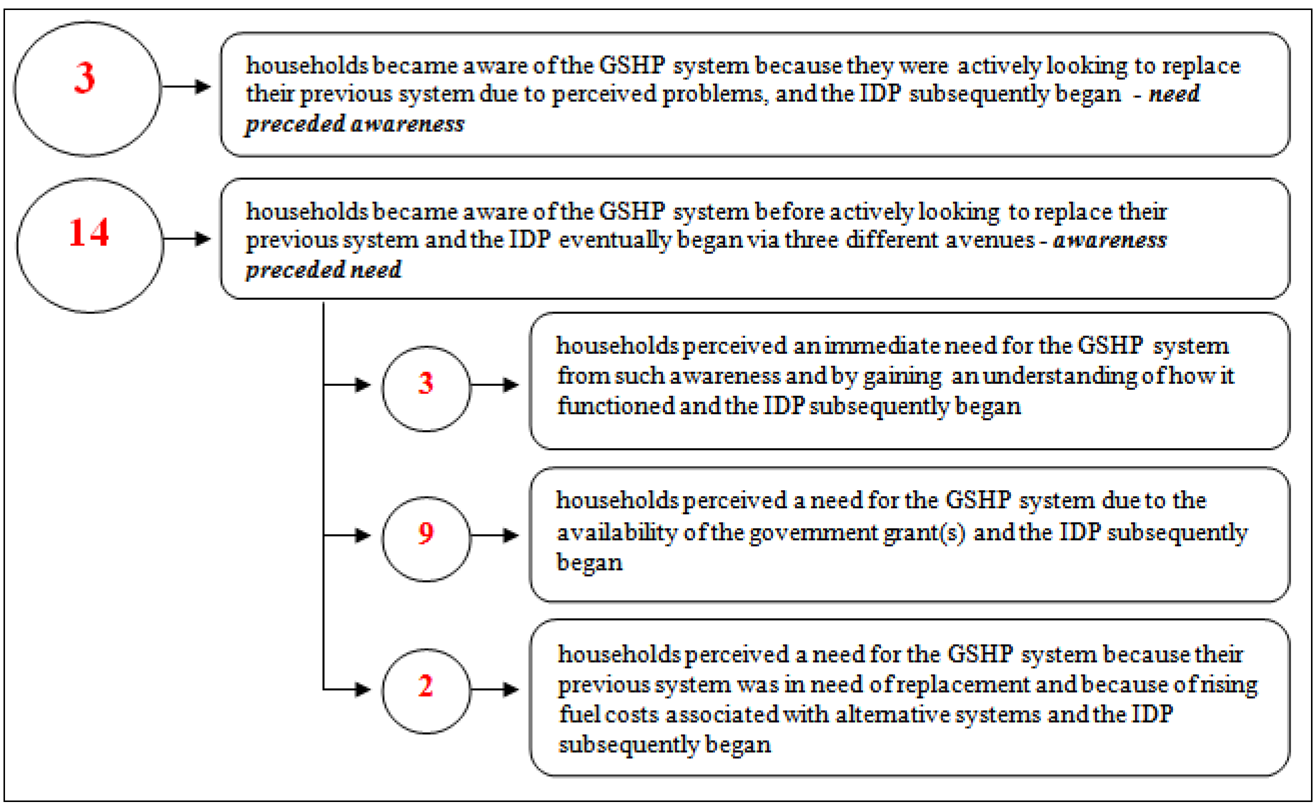

Figure 5-1 How Households Became Aware of and Perceived a Need for the GSHP System (n=17)

As Figure 5-1 indicates, the majority (14 of 17) of household decision-making units played a relatively passive role in becoming aware of, and perceiving a need for, the GSHP system. Three of these 14 households perceived an immediate need for a GSHP system from such awareness, and the IDP subsequently began, while the remaining 11 households were satisfied with their previous system or were not motivated to adopt a GSHP system once they became aware of it. This correlates to one of Rogers' (2003, p.172) findings, in that individuals do not always recognize when they have a problem with their previous system, thus will not begin the IDP until they perceive a need for the innovation.

However, this does not suggest that some of the 11 households did not perceive a need for a GSHP system at the point of awareness; just that they were not yet motivated to adopt for different contextual reasons. For example, household 12 stated that "we looked at putting in geothermal for this house about 10 years [prior to when it was eventually installed], but at that time, after we received a quote, we felt that the price was a little high, so instead, we installed an oil and wood combination system that was much more affordable." In this case, it is evident that the household was interested in adopting a GSHP system, therefore perceived a need for it, but ultimately installed an alternative heating system, due to the perceived high initial capital cost of adopting a GSHP system at that time. Therefore, it is evident that a need can precede awareness and vice versa, in the adoption of GSHP systems, however, due to barriers such as the high initial capital cost, adoption does not always immediately take place.

Findings from this research indicate that awareness or a perceived need for the GSHP system alone is not always enough to motivate these households to adopt; however it can create a motivation to learn more about said system which can lead to future adoption. As Figure 5-1 illustrates, nine of the 11 households that were not previously motivated to adopt a GSHP system from initial awareness, claimed that they perceived a need for the system when they became aware of the government grant(s). This indicates that a financial incentive can have a strong influence on households' perception of their previous system and can create a perceived need, thereby initiating these households' IDP. For example, household 9 stated that "the government grant was the impetus for us to look into it further" while household 10 claimed that "it was the advertising about the grants that sparked my interest." This illustrates that the availability of the government grant(s) potentially allowed households to shift their attention away from the high initial cost of the system - the most frequently identified barrier to adoption - to other advantageous characteristics of the system, thus increasing its relative advantage over previous practices. This finding is consistent with results from Mahapatra and Gustavsson's (2009) study, which showed that a financial subsidy created (or made aware of) a need among homeowners to adopt an innovative low-carbon heating system, that beforehand, were not actively seeking to replace their previous system.

Furthermore, Mahapatra and Gustavsson (2009) argued that the provision of a financial subsidy created cognitive dissonance among homeowner participants, which resulted in a change of homeowner behaviour, from no intention of replacing their previous system, to adopting an innovative low-carbon heating system. It can be argued that some of these nine household decision-making units possibly felt a level of cognitive dissonance due to the presence of a financial incentive, as for example, five households indicated that they adopted a GSHP system sooner than they otherwise would have, so that they would receive the government grant(s). For instance, household 16 claimed that the government grant "moved our decision-making process along faster, because we had to have our system installed before November in order to receive the grant." Similarly, household 6 stated that "the grants really made it happen for us... they really sped up our decision, because we had the sense that the federal grant was going to disappear soon... the grants probably made us get geothermal sooner than we otherwise would have." Moreover, household 10 asserted that they installed their GSHP system when they did "because the grant program was soon ending, and if we installed the system now, we could get quite a bit of money back from the government."

The remaining two households (Figure 5-1) that were not motivated to adopt a GSHP system at the point of awareness, eventually perceived a need for the system because their previous system was in need of replacement and because of rising fuel costs associated with their previous system, or alternative "lower cost" systems, such as oil or propane furnaces. In summary, awareness or perceived needs or problems do not always provide a very complete explanation of why decision-making units began the IDP. Other, external factors, such as the financial incentive or rising fuel costs, played a significant role in initiating households' IDP by increasing the relative advantage of the GSHP over previous and alternative systems. Therefore, it is evident that a need was a precondition for the adoption of the GSHP system, however, the way in which a need was perceived, ranged across household decision-making units. This finding is consistent with Mahapatra and Gustavsson's (2008a, 2008b, 2009) studies, where they identified that a perceived need for a new heating system, based on dissatisfaction with their existing system, is a household's first step towards adopting a low-carbon residential heating system.

5.3 Characteristics of Household Decision-Making Units

The second objective of this research is to identify characteristics of household decision-making units to discover commonalities within such data that may have influenced adoption behaviour. This section will address the prominent findings related to household decision-making units' sociodemographic characteristics and technical knowledge.

5.3.1 Sociodemographic Characteristics

Regarding sociodemographic characteristics, six interesting findings have emerged from the results that are worth discussing. These findings relate to gender, age, education, occupation type, household income and house size.

First, in terms of gender, the majority (15 of 17) of household decision-making units contained at least a male participant; seven of these were two-person, each involving a male and female participant. However, after consulting the interview transcripts for each of the seven two-person decision-making units, it became evident that male participants contributed substantially more in the interview process, in all but one of the cases, in which the male and female participant each contributed equally. This finding suggests that male householders were more engaged in the adoption process compared to their female counterpart, for households that had a two-person decision-making unit. This confirms findings in previous studies (e.g. Jager, 2006; Michelsen & Madlener, 2011; Ozaki & Sevastyanova, 2011) that men are predominantly involved in the decision-making process of high-involvement residential RETs. Nevertheless, it is still insightful that seven of the 17 household decision-making units reported that both a male and female householder were collectively engaged in their respective adoption process.

The age of the household decision-making units (using the average age group for the seven two-person decision-making units) was wide ranging; the median age group was 40-49, while the youngest was 18-29 and oldest was 70 years of age or older, which in fact, included two separate decision-making units. This indicates that household decision-making units, regardless of age, perceived the adoption of a GSHP system as worthy of investment. For example, the decision-making unit of household 5 was 70 years of age or older at the time of adoption and claimed that a main driver for adoption for him or her was the length of payback, as "the installation company said that the system would pay for itself in *only* 10 years." This finding is interesting because this individual stated that he or she only plans to live in the same house for 12 more years, from the point of adoption, indicating that he or she would presumably only be saving money in operating costs for two more years after obtaining a return on their investment. Moreover, this individual did not mention anything about the GSHP system increasing the value of their house, in terms of a driving factor influencing their adoption decision. This finding contradicts what Mahapatra and Gustavsson (2008a) found, where older individuals were less likely to adopt an innovative low-carbon heating system due to less income post-retirement and/or because they do not expect to obtain a return on their investment during their occupancy of the house. Furthermore, approximately half (8 of 17) of the household decision-making units in the study were 50 years of age or older at the time of adoption, refuting findings from a study conducted by Potoglou and Kanaroglou (2007) that individuals over the age of 45 years were more hesitant in adopting high-involvement RETs, such as a hybrid electric vehicle, due to the perceived length of payback and risks associated with the technology.

In terms of education, the majority (14 of 17, or approximately 82 percent) of household decision-making units in the study sample included at least one individual who has attained a university degree (10) or apprenticeship/trades certificate (4), prior to the adoption of their GSHP system. As a basis for comparison, approximately 56 percent of the Ontario population over the age of 18 has attained a university degree (25 percent) or college diploma or trade certificate (29 percent) (data are for 2012 and are taken from Statistics Canada, 2014). This finding indicates that, in general, household decision-making units in the study sample are highly educated, which may have influenced their adoption behaviour. This finding is compatible with two separate studies that examined the impact of education levels on the adoption of solar photovoltaic (PV) systems, where they found that households with more education were more likely to adopt (i.e. Guagnano et al., 1986; Jager, 2006).

Moreover, an interesting finding related to householders' occupation type and adoption behaviour, is that three out of the five household decision-making units that had at least one individual employed in the field of natural resources and agriculture did not perceive the initial cost of the GSHP system as a barrier to adoption. Interestingly, there were only five household decision-making units in the entire study sample who did not perceive the initial cost of the GSHP system as a barrier to adoption; three of these being the aforementioned. Indeed, one of these three decision-making units also did not receive a government grant, indicating that householders employed in the natural resources and agriculture profession may be more comfortable, or prepared, to deal with the frequently identified barrier of the high initial capital cost associated with the adoption of said systems. This could be a result of these householders being accustomed to making capital intensive investments, for example, on capital intensive farm equipment or machinery, allowing them to focus their attention beyond the initial cost of the system, and on the long-term benefits that they perceive the GSHP system will have.

Results also indicated that household decision-making units in the study sample may have been more wealthy than the median Ontario household at the time of adoption (or retirement). The median after-tax household income level in the study sample was calculated to be between $70,994 - $98,777, or $84,877, which is approximately $11,600 more than the median of $73,290 for Ontario (data are for 2011 and are taken from Statistics Canada, 2013a). Indeed, seven of the 17 households in the study sample had a pre-tax annual income of more than $150,000, including two households with pre-tax annual incomes of between $200,000 - $249,999 and two households more than $250,000. These figures indicate that, in general, rural Ontario households with larger disposable incomes may be more inclined to adopt a GSHP system, which is consistent with Jager's (2006) findings that households with higher income levels were more likely to adopt a solar PV system.

However, in the present study, the correlation between household income and the decision to adopt a GSHP system does not necessarily imply causation or hold a high level of explanatory power. For example, household 17, whose pre-tax annual household income was more than $250,000 at the time of adoption, claimed that they would not have installed a GSHP system without receiving both government grants, valuing $8,750. Indeed, household 17 argued that "...the grants were a huge catalyst... if the grants weren't there, [they] wouldn't have went with geothermal." Conversely, household 8, whose pre-tax annual household income was between $80,000 - $89,000 at the time of adoption, received the provincial grant ($4,375) only, and stated that they would still have installed a GSHP system without the presence of any financial incentive. The influence of the government grant(s) on household decision-making units adoption behaviour will be discussed in detail in section 5.5.

Lastly, the median house size by square footage (not including basement) in the study sample was 2,400, which is 60 percent larger than of the average single-detached house in Ontario of approximately 1,500 square feet, according to Statistics Canada (2007). Interestingly, 15 of the 17 houses in the study sample were larger than 1,500 square feet, including five houses larger than 3,500 square feet, and three houses larger than 4,000 square feet, indicating that household decision-making units in the study sample, on average, have larger sized homes, which may have influenced adoption behaviour. This assertion must be explored with caution, however, as houses in rural areas may *all* be relatively larger, due to more affordable land and available space, compared to urban areas. Unfortunately, upon an extensive desktop search, there are no statistics available for single-detached house sizes in *rural* Ontario (or Canada), for a more accurate comparison. Nevertheless, these findings are comparable to results from Caird et al. (2010) survey of 546 United Kingdom householders that had installed a microgeneration heat system, where they found that approximately 60 percent of adopters live in larger detached homes located in rural areas off United Kingdom's natural gas network.

In summary, household decision-making units in the study sample included both male and females, albeit in the seven cases that involved a two-person decision-making, males were seemingly more engaged in their respective adoption process. At the time of adoption, household decision-making units ranged in age, from between 18-29 to 70 years of age or older, and for the majority were highly educated, by receiving some of post-secondary education, held a range of different occupations, and on average, had higher household income levels compared to Ontario's median, and lived in larger houses compared to Ontario's average single-detached house.

5.3.2 Technical Knowledge

This section briefly presents two interesting findings that have emerged from the results relating to household decision-making units' self-reported ability to understand and apply technical knowledge, in general, and their perception of the GSHP system as a simple or complex technology.

First, the majority (11 of 17) of household decision-making units self-reported that they have a strong ability to understand and apply technical knowledge, while the remaining six reported to have an average ability. This finding is consistent with Rogers' (2003, p.282) hypothesis that earlier adopters must have a strong ability to understand and apply technical knowledge and suggests that technical knowledge may positively influence adoption behaviour in the context of residential GSHP systems. This finding is consistent with results from Caird et al.'s (2008) review of empirical studies in the United Kingdom on the household adoption of low and zero-carbon technologies, including GSHP systems, where they found that strong technical knowledge was a precondition for adoption.

Second, the majority (14 of 17) of household decision-making units also self-reportedly perceived GSHP systems as a simple technology, while only three households reportedly perceived them as a complex technology. This finding is surprising, as different studies in the literature (e.g. Caird & Roy, 2008; Caird et al., 2012) have illustrated that households who have adopted a microgeneration heat system, including GSHP systems, typically perceived them to be relatively complex. Although in both cases households still adopted a GSHP system, regardless of their perception towards the technology, it is still of interest that the majority of households in the present study perceived GSHP systems as a simple technology, perhaps indicating that they engaged in a more extensive search for, and analysis of, information, and thus better understood the technology and how it functioned. Conversely, this could be a result of household decision-making units having higher levels of education in general.

5.4 Significance of Drivers for and Barrier to the Adoption of GSHP Systems

The third objective of this research is to identify the perceived characteristics of the GSHP system that promoted (drivers) and hindered (barriers) adoption and their respective significance. This section will discuss the prominent findings that have emerged from the results related to the perceived characteristics of the GSHP system influencing adoption.

This thesis not only identified a total of 27 different factors that influenced the adoption of GSHP systems in rural southwestern Ontario, it also sought to identify the significance of each of these factors. Specifically, section 4.4.2 of the results chapter identified the range of factors considered across all 17 household decision-making units, including sample quotations (Table 4-12). It also identified the frequency and manner (i.e. prompted or unprompted) in which each of the factors was perceived and identified (Table 4-13). Finally, it identified the significance of the factors influencing adoption (Figure 4-13). When analyzing the frequency of factors influencing adoption, including their prompted nature, several prominent findings have emerged which are discussed below.

First, cost savings was identified as a driver for adoption across all 17 household decision-making units in the study sample, including 16 unprompted responses. All but one of the households explicitly stated that cost savings was a driver for adoption, due to perceived lower operating costs (i.e. monthly or annual heating and cooling bills) relative to their previous system. Indeed, Table 4-1 illustrated that all but one of the household decision-making units stated that their previous space heating system was expensive to operate. However, in terms of the 11 space cooling systems that were displaced, only four decision-making units claimed that it was expensive to operate.

Second, all 13 household decision-making units that received a government grant identified it as a driver for adoption, including 10 unprompted responses. Only 5 of these 13 decision-making units stated that they would still have adopted a GSHP system without the presence of the government grant(s), indicating that it was a major catalyst for adoption. The influence of the government grant(s) on adoption behaviour will be discussed further in section 5.5.

Third, 12 of the 17 household decision-making units identified factors related to sustainability as a driver for adoption, including 11 unprompted responses. Of the five decision-making units that did not identify factors related to sustainability as a driver for adoption, three explicitly claimed that environmental considerations or issues did not play a role in their decision. For example household 2 claimed that they "...are not really influenced by environmental reasons... [they're] not going to spend thousands of dollars just to be green." Moreover, household 15 stated that they could "...care less about the environment... [it] wasn't an influencing factor because the volume of oil that I would be using instead doesn't really have a negative impact on the environment." Lastly, household 17 claimed that they are the "...wrong [person] to be jumping up and down about sustainability... that has never resonated with me."

In addition to the above three drivers, the ability to provide space cooling with the same system, the opinion of others, and the pleasure or satisfaction of owning and operating a RET, were the three other most frequently identified factors that were considered as drivers for adoption by nine (including five unprompted responses), eight (including one unprompted response) and eight (including zero unprompted responses) household decision-making units respectively. Out of these three factors, it is clear that the system's ability to provide space cooling was the most prominent driver for adoption, five of the nine households explicitly identified it as a driving factor in their decision.

Three other factors that were identified as drivers for adoption among certain households that were deemed insightful, include the GSHP system's perceived safety, cleanliness (sanitation - not environmentally-related) and convenience, compared to the previous system that it was displacing, which predominantly included an oil furnace. First, six of the seven households that claimed safety was a driving factor, displaced an oil furnace, including one household that displaced an oil furnace in combination with a wood stove, while the other household displaced a propane furnace. Four of these seven responses were unprompted. Second, all five of the households that claimed cleanliness was a driving factor, displaced an oil furnace, including one household that displaced an oil furnace in combination with a wood stove. Two of these five responses were unprompted. Third, the three households that claimed convenience was a driving factor for adoption displaced some form of a combination system; the first household displaced an oil furnace combined with a wood stove, the second displaced an oil furnace combined with a corn stove, and the third displaced electric baseboard heaters combined with a wood pellet stove. Two of these three responses were unprompted, with both households explicitly claiming that their previous system was a "total inconvenience" or "huge hassle." Each of these households were using wood, corn or wood pellets as an alternative heating fuel to offset costs associated with their oil furnace or electric baseboards. Upon analysis, there are no other significant correlations between drivers for adoption and type(s) of system that was displaced.

The most frequently identified barrier to adoption (i.e. factor that hindered or delayed adoption) was the initial cost of the system, identified by 12 household decision-making units, including 11 unprompted responses. This was the only indentified barrier to adoption that was unprompted. Nine of these 12 decision-making units received the government grant(s), and explicitly stated that the government grant(s) is what enabled them to overcome the high initial cost and adopt a system. The other three households claimed that they were able to overcome the high initial cost of the GSHP system because of perceived long-term cost savings, and for two of these three households, because the GSHP system would increase their property value.

While the high initial cost of the GSHP system was identified as a barrier to adoption by 12 of the 17 households the study sample, all but one (16 of 17) household perceived it to be one of the biggest barriers preventing adoption for *other* rural Ontario households that heat with oil, propane or electricity. Indeed, household 3 claimed felt that "...people are only concerned with the short-term and don't look at the long-term potential savings... if they can buy a new furnace for $5-10,000 they are going to do that."

While the purpose of Table 4-13 was to identify the frequency and manner in which each of the factors were perceived and identified, Figure 4-13 presented the results of the identified significance of factors influential to household decision-making units in their decision to adopt a GSHP system. When examining significance, the range of factors reduced from 27 to 16, and were categorized as being of primary or secondary significance. Cost savings, the government grant(s), and factors related to sustainability remained the three most significant drivers for adoption, followed closely by the system's ability to provide space cooling. The initial cost of the system remained a significant barrier to adoption, however, all households were eventually able to overcome it. When evaluating each of the 16 factors (Figure 4-13) in terms of their level of significance (i.e. primary or secondary), it became clear that sustainability as a driver for adoption became less significant across household decision-making units. While sustainability was originally identified as a driver for adoption by 12 households, it was only of primary significance for five households and secondary significance for three. It was deemed through coding that the remaining four households were not significantly motivated by factors related to sustainability. Nevertheless, factors related to sustainability were still a significant driver for adoption. From among the nine households that originally identified the GSHP system's ability to provide space cooling as a driver for adoption, it was deemed to be of primary significance for five households and of secondary significance for two households, indicating that it was indeed a significant driver for adoption as well.

In summary, financial factors, such as cost savings and the government grant(s) were the most significant drivers that enabled households to adopt a GSHP system, while the initial cost of the system was a significant hindrance in the adoption process. Secondary to financial factors, were factors related to sustainability and the system's ability to provide space cooling. Both of these non-monetary factors were also deemed significant to the decision of households to adopt a GSHP system.

Interestingly, during primary interviews, the expression "no brainer" was used 11 times across six different household decision-making units. Out of the 11 times the expression was used, three times it was related to cost savings, while five times it was related to the government grant(s). The other three times the expression was used, it was related to the system's ability to provide both space heating and cooling in the same technology. The use of this expression may indicate that these six household decision-making units felt that their decision to adopt a GSHP system was rather simple, based on their circumstances and perceived needs.

These findings are comparable with those found in the literature on the household adoption of high-involvement low-carbon residential heating systems, where financial factors are the most frequently identified and significant drivers for adoption. For example, in Mahapatra and Gustavsson's (2008a) study on the adoption of high-involvement low-carbon residential heating systems in Sweden, they found that households were predominantly motivated by annual heating cost savings, followed by factors related to functionality. In this specific study, factors related to sustainability, such as security of fuel supply and environmental benignity, were identified as drivers for adoption, however far less significant than cost savings and functionality. In Michelsen and Madlener's (2013) study on motivational factors influencing homeowners' decisions on the adoption of a high-involvement low-carbon residential heating system in Germany, they found that the government grant was the key driver for adoption, followed by cost aspects. This same study found that factors related to sustainability were not regarded significant to homeowners' adoption decisions. Conversely, in Caird et al.'s (2010) study on the adoption of microgeneration heat technologies in the United Kingdom, they found that households were almost identically motivated by factors related to sustainability and cost savings. Specifically, they found that 75 and 72 percent of households in the study sample were driven to adoption by perceived reductions in carbon dioxide emissions and to save money on fuel bills, respectively. In general, it is evident that in the adoption of a high-involvement low-carbon residential heating system, including findings from the present study on the adoption of GSHP systems, that the majority of households are predominantly influenced by financial factors, such as cost savings or the availability of a government grant, while some households identify factors related to sustainability as key drivers. Unfortunately, in the context of the GSHP system, no other research has been found that investigates the influence of the system's ability to provide space cooling (or supplement hot water heating) on household adoption.

5.5 The Influence of the Government Grant(s) on Adoption Behaviour

The fourth objective of this research is to identify the influence of change agent programs on adoption behaviour. The specific change agent program that this study addressed was the Natural Resources Canada's ecoENERGY retrofit program (a federal government program) that offered a $4,375 grant for homeowners that retrofitted their house with a GSHP system between April 2007 and March 2012. During the first three years of the program, the Ontario government matched the $4,375 grant, doubling the value of the grant to $8,750. When considering the average cost for a horizontal installation in Ontario is $24,464 (CGC, 2012a), both grants would cover approximately 36 percent of the initial cost, while one grant would cover approximately 18 percent.

This chapter has already established that the presence of the government grant(s) created a perceived need for the GSHP system among nine of the 17 household decision-making units, ultimately initiating their IDP. It has also illustrated that out of the 13 decision-making units that received the government grant(s), only five stated that they would still have adopted a GSHP system without the availability of the government grant(s). When analyzing these 13 households with respect to (1) the type of grant(s) they received, and the respective value, and (2) their household income levels, several insights have emerged.

First, out of the five household decision-making units that claimed they still would have adopted a GSHP system without the government grant(s), three received just the federal grant, one received both the federal and matching provincial grant and one received $1,500 from a source that could not be recalled. The one household that received both the federal and matching provincial grant is also the same household that inherited money from a family friend and identified it as a driver for adoption (H14: Table 4-13). In particular, they claimed that the government grants "...played a huge role and really made it a no brainer" but still would have adopted a GSHP system without the grants because they "...wanted to invest the inherited money into something positive." Second, out of the eight household decision-making units that stated they would not have adopted a GSHP system without the presence of the government grant(s), seven households received both the federal and matching provincial grant, while one household received just the federal grant.

As evident from the above findings, the polarization between willingness to still adopt a GSHP system without the presence of the government grant(s) is strongly correlated to the type of grant and respective value that the household decision-making unit received. The majority (six of seven) of the households that received both grants ($8,750) claimed that they would not have adopted a GSHP system without the government grants, while the one household claimed they still would have, because they wanted to invest the money they inherited into something positive. In contrast, the majority (four of five) of households who received just the federal grant ($4,375), and the one household that received $1,500, claimed that they still would have adopted a GSHP system without the financial incentive. However, it must be noted that it is unknown whether the six households that received both grants, who stated that they would not have adopted a GSHP system without them, would have adopted a system in the presence of a smaller financial incentive (e.g. just one of the grants). For these households, it can be argued that there is a positive relationship between willingness to adopt a GSHP system and the financial value of the grant(s); as the value of the grant decreases, so does willingness to adopt a system.

Moreover, when analyzing household income levels across the 13 household decision-making units that received the government grant(s), it is apparent that the median household income level is the same for the group of households that would (and would not have) still adopted a GSHP system without the presence of the grant(s), which is between $100,000 - 149,999. This indicates that, in general, households that received both grants ($8,750) were more significantly influenced by the financial incentive, compared to households that received just the federal grant ($4,375). For example, household 17, whose income level was greater than $250,000, claimed that they would not have adopted a GSHP system without the $8,750 grant that they received, whereas household 8, whose income level was between $80,000 - 89,999, stated that they would still have adopted said system without the $4,375 grant. Therefore, it is clear that some households may place greater importance on the GSHP system's long-term benefits, whereas others are more concerned with the short-term and capital outlay.

In summary, regardless of household income levels, the government grant(s) were generally perceived as a significant drivers for adoption; in eight cases, households explicitly claimed that they would not have adopted a system without the financial incentive. These findings are most closely related to those in Mahapatra and Gustavsson's (2008a, 2008b) studies on the adoption of high-involvement low-carbon residential heating systems in Sweden, where they found that households of all age and income groups were heavily influenced to adopt a low-carbon heating system because of the availability of the government subsidy that covered approximately 30 percent of the initial cost. The presence of a financial incentive has been found to be a strong catalyst for adoption in several other studies on the household adoption of high-involvement low-carbon heating systems (e.g. Caird et al., 2010; Caird et al., 2007, Michelson & Madlener, 2013) indicating the success of such financial programs in facilitating the adoption of capital intensive residential renewable energy technologies (RETs).

5.6 Communication Channels and Information Sources

The fifth and final objective of this research is to identify the communication channels that household decision-making units used in their adoption process and what information sources were regarded as the most useful in helping them make an informed decision to adopt a GSHP system.

The majority (15 of 17) of household decision-making units in the study sample collected information from both mass media and interpersonal channels to inform their decision to adopt a GSHP system. In terms of creating awareness, the majority (14 of 17) of household decision-making units became aware of and gained an understanding of how GSHP systems functioned from interpersonal information sources (Figure 4-11). This finding rejects Rogers' (2003, p.205) hypothesis that mass media channels are relatively more important for knowledge creation than interpersonal channels. In particular, 11 of these 14 household decision-making units became aware of GSHP systems from either a friend, family member or neighbour who already had a GSHP system installed in their house, or was knowledgeable about these systems, indicating that word-of-mouth communication is important in spreading awareness for said systems. This finding may be attributed to the degree of social participation in which household decision-making units in the study sample claimed to have. The majority of households (10 of 17) in the study sample claimed to have a high degree of social participation, while five claimed to have an average degree, meaning that these households may engage in more social behaviour, and thus placed themselves in social situations that may have led to their awareness of GSHP systems. Interestingly, the two households that claimed to have a low degree of social participation became aware of GSHP systems via mass media communication channels.

It can be argued that mass media channels were less prevalent in the present study sample for creating awareness of GSHP systems potentially due to insufficient mass media marketing and advertising involving media such as the radio, television, newspaper, etc. in the Ontario context. Indeed, lack of consumer awareness and/or knowledge of GSHP systems was the second most frequently perceived barrier to adoption facing other rural Ontario households (behind high initial capital cost), identified by 14 of the 17 households in the study sample (Table 4-14). Several of these respondents also stated that they felt there *is* enough information readily accessible for households to learn about GSHP systems, however, they need to be motivated to look for the information first, as in most cases, it is not adequately advertised to them via mass media communication channels. For example, household 11 argued that "...there is plenty of information out there on these systems, but it's not always presented to households... they have to go searching for the information themselves and they will only do that if they [perceive] a problem with their current system first." Although lack of awareness and/or knowledge of GSHP systems cannot be attributed solely to lack of mass media marketing and advertising, it definitely illuminates that households in the study sample perceive a significant lack of awareness of said systems for other rural Ontario households.

As Table 4-15 indicated, the majority (13 of 17) of households sought a personal evaluation from either a friend, family member, neighbour or work colleague who had previously adopted a GSHP system for their respective house (11), or via a client testimonial from the GSHP installation company they were dealing with (2), prior to making their adoption decision. This is consistent with findings from Caird & Roy's (2010) study, where the majority of households reportedly sought impartial information from other households who had already adopted a microgeneration heat system, prior to adopting a system themselves. Conversely, this finding contradicts Rogers' (2003) hypothesis that innovators typically adopt an innovation independent of interpersonal information sources.

Moreover, as Table 4-16 illustrated, GSHP installation companies were the most frequently identified source of information that was perceived by households as being the most useful and credible in helping inform their decision to adopt a GSHP system. Indeed, 11 of the 17 household decision-making units explicitly stated that GSHP installation companies, including sales representatives, installers and technicians, were the most useful and credible source of information in helping to inform their adoption decision. Mahapatra and Gustavsson (2008a, 2008b) also found in their studies that installers/vendors were perceived to be the most important source of information among households in the adoption of a low-carbon residential heating system.

In addition, nine of the 17 households in the study sample also identified personal evaluations from either a friend, family member, neighbour or work colleague who had previously adopted a GSHP system for their respective house, as one of the most useful and credible sources of information helping to inform their decision to adopt a GSHP system. This finding is compatible with numerous different studies in the literature on the adoption of high-involvement residential low-carbon heating systems, where households generally place a high level of importance on personal evaluations from people in their interpersonal network that have direct experience with the RET in consideration (e.g. Caiert et al., 2007; Caird & Roy, 2010 Mahapatra & Gustavsson, 2008a, 2008b; Michelson & Madlener, 2013).

The most useful and credible mass media information source was the internet, where three households explicitly identified it as being an important source of information in their respective decision-making process. Interesting, one of these decision-making units was the youngest in the study sample, falling in the age group of 18-29 years, while the other two were in the second youngest age group of 30-39 years, indicating that younger householders may perceive the Internet as a more useful and credible source of information in the adoption of high-involvement residential RETs, compared to older householders. This finding echoes Kaenzig and Wüstenhagen's (2008) study where they found that internet sources were more commonly utilized and valued in the adoption of residential microgeneration heating systems by younger respondents.

In terms of information sources that were perceived as being *not* useful and credible, it was interesting to discover that 14 of the 17 household decision-making units stated that they were unaware of any and that each source played its own role in their respective decision-making processes. In summary, these findings indicate that, in general, interpersonal communication channels were relatively more important than mass media channels, for both knowledge creation and for helping households make an informed decision to adopt a GSHP system. This was also the consensus reached by Mahapatra and Gustavsson (2008a, 2008b) in their studies, where interpersonal communication channels were given greater preference than mass media channels throughout households' decision-making process, from knowledge to adoption. Hence, based on these findings, it can be argued that interpersonal communication channels will continue to play an important role in creating awareness of GSHP systems and helping to inform potential households' adoption decisions.

5.7 Evaluation of the Innovation Decision-Process Model

The IDP model including the five determinants of adoption demonstrated to be a practical and effective theoretical framework for guiding the present study, namely to describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. The IDP model was employed to achieve three purposes. The first was to describe and explain behaviour and to identify important behavioural drivers behind households' decisions to adopt a GSHP system. The second was to guide the collection of empirical data on a relatively underdeveloped area of research, i.e. household adoption of GSHP systems in rural southwestern Ontario, while the third and final purpose was to provide a foundation for interpreting research findings. It can be argued that the IDP model and five determinants of adoption were of utility for achieving all three purposes.

First, the IDP model including the five determinants of adoption provided a comprehensive and adaptable foundation for exploring household decision-making and the factors that influenced it, in the context of the residential adoption of GSHP systems. The IDP model provided the researcher with a foundation for investigating household behaviour as a process, from a household's initial awareness of the GSHP system, to forming an attitude towards the characteristics of the system, to analyzing the perceived costs and benefits associated with the system, to reaching a decision to adopt it, and to confirmation of that decision. The five determinants of adoption permitted research to focus on all aspects and stages of household decision-making, which allowed for a more in-depth understanding of the different factors and intricacies that influenced the residential adoption of GSHP systems and their respective significance.

Second, the IDP model including the five determinants of adoption provided a holistic framework to guide the collection of empirical data on household adoption experiences to achieve the research purpose and objectives of this thesis. The IDP model helped guide the formation and structure of the interview guide that was utilized in this study to explore the factors influencing the residential adoption of GSHP systems in rural Ontario, that prior to this research, were unknown. Therefore, the IDP model was of utility for guiding primary data collection on a relatively underdeveloped area of research, i.e. household adoption of GSHP systems in rural southwestern Ontario.

Third, the IDP model including the five determinants of adoption provided a practical foundation for interpreting research findings and for comparing and contrasting these findings to previous studies in the literature that have investigated at least one of the five determinants of adoption, in the context of the adoption of high-involvement residential RETs.

In summary, it can be argued that the IDP model including the five determinants of adoption as a theoretical framework can be of utility for organizing and guiding similar studies that aim to describe and explain adoption behaviour, in the context of high-involvement residential RETs.

5.8 Summary

This chapter set out to analyze and interpret the prominent research findings that have emerged from the results that were presented in chapter 4. This chapter reflected upon the research findings with respect to the five objectives that were established at the end of chapter 2. Analysis of these findings has demonstrated that the five determinants of adoption: 1) prior conditions; 2) characteristics of the decision-making unit; 3) perceived characteristics of the GSHP system; 4) change agent programs; and 5) communication channels, each play a different but influential role in the residential adoption of GSHP systems in rural southwestern Ontario. The following chapter will return to each of these determinant of adoption, by synthesizing the main empirical findings with respect to each of the five research objectives, in order to describe and explain the residential adoption of GSHP systems in rural southwestern Ontario.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

The purpose of this thesis was to describe and explain the factors that influence the residential adoption of ground source heat pump (GSHP) systems in rural southwestern Ontario. This research purpose was motivated by the fact that - although GSHP systems can contribute substantially to the reduction of energy consumption and greenhouse gas (GHG) emissions, while simultaneously reducing space heating, cooling and water heating costs - they remain one of the least understood and adopted RETs in Ontario's residential sector.

Prior to the present study, as the literature review in chapter 2 demonstrated, minimal research has been conducted on the household adoption of GSHP systems and the factors that influence it, generally, and more specifically, in Ontario. As a result, little is known about the households who adopt GSHP systems and what factors influence their decision-making process. Therefore, this thesis aimed to shed light on this research problem, which if understood, could help contribute to a better design of policy instruments and marketing strategies, for targeting households that do not have access to natural gas and continue to heat and cool with fossil fuel or electric-based systems in rural Ontario.

To fill this gap in knowledge, a case study was conducted in rural southwestern Ontario to investigate a sample of households that have adopted a GSHP system to learn about their adoption experiences, including the factors that influenced their decision-making process. To guide this research, Rogers' (2003) innovation decision-process (IDP) model including the five determinants of adoption, was selected as a theoretical framework. Specific objectives of this thesis were to:

1) Identify how households perceived a need for the GSHP system.
2) Identify characteristics of household decision-making units to discover commonalities that may have influenced adoption behaviour.
3) Identify the perceived characteristics of the GSHP system that promoted and hindered adoption and their respective significance.
4) Identify the influence of change agent programs on adoption behaviour.

5) Identify the communication channels that household decision-making units used in their adoption process and what information sources were regarded as the most useful.

By achieving each of these objectives, a comprehensive understanding of the factors that influence the residential adoption of GSHP systems for a sample of households in rural southwestern Ontario can be achieved. Results from the 17 in-depth, face-to-face interviews were presented in chapter 4, while chapter 5 analyzed and interpreted the prominent findings that emerged from these results. The purpose of this chapter is to summarize these findings and discuss their policy and industry implications. Specifically, section 6.2 of this chapter will synthesize the main empirical findings with respect to each of the research objectives of this study. Section 6.3 and 6.4 will then discuss the policy and industry implications of these findings, respectively. Section 6.5 will then make recommendations for future research, while section 6.6 will conclude this chapter by providing a brief summary and final remarks.

6.2 Conclusions Against the Research Objectives

As identified above, five research objectives were set in support of the overall purpose of this thesis, namely to describe and explain the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. This section will synthesize the main empirical findings of this research with respect to each of the five objectives. First, however, it must be reminded that all conclusions drawn from this thesis are with respect to the given sample, and one should be cautious not to generalize findings to the broader population, as this sample cannot be said to be representative, for the reasons identified in chapter 3.

Objective 1: To identify how households perceived a need for the GSHP system.

First, it became evident that a perceived need for the GSHP system was a precondition for adoption across all 17 household decision-making units in the study sample, however, the perceived need did not always stem from a perceived problem with their previous space heating system. Indeed, the way in which households perceived a need for the GSHP system is wide ranging. Specifically, three households were actively looking to replace their previous space heating system due to perceived problems and dissatisfaction when they became aware of, and perceived a need for, the GSHP system. The remaining 14 households were not actively looking to replace their previous system due to perceived problems when they perceived a need for the GSHP system, thus their perceived need played a relatively passive role. Three households perceived a need for the GSHP system from initial awareness; nine households perceived a need for the GSHP system due to the availability of the government grant(s); and two households perceived a need for the GSHP system because their previous system was in need of replacement and because of rising fuel costs associated with alternative systems.

In summary, there was not always a direct link between households' perceived problems and perceived needs. In many cases, external factors such as the availability of a government grant, created cognitive dissonance among households, which subsequently created a perceived need for the GSHP system and overt behavioural change.

Objective: 2: To identify characteristics of household decision-making units to discover commonalities that may have influenced adoption behaviour.

Several commonalities were identified between household decision-making units' sociodemographic characteristics and technical knowledge, that may have influenced adoption behaviour. Specifically, it was found that in households that involved a two-person decision-making unit, males were apparently more engaged in their respective adoption process. At the time of adoption, household decision-making units ranged in age, from between 18-29 to 70 years of age or older, with a median age group of 40-49. Next, it was found that household decision-making units were typically highly educated, with at least one individual attaining some form of post-secondary education, held a range of different occupations at the time of adoption, and on average, had higher household income levels compared to Ontario's median, and lived in larger houses compared to Ontario's average single-detached house. Lastly, it was found that all 17 household decision-making units in the study sample self-reportedly have an average (6) or strong (11) ability to understand and apply technical knowledge, and for the most part, perceive GSHP systems as a simple, rather than complex, technology.

While it is not prudent from a research perspective to develop a set of hypotheses based on the above findings as this sample cannot be said to be representative, it can be argued that education and income levels, house size, and ability to understand and apply technical knowledge are relatively more important characteristics than gender, age and occupation types for positively influencing adoption behaviour.

Objective 3: To identify the perceived characteristics of the GSHP system that promoted and hindered adoption and their respective significance.

While 27 different factors were considered by household decision-making units in the adoption of a GSHP system, it became evident upon analysis that the most significant drivers for adoption were cost savings and the government grant(s), followed by factors related to sustainability and the system's ability to provide space cooling. The most significant barrier to adoption was the initial cost, however, every household was eventually able to overcome this hindrance, including nine households who explicitly stated that the government grant(s) is what ultimately enabled their decision to adopt a GSHP system.

Objective 4: To identify the influence of change agent programs on adoption behaviour.

It was discovered that change agent programs, i.e. the federal and provincial government grant(s) through the ecoENERGY retrofit program, significantly influenced adoption behaviour. The government grant(s) were influential in creating a perceived need for the GSHP system for nine households, and were identified as a driver for adoption for all 13 households that received the grant(s). Only five of these households claimed that they would still have adopted a GSHP system without the presence of the financial incentive, indicating that it was a significant enabler for adoption for the other eight households. It was determined that regardless of household income levels, those that received both grants were more significantly influenced by the financial incentive opposed to those who received just one grant, i.e. half the amount.

Objective 5: To identify the communication channels that household decision-making units used in their adoption process and what information sources were regarded as the most useful

Lastly, it was found that interpersonal communication channels were more prominent in creating awareness for GSHP systems *and* for helping decision-making units make an informed decision to adopt said systems, compared to mass media information channels. Prior to adopting a system, the majority of households sought a personal evaluation from either a friend, family member, neighbour or work colleague who had previously adopted a system in their respective house. The majority of households claimed that the GSHP installation companies were the most useful and credible information sources in helping them make an informed decision, closely followed by the personal evaluations from their interpersonal network. Mass media channels played a relatively insignificant role in both knowledge creation and informing households' adoption decisions. It can be argued that this may be attributed to a lack of mass media marketing and advertising in the Ontario context. Hence, word-of-mouth recommendations are vital for creating awareness for GSHP systems among rural Ontario households and for persuading them to adopt.

6.3 Implications for Policy

Findings from this study have implications for policy. As identified in the previous two chapters, the government grant(s) was a significant driver for adoption. Only five of the 13 households who received a government grant would have still purchased a GSHP system without it. The government grant(s) were also successful in creating awareness and a perceived need for the GSHP system, that otherwise may not have facilitated adoption. Despite the significant impact of the government grant(s) on adoption behaviour, there is currently no longer any policy instrument in effect in Ontario to encourage the adoption of GSHP systems, such as financial incentives (e.g. government grants) or regulations (e.g. building codes). The majority of financial incentives are aimed at the development and diffusion of renewable electricity technologies, whereas renewable heat technologies receive little attention and support (Jagoda et al., 2011). As identified in chapter 1, GSHP systems were not even referenced to in Ontario's LTEP (Government of Ontario, 2013), demonstrating little recognition and support for the technology, specifically, and a lack of political foresight for renewable heat, in general. In order to increase the adoption of said systems, it is critical that the provincial and/or federal government increases their level of financial support for renewable heat, alongside the far more loudly trumpeted renewable electricity. Three policy recommendations can be made based on the findings from this thesis:

1. Re-introduce the government grant(s) program to incent and reward homeowners that do not have access to natural gas and currently heat and cool with fossil fuel or electric-based systems to retrofit their house with a GSHP system. Prior to the implementation of

such a program, research should be conducted to determine what is the most appropriate (i.e. cost effective) value for the grant. Another suggestion is that the amount of the grant could be determined by specific sociodemographic characteristics, such as the household's income level, to reduce the number of free riders.

2. Make GSHP systems mandatory for new construction houses in areas where natural gas is not available. This could be made a regulation through Ontario's Building Code.
3. Alternative economic programs should be considered as well, such as low interest loans or tax reductions.

6.4 Implications for Industry

Having identified the five determinants of adoption and the specific intricacies that influence the adoption of GSHP systems in the Ontario context, the following recommendations are proposed for the improvement of industry marketing.

1. While financial factors such as cost savings, the government grant(s) and the initial cost of the GSHP system were the most significant factors considered by the majority of decision-making units in their respective adoption process, it must be recognized that factors related to sustainability and the system's ability to provide space cooling were highly influential as well. Therefore, it is important for non-monetary factors, such as emotional or attitudinal variables, to be considered in parallel when developing and implementing industry marketing programs such as dissemination activities (e.g. information campaigns).
2. Considering that interpersonal communication channels were most effective in both knowledge creation and for persuading households to adopt a GSHP system, industry could implement a "word-of-mouth recommendation incentive," to financially reward households for recommending the purchase of a GSHP system to other households when a sale is made, based on that recommendation.
3. Improve mass media marketing efforts, through media such as the internet, radio or television, as they remain less effective in comparison to interpersonal channels, according to this study sample. Social media marketing, for example, has gained popularity in recent years for its effectiveness in reaching wide scale audiences cost-

effectively. This is one mass media marketing effort that should be exploited in the Ontario context to increase awareness of GSHP systems.

4. Marketing efforts should be oriented towards the cohort of rural households that have: some form of post-secondary education, above Ontario median household income levels and live in larger houses compared to Ontario's average single-detached house.
5. Industry should develop an improved relationship with Ontario home builders, to lobby the Ontario Building Code to make it mandatory for new construction houses in rural areas that do not have access to natural gas to have a GSHP system installed.

Industry marketers must recognize, however, that different consumer segments will not be reached through the same communication channels, and that marketing efforts should be tailored for different target audiences.

6.5 Recommendations for Future Research

Moving forward, there are opportunities for further research on the factors that influence the residential adoption of GSHP systems both in the rural Ontario context, and in general. Three potential avenues for future research that were deemed to be of interest are identified below.

First, as evidenced in chapter 4, the 17 primary interviews of this study yielded a substantial amount of insightful data which were subsequently not all given adequate research attention, namely due to the objectives and scope of this thesis. Thus, having already collected plentiful empirical data, future researchers could formulate different objectives with such data to reach new and insightful conclusions, to further our understanding of the factors that influence the residential adoption of GSHP systems and to develop theory in this field of research.

Second, a natural continuation of this study would be to obtain data for a larger sample to produce more generalizable results. With the completion of this partly exploratory study, a more structured approach, namely survey research, could be employed to collect data on a larger population in rural Ontario from which findings could be more readily generalized.

Third, it has been suggested that to improve the level of adoption of a specific residential RET, one must understand the gap that exists between early adopters and the early majority (Faiers & Neame, 2006). With this in mind, a future study could sample both of these populations, to identify potential differences in, for example, sociodemographic and household characteristics and attitudes towards the perceived characteristics of the GSHP system, to isolate what factors are preventing adoption for the early majority.

6.6 Conclusion

This chapter accomplished four tasks. First, it synthesized the main research findings with respect to each of the five objectives of this thesis, therein identifying the factors that influence the residential adoption of GSHP systems in rural southwestern Ontario. It then discussed the implications that research findings have for policy and industry, respectively. Last, the chapter concluded by providing three recommendations for future research.

In transitioning Ontario's residential sector towards a more sustainable and affordable energy future, it is integral that GSHP systems begin to receive more support and consideration by the federal and/or provincial governments, along with other renewable heat technologies. GSHP systems, in particular, offer a significant potential to reduce household energy consumption and the associated GHG emissions, all while reducing home heating and cooling costs.

References

Adachi, C. & Rowlands, I. H. (2009). The Role of Policies in Supporting the Diffusion of Solar Photovoltaic Systems: Experiences with Ontario, Canada's Renewable Energy Standard Offer Program. *Sustainability*, *2*(1), 30–47.

Arkesteijn, K. & Oerlemans, L. (2005). The early adoption of green power by Dutch households. *Energy Policy*, *33*(2), 183–196.

Babbie, E. 2001. *The Practice of Social Research* (9th ed.). Toronto: Nelson Thomson Learning.

Babbie, E. (2007). *The Practice of Social Research* (11th ed.). Belmont: Thomson Wadsworth.

Bakirci, K. (2010). Evaluation of the performance of a ground-source heat-pump system with series GHE (ground heat exchanger) in the cold climate region. *Energy*, *35*(7), 3088-3096.

Bayer, P., Saner, D., Bolay, S., Rybach, L. & Blum, P. (2012). Greenhouse gas emission savings of ground source heat pump systems in Europe: A review. *Renewable and Sustainable Energy Reviews*, *16*(2), 1256–1267.

Bryman, A., Teevan, J. J. & Bell, E. (2009). *Social Research Methods* (2nd ed.). Don Mills, ON: Oxford University Press.

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

Caird, S. & Roy, R. (2010). Adoption and Use of Household Microgeneration Heat Technologies. *Low Carbon Economy, 1*, 61–70.

Caird, S., Roy, R. & Potter, S. (2012). Domestic heat pumps in the UK: user behaviour, satisfaction and performance. *Energy Efficiency, 5*(3), 283-301.

Canadian GeoExchange Coalition. (2010a). *Comparative Analysis of Greenhouse Gas Emissions of Various Residential Heating Systems in the Canadian Provinces.* (April 2010). Retrieved July 30, 2014 from: http://www.geo-exchange.ca/en/UserAttachments/article63_GES_Final_EN.pdf

Canadian GeoExchange Coalition. (2010b). *The State of the Canadian Geothermal Heat Pump Industry 2010: Industry Survey and Market Analysis.* (November 2010). Retrieved July 30, 2014 from: http://www.geo-exchange.ca/en/UserAttachments/article64_Industry%20Survey%202010_FINAL_E.pdf

Canadian GeoExchange Coalition. (2011). *The Role of Ground Source Heat Pumps for a Canadian Sustainable Energy Strategy*. Presentation to the Standing Senate Committee on Energy, the Environment and Natural Resources, February 8, 2011. Ottawa, Canada. Retrieved on November 12, 2012 from: http://www.geo-exchange.ca/en/UserAttachments/flex1102_EENR_02_2010_E.pdf

Canadian GeoExchange Coalition. (2012a). *The State of the Canadian Geothermal Heat Pump Industry 2011: Industry Survey and Market Analysis.* (February 2012). Retrieved April 30, 2014 from: http://www.geoexchange.ca/en/UserAttachments/article81_Final%20Stats%20Report%202011%20-%20February%206,%202012_E.pdf

Canadian GeoExchange Coalition. (2012b). *Canadian Geothermal Heat Pump Industry Technology Roadmap: Final Report*. (March 2012). Retrieved July 30, 2014 from: http://www.geo-exchange.ca/en/UserAttachments/article84_Roadmap_FINAL_E.pdf

CanmetENERGY. (2005). *Ground-Source Heat Pump Project Analysis*. Natural Resources Canada. In RETScreen Engineering & Cases Textbook (p.5-68). RETScreen International.

Claudy, M., Michelsen, C., Driscoll, A. O. & Mullen, M. (2010). Consumer Awareness in the Adoption of Microgeneration Technologies :an Empirical Investigation in the Republic of Ireland. *Renewable and Sustainable Energy Review*, *14*(7), 2154–2160.

Curtis, R., Lund, J., Sanner, B., Rybach, L. & Hellström, G. (2005). *Ground Source Heat Pumps - Geothermal Energy for Anyone , Anywhere: Current Worldwide Activity*. Proceedings World Geothermal Congress (pp. 24-29). Antalya, Turkey (April 2005).

Dabholkar, P. A. & Bagozzi, R. P. (2002). An attitudinal model of technology-based self service: Moderating effects of consumer traits and situational factors. *Journal of the Academy of Marketing Science*, *30*, 184-201.

David Suzuki Foundation. (2004). *Smart Generation: Powering Ontario with Renewable Energy*. Full Report. Retrieved April 4, 2012 from: http://www.davidsuzuki.org/publications/downloads/2004/Smart_Generation_full_report.pdf

Diamantopoulos, A., Schlegelmilch, B.B., Sinkovics, R.R. & Bohlen, G.M. (2003). Can socio-demographics still play a role in profiling green consumers? A review of evidence and an empirical investigation. *Journal of Business Research, 56,* 465-480.

Diamond, D. (2009). The impact of government incentives for hybrid-electric vehicles: Evidence from US states. *Energy Policy, 37*(3), 972-983.

Dunn, K. (2000). "Interviewing", In I. Hay (Ed.). *Qualitative Research Methods in Human Geography*. Melbourne: Oxford University Press.

Environmental Commissioner of Ontario. (2014, April). Top Ten List for Energy Planning in Ontario [Web log post]. Retrieved August 6, 2014 from: www.eco.on.ca/blog/2014/04/16/top-ten-list-energy-planning-ontario/

Faiers, A. & Neame, C. (2006). Consumer attitudes towards domestic solar power systems. *Energy Policy, 34*(14), 1797-1806.

Faiers, A., Neame, C. & Cook, M. (2007a). The adoption of domestic solar-power systems: Do consumers access product attributes in a stepwise process? *Energy Policy*, *35*(6), 3418-3423.

Faiers, A., Cook, M. & Neame, C. (2007b). Towards a contemporary approach for understanding consumer behaviour in the context of domestic energy use. *Energy Policy, 35*(8), 4381-4390.

Faiers, A. (2009). *Understanding the Adoption of Solar Power Technologies in the UK Domestic Sector*. (Doctoral dissertation). School of Applied Sciences. Cranfield University, Cranfield, United Kingdom.

Frey, J. (2004). "Telephone Surveys", in M. Lewis-Beck, A. Bryman, & T. Liao (eds). *The Sage Encycl. of Soc. Sci. Research Methods* (Thousand Oaks, CA: Sage Publications).

Garling, A. & Thorgorsen, J. (2001). Marketing of electric vehicles. *Business Strategy and the Environment, 10*, 53-65.

Guagnano, G., Hawkes, G. R., Acredolo, C. & White, N. (1986). Innovation perception and adoption of solar heating technology. *Journal of Consumer Affairs, 20*(1), 48-64.

Gorden, R. L. 1987. *Interviewing: Strategy, Techniques, and Tactics* (4th ed.). Chicago, IL: The Dorsey Press.

Gosling, S. D., Rentfrow, P. J. & Swann Jr., B. (2003). A very brief measure of the Big-Five personality domains. *Journal of Research in Personality, 37*, 504-528.

Government of Ontario. (2013). Achieving Balance: Ontario's Long-Term Energy Plan. Retrieved July 30, 2014 from: http://www.energy.gov.on.ca/docs/LTEP_2013_English_WEB.pdf

Hanova, J., & Dowlatabadi, H. (2007). Strategic GHG reduction through the use of ground source heat pump technology. *Environmental Research Letters*, *2*(4), 044001.

Harmancioglu, N., Droge, C. & Calantone, R. J. (2009). Theoretical lenses and domain definitions in innovation research. *European Journal of Marketing*, *43*(1/2), 229-263.

Hatherton, D. (2009, April 20). From the Ground Up. *National Post*. Retrieved August 7, 2012 from: http://www.nationalpost.com/related/topics/From+ground/1506903/story.html

Hughes, L. & Chaudhry, N. (2011). The challenge of meeting Canada's greenhouse gas reduction targets. *Energy Policy, 39*, 1352-1362.

Human Resources and Skills Development Canada. (2011). Occupational Structure by Skill Type. Retrieved 12 June 2014 from: http://www5.hrsdc.gc.ca/NOC/English/NOC/2011/OccupationIndex.aspx

Independent Electricity System Operator. (2014). Ontario's Supply Mix. Retrieved July 30, 2014 from: https://ieso-public.sharepoint.com/Pages/Ontario%27s-Power-System/Supply-Mix/default.aspx

Intergovernmental Panel on Climate Change. (2011). *Special Report on Renewable Energy Sources and Climate Change Mitigation*. Retrieved July 29, 2014 from: http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch01.pdf

Jackson, T. (2005). *Motivating Sustainable Consumption: A review of evidence on consumer behaviour and behavioural change*. A Report to the Sustainable Development Research Network (January). Sustainable Development Research Network. Retrieved November 12, 2012 from: http://www.c2p2online.com/documents/MotivatingSC.pdf

Jager, W. (2006). Stimulating the diffusion of photovoltaic systems: A behavioural perspective. *Energy Policy*, *34*(14), 1935–1943.

Jagoda, K., Lonseth, R., Lonseth, A. & Jackman, T. (2011). Development and commercialization of renewable energy technologies in Canada: An innovation system perspective. *Renewable Energy*, *36*(4), 1266-1271.

Janssen, M. A. & Jager, W. (2002). Stimulating diffusion of green products: co-evolution between firms and consumers. *Journal of Evolutionary Economics, 12*, 283-306.

Jansson, J., Marell, A. & Nordlund, A. (2010). Green consumer behavior: determinants of curtailment and eco-innovation adoption. *Journal of Consumer Marketing*, *27*(4), 358–370.

Jansson, J. (2009). Car(ing) for our environment? Consumer eco-innovation adoption and curtailment behaviors: The case of the alternative fuel vehicle. (Doctoral dissertation) University of Umeå, School of Business. Umeå, Sweden.

Jansson, J. (2011). Consumer Eco-Innovation Adoption: Assessing Attitudinal Factors and Perceived Product Characteristics. *Business Strategy and the Environment, 20*, 192–210.

Kaplan, A. W. (1999). From passive to active about solar electricity: Innovation decision process and photovoltaic interest generation. *Technovation, 19*, 467-481.

Kaenzig, J. & Wüstenhagen, R. (2008). Understanding the Green Energy Consumer. *Marketing Review St. Gallen*, *25*(4), 12–16

Keirstead, J. (2007). Behavioural responses to photovoltaic systems in the UK domestic sector. *Energy Policy, 35*(8), 4128-4141.

Kikuchi, E., Bristow, D., & Kennedy, C. A. (2009). Evaluation of region-specific residential energy systems for GHG reductions: Case studies in Canadian cities. *Energy Policy, 37*(4), 1257–1266

Labay, D. G. & Kinnear, T. C. (1981). Exploring the Consumer Decision Process in the Adoption of Solar Energy Systems. *Journal of Consumer Research*, *8*(3), 271-278.

Lambert-Pandraud, R. G., Laurent, G. & Lapersonne, E. (2005). Repeat purchasing of new automobiles by older consumers: Empirical evidence and interpretations. *Journal of Marketing, 69*(2), 97-113.

Laroche, M., Bergeron, J. & Barbaro-Forleo, G. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. *Journal of Consumer Marketing, 18*(6), 503–520.

Laurent, G. & Kapferer, J. N. 1. (1985). Measuring consumer involvement profiles. *Journal of Marketing Research, 22*(1), 41-53.

Lambert-Pandraud, R. G., Laurent, G. & Lapersonne, E. (2005). Repeat purchasing of new automobiles by older consumers: Empirical evidence and interpretations. *Journal of Marketing, 69*(2), 97-113.

Lovett, F. (2006). Rational Choice Theory and Explanation. *Rationality and Society, 18*(2), 237-272.

Mahapatra, K. & Gustavsson, L. (2008a). Innovative approaches to domestic heating: homeowners’ perceptions and factors influencing their choice of heating system. *International Journal of Consumer Studies*, *32*, 75-87.

Mahapatra, K. & Gustavsson, L. (2008b). An adopter-centric approach to analyze the diffusion patterns of innovative residential heating systems in Sweden. *Energy Policy, 36*, 577-590.

Mahapatra, K. & Gustavsson, L. (2009). Influencing Swedish homeowners to adopt district heating system. *Applied Energy, 86*(2), 144–154.

Martinez, E., Polo, Y. & Flavián, C. (1998). The acceptance and diffusion of new consumer durables: differences between first and last adopters. *University Business*, *15*(4), 323-342.

McDonald, H. & Alpert, F. (2007). Who are "innovators" and do they matter?: A critical review of the evidence supporting the targeting of "innovative" consumers. *Marketing Intelligence & Planning, 25*(4), 421-435.

McKinsey & Company. (2007). *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? U.S. Greenhouse Gas Abatement Mapping Initiative*. Executive Report (December, 2007). Retrieved July 30, 2014 from: http://www.mckinsey.com/client_service/sustainability/latest_thinking/reducing_us_greenhouse_gas_emissions

Michelsen, C. C., & Madlener, R. (2010). *Integrated Theoretical Framework for a Homeowner’s Decision in Favor of an Innovative Residential Heating System.* Institute for Future Energy Consumer Needs and Behaviour Working Paper No. 2/2010. School of Business and Economics. RWTH Aachen University, Aachen, North Rhine-Westphalia, Germany.

Michelsen, C. C. & Madlener, R. (2013). Motivational factors influencing the homeowners' decisions between residential heating systems: an empirical analysis for Germany. *Energy Policy, 57*, 221-233.

Mills, B. F. & Schleich, J. (2009). Profits or preferences? Assessing the adoption of residential solar thermal technologies. *Energy Policy*, *37*(10), 4145-4154.

Moreau, C. P., Lehmann, D. R. & Markman, A. B. (2001). Entrenched knowledge structures and consumer response to new products. *Journal of Marketing Research, 38*(1), 14-29.

National Energy Board. (2013). Canada's Energy Future 2013 - Energy Supply and Demand Projections to 2035 - An energy Market Assessment. Retrieved July 30, 2014 from: http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.html

Natural Resources Canada. (2014a). Comprehensive Energy Use Database Table: Residential Sector - Ontario. Office of Energy Efficiency. Retrieved August 29, 2014 from: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=on&rn=2&page=4&CFID=33613054&CFTOKEN=e1199cbd29a4f64d-7DAEE8F5-E0C6-5E43-875C1C9D3D493BBB

Natural Resources Canada. (2014b). Ground-Source Heat Pumps (Earth-Energy Systems). Retrieved August 1, 2014 from: http://www.nrcan.gc.ca/energy/publications/efficiency/heating-heat-pump/6833

NextEnergy. (2012). How It Works. Retrieved July 31, 2014 from: http://www.nextenergy.ca/how-it-works.php

Nguyen, H. V, Lam, Y., Law, E., Alavy, M., Walsh, P. R., Leong, W. H. & Dworkin, S. B. (2014). An analysis of the factors affecting hybrid ground-source heat pump installation potential in North America. *Applied Energy*, *125*, 28–38.

Oak Ridge National Laboratory. (2010*). Assessment of National Benefits from Retrofitting Existing Single-Family Homes with Ground Source Heat Pump Systems*. Final Report (August 2010). Retrieved August 2, 2014 from: http://www.energy.ca.gov/2013_energypolicy/documents/2013-03-21_workshop/background/Liu_GSHP_Report_8-30-2010.pdf

Omer, A. M. (2007). Ground-source heat pump systems and application. Renewable and *Sustainable Energy Review, 12*(2), 344-371.

Ontario Federation of Agriculture. (2013). Turning up the heat for natural gas expansion in rural Ontario. Retrieved July 30, 2014 from: http://www.ofa.on.ca/media/news/Turning-up%20the%20heat-for-natural-gas-expansion-in-rural-Ontario

Ontario Power Authority. (2014). FIT/microFIT Price Schedule Changes. Retrieved 17 July 2014 from: http://microfit.powerauthority.on.ca/sites/default/files/2013-FIT-Price-Comparison-Table.pdf

Ozaki, R. (2011). Adopting sustainable innovation: What makes consumers sign up to green electricity? *Business Strategy and the Environment*, *20*(1), 1-17.

Ozaki, R. & Sevastyanova, K. (2011). Going hybrid: An analysis of consumer purchase motivations. *Energy Policy*, *39*(5), 2217-2227.

Painuly, J. P. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy, 24,* 73-89.

Palys, T. 2003. *Research Decisions: Quantitative and Qualitative Perspectives*. Scarborough, ON: Thomson Canada Limited.

Palys, T. & Atchison, C. (2008). *Research Decisions: Quantitative and Qualitative Perspectives* (4th ed.). Toronto, ON: Thomson Nelson.

Parthasarathy, M., Rittenburg, T. L., & Ball, A. D. (1995). A re-evaluation of the product innovation-decision process: the implications for product management. *Journal of Product & Brand Management*, *4*(4), 35–47.

Pembina Institute. (2011). *Behind the Switch: Pricing Ontario Electricity Options*. July 2011. Retrieved July 30, 2014 from: http://www.pembina.org/reports/behind-the-switch-final.pdf

Peter, R., Dickie, L. & Peter, V. M. (2005). Adoption decision process for a high-tech innovation. *Journal of Consumer Behaviour, 4*, 103-125.

Pickett-Baker, J. (2011). *Domestic Adoption of Renewable Technologies: Innovativeness, Adoption Behaviour and Individual Needs*. Imperial College Business School, London, United Kingdom. Paper presented at DIME-DRUID ACADEMY: Winter Conference (January 20-22, 2011).

Potoglou, D. & Kanaroglou, P. S. (2007). Household demand and willingness to pay for clean vehicles. *Transportation Research Part D: Transport and Environment, 12*(4), 264-274.

Randolph, J. & Masters, G. M. (2008). Energy for Sustainability: Technology, Planning, Policy. Washington: Island Press.

Rao, K. U. & Kishore, V. V. N. (2010). A review of technology diffusion models with special reference to renewable energy technologies. *Renewable and Sustainable Energy Policy Reviews, 14*(3), 1070-1078.

Reddy, S. & Painuly, J. P. (2004). Diffusion of renewable energy technologies - barriers and stakeholders' perspectives. *Renewable Energy, 29*, 1431-1447.

Robson C. (2002) Real World research; a resource for social scientists and practitioner researchers (2nd Edition). Oxford, UK: Blackwell Publishing.

Roehrich, G. (2004). Consumer innovativeness: Concepts and measurements. *Journal of Business Research*, *57*, 671-677.

Rogers, E. M. (1962). *Diffusion of Innovations*. New York: Free Press of Glencoe.

Rogers, E. M. (1983). *Diffusion of Innovations*, Third ed. New York: Free Press.

Rogers, E. M. (1995). *Diffusion of Innovations*, Fourth ed. New York: Free Press.

Rogers, E. M. (2003). *Diffusion of Innovations*, Fifth ed. New York: Free Press.

Schwarz, N. & Ernst, A. (2009). Agent-based modeling of the diffusion of environmental innovations: An empirical approach. *Technological Forecasting and Social Change, 76*(4), 497-511.

Self, S. J., Reddy, B. V. & Rosen, M. A. (2013). Geothermal heat pump systems: Status review and comparison with other heating options. *Applied Energy, 101*, 341-348.

Singleton, R. A. & Straits, B. C. (2005). *Approaches to Social Research* (4th ed.). New York, NY: Oxford University Press.

Skjevrak, G. & Sopha, B. M. (2012). Wood-Pellet Heating in Norway: Early Adopters' Satisfaction and Problems That Have Been Experienced. *Sustainability*, *4*(6), 1089–1103.

Sovacool, B. K. (2009). Rejecting renewables: The socio-technical impediments to renewable electricity in the United States. *Energy Policy, 37*(11), 4500-4513.

Southwest Economic Alliance. (2014). SWEA Region. Retrieved 30 April 2014 from: http://swea.ca/swea-region/

Statistics Canada. (2014). Indicators of Well-being in Canada: Learning - Education Attainment. Retrieved August 18, 2014 from: http://www4.hrsdc.gc.ca/.3ndic.1t.4r@-eng.jsp?iid=29

Statistics Canada. (2013a). Median total income, by family type, by province and territory. Retrieved June 12 2014 from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil108a-eng.htm

Statistics Canada. (2013b). Private households by structural type of dwelling, by province and territory. June 12 2014 from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil55b-eng.htm

Statistics Canada. (2007). Office of Energy Efficiency: The Stock of Dwellings in Canada. Retrieved June 12, 2014 from: http://oee.nrcan.gc.ca/publications/statistics/sheu-summary07/stock-dwellings.cfm?attr=0

Straub, E. T. (2009). Understanding Technology Adoption: Theory and Future Directions for Informal Learning. *Review of Educational Research*, *79*(2), 625–649.

Sultan, F. & Winer, R. (1993). Time preferences for products and attributes and the adoption of technology-driven consumer durable innovations. *Journal of Economic Psychology, 14*, 587-613.

Tapaninen, A., Seppänen, M. & Mäkinen, S. (2009). Characteristics of innovation: a customer-centric view of barriers to the adoption of renewable energy system. *International Journal of Agile Systems and Management, 4*(1/2), 98-113.

Tellis, G. J., Yin, E. & Bell, S. (2009). Global consumer innovativeness: Cross-country differences and demographic commonalities. *Journal of International Marketing*, *17*, 1-22.

Thorsteinsson, H. H. & Tester, J. W. (2010). Barriers and enablers to geothermal district heating system development in the United States. *Energy Policy, 38*(2), 803-813.

U.S. Department of Energy. (2012). Choosing and Installing Geothermal Heat Pumps. Retrieved August 1, 2014 from: http://energy.gov/energysaver/articles/choosing-and-installing-geothermal-heat-pumps

U.S. Environmental Protection Agency. (1993). *Space Conditioning: The Next Frontier*. Report 430-R-93-004.

Velayudhan, S.K. (2003). Dissemination of solar photovoltaics: a study on the government programme to promote solar lantern in India. *Energy Policy*, *31*(14), 1509-1518.

Vishwanath, A. & Chen, H. (2011). Towards a Comprehensive Understanding of the Innovation-Decision Process: A Relational Model of Adopter Choice. In Vishwanath, A. & Barnett, G.A. (Eds.) *Advances in the Study of the Diffusion of Innovations: A Communication Science Perspective* (pp. 9-32). New York: Peter Lang.

Wang, G., Dou, W. & Zhou, N. (2008). Consumption attitudes and adoption of new consumer products: a contingency approach. *European Journal of Marketing*, *42*(1/2), 238–254.

Wilson, C. & Dowlatabadi, H. (2007). Models of Decision Making and Residential Energy Use. *Annual Review of Environment and Resources*, *32*(1), 169–203.

Yin, R. (2003). *Case Study Research: Design and Methods* (3rd ed.) (vols. 5). Thousand Oaks, CA: Sage Publications.

Appendices

Appendix A - Gatekeeper Recruitment Letter and Consent Form

Date

Dear Waterloo Energy Products / Bostech Mechanical,

This letter is a request for Waterloo Energy Products' / Bostech Mechanical's assistance with a project I am conducting as part of my Master's degree in the Department of Environment and Resource Studies at the University of Waterloo, under the supervision of Dr. Ian Rowlands. The title of my research project is "Household Decision-Making Dynamics Associated with Renewable Energy Technologies: A Case Study of Consumer Experiences in the Adoption of Residential Geothermal Energy Systems in Rural Southwestern Ontario." I would like to provide you with more information about this project that investigates the factors that influence the residential adoption of geothermal energy systems.

Knowledge and information generated from this study may be of importance to Waterloo Energy Products / Bostech Mechanical as well as homeowners interested in purchasing a geothermal energy system, and to the broader research community. It is my hope to connect with *homeowners in rural southwestern Ontario who have retrofitted their household with a geothermal energy system in the last five years* to invite them to participate in this research project. I believe that because they have adopted a system, they are well suited to speak to the various factors involved in the adoption process, such as the drivers for adoption, potential barriers to adoption, information sources that were used to help inform their adoption decision, and sociodemographic characteristics that may have influenced the adoption process. For this study, I am aiming to conduct 45-60 minute interviews with these homeowners to gather their adoption experiences. Findings from this research will be presented in a Master's Thesis, to the broader research community, and to Waterloo Energy Products / Bostech Mechanical.

To respect the privacy and rights of Waterloo Energy Products / Bostech Mechanical and its customers, I cannot contact these homeowners directly. Thus, I am asking for Waterloo Energy Products' / Bostech Mechanical's assistance for the recruitment of interview participants by emailing or phoning all homeowners who meet the research population criteria of this study. An email and telephone script will be provided for Waterloo Energy Products / Bostech Mechanical for recruitment purposes. An information letter will also be provided for Waterloo Energy Products / Bostech Mechanical that contains detailed information about this study, as well as interview consent forms. Contact information for me and my supervisor will be contained in the information letter. If a homeowner is interested in participating they will be invited to contact me, Mark Goody, to discuss participation in this study in further detail.

Participation of any homeowner is completely voluntary. Each homeowner will make their own independent decision as to whether or not they would like to be involved. All participants will be informed and reminded of their rights to participate or withdraw before any interview, or at any time in the study. To support the findings of this study, quotations and excerpts from the stories will be used labelled with codes to protect the identity of the participants. Names of participants will not appear in the thesis or reports resulting from this study.

If Waterloo Energy Products / Bostech Mechanical wishes the identity of the organization to remain confidential, a pseudonym will be given to the organization. All paper field notes collected will be locked up in Dr. Ian Rowlands' office and will be confidentially destroyed after one year. Further, all electronic data will be stored for one year on a CD with no personal identifiers. Finally, only myself and my supervisor, Dr. Ian Rowlands in the Department of Environment and Resource Studies at the University of Waterloo will have access to these materials. There are no known or anticipated risks to participants in this study.

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics, University of Waterloo. However, the final decision about participation belongs to Waterloo Energy Products / Bostech Mechanical and the homeowners who meet the research population criteria. If you have any comments or concerns with this study, please feel free to contact Dr. Maureen Nummelin, Director, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or maureen.nummelin@uwaterloo.ca.

If you wish to assist in the recruitment of interview participants or would like additional information to assist you in reaching a decision about participation, or have any questions regarding this study please contact me at 519-503-0212 or by email at mgoody@uwaterloo.ca. You may also contact my supervisor, Dr. Ian Rowlands at (519) 888-4567 ext. 32574 or email at irowlands@uwaterloo.ca.

I hope that the results of my study will be beneficial to Waterloo Energy Products / Bostech Mechanical as well as homeowners interested in purchasing a geothermal energy system, and to the broader research community. I very much look forward to speaking with you and thank you in advance for your assistance with this project.

Sincerely,

Mark Goody
Department of Environment and Resource Studies University of Waterloo
(519) 503-0212
mgoody@uwaterloo.ca

Dr. Ian Rowlands
Department of Environment and Resource Studies
University of Waterloo
(519) 888-4567 ext. 32573
irowlands@uwaterloo.ca

Company Permission Form

We have read the information presented in the information letter about a study being conducted by Mark Goody of the Department of Environment and Resource Studies at the University of Waterloo, under the supervision of Dr. Ian Rowlands at the University of Waterloo. We have had the opportunity to ask any questions related to this study, to receive satisfactory answers to our questions, and any additional details we wanted.

We are aware that the name of our organization will only be used in the thesis or any publications that comes from the research with our permission.

We were informed that this organization may withdraw from assistance with the project at any time. We were informed that study participants may withdraw from participation at any time without penalty by advising the researcher.

We have been informed this project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo and that questions we have about the study may be directed to Mark Goody at 519-503-0212 or by email at mgoody@uwaterloo.ca or Dr. Ian Rowlands at (519) 888-4567 ext. 32574 or email at irowlands@uwaterloo.ca.

We were informed that if we have any comments or concerns with in this study, we may also contact the Director, Office of Research Ethics at (519) 888-4567 ext. 36005.

We agree to help the researcher recruit participants for this study from among homeowners who are customers of Waterloo Energy Products / Bostech Mechanical.

__YES __NO

We agree to the use of the name of Waterloo Energy Products / Bostech Mechanical in any thesis or publication that comes of this research.

__YES __NO

If NO, a pseudonym will be used to protect the identity of the organization.

Director Name: ___________________________________ (Please print)

Director Signature: ________________________________

Witness Name: _____________________________________ (Please print)

Witness Signature: _________________________________

Date: ___________________________________

Appendix B - Recruitment E-mail Prepared by Researcher for Company

Dear (insert participant name),

This is (insert name/position) from (insert company name). Recently, our company has partnered with a Master's student, Mark Goody, from the Department of Environment and Resource Studies at the University of Waterloo for a one-time study regarding the adoption of residential geothermal energy systems in rural southwestern Ontario. As part of Mark's research, he is conducting interviews with homeowners to learn about the factors that influence the residential adoption of geothermal energy systems. The objectives are to understand how homeowners make decisions regarding the adoption of said systems and to identify and explain the factors that either promote or hinder adoption and to evaluate the degree to which such factors are influential.

I believe that because you have adopted a residential geothermal energy system in rural southwestern Ontario, you are well suited to speak to the various factors involved in the adoption process and thus; you might be interested in participating in his study. Interviews can take place in-person at a time and location of convenience to you or by telephone or Skype and will last approximately 45-60 minutes. In particular, Mark is interested in interviewing the key household decision-maker(s) involved in the adoption process.

This study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. **If you wish to participate in this study or would like additional information to assist you in reaching a decision about participation, please contact Mark at (519) 503-0212 or by email at mgoody@uwaterloo.ca.**

Attached to this email is an information letter prepared by Mark with more details about the study and what your involvement would entail if you decide to take part. We hope that the results of this study will be of benefit to the Ontario geothermal energy industry as well as homeowners interested in purchasing a geothermal energy system, and to the broader research community.

Sincerely,

(insert name, company name)

Appendix C - Information Letter and Consent Form

Dear Homeowner,

My name is Mark Goody and I am a Master's student working under the supervision of Dr. Ian Rowlands in the Department of Environment and Resource Studies at the University of Waterloo. **I am writing this letter to invite you to participate in a 45 minute interview for my study regarding the adoption of residential geothermal energy systems.** I would like to provide you with more information about this project and what your involvement would entail if you decide to take part.

In recent years, concerns over the status of energy supply and the impacts of climate change have led to various studies investigating cleaner energy resources. Renewable energy technologies, such as geothermal energy systems, are attractive and viable options for residential heating and cooling, especially for households currently using electric and fossil fuel-based systems.

The purpose of this study is to investigate the factors that influence the residential adoption of geothermal energy systems in rural southwestern Ontario. When faced with the opportunity to adopt a cleaner technology, it is important to understand how homeowners with unique values respond. People like yourself provide a valuable knowledge-base regarding rural homeowner perspectives into the adoption of geothermal energy systems, and as such, I would like to invite you to take part in this study. I believe that because you have adopted a geothermal energy system, you are well suited to speak to the various factors involved in the adoption process, such as the drivers for adoption, potential barriers to adoption, information sources that were used to help inform the adoption decision, and sociodemographic characteristics that may have influenced the adoption process. In particular, I am interested in interviewing the key household decision-maker(s) involved in the adoption process.

Participation in this study is voluntary. It will involve an interview of approximately 45 minutes in length (depending on your interest) to take place in-person at a time and location of convenience to you or by telephone or Skype. You may decline to answer any of the interview questions if you so wish. Further, you may decide to withdraw from this study at any time without any negative consequences by advising me. With your permission, the interview will be audio recorded to facilitate collection of information, and later transcribed for analysis. Upon request, I will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or clarify any points. All information you provide is considered completely confidential. Your name will not appear in any thesis or report resulting from this study; however, with permission anonymous quotations may be used. Data collected during this study will be retained for one year in a secured electronic format or in my supervisor's office at the University of Waterloo. Only the researcher and supervisor associated with this project will have access. There are no known or anticipated risks to you as a participant in this study.

If you wish to participate in this study and would like to arrange a time and location for the interview or would like additional information to assist you in reaching a decision about participation, **please contact me at (519) 503-0212 or by email at mgoody@uwaterloo.ca**.

You can also contact my supervisor: Dr. Ian Rowlands at (519) 888-4567 ext. 32574 or email at irowlands@uwaterloo.ca if you have any questions about this study.

If you choose to participate in this study, a participant consent form is included below, which can be filled out and returned to me either electronically using Adobe EchoSign, by scan and email, or in-person at the time and location of the interview. If the interview takes place via telephone or Skype, and the consent form has not been received electronically, a verbal consent form will be used instead.

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Maureen Nummelin, the Director, Office of Research Ethics at 519-888-4567 ext. 36005 maureen.nummelin@uwaterloo.ca.

I hope that the results of my study will be of benefit to the Ontario geothermal energy industry as well as homeowners interested in purchasing a geothermal energy system, and to the broader research community.

I very much look forward to speaking with you and thank you in advance for your assistance in this project.

Sincerely,

Mark Goody

Candidate for Master of Environmental Studies
Department of Environment and Resource Studies
University of Waterloo

Participant Consent Form

By signing this consent form, you are not waiving your legal rights or releasing the researcher(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about the study being conducted by Mark Goody of the Department of Environment and Resource Studies at the University of Waterloo under the supervision of Dr. Ian Rowlands. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact Dr. Maureen Nummelin, the Director, Office of Research Ethics at 519-888-4567 ext. 36005 or maureen.nummelin@uwaterloo.ca.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

__YES __NO

I agree to have my interview audio recorded.

__YES __NO

I agree to the use of anonymous quotations from open-ended responses in any thesis or publication that comes of this research.

__YES __NO

Participant Name(s): ____ (Please print)

Participant Signature(s): ____

Date: ____________________________

Appendix D - Interview Guide

Section A - Prior Conditions

A1. To begin with, how and when did you first become aware of residential geothermal energy systems?
Follow-up questions/Prompts for researcher:

Awareness:

A-1) Did you become aware of geothermal energy systems *before* you were actively looking to replace your previous system? If so, did such awareness of geothermal systems create a *need or desire* to purchase the system?

A-2) Did you become aware of geothermal energy systems because you were *actively looking* to replace your previous system?

A2. Do you think that there is a general lack of awareness of geothermal energy systems for residential heating and cooling?

A3. With a general timeline, when did you first become interested in purchasing a geothermal energy system for your house?

A4. When was your geothermal system installed?

A5. What was your opinion of the installation process of your geothermal system on your property?
Follow-up questions/Prompts for researcher:

Installation Process:

IP-1) Was there any disruption to your property? If so, was it less than, equal to, or more than you had anticipated, due to the nature of the installation process?

A6. What previous space heating and cooling system did your house have?
Heating:______________________________Cooling:________________________________

A7. How old was this system at the time you had your geothermal system installed?

A8. Did you experience any problems with your previous heating and cooling system? If so, what were they?

A9. Did you consider installing any other type of heating and cooling system instead of a geothermal system? If so, what system(s) did you consider?

A10. At the time of installation, did you experience any degree of *uncertainty or skepticism* towards the performance of geothermal technology?
Follow-up questions/Prompts for researcher:

Uncertainty:
U-1) Were you confident that the system would result in positive consequences?

A11. Would you describe your *ability* to understand and apply technical knowledge as *strong*, *average*, or *weak* and why?

A12. Do you think that geothermal energy systems are a simple or complex technology?

A13. Social participation refers to "one's degree of interaction and social exchange between one or more persons in a community or society." Would you describe yourself as having a *high*, *average*, or *low* degree of social participation and why?

I am now going to ask five questions that use a rating scale of 1 to 5, with 1 being not at all, and 5 being very, for each question. Please choose the number along this scale, for each of the questions, that best describes you.

A14. On a scale 1 to 5, how *interconnected* are you to people that live *within* the rural region that you live in and why? (*Connectedness* is the degree to which an individual is linked to others).

Not at all ←——————————→ Very
1 2 3 4 5

A15. On a scale 1 to 5, how *interconnected* are you to people that live *outside* of the rural region that you live in and why? (Again, *connectedness* is the degree to which an individual is linked to others).

Not at all ←——————————→ Very
1 2 3 4 5

A16. On a scale 1 to 5, how *favourable* is your attitude towards *trying new things or new ways of doing things* and why?

Not at all ←——————————→ Very
1 2 3 4 5

A17. On a scale 1 to 5, how *willing* are you to *take risks* and why?

Not at all ←——————————→ Very
1 2 3 4 5

A18. On a scale 1 to 5, how *favourable* is your attitude towards *science* and why?

Not at all ←——————————→ Very
1 2 3 4 5

A19. Which of the following two statements do you most agree with?
1) Human beings can *solve* environmental problems through the use of technology. **OR**
2) Human beings *create* environmental problems through the use of technology.

A20. Here are two more statements; which of the following do you most agree with?
1) Human beings have the power to control the future. **OR**
2) Human beings are powerless and the future is determined by fate (e.g. all events are predetermined and therefore inevitable).

Section B - Perceived Characteristics of the GSHP System Influencing Adoption

B1. What were the most significant factors *promoting* or *hindering* your decision to purchase a geothermal energy system?
Follow-up questions/Prompts for researcher:

Financial:
F-1) Did money play a role in your decision?
F-2) Did the initial cost of the system influence your decision?
F-3) Did monthly operating costs influence your decision?
F-4) Did the length of payback influence your decision?
F-5) Did you apply for and receive any government grants? If yes, what was the grant and associated value?____________________________
F-6) What role did the grant play in your decision? (Skip if F-2 was answered "no")
F-7) Would you have purchased a geothermal system *without* the grant? (Skip if F-2 was answered "no")
F-8) Do you think that the government should always have some form of a financial incentive available to homeowners for installing a geothermal system?

Environmental:
E-1) Did environmental considerations or issues play a role in your decision?
E-2) Did the phenomenon of climate change influence your decision?
E-3) Did wanting to reduce your greenhouse gas emissions influence your decision?
E-4) Did wanting to reduce your demand on fossil fuels influence your decision?
E-5) Did you want to own renewable energy technology to demonstrate environmental commitment?
E-6) Did you want to own a renewable energy technology to gain a level of pleasure or satisfaction?

Technological:
T-1) Did the technological nature of the system influence your decision?
T-2) Did the system's ability to provide heating and cooling, influence your decision?

T-3) Did the perceived quality of heating and cooling provided by geothermal energy systems influence your decision?
T-4) Did wanting to have a "cutting-edge" (or innovative/advanced) technology influence your decision?
T-5) Did the fact that you would no longer need to have oil/propane delivered and connected to your house influence your decision? (Skip if house previously had an electric-based heating system)

Social:
S-1) Did the opinion of any of your family, friends work colleagues or neighbours affect your decision to purchase a geothermal system?
S-2) Did you want to lead by example, and encourage other homeowners to adopt geothermal as well?
S-3) Would you suggest that there are any risks associated with purchasing a geothermal energy system? If so, what are they, and did you face any of them? (e.g. financial or technological risks)
S-4) Were there any household disagreements with purchasing your geothermal system? (e.g. was it a mutual household decision to purchase a geothermal system or did one or more household members not want to purchase the system?)

Visual:
V-1) As you know, geothermal energy systems are not a visible "outside" technology, unlike rooftop solar panels. Did this fact influence your decision?

B2. We are now moving on to section 3 of 4 of the interview process, but before we begin, are there any other major factors that promoted or hindered your decision to purchase a geothermal energy system that you wanted to mention at this point?

Section C - Communication Channels

C1. What information sources or materials did you use to inform your decision to purchase a geothermal energy system?

Follow-up questions/Prompts for researcher:

Mass Media Channels:

MMC-1) Did you use mass media information channels, such as the television, newspaper, radio, internet or another form of mass media, to help inform your decision to purchase a geothermal system? If so, what sources did you use?

Interpersonal Channels:

IC-1) Did you seek any advice or information from another homeowner who already had installed a geothermal energy system, prior to purchasing a system yourself?

C2. What information source(s) did you find the *most* and *least* useful and credible in helping you make the decision to purchase a system and why?

Section D - Overall Adoption Experience

D1. How would you describe your overall *experience* in learning about and purchasing a geothermal energy system - positive, mixed or negative?

D2. Are you currently satisfied with your decision to purchase a geothermal energy system? Why or why not?

D3. Have you recommended purchasing a geothermal energy system to anyone yet? If not, would you recommend this purchase in the future?

D4. What do you think are the 3 biggest reasons or barriers that are preventing other rural Ontario households that heat with oil, propane and electricity from converting to a geothermal energy system?

D5. Is there anything else that you would like to mention about purchasing a geothermal energy system that you feel I did not ask about or should have asked about?

Section E - Characteristics of Decision-Making Unit and Household

To be filled out by the key decision-maker(s) involved in the adoption process. Please note that this information is confidential and will not be used to identify participants in any way. You may decline to answer any of the questions below. These questions are being asked to help determine any correlations between household characteristics and adoption processes.

E1. Male ___ Female ___

E2. Please indicate the age group you were in at the time of installation:

18 - 29 ___ 50 - 59 ___
30 - 39 ___ 60 - 69 ___
40 - 49 ___ 70 + ___

E3. Please indicate the number of people in each of the following age groups that lived in your house at the time of installation:

10 or younger ___ 30 - 39 ___ 60 - 69 ___
11 - 19 ___ 40 - 49 ___ 70 + ___
20 - 29 ___ 50 - 59 ___

E4. What is the approximate square footage of your house? __ __ __ __ sq ft.

E5. What year was this house built? _________.

E6. How long have you lived in this house for? _________years.

E7. How long (roughly) do you intend to live in this house for, based on current plans? _________years.

E8. What was the approximate annual income (before taxes) of your household at the time of installation *(or if retired, at the time of retirement)*?

Under $30,000 ___ $60,000 - $69,999 ___ $100,000 - $149,999 ___
$30,000 - $39,999 ___ $70,000 - $79,999 ___ $150,000 - $199,999 ___
$40,000 - $49,999 ___ $80,000 - $89,999 ___ $200,000 - $249,999 ___
$50,000 - $59,999 ___ $90,000 - $99,999 ___ $250,000 and over ___
Prefer not to say ___

E9. Please indicate the highest level of education you have obtained at the time of installation:

No high school ___
Completed high school ___
College diploma ___
Apprenticeship or trades certificate ___
Some university ___
University degree (Bachelor) ___
Graduate degree (Master of Ph.D.) ___
Professional degree (M.D., LL.D., P.Eng, etc.) ___

E10. What was your *job title* and *place of employment* at the time of installation *(or if retired, at the time of your retirement)*?

____

E11. Please list any other *energy efficient* technologies that your household has purchased in the last 10 years:

E12. Would you ever consider buying an electric or hybrid vehicle? Yes___ No___ Maybe___

If **yes**, please list 2-3 reasons why:
1. ______________________________ 3.______________________________
2. ______________________________
You're welcome to list more if you wish:

If **no**, please list 2-3 reasons why:
1. ______________________________ 3.______________________________
2. ______________________________
You're welcome to list more if you wish:

E13. Please choose the ONE statement below that best describes your *willingness* to try new products?
___ I am excited about new products and am usually one of the first people to try them out.
___ I am willing to try new products, but generally wait until someone I know has first to see how they like them.
___ I tend to hold off on new products until a majority of the people I know have purchased and are using them.
___ I am generally one of the last people to buy new products or try out something new.
___ I do not welcome new products and instead prefer to use or do what I have done in the past.

Appendix E - Feedback Letter

Dear Homeowner(s),

I would like to **thank you for your participation in this study** entitled "Household Decision-Making Dynamics Associated with Renewable Energy Technologies: A Case Study of Consumer Experiences in the Adoption of Residential Geothermal Energy Systems in Rural Southwestern Ontario." As a reminder, the purpose of this study is to investigate the factors that influence the residential adoption of geothermal energy systems in rural southwestern Ontario. The objectives are to understand how rural homeowners make decisions regarding the adoption of geothermal energy systems and to identify and explain the factors that either promote or hinder adoption and to evaluate the degree to which such factors are influential.

Without your contribution, the results produced from this research would not be as insightful and valuable. The data collected during interviews will contribute to a better understanding of the factors that influence the residential adoption of geothermal energy systems. In turn, this can help inform industry marketing and operations and policy-making regarding the adoption of geothermal energy systems in Ontario.

Please remember that any data pertaining to you as an individual participant will be kept confidential. Findings from this research will be presented in a Master's Thesis and to the broader research community. If you are interested in receiving information regarding the results of this study, or would like a summary of the results, please let me know, and when the study is completed, anticipated by September 2014, I will send you a document. In the meantime, if you have any questions or comments about the study, please do not hesitate to contact me by email or telephone as noted below.

As with all University of Waterloo projects involving human participants, this project was reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Maureen Nummelin, the Director, Office of Research Ethics, at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

Sincerely,

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Appendix F - Full List of Factors Influencing Household Adoption of GSHP Systems

Factor	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17
Initial cost of system			**B**		**B**	*b*	**B**	**B**	**B**		**B**		**B**	**B**	**B**	**B**	**B**
Cost savings	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	*d*	**D**	**D**	**D**
Length of payback					*d*	*d*	**N**	**N**	**D**		**N**	**N**	**D**			**D**	*d*
Government grant	**D**	**D**	*d*	*d*		**D**		*d*	**D**	**D**	**D**		**D**	**D**		**D**	**D**
Inheritance of money													**D**				
Investment			**D**				**D**			**D**				*d*	*d*		
Increase property value							**D**			**D**	*d*			**D**	**D**		
Sustainability	**D**		**D**	**D**		**D**	**D**		**D**	**D**	**D**	**D**	**D**	*d*		**D**	
Demonstrate environmental commitment			*d*	*d*		*d*							*d*			*d*	
Pleasure of using a RET			*d*	*d*		*d*	*d*		*d*		*d*		*d*			*d*	
Technological nature of system		*d*				*d*			*d*			*d*					*d*
Cutting-edge technology			*d*			*d*											*d*
Reliability			**D**		*d*	*d*					**D**	*d*		**D**	*d*		
Ability to provide space cooling	**D**		**D**	*d*	**N**	*d*	**N**	**N**	*d*	**N**	**D**	**D**		**D**	**N**		*d*
Quality of heating	*d*	*d*								*d*		*b*		*d*		*d*	*d*
No delivery of oil/propane				*d*		**D**							**D**		*d*		
Maintenance free				*d*										*d*			
Clean (sanitary)	*d*		*d*									**D**	**D**			*d*	
Safe	*d*		*d*			**D**	*d*					**D**	**D**		**D**		
More convenient										*d*		**D**		**D**			
Opinion of others		*d*				*d*	*d*		*d*	*d*	**D**	*d*	*d*				
Lead by example	*d*		*d*	*d*	*d*	*d*						*d*	*d*				
Financial risk			*b*					*b*							*b*	*b*	
Technological risk						*b*				*b*	*b*	*b*			*b*	*b*	
Household disagreements																*b*	
Aesthetics risk								*b*	*b*								*b*
Not visible	*d*		*d*					*d*		*d*		*d*	*d*	*d*			

Legend: **D** = Driver, unprompted; *d* = Driver, prompted
B = Barrier, unprompted; *b* = Barrier, prompted
N = Neutral, unprompted