Barrier Assessment:

Uptake of Air Source Heat Pump Technologies in Ontario's Multi-Unit Residential Sector

Prepared for:

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Table of Contents

Acronyms

ASHP	Air Source Heat Pumps
DSHP	Ductless Split Heat Pump
GAHP	Gas Absorption Heat Pump
HVAC	Heating, Ventilation and Air Conditioning
MURB	Multi-Unit Residential Building
VRF	Variable Refrigerant Flow Heat Pump

Introduction

Heat pump technology has been noted to reduce greenhouse gas (GHG) emissions and reliance on fossil fuels, while providing space heating, space cooling and domestic hot water (Patel et al., 2015). The main benefit of heat pumps is that they can provide more heating output for the same energy input when compared with conventional alternatives, such as baseboard electric resistance heaters. They do this by extracting useful heat energy from the air or ground. As such, Ontario's most recent Climate Change Action Plan (CCAP) stated that the provincial government intends to make Ontario "one of the easiest and most affordable jurisdictions in North America" for home or business heat pump retrofits (Ontario, 2016). This report follows a recognition that despite the potential for heat pumps to contribute to climate change efforts and GHG reduction strategies, heat pump systems have seen lower than expected uptake in a number of international jurisdictions (Gleeson, 2016; Northeast Energy Efficiency Partnerships, 2017). This research therefore seeks to understand potential barriers that heat pumps may encounter in the Ontario context. The report aims to identify all key barriers to uptake of three air-source heat pump (ASHP) technologies: **ductless split heat pumps** (DSHPs), **gas absorption heat pumps** (GAHPs) and **variable refrigerant flow heat pumps** (VRF).[1] Specifically, our assessment considers the uptake of these technologies within Ontario's multi-unit residential building (MURB) sector.

Table 1: Summary of ASHP technologies considered in this report

Technology	Description
Ductless split heat pumps (DSHPs)	A DSHP system consists of an outdoor compressor/condenser unit connected to one or more indoor air handlers via small diameter refrigerant piping that can be run on the interior or exterior of a building. DSHPs can be appropriately sized for a single room or a large home. Multiple DSHP systems can be used to heat larger buildings.
Gas absorption heat pumps (GAHPs)	Gas absorption heat pumps are less efficient than their electric counterparts but more efficient than other gas heating technologies like furnaces and condensing boilers. This is because the gas energy is supplemented with heat energy extracted from the outdoor air via an outdoor fan coil. GAHPs are not as scalable as electric heat pumps but models suitable for MURB applications are available in Canada.
Variable refrigerant flow (VRF)	A VRF system is similar to a DSHP in that heat energy is transported throughout a building via small-diameter refrigerant piping. However, a VRF system has a larger capacity and the capability to connect with more indoor air handlers, making it well-suited to larger buildings. Some VRF system also

[1] It should be noted that while both GAHPs and VRF systems may be applicable to other building sub-sectors (i.e. commercial-institutional-industrial properties), assessment of barriers in these sectors is outside of the scope of this research.

heat pumps	have heat recovery features where waste heat from one part of a building can be used elsewhere within the building.

The report is organized into three sections: (1) market barriers and market failures, (2) behavioural and consumer preference barriers, and (3) political-institutional barriers. This classification is based on an extensive literature review which incorporated a variety of academic and grey literature sources. Each section concludes with a brief summary of key findings as well as a qualitative barrier rating. Barriers were rated in a workshop survey with 39 stakeholders from a variety of sectors (see Figure 1).[2] While results of this survey are not scientific, they do provide valuable insight on how the identified barriers are perceived within the Ontario context.

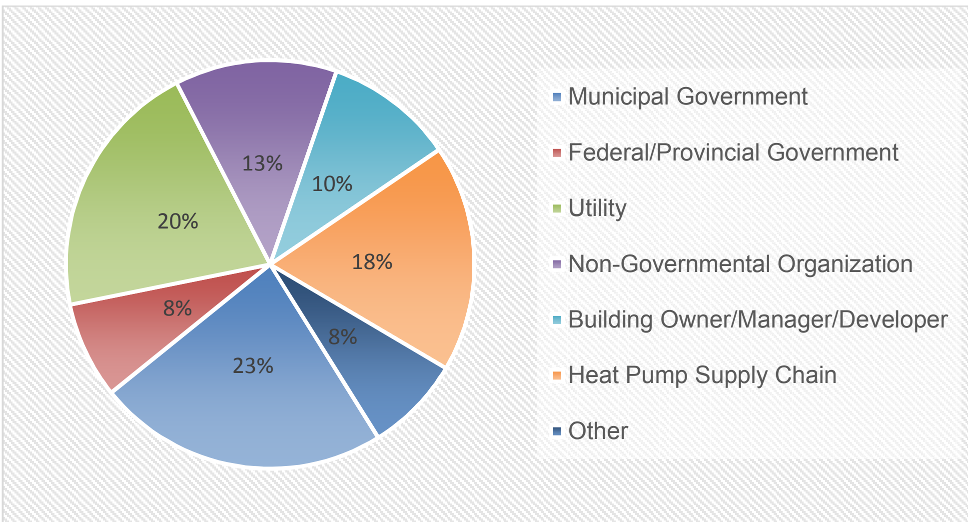

Figure 1. Workshop attendees by sector.

As can be seen throughout this report, there exists significant overlap between many of these barriers. Categorizing and exploring barriers individually allows for a more thorough exploration into particular issues, but it should be noted that individual barriers alone likely do not explain inaction or low uptake of technologies. Rather, this paper reveals a complex landscape where large-scale uptake is impeded by a combination of these interrelated barriers. In order to overcome this challenge, the findings suggest that a holistic approach which addresses barriers collectively will be the most effective approach for greater uptake of ASHP retrofits.

[2] The Heat Pump Symposium took place on March 20, 2018 at the Toronto and Region Conservation office in Vaughan, Ontario. The workshop provided an overview of heat pump research results from projects conducted by Toronto and Region Conservation's Sustainable Technologies Evaluation Program, the Ontario Climate Consortium, and the Toronto Atmospheric Fund. Feedback from attendees provided barrier ratings, and also identified a number of gaps in preliminary findings which were later re-examined and improved.

Market Barriers

Market barriers, in the context of energy efficiency, refer to “any market-related factor that inhibits energy efficiency improvements” (IPCC, 2001). Our analysis identifies three primary market barriers: upfront costs, operational costs and risk. Additionally, our overview includes a specific subset of market barriers, referred to as *Market Failures*. Market failures occur when one or more of the conditions necessary for markets to operate efficiently are not met (OECD/IEA, 2007). They have been noted in literature to be an important subset to identify because, according to some economists, “only those barriers that are market failures lead to inefficient allocation of resources” (OECD/IEA, 2007). Therefore, even governments who tend to be skeptical of government intervention and interference with the natural behaviour of markets may see a need to act in order to let free markets operate effectively. As such, this section includes discussion of three market failures: split-incentives within tenant-landlord relationships, inaccurate or insufficient information, and shortage of industry knowledge and capacity.

A. Upfront Cost
B. Operational Cost
C. Risk
D. Split Incentives
E. Inaccurate/Insufficient Information
F. Shortage of Industry Knowledge and Capacity

Upfront Cost

High upfront cost represents the principal barrier for immature or novel technologies (IEA, 2014). Installation costs represent a particular challenge, as installing these new technologies is likely to be a significant financial investment for customers (Carbon Trust and Rawlings Support Services, 2016). Overcoming this barrier remains a challenge for all of the featured technologies, but as this section will demonstrate, upfront cost is likely a most significant challenge for gas absorption heat pumps.

In a residential setting, a single air-source heat pump installation for a home or an apartment unit may cost between $5,000 to $16,000 (including equipment and installation), depending on type of equipment (ductless, ducted, central, etc.), size of the equipment, complexity of the installation and the system being replaced (IESO, 2017). An advantage of **air source heat pumps** (ASHPs) is that they generally have lower installation costs than ground source heat pumps, as there is no need for a ground heat exchanger (BSRIA, 2009). **Ductless split heat pumps** (DSHPs), a subset of ASHPs, are quite easy to install compared to other heat pump technologies such as central ASHPs and ground source heat pumps—though costs remain higher than those for conventional heating systems. DSHPs are compact, combine heating and cooling, do not require ducts, can be mounted outside, are available in smaller capacities for apartment and individual rooms, and have been demonstrated to work at high efficiencies (Patel et al., 2015).

For **VRF systems,** literature suggests that installed costs are highly variable, project dependent, and difficult to pin down (Goetzler et al., 2007). VRF systems were invented in Japan and have been in use for almost three decades; they are widely used in Asia, Europe, and South America, but are relatively unknown in North American markets (Curtland, 2012). Being new to the Canadian market likely has a major impact on cost; where, while equipment costs have been noted to be similar in North American and European markets, American contractors may bid a high installation cost because they are less familiar with the product and need to build a larger contingency (Goetzler, 2007).

High upfront cost is a significant challenge for **gas absorption heat pumps** (GAHPs), as they tend to be more expensive than electric heat pumps. In other jurisdictions the upfront costs have been found to be roughly 3-4 times more expensive than gas boilers (UK 2016). Additionally, as was seen with VRF heat pumps, being new to the Canadian market is likely to have an impact on upfront cost. Due to their relatively high capital costs, some researchers have argued that commercially available gas absorption heat pumps are not economically viable for most applications (Garrabrant et al., 2016). However, low-cost component designs and production methods have led some experts to project that the total installed cost will be brought down to 40-50% of the current installed cost of some current GAHP models, therefore bringing absorption heat pumps in line with the 3-4 year payback period that MURB building owners typically look for in capital projects (Garrabrant et al., 2016). Air source GAHPs pumps do have an advantage over their ground and water source counterparts because they do not require a borefield. Ground and water source GAHPs have higher upfront costs because boreholes need to be drilled for ground heat exchanger (Patel et al., 2015).

Operational Costs

The relative savings associated with operational costs will depend not just on the energy source of the specific technology, but also the available energy sources available in the region (i.e. electricity, oil, propane or natural gas), the relative costs of those different energy sources (including any carbon tax or emissions trading policies that may be in place), and the local climate. By running an electric heat pump, less gas or oil will be used, but more electricity. If living in an area where electricity is expensive, operating costs may be higher with electricity-based heat pumps (Natural Resources Canada, 2017b).

The IESO notes that, in the Ontario market, electric heat pump technology is likely limited to homes that currently heat with electricity due to the energy and financial savings homeowners can realize (IESO, 2017). They note that the typical annual operating cost of an electric cold climate ASHP is more that 120% of typical operating costs of a natural gas home heating system, and that natural gas costs would need to increase more than 50% for electric heat pumps to be financially competitive with gas furnaces from a homeowner's perspective (IESO, 2017). However, for Ontario's electrically heated homes and MURBs, there may be opportunities for growth for DSHPs and VRF systems. VRF systems show considerable energy savings over conventional HVAC systems (Park, 2013); and DSHP retrofits have been shown to be highly cost effective compared to baseboard heating (Dentz et al, 2014). Dentz et al. (2014), argues that electric resistance is by far the most suitable for retrofit, which highlights the opportunity for cost-effective retrofits in Ontario's MURB sector—where 23.8% (405,000 units) are electrically heated (Toronto Atmospheric Fund, 2016).

Meanwhile, for residences heated by natural gas, gas absorption heat pumps keep operating costs low by avoiding a switch to a more expensive energy source (Toronto Atmospheric Fund, 2017). Garrabrant et al. (2016) calculated that when annual energy and operating cost savings of the GAHP were calculated against standard and condensing furnaces, there were found to be significant. These savings were noted to be important because they are needed to reduce the payback and improve the likelihood of adoption (Garrabrant et al., 2016).

Additionally, ASHPs typically have a long life expectancy and lower maintenance costs than many alternatives (BSRIA, 2009). Heat pumps have a longer working life than conventional domestic boilers—25 years vs 15 years (Singh, 2010).

Risk (Real and/or Perceived)

The rejection of particular energy-efficient technologies may represent a rational response to perceived risk (Maiorano, 2012). Risks can include (1) cost-related concerns such as hidden costs or fluctuating energy prices, as well as (2) technology-related risks such as poor installations, true efficiency in the field or safety concerns.

The risk of hidden costs is commonly cited as a risk of energy efficiency retrofits. Some researchers have argued that information and search costs may be ignored or underestimated, where additional time and/or money may be spent acquiring new information, installing new equipment, and supporting increased maintenance that may be associated with the energy efficient equipment (Golove and Eto, 1996). Additionally, while perceived risk of future energy cost savings is a barrier, it is often understudied and may be overlooked by policymakers (Qiu et al., 2014). If the price of electricity falls, then the return on the investment may fall as well (Gillingham and Palmer, 2013)—a risk exacerbated by the irreversibility of such investments. For electric heat pumps, the risk of fluctuating energy prices may be greatest if the retrofit requires making a switch from natural gas to electric. Another consideration is the politicization of energy prices in Ontario (e.g. the introduction of the *Fair Hydro Plan*[3]), where lower electricity rates benefit consumers but may hinder certain conservation efforts.

In terms of technology-related risks, engineering simulations may assume perfect installations and maintenance of the energy efficiency investments, thereby overstating the projected energy savings—a concern that has been noted of ASHP installations in the Ontario context (IESO, 2017). Literature notes that VRF systems are still poorly supported in whole building simulation tools; some caution is warranted in interpreting the outcomes for the VRF cases, as the results may be overly optimistic (Park, 2013) The lack of VRF system modules in building energy simulation programs used in the Canadian industry has led to designers using

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[3] Ontario's Fair Hydro Plan. https://www.ontario.ca/page/ontarios-fair-hydro-plan

'workaround' methods, such as zonal air-source heat pumps, to try to resemble a VRF system. These workarounds have been argued to lead to inaccurate predictions of the energy savings for the system (Kani-Sanchez and Richman, 2017).

Another specific concern for VRF systems is the potential leaks due to having a system with long refrigerant piping runs and many connections. Amarnath and Blatt (2008) note that such leaks may be difficult to detect and repair in the field, and there is a perception among engineers and building owners that this could cause safety issues due to the large quantities of refrigerant that could be released.

Qiu et al. (2014) argue that policies that aim solely to address the price barrier by providing rebates to lower purchase costs do not address the buyer's willingness to accept the risk of adopting a new technology. It is argued that policymakers should ensure that policies also limit investor risk (Gooding and Gul, 2016).

Split Incentives

A significant barrier to uptake of these technologies is known as the "split incentives" problem, which refers to situations where participants in an economic exchange have different goals or incentives (OECD/IEA, 2007). In the context of tenant-landlord relationships, a considerable challenge arises when the landlord provides the tenant with appliances, but the tenant is responsible for paying bills associated with these appliances. In this situation tenants and landlords have different goals: the landlord is seeking lower capital costs when purchasing appliances, while tenants are seeking lower energy bills. The landlord is incentivized to buy the cheapest appliance, but this may not be the most efficient option for residents (OECD/IEA, 2007). As investors in new technologies, building owners may not receive the benefits which accrue to their tenants when tenants pay for heating, cooling and utilities (IEA 2014), and therefore may see little reason to invest. Studies have shown that, due to this barrier, energy efficiency expenditures are mainly undertaken in owner-occupied as opposed to renter-occupied dwellings (Charlier, 2014). Research therefore suggests that the challenge of split-incentives between tenants and landlords can lead to underinvestment in energy efficiency expenditures (OECD/IEA, 2007).

In the case of the electrically-heated MURB sector in Ontario, this is of particular importance, as about 45% of these rental apartments are suite metered (Toronto Atmospheric Fund, 2016)—suite meters are electrical meters that a landlord can install in individual units to measure how much electricity is used (Landlord and Tenant Board, 2011). In 2010, regulatory amendments were made under the *Residential Tenancies Act*[4] and the *Energy Consumer Protection Act*[5] providing tenant protection in regard to suite meters. Under the new rules, if a landlord wishes to install a suite meter, they must seek informed consent from existing tenants

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[4] See Residential Tenancy Act. https://www.ontario.ca/laws/regulation/r10389#BK41
[5] See O. Reg. 389/10 under the Energy Consumer Protection Act. https://www.ontario.ca/laws/regulation/r10389#BK59

and also provide prospective tenants with information before rental agreements are signed (Government of Ontario, 2011). However, there is an exemption for units that are electrically heated: if a unit is electrically heated, the tenant cannot be required to pay for heat and the cost must be separated from other electricity consumption. This exemption only applies to suite meters installed after the day this regulation came into force—January 1, 2011.

In addition to causing underinvestment in energy efficiency retrofits, the landlord-tenant problem also has social implications for renters. Charlier (2014) showed that tenants are double penalized because (1) they have to pay a large amount of energy expenditures due to the fact that they live in less energy efficient housing units, and (2) they are more likely to live with low-income than homeowners so are therefore not able to invest in energy saving systems. In consideration of benefits commonly associated with energy efficiency retrofits (e.g. improved health, air quality and comfort) these tenants may be paying high costs while being unable to benefit from such factors. In the case of suite metered units, mixed views exist about the impact on low-income tenants. While suite meters allow tenants to pay for electricity based on their actual consumption, thereby allowing them to participate in electricity conservation efforts, it has also been argued that suite meters may create additional financial burden and uncertainty for tenants who are already struggling to maintain their housing (Shelter, Support and Housing Administration, 2017). Combined with the split-incentives problem, suite metering in electrically heated units may therefore negatively impact low-income tenants on multiple fronts.

Opportunity:

Although landlords may not receive the economic benefit associated with energy savings, there is an opportunity for landlords to advertise new ASHP heating systems to potential tenants. The Toronto Atmospheric Fund (2016) notes that landlords may see the value of retrofitting heat pumps if they are aware of the benefits for residents, as this could reduce tenant turnover and vacancies, and increase property values.

In Ontario, the IESO's Heating and Cooling Incentive Program offers rebates for air-source heat pumps to renters with permission from the landlord. See "Insufficient Incentives" section below for further details.

Inaccurate/Insufficient Information

This barrier includes three separate but related factors: (1) insufficient available information (i.e. lack of data on featured low-carbon technologies), (2) inaccurate information being put forward to energy users, and (3) information as a principal-agent problem.

In terms of insufficient available information, this is a barrier for all of the featured technologies. For ASHPs, literature in North America has been focused on newer cold climate ductless mini-split models (Patel et al., 2015), but there remains a lack of technical and financial data (the Toronto Atmospheric Fund, 2016). In particular, the literature on DSHP retrofits in MURBs is relatively small—a gap this research aims to address. For GAHPs, there is even less experience/performance data for domestic scale gas products (Carbon Trust and Rawlings

Support Services, 2016). The Toronto Atmospheric Fund's (2015) study noted that information on GAHPs was limited for their research because it is a newer technology compared to electric heat pumps (Patel et al., 2015). They stated that in some cases the exact model of the heat pump was omitted from the available studies and that the available literature in online databases for GAHP was also limited. The data areas with the least information available included cost and cold climate data. Furthermore, most studies provided limited information about retrofits and used no quantitative values in their discussion for this topic.

Although VRF systems have been in use for decades in Japan and China, there is a considerable lack of studies in US and Canadian markets. Although various simulation studies on VRF systems have been completed, a limited number have been validated with real-time occupied building and weather data—specifically, the heating mode of a VRF system under a cold climate. Additionally, some of the more subtle energy efficiency advantages may be overlooked—such as reduction in duct losses, the ease of electrical submetering, and the higher part load efficiency (Goetzler, 2007). The performance of VRF systems in the US has been measured mainly in laboratories, but these measurements may not represent performance in a real building. Performance measurement of VRF systems in real buildings is challenging due to the complexity of the system and occupancy-related uncertainties (Im et al., 2016). These systems can be complex to simulate and not all system components can be accounted for in the modelling program. There is not a lot of data to understand the efficiency of heat recovery VRF systems in the Canadian climate, with some areas experiencing very cold winters and hot, humid summers (Kani-Sanchez and Richman, 2017).

Inaccurate information can cause energy consumers to make suboptimal energy efficiency investments—and research in this area suggests that this challenge is widespread (OECD/IEA, 2007). Consumers may be poorly informed about technology characteristics, energy efficiency opportunities and financial opportunities.

Perceptions of ASHP technology may present an additional barrier in the absence of current and accurate information. In particular, energy consumers may have outdated concerns about noise or ability to function in the cold from previous experiences or word-of-mouth knowledge sources. Without information designed for specific groups, end users may end up being misinformed with imperfect information, or seek out alternative sources of information with inaccurate data. In order for this market to flourish, NEEP (2017) argues that consumer awareness of and confidence in ASHPs as a cold-climate technology must be solidified. They note that information ensuring that ASHPs operate efficiently at cold temperatures must come from a variety of trusted stakeholders—such as government agencies, utility/energy efficiency programs, or a coordinated regional platform funded by such organizations. In the Ontario context, the IESO (2017) noted from their lessons learned from heat pump programs that there were misconceptions about heat pumps among energy users. These misconceptions were related to heat pump performance and association with old designs of heat pumps. They recommend that education must be a component of any heat pump offering.

Principal-agent (PA) problems refer to the potential difficulties that arise when “two parties engaged in a contract have different goals or information” (OECD/IEA, 2007). Issues with information are noted to be a PA problem when the access to information varies between different actors. For example, manufacturers may know the efficiency of their products but not be required to pass on accurate information to purchasers, therefore leaving neither landlords or tenants with adequate information to make informed decisions. Alternatively, information may be asymmetric, with landlords having access to information regarding energy efficiency labels, but failing to pass on that information accurately to tenants (OECD/IEA, 2007).

Shortage of Industry Knowledge and Capacity

Shortages of skills and knowledge associated with these technologies are seen along multiple steps along the retrofit process, such as design and installation. Gleeson (2016) notes that the energy performance of heat pumps is not just dependent on the technical performance of the heat pump itself, but also on the design, installation, commissioning and operation of the entire heating system. Additionally, a high level of expertise is needed to tailor solutions to a wide range of property types (Gooding and Gul, 2016). It is argued that while heat pumps can deliver renewable heat, the performance of individual systems is more sensitive than fossil fuel boilers because boilers have a "thermal advantage" which can mask poor installations. As such, the UK (a jurisdiction with an ambitious goal for large-scale heat pump growth) has encountered significant challenges with low performance in heat pump field trials—the low performance in trials has been linked to the quality of installation, as opposed to heat pump model, envelope losses or a perceived lack of underfloor heating (Gleeson, 2016).

In the Canadian context, research suggests that there is a need for more expertise in identifying and coordinating the priorities for potential upgrades, managing the upgrade process, and carrying out post-improvement audits of low carbon HVAC technologies generally (Energy and Mines Ministers' Conference, 2016). There has also been a lack of capacity of trained installers for electric heat pumps (Carbon Trust and Rawlings Support Services, 2016). In Ontario, the IESO (2017) argues that capability building is needed as contractor and builder knowledge was seen as a barrier learned from Ontario's experience with heat pump programs—they also note that there is variability in the quality of installs of ASHPs. Specifically, installation issues related to a lack of space on electrical panels for both ASHPs and backup heat. The IESO also notes that following installation, proper maintenance is critical to ensuring that heat pumps operate efficiently and have a long service life. They advise that retrofits benefit from a competent service contractor to maintain filters and coils, as this will have a "dramatic" impact on service performance.

For technologies new to the Canadian market—including both GAHPs and VRF systems—the skills and knowledge gap will likely be more significant. An additional challenge for GAHPs is the use of ammonia as the refrigerant. While this does not contribute to GHG emissions, ammonia is toxic, and as such specialist training is required (Carbon Trust and Rawlings Support Services, 2016). Additionally, Erikson et al. (2017) note that as a combination space & water system, GAHPs may face challenges with contractors and builders, including problems with training and a crossing of trades (i.e. HVAC and plumbing). The report also notes that as the majority of these systems are engineered in the field, some are installed without proper controls or fan coil sizing for high performance.

Key Findings

Market Barriers: Cost and Risk

1. **DSHPs** are found to be highly cost effective when compared to baseboard heating. With 23.8% of Ontario MURBs being electrically heated, DSHPs have significant opportunities for growth in this sector. For homes heated with natural gas, this technology is not yet economical from a consumer perspective. These heat pumps also have the benefit of incentives in Ontario - which will be discussed later in the Political-Institutional Barriers section.

2. While **GAHPs** keep operating costs low by avoiding a switch to a more expensive energy source, the high upfront costs have been argued by some researchers to make GAHPs uneconomical in most applications. However, low cost component designs and production methods have led some experts to project that the total installed cost will decline considerably—potentially putting them within a desirable payback period.

3. Like other electric heat pump systems, **VRF systems** are best suited for electrically heated buildings. VRF systems have been in use for almost three decades in Asia, Europe and South America, but are still relatively unknown in North American markets—being so new to the Canadian market has a negative impact on upfront costs.

4. Real and/or perceived risks include cost-related concerns such as hidden costs or fluctuating energy prices, as well as technology-related risks such as poor installations, true efficiency in the field or safety concerns.

Market Failures: Split Incentives, Access to Information, and Industry Knowledge and Capacity

1. Considering that 45% of units in Ontario's electrically-heated MURBs are individually suite metered, achieving large-scale uptake in this sector will require that the split incentives issue be meaningfully addressed. The Political-Institutional Barriers section will discuss potential incentive strategies in greater detail.

2. Access to sufficient and accurate information is another significant barrier for all featured technologies, but is likely more keenly felt for GAHPs and VRF systems as new technologies in the Canadian market.

3. Lessons from jurisdictions show us that a lack of industry knowledge and capacity can lead to unexpected performance issues down the road. This barrier has also been noted in the Canadian and Ontarian context, and will need to be more adequately addressed in order to achieve large-scale uptake.

Barrier Ratings

Figure 2. Market barrier and failure ratings. Note that barriers were rated 1 (lowest) to 5 (highest) through an informal workshop survey. See introduction for details.

Behavioural and Consumer Preference Barriers

Although traditional economic theory tells us that consumers assess all relevant options and make rational, utility-maximizing decisions, consumers may not act in this way in reality. Behavioural economists point out that behavioural factors frequently lead consumers to forgo purchases of efficient appliances that would in fact provide them with a net monetary gain (Fujita, 2011).

This assessment considers a number of behavioural and consumer preference barriers that have been noted in literature to impact the uptake of energy efficiency generally—as well as consideration of specific impacts on the uptake of the featured technologies within Ontario's MURB sector, where possible.

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1. *Trust/Credibility*
2. *Consumer Inertia*
3. *Hassle Factor*
4. *Aesthetic Preferences*

Trust/Credibility

Trust is an important barrier to consider when trying to encourage uptake of low-carbon technologies—whether it is trust in policymakers, non-profit organizations, private businesses, contractors, etc. Trust and credibility are factors that energy consumers are likely to consider when evaluating energy decisions, making cost-benefit appraisals or when assessing risk (Fredericks et al., 2015). Literature suggests that while trust is commonly understudied in comparison with more traditional barriers, it can sometimes eclipse other barriers to uptake of these technologies (Reames, 2016).

Trust can refer to either competence or integrity-based trust, and is relevant to many actors involved in the retrofit process. For instance, if individuals considering retrofits do not trust the individuals, organizations or agencies offering rebates or incentives, they may be unlikely to consider such offers. Additionally, distrust in governments, public institutions, or general distrust in others may be a greater barrier in particular communities that have historical or socioeconomic reasons for social exclusion (e.g. low-income or otherwise marginalized communities). Reames (2016) study showed that people perceived to be "outsiders" of a particular community may not be seen to be trustworthy. This may include such individuals as contractors coming into homes or employees/volunteers involved in demonstration projects. This study also notes that although crime is not often considered as a barrier to energy upgrades, it can manifest as a barrier for residents to accept in-home installations where high criminal activity is a problem (Reames, 2016).

For property owners in Ontario's MURB sector, this barrier may impact a decision to upgrade if there is reluctance from residents to participate. As well, if residents do not trust the advice given to them regarding how to effectively use these new technologies, the degree to which these technologies achieve energy or cost savings will be reduced (e.g. understanding when to switch from heat pumps to baseboard heating).

Consumer Inertia

Consumer inertia is an important barrier to consider because it may prevent energy users from switching to a new technology even when it is a logical choice. Research in this area suggests that entrenched routines and habits may limit retrofit levels; such routines are difficult to break and may lead to issues related to energy efficiency being delayed or avoided altogether (Gooding and Gul, 2016). Habits and routines contain “ready-made solutions to common problems” (Maréchal, 2009), making them a go-to option for many energy users. This is relevant to both individuals and organizations, as habits and routines are closely linked with the concepts of “lock-in” and “path dependency” (Maréchal, 2009)—the tendency of a traditional practice to continue even if better alternatives are available.

Some researchers have noted that GAHPs may help to overcome this barrier because customers are likely already familiar with gas fired heating—as such, customers may notice little difference between the technologies (Climate XChange, 2017).

Hassle Factor

The “hassle factor” involved in ASHP system retrofits involves several considerations throughout the retrofit process—(1) the disruption in the home, (2) the time it takes to find information, and/or (3) the time it takes to find appropriate financing (CBI, 2016). Lessons from other jurisdictions suggest that overcoming the hassle involved from these areas is vital for improving uptake of ASHP retrofits.

In terms of disruption of the home, DSHPs offer energy efficiency without the hassle or expense of installing expensive ductwork. The system consists of an outdoor compressor/condenser unit connected to one or more indoor air handlers located in each room, and no ductwork is needed. VRF systems are also noted to be less disruptive to fit into existing buildings (particularly when occupied), and its modular format lends itself to phased installations (Bhatia, 2014). Bhatia (2014) also notes that VRF ductwork is smaller than ducting in standard ducted systems because it is required only for the ventilation system—it is therefore minimized or eliminated completely.

As energy users consider the wide range of options available to them, information should be easily accessible and easy to understand. NEEP (2017) notes that information on heating systems and available incentives should be easily found on such sources as utility and government websites. Information regarding the benefits and deciding factors of heat pump systems should be included along with traditional heating systems. They recommend that messaging should be available through a variety of channels (e.g. TV, radio, online) with a consistent, basic educational message.

In addition to overcoming other barriers discussed within this report, such as high upfront costs, split-incentives and rent controls, the hassle involved in finding an appropriate financing tool is an important consideration for policymakers. One UK study investigated an incentive being used to encourage heat pump uptake, where uptake had been lower than anticipated. They found that adoption was sensitive to noneconomic factors and there was a level of “hassle factor” above which uptake of heat pump technology fell away rapidly “despite the existence of a robust economic incentive.” They recommended that simplification of the installation and application process would be of benefit, potentially in the form of a “one stop shop” for retrofits (Snape et al., 2015).

Energy Efficiency For All (EEFA) (2017) explains that a one-stop shop includes every step of the retrofit process, including (but not limited to) initial assessments and audits, identifying funding and finance, hiring contractors, and quality assurance. They also differentiate between an “incomplete” and a “true” one-stop shop: the incomplete model refers customers to necessary information or actors (e.g. providing a list of qualified contractors for consumers to contact themselves), while the true model established a single point of contact for consumers throughout the retrofit process (e.g. providing assistance evaluating bids and selecting a contractor, facilitating scheduling, and remaining involved in communication between parties). They argue that this helps property owners navigate the retrofit process and significantly reduce hassle, while also becoming a trusted advisor. GreenON rebates bring us closer to this reality—by providing a list of participating contractors, and having contractors submit rebate applications on a property owner’s behalf. There may, however, be potential for further integration in this area moving forward by providing further assistance for building owners to navigate entire retrofit process, particular in the MURB sector.

Aesthetic Preferences

Aesthetics may be a barrier for some energy efficiency retrofits if consumers are more satisfied with traditional heating and cooling alternatives. In the case of ASHP, some these appliances can take up more space than conventional heating systems and some consumers may have a negative perception of the aesthetics of having a unit on the exterior of their home (Carbon Trust and Rawlings Support Services, 2016). However, there are significant differences between the featured technologies.

Natural Resources Canada (2017) notes that DSHPs are ideal for retrofit in homes with hydronic or electric resistance baseboard heating. They are wall-mounted, free-air delivery units that can be installed in individual rooms of a house. Up to eight separate indoor wall-mounted units can be served by one outdoor section (Natural Resources Canada, 2017a). DSHPs are also an ideal fit for multi-unit residential buildings as they are the most compact, perform both heating and cooling, do not require ducts, can be wall mounted, and are available in smaller capacities to better suit apartments and individual rooms. One case study notes that residents found that the removal of window A/C units improved aesthetics (Patel et al., 2015). VRF systems are noted to be extremely versatile for the requirements of different building types—indoor units come in different capacities and multiple configurations such as wall-mounted, ceiling-mounted, cassette suspended and concealed ducted types. Both indoor and outdoor units are also so quiet that they can be placed anywhere (e.g. outdoor units can be placed right under a window) (Bhatia, 2014).

Unlike the other featured technologies, it is difficult to reduce the size of GAHPs in order to suit domestic properties (Carbon Trust and Rawlings Support Services, 2016) and therefore aesthetic preferences is likely a greater barrier for this reason.

Key Findings

1. Literature suggests that trust is a commonly understudied barrier, but in certain contexts it can sometimes be so significant that it may eclipse other barriers to uptake of energy efficiency retrofits. Trust can refer to either competence or integrity-based trust, and is relevant to many actors involved in the retrofit process.

2. Consumer inertia, specifically related to habits and routines, prevents users from switching to new technologies even when it is the rational choice. Some researchers suggest GAHPs may help overcome this barrier because users are already familiar with gas fired heating.

3. The hassle involved with heat pump installations has been noted to be a significant obstacle—where the hassle of the disruption in the home, the time it takes to find information, and the time it takes to find appropriate financing has been argued to prevent retrofits even with robust incentive offerings. Ontario may lack a "true one-stop shop," which could significantly reduce hassle for property owners.

4. Aesthetics is a major barrier for GAHPs because it is difficult to reduce the size to suit domestic properties, while DSHPs and VRF systems are ideal for home retrofits.

Barrier Ratings

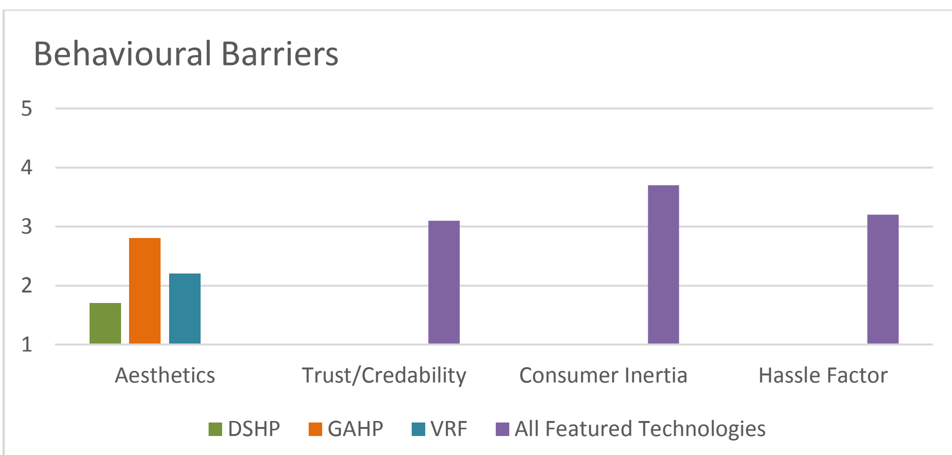

Figure 3. Behavioural barrier ratings. Note that barriers were rated 1 (lowest) to 5 (highest) through an informal workshop survey. See introduction for details.

Political-Institutional Barriers

Although various scholars have looked at different forms of barriers (e.g. economic, behavioral, organizational, and cultural), some point out that the attention to political-institutional barriers has been limited. Langlois-Bertrand et al. (2015) argue that a specific understanding of these barriers can play a critical role, as efforts to overcome other types of barriers are likely to be insufficient without careful consideration of their political-institutional counterparts, which may prove very difficult to eliminate.

This final section provides an overview of political-institutional barriers relevant to the Ontario context.

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1. *Insufficient Financing and Incentives*
2. *Natural Gas Expansion*
3. *Rent Control*
4. *Grid Challenges*

Insufficient Financing and Incentives

Although consumers may recognize that investing in more efficient appliances will lead to net savings, they may not have sufficient savings available to purchase a more costly appliance. Access to appropriate financing and incentives is therefore a vital factor for large uptake of ASHP systems in this sector. A challenge is that such projects are often only pursued with relatively short pay-back periods of roughly 2-3 years (McEwen and Miller, 2014). Capital costs for commercial/private sector entities also borrow at a higher cost than the public sector, and are often required to have these shorter-term paybacks (King and Bradford, 2013).

In addition to providing sufficient economic amount, incentives should be structured in a way that makes them widely accessible. Some challenges related to incentives include amount of time, as rebates must be applied for and may take weeks to be refunded, as well as upfront costs, where rebates are not useful for consumers who simply do not have savings or credit to cover the first cost of an appliance (Fugita, 2011). While DSHPs have an advantage in the Ontario context due to a variety of incentive programs, they may not address some of the aforementioned challenges associated with rebates. Some programs available for ASHP retrofits include: the Green ON Installations Program through the provincial government's Ontario Green Fund, which offers a rebate of up to $5,800 for ASHPs for homeowners of detached homes, townhouses or semi-detached (not applicable to the MURB sector)[6]; the

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[6] GreenON Rebates for Air-Source Heat Pumps. https://www.greenon.ca/programs/greenon-rebates-air-source-heat-pumps

Heating and Cooling Incentive Program through the IESO, which offers up to $1,900 for ductless ASHPs[7]; and the Home Energy Conservation incentive through Enbridge Gas Distribution and Union Gas, which offers up to $4,000 for homeowners of detached homes, townhouses or semi-detached (not applicable to the MURB sector)[8].

Due to high upfront costs and the split-incentives problem between landlords and tenants in many multi-unit residential buildings, finding robust economic incentives is vital for encouraging uptake. As was mentioned in the Split-Incentives section of this report, in Ontario, the IESO's Heating and Cooling Incentive Program offers rebates for ASHPs to renters with permission from the landlord. However, tenants are also more likely to live with low-income housing than homeowners and may not be able to invest in energy saving systems (Charlier, 2014). Rebates for such products likely do not overcome the barrier of upfront costs, especially considering the likelihood of yearly leases.

Opportunity:
The Ontario government has enabled local improvement charges—a financing mechanism for municipalities where a homeowner can finance energy improvements through payments tied to the property, rather than the property owner, as an additional line item on their property tax bill—through regulation under the Municipal Act (2001) and the City of Toronto Act (2006) (Government of Ontario, 2015). Through the City of Toronto's Hi-RIS program, property owners can obtain a low-interest loan to cover the cost of home energy improvements through such a local improvement charge. Property owners are eligible for air source heat pump retrofits (Toronto, 2018).

Natural Gas Expansion

Ontario has committed to reduce its GHG emissions to 15% of 1990 levels by 2020, 37% by 2030 and 80% by 2050. In order for the province to reach these targets, the 2015 Climate Change Action Plan (CCAP) has included "buildings and homes" as a targeted action area, with an aim to reduce emissions from fossil fuels in buildings, improve energy efficiency, encourage additional choice for homeowners, promote low-carbon energy supply and products, and increase training and technical capacity for the sector. The plan states its intention to make Ontario one of "the easiest and most affordable jurisdictions in North America" for property owners to install clean energy systems such as heat pumps.

While these policy objectives are a positive sign for ASHP technologies, they may stand in conflict with Ontario's current approach to natural gas policies and subsidies. Love (2015) notes that while energy conservation measures are already cost effective in Ontario, it would be

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[7] Save on Energy Heating & Cooling Program Terms and Conditions. https://saveonenergy.ca/Consumer/Programs/HVAC-Rebates/Terms---Conditions.aspx.

[8] Home Energy Conservation Incentive Program. https://ohecip.ca/en/

even more valuable if traditional energy supplies were not subsidized. In 2017, Ontario's provincial government announced spending of $100 million to build natural-gas lines and help rural Ontarians get off electric heat. While the natural gas expansion in rural Ontario is outside of the scope of this report, such a subsidy impacts the potential for growth of electricity-based heat pumps. Considering that upfront costs for these technologies remains a significant barrier to uptake, research notes that equipment and installation costs must be brought down through economies of scale (NEEP, 2017). Subsidizing natural gas expansion throughout the province is therefore a noteworthy barrier to large-scale uptake in Ontario.

Rent Control

Rent controls in Ontario ensure a maximum percentage by which rent can be increased each year—currently it is capped at 2.5%. Previously, this applied to only pre-1990 buildings, but recently rent controls were expanded to all units in Ontario through *Ontario's Fair Housing Plan*. While rent controls are an important tool for keeping housing costs affordable, they do limit the ability for building owners to recoup the cost of energy efficiency investments.

Grid Challenges

Research from the UK and Northeastern US notes that there may be impacts on the electricity grid associated with large-scale electrification of heat supply. For instance, "a broad deployment of electrically powered ASHPs will have significant impacts on the electric grid (including capacity/peak load), use of delivered fuels, natural gas infrastructure, and GHG emissions" (NEEP, 2017). Policymakers may withhold support for electrification generally and for ASHPs more specifically until such impacts are further understood, which could limit the near and long-term growth of this technology (NEEP, 2017). In order to address this concern, more research in this area is needed. Electricity system costs resulting from large uptake of electric heat pumps should be investigated in great detail in the Ontario context. This investigation should consider a comprehensive plan that includes ways to mitigate costs, such as energy efficiency improvements, demand side management, energy (heat) storage, and flexible low-carbon generation (Committee on Climate Change, 2016).

Research from the UK has found that large scale uptake of electric heat pumps can create challenges for the grid due to increased load during peak times (Love et al., 2017). Through their research, they found that with 20% of households using electric heat pumps, peak grid demand increased by 14%. An American study done by KEMA (2009) on ductless heat pumps, found both summer and winter peak reductions when displacing electric resistance. A more difficult question arose when electric heat pumps are used to replace or displace oil or other fuels in homes. If these heat pumps displace older, inefficient cooling systems, there will still be a decrease in summer demand. In the winter, however, shifting from fossil fuels to ASHPs will increase winter electricity demand (NEEP, 2017).

In contrast with electricity-based heat pumps, GAHPs may help to overcome this particular risk because for properties that are already connected to the gas grid, GAHPs can be installed with no or limited upgrades to existing gas heating systems, and can often operate with existing heat distribution systems and provide domestic hot water (Climate XChange, 2017). It is argued that deployment of gas absorption heat pumps in the on-gas and off-gas grid markets will enable cost and CO_2 reductions allowing efficient use of existing infrastructure (Ecuity, 2013).

DSHPs have the potential to reduce peak electricity demand by 40%–60% as compared to electric resistance heated buildings during both heating and cooling seasons, assuming the buildings already have cooling—if not, there is potential to increase summer electricity demand and energy consumption (Dentz et al., 2014).

Key Findings

1. While incentive programs for air-source heat pumps are available, being rebates, they frequently do not overcome the barrier of upfront costs. Additionally, incentives fail to address a significant barrier in the MURB sector—the split-incentives between landlords and tenants.

2. The natural gas expansion in rural Ontario limits the potential for growth for electric heat pumps. Though this does not directly impact electrically heated MURBs, it may limit the upfront cost reductions that come along with economies of scale. Such subsidies for natural gas potentially benefit the uptake of GAHPs.

3. Rent control limits the ability for building owners to recoup the cost of investments. This barrier may be more significant for GAHPs due to less available incentives and higher upfront costs.

4. Grid challenges may be a barrier for large-scale uptake of electric heat pumps (i.e. large-scale electrification) in relation to peak summer demand if buildings did not previously have cooling options. GAHPs, meanwhile, may help overcome this barrier for properties already connected to the gas grid.

Barrier Ratings

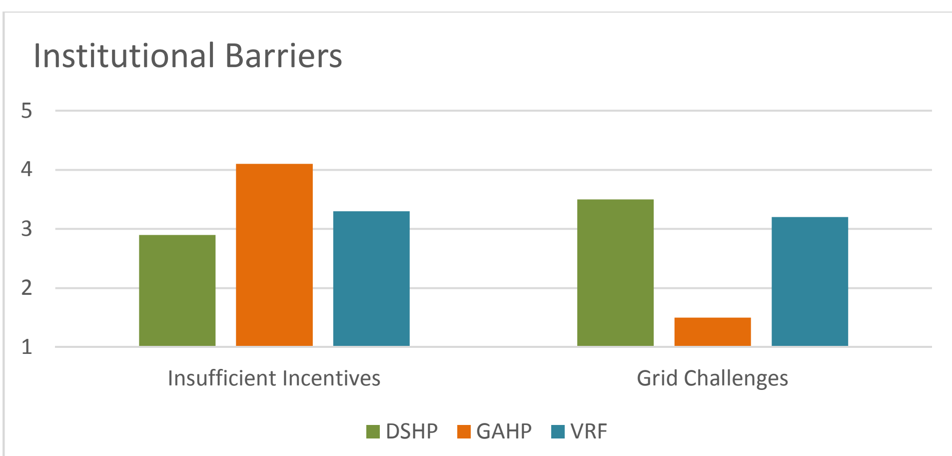

Figure 4. Institutional barrier ratings. Note that barriers were rated 1 (lowest) to 5 (highest) through an informal workshop survey. See introduction for details.

Summary and Discussion

This report categorizes and explores barriers to air source heat pump adoption in Ontario MURBs in an effort to develop a more thorough understanding of particular issues. However, the research exposes a complex landscape where individual barriers are highly interconnected. In order to encourage large-scale uptake of these and other low-carbon HVAC technologies, policymakers should seek a holistic approach that addresses barriers simultaneously.

Considering that electric ASHPs will likely not be competitive with natural gas for the foreseeable future, and that such a high percentage of MURBs are electrically heated, there is considerable room for growth in this sector. Some key takeaways from the research include:

- Contextual market factors—including domestic gas reserves, and proportion of households with a gas grid connection, availability of low cost/high volume electricity supplies (e.g. hydro and nuclear)—influence the effectiveness of policies designed to stimulate uptake. This is the major barrier in the Ontario context.
- Complex barriers require integrated policy framework including direct incentives, indirect taxes, technical standards, building regulations, promotion, education, etc.
- Although there are a growing number of incentives for ASHPs in Ontario, current after-the-fact rebate programs may not address the lack of upfront capital of individuals and businesses. An additional challenge for the uptake of these technologies in MURBs is that many landlords lack a financial incentive to purchase higher costing systems when tenants will be the ones to accrue the benefits.

In addition, the research has identified the shortage of industry knowledge and capacity as a significant barrier where further research is needed. In addition to slowing the uptake of ASHPs, lessons from jurisdictions show us that a lack of industry knowledge and capacity can lead to unexpected performance issues in the future. This barrier has also been noted in the Canadian and Ontarian context, but has remained understudied.

Moving forward, the Ontario Climate Consortium team will be collaborating with The Atmospheric Fund (TAF) in order to gain a better understanding of knowledge and capacity gaps and identify opportunities for overcoming them. This research will consider opportunities to align and consolidate education, training and awareness raising efforts for such stakeholders as HVAC contractors, engineers, suppliers, maintenance firms, inspectors, builders and building owners/managers. In order to identify best practices and strategies for implementation, the research will investigate the experiences of other jurisdictions and assess the practicality of replication in Ontario.

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