

Pump up the (heat pump) volume! Why supply chain strategies are critical to heating technologies market transformation.

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ABSTRACT

Heat pumps are widely viewed as a key technology for decarbonizing space and water heating, offering efficiencies that can exceed 300%. In addition to saving energy, heat pumps can reduce consumer costs, drive economic development, and increase the utilization of existing electricity systems. However, many market barriers are limiting the uptake of heat pump technologies. One of these barriers is the lack of suitable technology availability as manufacturers and vendors are often reluctant to introduce leading-edge proven technologies to the North American market.

Utility demand side management programs typically focus on increasing market demand for efficient products, however, strategies to increase the supply of heat pumps are also required for market transformation. In 2021, the Vancouver Economic Commission engaged Dunsky Energy + Climate Advisors to do just that for the province of British Columbia (BC), Canada.

Using the BC Heat Pump Attraction Strategy as a case study, our paper will explore the critical role that technology supply chain strategies can play in transforming the heat pump market. The case study is unique as it is being led by a local economic development commission while being focused primarily on greenhouse gas (GHG) emissions reductions. The attraction strategy aims to increase the supply of heat pumps most compatible with BC's building stock that can reduce GHG emissions through high seasonal efficiencies (including in cold-climate zones) and low refrigerant impacts.

Introduction

Electrification is a key lever to address the greenhouse gas (GHG) emissions coming from the use of natural gas in buildings. In Vancouver, British Columbia (BC), these emissions account for 54% of the total emissions and are almost exclusively associated with space and water heating (VEC, 2019a). Increasing the availability of heat pump technologies is one of the core strategies to enable a clear and coordinated market transformation for both existing building and new construction sectors. While market actors recognize that strategies focused on increasing market demand will be critical, a concerted effort in the form of technology acceleration and attraction will be needed to increase the rate at which heat pumps are supplied to the BC market, both in terms of volume and product diversity.

This paper leverages findings from the Heat Pump Technology Attraction Strategy developed for the Vancouver Economic Commission by Dunsky Energy + Climate Advisors, in partnership with FRESCo. Secondary research and interviews with local heat pump suppliers and global manufacturers are used to clarify BC heat pump market needs, availability, and gaps, as

well as barriers that manufacturers are facing to increasing the supply and diversity of heat pump technologies to the BC market. Eight (8) strategies elaborated to overcome these barriers are then presented. While this paper focuses on the BC market, the heat pump attraction strategy presented is relevant for any other jurisdictions facing similar building decarbonization supply chain challenges.

Methodology

These findings are based on secondary research, interviews with suppliers and manufacturers, and internal industry expertise in heat pump technology and the BC market. Heat pump availability and gaps are based on a review of available reports and studies that have been published in BC and neighboring jurisdictions. Additional information regarding technology availability was gathered through interviews with five (5) local suppliers, designers, and/or installers. To explore barriers and solutions to increasing the supply of heat pumps to the BC market, targeted interviews were completed with nine (9) global manufacturers.

Key Findings

Heat Pump Needs

To achieve its decarbonization goals, BC needs heat pumps that are compatible with new and existing building stock and that maximize GHG emissions reductions through low global warming potential (GWP) refrigerants and/or low refrigerant leakage (VEC, 2019a; Delphi Group, 2019). To be compatible with the BC building stock, heat pump technologies are needed to serve a variety of applications, end-uses, building types, and climate zones, as shown in Table 1.

Table 1. BC Heat Pump Market Needs

Applications	• Retrofit • New construction
End-uses	• Space heating • Water heating
Building types	• Single-family residential • Multi-family residential • Small/medium commercial & institutional (C&I) • Large C&I
Climates	• Zones 4, 5, 6 and 7, with some marine (temperate humid) areas

BC heat pump market needs are determined by technology requirements specific to each application (BC Housing, 2018). In new construction, engineers have the flexibility to design the distribution system to optimize heat pump performance, whereas in retrofit applications, options

are more limited. To reduce the cost and complexity of heat pump installation in existing buildings, BC needs heat pumps that are compatible with or circumvent the existing distribution systems. In addition, in retrofit applications, heat pumps needs are prescribed by the capacity of the building's existing main electrical service and/or available space on the electrical panel. For example, in residential and small commercial buildings, installing 240V equipment in suites may require wiring upgrades, whereas 120V equipment (including “plug-in” units) avoids the cost and complication associated with these upgrades.¹

To achieve their full potential, heat pumps must be properly sized to buildings' demands. Oversizing tends to reduce efficiency and shorten the life of the equipment because the compressor cycles on and off frequently. Heat pumps are also associated with higher upfront costs per unit of capacity than fossil-fuel fired systems, so oversizing them is expensive. It is therefore important that a full range of heat pump capacities be available to meet the needs of different building types, from very low capacity units for well-insulated apartments, to very high capacity units for large commercial buildings.

Heat pumps needs are also influenced by location-specific considerations, including local permitting regulations and climate. For example, in BC, some municipal permitting regulations have specific requirements regarding the location of outdoor units (e.g., cannot be wall-mounted on a building's exterior walls). Such limiting requirements call for heat pumps that offer flexible mounting options. The large variations in climate across the province mean that there is a need for heat pumps suitable for marine (temperate humid) areas as well as colder regions. For the latter, cold-climate specific air source heat pump models, which can maintain reasonable capacity and efficiency at very low outdoor air temperatures, are required.

Finally, to meet ambitious climate goals and emissions reduction targets, there is a growing need for heat pumps using low-GWP refrigerants and/or with low refrigerant leakage. Refrigerant leakage is a source of GHG emissions that needs to be addressed to maximize the environmental benefits of heat pumps. The impact of refrigerant leakage can be decreased by reducing refrigerant leakage and/or by reducing the GWP of the refrigerant used (New Buildings Institute, 2021). HFC refrigerants, such as R-410A – the most commonly used refrigerant in air conditioning and heat pump systems today – have high GWPs of the order of 2000. Regulations are increasingly driving global manufacturers to use lower GWP refrigerants.² These fall into two categories: Mid-GWP refrigerants such as R-32 (GWP=677), and low-GWP refrigerants such as R-744 (CO₂) and R-290 (Propane, GWP < 1). Following the trend globally, BC needs access to heat pumps with low-GWP refrigerants to meet its climate goals.

Heat Pump Availability and Gaps

This section summarizes the availability of different heat pump technologies to meet the BC market needs identified in the previous section and highlights where key gaps remain. Most of BC's heating electrification needs can be met by technologies that are already available in the BC market (Table 2). Product availability has improved significantly in the last few years as a

¹ Most multi-unit residential buildings in BC have 208/120V 3-phase services available for central heat pumps, and 120/208V single-phase available in suites. Large commercial buildings in Canada use 600V 3-phase service.

² For example, REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

result of increased demand driven by incentives, tightening municipal building codes, and increases in carbon price. As such, the needs of single-family homes and new constructions are overall well met by the current supply of heat pumps to the BC market. However, not all products are well-known by local suppliers, and some key gaps remain. Importantly, the identified gaps represent a significant part of the building stock, including heat pumps for multi-family residential buildings, C&I buildings, and retrofits. Availability and gaps for space and water heating end-uses are explored in more detail below.

Table 2. Summary of BC Heat Pump Technology Availability and Gaps

Widely Available	Key Gaps
Air-to-air heat pumps • Cold-climate and standard • Ducted and ductless • Residential and commercial models Heat pump water heaters (HPWHs) • Split and in-room models	• 120V “plug-in” units • Low-capacity units (< 9kBtu/h) • Heat pumps with low-GWP refrigerants • Cold-climate units (all-in-ones & HPWHs) • Heat pumps with integrated ventilation • Higher temperature air-to-water units

Space Heating

Table 3 summarizes the availability of different heat pump technologies for space heating and how well they fulfill BC market needs and demand. Most needs are covered by products that are currently available, but some gaps do remain, particularly regarding low-GWP refrigerants for most product types. Given the high percentage of multi-family buildings in BC’s two most populous cities, Vancouver and Victoria, the demand for 120V “plug-in” and low-capacity units is high. Some 120V in-room units (packaged terminal heat pumps (PTHPs) and ductless mini-splits) are available, however, model choices are limited and insufficient to supply their large market application for small square footage space heating like in apartments. Additionally, there is a similar gap attributed to smaller models with capacities < 9kBtu/h needed to serve apartments and individual rooms. As emphasized in Table 3, while almost all heat pumps can cover both space heating and cooling needs, very few heat pump models can cover additional end-uses (e.g., models with integrated ventilation or models offering both space and water heating). Finally, cold-climate hydronic (-to-water) heat pumps necessary to serve the colder interior regions (climate zones 5, 6, and 7) are not widely available.

Table 3. Summary of Space Heating Technology Availability and Gaps

		Ducted			In-room			Hydronic	
		Split air-to-air	Ground Source water-to-air	Rooftop	All-in-one (PTHP)	Ductless mini-split	VRF	Air-to-water	Ground source water-to-water
Building types	Single-family	✓	✓		✓	✓		✓	✓
	Multi-family				✓	✓	✓	✓	✓
	Small/medium C&I	✓	✓	✓	✓	✓	✓	✓	✓
	Large C&I			✓			✓	✓	✓
Building stock compatibility	Matches or replaces distribution system	●	●	●	●	●	●	●	●
	Required voltages and capacities	●	●	●	●	●	●	●	●
	Cold-climate performance	●	●	●	○	●	●	●	●
Climate impact	Low-GWP refrigerants	○	●	●	●	○	○	●	●
Additional end-uses	Space cooling	●	●	●	●	●	●	●	●
	Ventilation	○	○	●	○	○	○	○	○
	Water heating	○	●	○	○	○	○	●	●

Legend: ● Need fully covered by multiple models ● Need only partially covered or covered by few models
○ No models available to cover need

Water Heating

Table 4 summarizes the availability of different HPWH technologies and how well they fulfill demand. Most needs are at least partially covered, but the market is very dependent on a few key products. Remaining gaps include 120V systems to avoid expensive upgrades in residential retrofits, 600V systems for large commercial applications, and low-GWP (e.g., CO₂) HPWHs (especially packaged systems) to maximize environmental benefits.

Table 4. Summary of Water Heating Technology Availability and Gaps

		Split HPWH	Packaged HPWH
Building types	Single-family	✓	✓
	Multi-family	✓	✓
	Small/medium C&I	✓	✓
	Large C&I	✓	
Building stock compatibility	Required voltages and capacities	⦿	⦿
	Cold-climate performance	⦿	○
Climate impact	Low-GWP refrigerants	⦿	○
Additional end-uses	Space cooling	⦿	⦿
	Ventilation	○	○
	Space heating	⦿	○

Legend: ● Need fully covered by multiple models ⦿ Need only partially covered or covered by few models
○ No models available to cover need

Barriers

This section presents the most common barriers manufacturers face to increasing the supply and diversity of heat pump technologies to the BC market. Barriers are presented in order of most to least important. The extent to which these challenges deter different manufacturers depends on a variety of factors including company size and maturity, diversity/applicability of product line, manufacturing presence, size of market, etc. Note that while the global COVID-19 pandemic has had impacts on the supply of heat pumps to the BC market, addressing this barrier was out of scope for the purposes of this study.

Market Size

The small size of the BC market limits the amount of time and money that manufacturers are willing to invest in developing, certifying, and importing products that are needed to fill BC's market needs (VEC, 2019b). Although the North American market for air-to-air products is large and mature and heat pump technology supply for new construction was not found to be a barrier; supply is a barrier for retrofit applications, which often require more niche products (such as air-to-water heat pumps, cold-climate PTHPs, and high-voltage HPWHs). Interviewees suggested that the relatively small demand for the more niche heat pump technologies that BC is

lacking is not enough of an incentive to go through certification processes, and/or equipment modifications (e.g., voltage and frequency). Finally, strong growth in European heat pump market demand means that there can be competition for the supply of some specialized heat pump technologies (such as air-to-water units).

Workforce Training and Capacity

Developing a skilled heat pump workforce is required to meet the growing demand for heat pump installations, as it could otherwise pose a significant constraint on heat pump deployment. A lack of qualified workforce capacity not only limits growth, but also poses a reputational risk to manufacturers if systems are poorly designed, installed, or serviced. Even with packaged systems, heat pumps are less forgiving of poor design and installation than conventional combustion equipment. Installing split systems additionally requires knowledge of how to charge refrigerant piping. Local refrigeration technicians are already in very high demand, and the required skillset for installing air-to-water systems that are prevalent in BC overlaps with electricians, plumbers, and refrigeration technicians. Other challenges can arise as new, low-GWP refrigerants are introduced to the market. One such example is CO₂, as very few technicians are trained to maintain the necessary high pressure to correctly service products using this natural refrigerant. Manufacturers offer product-specific training programs but indicated concern about the low level of experience and capability of installers entering their programs. This barrier around workforce capacity is common and extends beyond the studied jurisdiction (EnergyTrust of Oregon, 2020; HPA, 2020; Scottish Government 2021; Advanced Heat Pump Coalition 2022).

Refrigerant Flammability Regulation

Hydrocarbon refrigerants such as propane (R-290) are efficient and have lower environmental impacts than their HCFC and HFC counterparts, but they are also highly flammable (classified as A3). This has historically limited their use in heating and cooling equipment to very small charge sizes. European refrigerant regulations have recently been updated to allow larger amounts of propane to be used in residential equipment such as split systems (IEC, 2022). As such, some global manufacturers indicated that they have high-performance R-290 air-to-water products commercially available in Europe that they cannot bring to the BC market because North American regulations on refrigerant flammability do not permit them. These products would be particularly pertinent to the BC market with its important penetration of hydronic systems in residential buildings, comparable to Europe but high compared to much of North America. In Canada and the US, an updated standard to be effective in January 2024 provides new regulations on mildly flammable A2L refrigerants such as R-32, (CSA, 2019a). This will allow some of the more innovative manufacturers to import mid-GWP refrigerant systems to North America. Nevertheless, refrigerant safety requirements in North America are still more conservative than European ones, such that barriers for some key products remain.

Energy Efficiency Standards

The lack of a Canadian-specific Energy Star standard for heat pumps means that many current programs champion only certain metrics such as cooling performance. The adoption of the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump

Specifications and Product List (NEEP, 2021) has addressed this issue in part. Yet, some of the performance data provided (e.g., at 5°F) are not necessarily derived from industry standard test procedures, and high-end manufacturers still feel that the actual cold-climate performance of their products is not sufficiently valued relative to the competition. In Canada, a new load-based testing standard (CSA EXP07) was recently developed, designed to better characterize the real-world performance of heat pumps in different climate zones, including very cold regions (CSA, 2019b). Currently, Natural Resources Canada (NRCAN) has indicated that manufacturer testing to this standard will be voluntary and they consider using it as a basis for incentive programs (NRCAN, 2021). Interviewed manufacturers were split on how this barrier is addressed, with some feeling that such a standard would allow them to differentiate their products based on real-world performance in the Canadian climate, and others feeling that it wasn't yet sufficiently developed, indicating it does not conduct an adequate evaluation of performance (efficiency) rather, the ability of a product to operate at such temperatures.

Certification Cost, Complexity, and Timelines

Manufacturers find the certification process too complex, expensive, and time-consuming. Despite support from federal and provincial regulators, certification know-how is deemed a barrier for first-time importers. Multiple global manufacturers mentioned that differences between the European and North American certification requirements and processes made it hard for them to understand how to get their products certified in North America. If the demand for the product is expected to be big enough, certification doesn't present as significant of a barrier; however, the overall certification investment (cost, timing, and support) needs to be commensurate with the expected market size. Specific issues raised included:

- The need for every component to be certified, which adds cost and limits the number of available components.
- The need to get full certification to bring a product over solely for testing, which makes it hard to de-risk the introduction of a new product into the market.
- Frequent, short notice changes in requirements, which are particularly hard on smaller manufacturers with limited engineering resources.

Solutions

The following solutions are proposed to address the barriers faced by manufacturers when considering whether to bring new products to the BC market. A range of different actors could play a role in leading and supporting these initiatives, from local, provincial, and federal governments to the Vancouver Economic Commission, industry associations, other non-government organizations, and regulatory agencies. Collaboration and coordination are critical for ensuring that efforts are not duplicated across jurisdictions and that additional trade barriers are not unintentionally created.

Overall, the proposed solutions aim to increase the value proposition for a range of key players. For governments, the solutions will help to increase technology options to support increasingly ambitious GHG emissions reduction targets via electrification of more building types. For manufacturers, the solutions will decrease the friction of entering or expanding coverage of the Canadian market, while offering growing demand for their products. For

building owners, the solutions will offer a wider range of products and possibly promote competition among suppliers, thereby facilitating heating electrification projects.

The primary solution for overcoming the barrier presented by the relatively small size of the BC market is to partner with other North American jurisdictions facing similar heat pump availability challenges. As discussed in this paper, while some of BC's heat pump needs are satisfied by mainstream technologies (e.g., air-to-air heat pumps), supplies are limited for more niche heat pump technologies and applications. If BC were to form a trade coalition with jurisdictions with similar technology needs, it could demonstrate to global manufacturers that the anticipated market demand justifies going through North American certification processes, and/or equipment modifications (e.g., voltage and frequency).

This trade coalition could include relevant jurisdictions that are geographically related or close (Toronto, Montreal, Pacific Northwest), with innovative policy environments that could help push for electrification and low-GWP product availability and adoption (California), and with comparable climates/building stocks (New York). This coalition could develop an assessment of combined market demand for similar heat pump product needs, making the investment of time and effort required to modify and certify products more worthwhile for global manufacturers. Harmonizing heat pump technology standards and requirements across these jurisdictions is also important for reducing costs and complexity for manufacturers. Quantifying the impact of strong building decarbonization policies, such as building codes and standards, on the future demand for heat pumps can play a critical role in making markets more attractive for manufacturers. Finally, the participation of the trade coalition members in relevant trade shows and exhibitions could help overcome the market size barrier by demonstrating to manufacturers that there is a sizable market for niche products as identified in the gaps section.

In addition to engaging directly with manufacturers, bulk procurement of heat pump technologies that are currently 'missing' from the market is another strategy to fill in gaps in heat pump supplies. Bulk procurement can offer a streamlined pathway to quickly address market supply needs and encourage innovation by encouraging the development of new products. The New York Clean Heat for All Challenge (NYC, 2021) is a recent example of a bulk procurement initiative to fill a specific heat pump market need. For this strategy to be effective in the BC context, the heat pump technology would need to be already certified in the North American market as global manufacturers are unlikely to be willing to go through the certification process for a single procurement initiative in the BC market.

The cost and complexity of entering a new market could also be circumvented by encouraging Canadian heat pump manufacturers and assembly companies to expand their range of products and/or expand their production capacities to meet local market needs. Heat pumps that are manufactured and/or assembled in Canada can gain more market share if they are tailored to suit domestic market needs and do not need to undergo equipment modifications. Furthermore, domestic manufacturers that focus on the Canadian market do not face the challenge of having to undergo multiple certification processes (e.g., North American and European).

Another key supply chain strategy identified is to increase the quality and capacity of the local workforce. As discussed in this paper, global manufacturers are concerned about the reputational risk associated with their equipment being installed poorly. Contractor training programs are needed to increase the supply of qualified installers. These programs can be

specifically tailored to prepare contractors for manufacturer training programs currently in the market. Contractor certification programs can also be used by utilities and government incentive programs to increase the number of heat pumps installed by ‘accredited’ or ‘registered’ installers.

In addition to contractor training programs, governments can also establish a hub or center for heat pump research, demonstration & training. This kind of hub can provide hands-on opportunities to educate, train, and upskill the local workforce. If co-located with a refrigeration school, hands-on teaching functions such as flare connections, refrigerant capture, weigh-in, and maintenance diagnosis could be combined. The hub could also offer product demonstrations to allow engineers, architects, regulators, suppliers, and prospective purchasers an opportunity to see heat pumps in action. For example, seeing products operating in a range of outdoor weather conditions throughout the year could help overcome concerns about cold weather performance. Additionally, the presence of a hub could attract heat pump manufacturers by further demonstrating that the market is serious and encourage suppliers to stock products.

One strategy for increasing the supply of low-GWP refrigerant heat pumps to meet BC market needs is to support the use of propane as a refrigerant. Realistically, since safety and flammability regulations in Canada are defined as part of a CSA standard and harmonized across North America, updates to the current flammability regulations (class 2 and class 3) would require an extensive review and lengthy amendment process. In addition, unlike in BC, many North American markets do not have high penetration of hydronic systems (i.e., less demand for propane air-to-water heat pumps common in Europe), which makes the justification for updating the standard more challenging. However, BC could collaborate with other jurisdictions that have similar product needs and explore opportunities for the relevant standards to be further updated. Similarly, BC can work with relevant players to reduce the barriers associated with and accelerate the introduction to Canada of high-efficiency heat pumps using natural refrigerants such as CO₂.

To increase the supply of cold-climate units, especially PTHCs, air-to-water heat pumps, and HPWHs, BC could assess options for setting minimum performance standards under EXP07. Although NRCAN sets the minimum energy efficiency and performance standard for heat pumps in Canada and has indicated that they will continue work on a load-based test standard for use in a voluntary qualified product listing (NRCAN, 2021), BC could require that heat pumps sold in the market achieve a level of performance under CSA EXP07 to encourage and recognize the higher performance of cold-climate heat pump models. However, there is a risk that this would create an additional burden on manufacturers that they do not face in other jurisdictions and create a disincentive to enter the market. To avoid this, BC could collaborate with NRCAN and other jurisdictions which have comparable climates to explore options to increase the adoption of CSA EXP07 (such as introducing a requirement for incentive programs). Harmonization of performance requirements with other jurisdictions would increase the market size and compensate for the additional certification costs faced by manufacturers.

Finally, additional guidance materials on the certification process could be developed to support manufacturers looking to export heat pumps to the BC market. This work could be developed and promoted by the trade coalition discussed above and could include a step-by-step comparison of how the North American certification process corresponds to European and other global standards. These guidance materials could be offered to global manufacturers along with

an information package with general information on market size, policy environment, and specific heat pump technology needs and opportunities.

Conclusion

This study demonstrates that while BC heat pump market needs are well served in single-family homes (including air-to-air heat pumps and heat pump water heaters), availability challenges exist in other key market segments, including heat pumps for multi-family residential buildings, C&I buildings, and retrofits applications, as well as heat pumps with low-GWP refrigerants. Global manufacturers indicated that although these products exist and are being offered elsewhere, the cost to enter the BC market is seen as too high relative to the potential market size. Supply chain strategies can help overcome these barriers, primarily by demonstrating the market for these products is sufficiently large by collaborating with other jurisdictions that have similar market needs (e.g., via a trade coalition). Investing in workforce training and demonstrations is another key strategy to address supply chain barriers since it can help manufacturers have more confidence that their heat pumps will be installed properly.

As cities, provinces, states, and countries look to introduce ever more ambitious building decarbonization strategies, ensuring an adequate supply of heat pump technologies to cover market needs will be critical to reaching climate goals. Other markets in North America that may be facing similar heat pump supply constraints can leverage the supply chain strategies identified in this study to overcome this challenge.

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