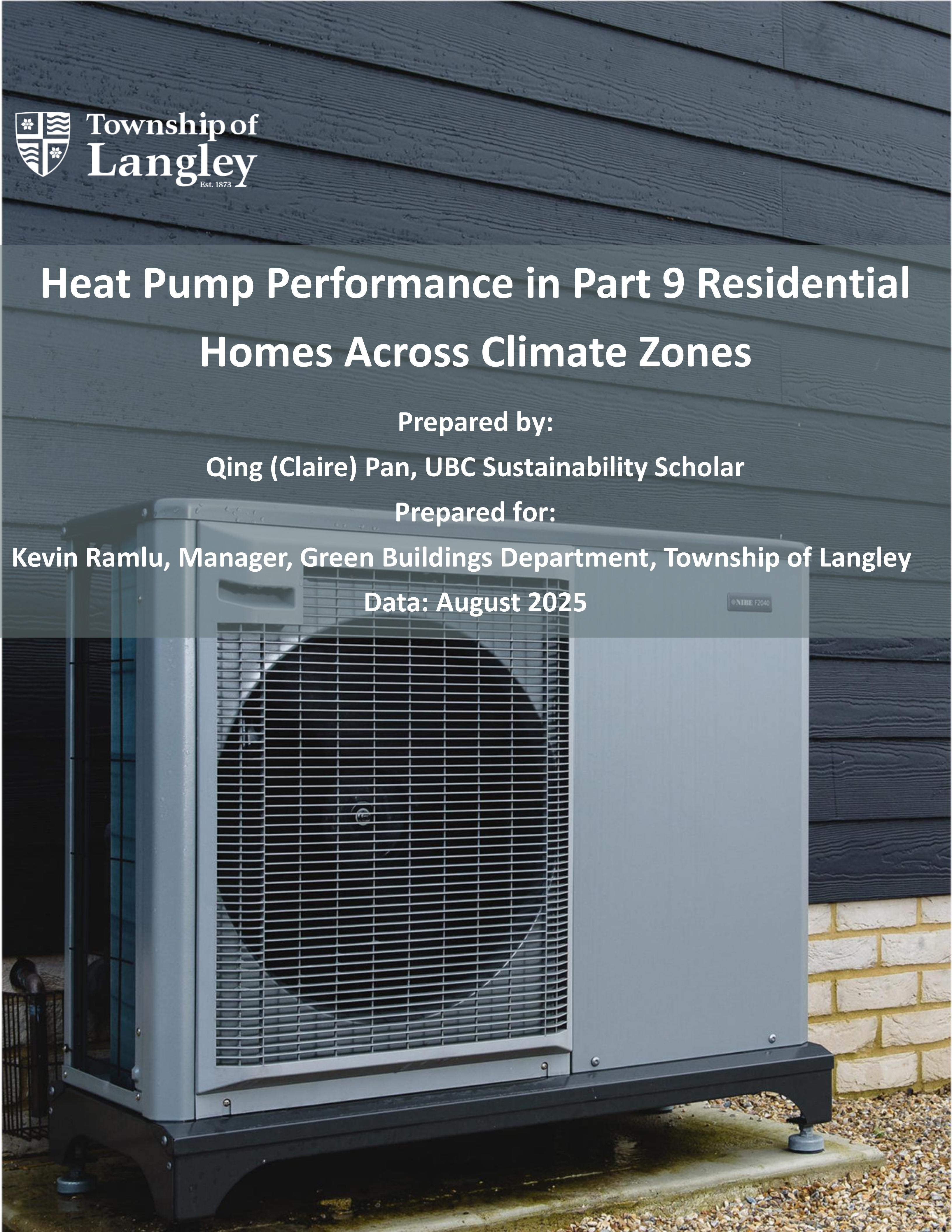

Township of Langley

Est. 1873

Heat Pump Performance in Part 9 Residential Homes Across Climate Zones

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Prepared for:

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Data: August 2025

Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of Township of Langley staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Township of Langley or the University of British Columbia.

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This research was conducted under the guidance of Kevin Ramlu, whose expertise, guidance, and continuous support made this project possible.

Ajeen Surendran, contributed significantly by modeling the Step Code home and providing real-world heating demand data, which brought strong practical relevance to the study. Throughout the process, he also offered valuable insights and direction.

Special thanks to Todd Backus, who provided methodological guidance and modeled the retrofit of a 1960s home to a net-zero standard which was very instrumental in advancing the research.

The author also sincerely thanks Karen Taylor, Senior Manager of Sustainability Scholars & Strategic Implementation at the UBC Sustainability Hub, for her administrative guidance and coordination throughout the project.

Contents

Executive Summary

This report evaluates the performance and applicability of residential air-source heat pumps across British Columbia's six primary climate zones (CZ 4 to CZ 8), focusing on their potential to meet space heating demands in alignment with the BC Energy Step Code and Zero Carbon Step Code targets.

The analysis is based on performance data from 84 heat pump models, collected from manufacturers and other verified sources. The core assessment criteria were whether a unit could deliver 100% of a building's heating demand at the local winter design temperature while maintaining a Coefficient of Performance (COP) above 1.0. Step Code 3, 4, and 5 homes—both single-family dwellings (SFDs) and townhouses—were modeled using archetypal designs located in representative climate zone cities and matched against heat pump performance to assess the feasibility of standalone operation without supplementary heating systems.

Findings show that heat pump performance declines sharply in colder conditions, limiting their application in northern or high-altitude regions (Zones 7A–8). In contrast, in milder zones (CZ 4 and warmer parts of CZ 5), majority of the analyzed models were able to meet heating requirements. In colder parts of CZ 5 and most of CZ 6, only a portion of heat pumps could meet the full load without supplementary heating. The analysis also shows that homes built to higher Step Code levels require less heating capacity, thereby increasing the number of compatible heat pump options. Townhouses consistently demonstrated higher compatibility due to lower heating demand resulting from smaller unit sizes and shared walls. Proper retrofits that reduce heating demand can also make standalone heat pump systems feasible, even for 1960s homes.

This report provides actionable guidance on where standalone heat pumps can be deployed, where supplementary systems may be required, and how policy and retrofit strategies can expand their applicability. Future work is recommended to incorporate practical heating buffers and address overheating protection considerations that may affect heat pump adoption.

1. Introduction

1.1 Context of the sustainable project

This project was initiated in 2025 by Kevin Ramlu, Green Building Manager at the Township of Langley, in collaboration with the UBC Sustainability Hub. Claire Pan, a UBC Sustainability Scholar, was selected to undertake the research.

The project was conducted primarily by Claire Pan between May 1 and August 15, 2025, with technical and strategic guidance from mentor Kevin Ramlu to ensure alignment with the Township's sustainability objectives. Administrative support was provided by Karen Taylor, Senior Manager of Sustainability Hub at UBC.

1.2 Project Objective

The objective of this project is to evaluate whether modern, commercially available heat pumps can serve as a reliable primary heating system for Part 9 residential homes across different climate zones in British Columbia, in alignment with the requirements of the BC Energy Step Code (ESC) and Zero Carbon Step Code (ZCSC).

Specifically, the study examines the performance of a range of heat pump models—from standard to cold-climate units—across various climate zone cities in BC. It aims to determine whether standalone heat pumps can sufficiently maintain indoor temperatures in Step Code-compliant homes.

1.3 Key Terms

- Part 9 Home

  A Part 9 Home refers to a residential building regulated under Part 9 of the BC Building Code (BCBC) or the National Building Code of Canada (NBC). These are low-rise residential buildings with three or fewer stories and a building area not exceeding 600 square meters. They include single-family homes, duplexes, townhouses, and small multi-family dwellings.

  (Government of British Columbia, 2024).

- HVAC

  HVAC stands for Heating, Ventilation, and Air Conditioning. HVAC systems are responsible for maintaining indoor thermal comfort and air quality by regulating temperature, airflow, and humidity.

  (Natural Resources Canada, 2023).

- Cold Climate Air Source Heat Pump (ccASHP)

A Cold Climate Air Source Heat Pump is a high-efficiency air-source heat pump designed to operate reliably in low ambient temperatures, typically down to –25°C or lower, while maintaining acceptable heating capacity.

(Northeast Energy Efficiency Partnerships [NEEP], 2023).

- Heating Degree-Days (HDD)

  Heating Degree-Days are a measure of heating demand, calculated as the cumulative difference between a base indoor temperature (usually 18°C) and the daily mean outdoor temperature whenever the latter is below the base. HDD is used to estimate seasonal energy needs for space heating.

  (Environment and Climate Change Canada, 2022).

- Climate Zones in BC

  Climate zones in British Columbia are categorized based on annual Heating Degree-Days below 18°C(HDD18). The BC Building Code delegates authority to local jurisdictions to determine applicable climate values, often based on Environment Canada data. Some locations may span multiple zones due to elevation or topographic variation.
  (BC Housing Research Centre, 2018).

2. Background

2.1 Regulatory Framework

2.1.1 Clean BC roadmap to 2030

The CleanBC Roadmap to 2030 outlines the Province of British Columbia's commitment to transitioning all new buildings to zero-carbon operations by 2030 (as shown in Figure 1). To support this goal, the roadmap identifies two key regulatory strategies:

1) Strengthening energy efficiency requirements in the BC Building Code through progressive updates to the Energy Step Code.

2) Implementing a carbon performance-based standard to cap operational greenhouse gas (GHG) emissions from new construction, known as the Zero Carbon Step Code.

Together, these two measures establish the regulatory foundation for building decarbonization in BC.

To support consistent implementation, the province released the BC Energy Step Code and Zero Carbon Step Code Handbook for Building Officials in March 2025, offering technical guidance on compliance pathways, performance metrics, and permitted energy sources.

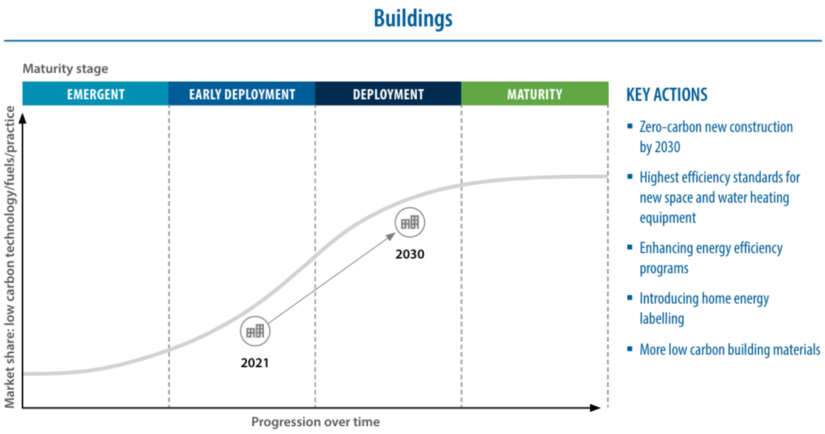


Figure 1. Building sector goals as outlined in the CleanBC Roadmap to 2030 (Government of British Columbia, 2021).

2.1.2 BC Energy Step Code

The BC Energy Step Code is a performance-based framework aimed at improving the energy efficiency of new buildings. For Part 9 residential buildings, all new homes are required to meet Step 3 as of 2023 (already in effect), and the provincial target is for all new Part 9 buildings to achieve Step 5 by 2032.

To reach higher steps, one key strategy is the adoption of more energy-efficient mechanical systems (as shown in Figure 2), which directly contributes to the reduction of Mechanical Energy Use Intensity (MEUI). Lower MEUI values indicate reduced energy demand, typically achieved through improved envelope performance and efficient mechanical systems. Therefore, the adoption of high-efficiency systems—such as heat pumps—can significantly support compliance with higher steps of the Energy Step Code.

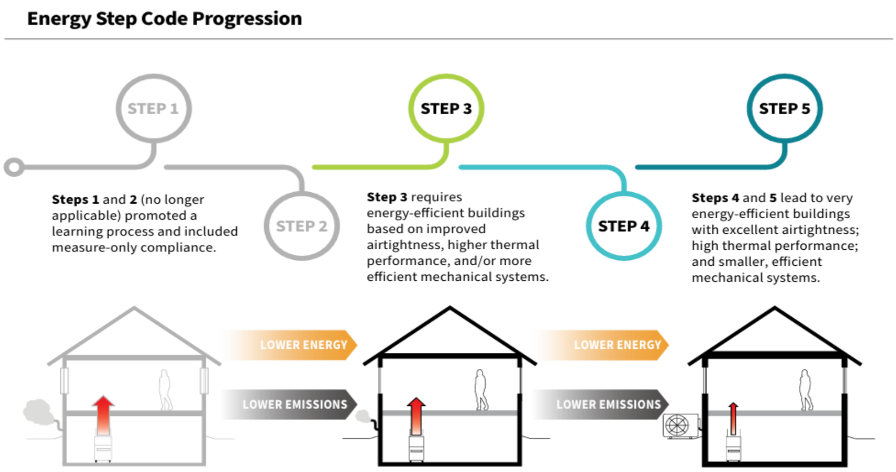


Figure 2. BC Energy Step Code progression (Government of British Columbia, 2025).

2.1.3 BC Zero Carbon Step Code

BC's Zero Carbon Step Code introduces limits on operational greenhouse gas (GHG) emissions (as shown in Figure 3). It complements the Energy Step Code by targeting GHG, encouraging electrification and reducing the use of fossil fuels like natural gas. Municipalities may choose to adopt ZCSC performance requirements.

The province has issued a timeline for ZCSC Emission Limit requirements from EL-1 to EL-4. EL-4 will be required throughout the province by 2030.

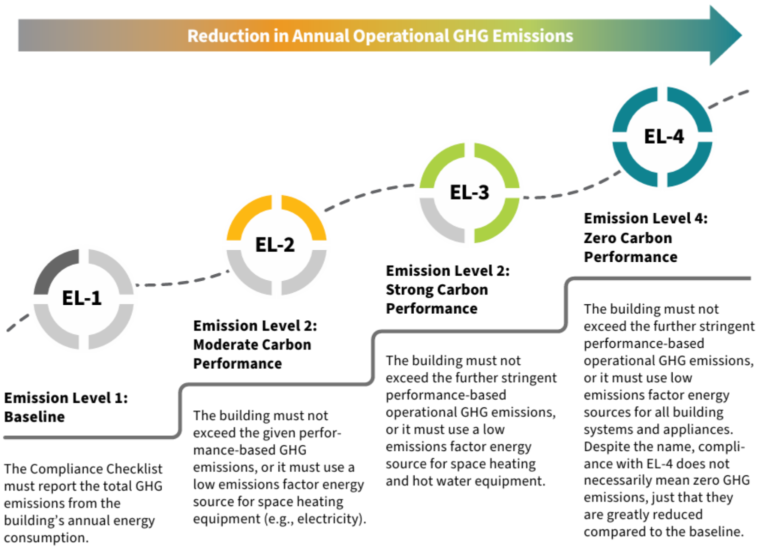


Figure 3. Summary of four emission levels in the BC Energy Step Code and Zero Carbon Step Code Handbook (Government of British Columbia, 2025)

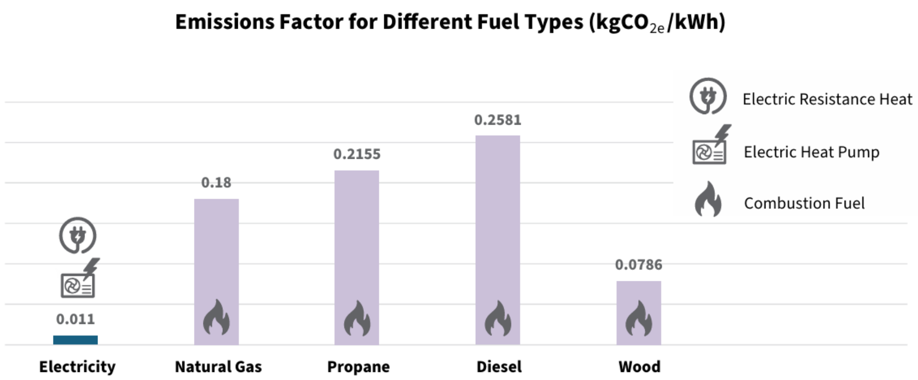


Figure 4. Emissions factors for common building fuel types (Government of British Columbia, 2025).

Compliance with the ZCSC can follow either a performance-based path or a prescriptive path, both of which rely on the GHG emissions factor of energy sources. Because electricity in BC is predominantly hydroelectric, it has a significantly lower emissions factor than natural gas or other combustion fuels (as shown in Figure 4). Therefore, utilizing electric-powered heating systems in BC plays a critical role in enabling buildings in BC to comply with the ZCSC requirements.

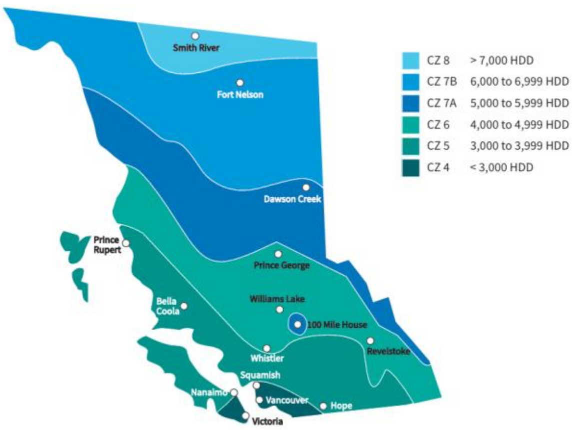
2.1.4 Design Temperature Specified in BC Building Code

According to the BC Building Code (BCBC) Section 9.33.3.1, space heating systems must be capable of maintaining an indoor air temperature of not less than 22°C in all living spaces when the outdoor winter design temperature is reached. Similarly, cooling systems must be capable of maintaining an indoor air temperature of not more than 26°C in at least one living space during the outdoor summer design temperature.

To comply with these safety requirements throughout the year, it is increasingly efficient and practical to adopt a single integrated system, such as heat pump, that can provide both heating and cooling. This dual functionality supports code compliance while reducing the complexity of mechanical design in new Part 9 homes.

2.2 Climate zones in British Columbia and Design Temperature

In British Columbia, climate zones are defined based on annual Heating Degree-Days (HDD) below 18°C, which reflect the cumulative demand for space heating. According to the BCBC, the province is divided into six main climate zones for building energy design: Zone 4, 5, 6, 7A, 7B, and 8. A higher zone number indicates colder conditions and greater heating demand. Most of the BC's population resides in Climate Zone 4 and the milder parts of Zone 5. 94% of BC's population resides in Climate Zone 4 and the milder parts of Zone 5 (Government of British Columbia, n.d.).



CZ 4 < 3,000 HDD				
Abbotsford	Duncan	Langley	Richmond	Surrey
Agassiz	Delta	Mission	Sechelt	Vancouver
Burnaby*	Maple Ridge	New Westminster	Sidney	Victoria
Chilliwack	Jordan River	North Vancouver*	Sooke	West Vancouver
Crofton	Langford	Port Renfrew	Squamish	White Rock

CZ 5 3,000 to 3,999 HDD				
Alberni	Courtenay	Ladysmith	Osoyoos	Queen Charlotte City
Ashcroft	Crescent Valley	Lillooet	Parksville	Salmon Arm
Bamfield	Gold River	Lytton	Penticton	Sandspit
Bella Bella	Grand Forks	Masset	Port Alberni	Tahsis
Bella Coola	Hope	Merritt	Port Alice	Tofino
Burnaby (SFU)	Kamloops	Montrose	Port Hardy	Trail
Cache Creek	Kaslo	Nakusp	Port McNeill	Ucluelet
Campbell River	Kelowna	Nanaimo	Powell River	Vernon
Castlegar	Kitimat Plant	Nelson	Prince Rupert	Youbou
Comox	Kitimat Townsite	Ocean Falls	Qualicum Beach	

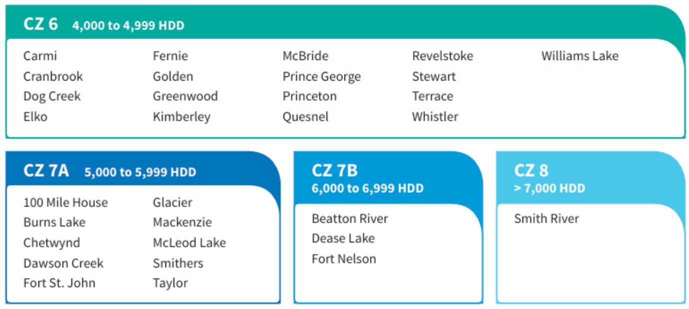


Figure 5. Climate zones and representative cities in British Columbia (BC Housing Research Centre, 2018).

Design temperatures are standardized reference values used for sizing heating and cooling systems in buildings. The design temperatures provided in the BCBC(2024) are based on average weather data between 1981 to 2006. This indicates that current design requirements are based on weather conditions that are outdated.

The winter design temperature—commonly known as the 2.5% January design temperature—is defined as the outdoor air temperature that is equal to or colder than the hourly temperature during the coldest 2.5% of hours in January. This value is typically used for size heating systems and represents a condition expected to occur for approximately 19 hours in a typical January.

In this study, the 2.5% winter design temperature is used as the basis for assessing whether a given heat pump model can independently meet the heating demand of a home in each BC climate zone—without the need for auxiliary systems.

The climate zone and design temperature were listed in Appendix A.

2.3 Heat Pump Technology Overview

A heat pump is a device that uses electricity to transfer heat from a lower-temperature source to a higher-temperature sink. Unlike conventional heating systems that generate heat through resistance or combustion, heat pumps move thermal energy using a vapor-compression refrigeration cycle, enabling both heating and cooling functions within a single system (U.S. Department of Energy, n.d.).

In heating mode, the heat pump extracts heat from the outdoor air, even at sub-zero temperatures, and transfers it indoors. In cooling mode, the process reverses: heat is removed from the indoor space and released outdoors, much like a standard air conditioner.

Because heat pumps transfer rather than generate heat, they are significantly more efficient than traditional heating systems such as electric baseboards or gas furnaces, which have a maximum efficiency close to 100%. In contrast, the Coefficient of

Performance (COP) for a typical residential air-source heat pump can range from 2.5 to 5.0 under mild conditions. This means a heat pump can deliver 2.5 to 5 times more thermal energy than the electrical energy it consumes, resulting in significantly reduced energy consumption, and therefore lower utility bills for the occupant.

Owing to their high efficiency, dual-function capability, and powered by BC's clean hydroelectricity, heat pumps are increasingly recognized as a key solution for helping buildings comply with both the Energy Step Code and the Zero Carbon Step Code. Additionally, they contribute to mitigating overheating risks, thereby supporting the broader climate objectives outlined in the CleanBC Roadmap to 2030 (Government of British Columbia, 2021).

For more information on how heat pumps operate, please see Appendix B.

2.3.1 Air-Source Heat Pumps

Air-Source Heat Pumps (ASHPs) are the most common residential heat-pump type in Canada. In heating mode, the outdoor unit acts as the evaporator, extracting ambient heat—even at sub-zero temperatures—and transferring it indoors; in cooling mode, the cycle reverses (Natural Resources Canada, 2023; U.S. Department of Energy, n.d.). A primary limitation of conventional ASHPs in British Columbia is the significant decline in heating output and efficiency at sub-zero outdoor temperatures.

Air-Source heat pumps can be further categorized based on the configuration of their indoor distribution system:

1) Ducted Systems
   In ducted configurations, the indoor coil is integrated within a central air handling unit connected to ductwork. Conditioned air (heated or cooled) is distributed throughout the building via the duct network.

2) Ductless Systems
   In ductless configurations, the indoor coil is integrated into a wall-mounted or floor-mounted unit located directly within the conditioned space. These systems operate by delivering heating or cooling locally, without relying on ductwork. Two main types are commonly used: the mini-split system, in which a single indoor unit is connected to a single outdoor unit to serve one room or zone; and the multi-split system, which connects multiple indoor units—each serving a separate room or zone—to a single outdoor unit, enabling individualized climate control throughout the building.

Air source heat pumps typically operate with higher efficiency when the temperature difference between the indoor and outdoor environment is relatively small. To maintain optimal performance, these systems generally supply a larger volume of air heated to a moderate temperature—typically in the range of 25°C to 45°C. This differs from conventional furnace systems, which supply a smaller volume of air but at significantly higher temperatures—usually between 55°C and 60°C. (Natural Resources Canada, 2023; U.S. Department of Energy, n.d.).

For more information on heat pump types and suitability for BC, please see Appendix C.

2.3.2 Technological Advancements in Heat Pumps

Although heat pumps are governed by the basic principles of thermodynamics, their real-world efficiency is often limited by operational losses such as compressor cycling losses, defrost operations, and refrigerant limitations. Nevertheless, recent innovations have significantly enhanced the performance of Cold Climate Heat Pumps (CCHPs), particularly in sub-zero environments. Key advancements include:

1) Variable-speed (inverter) compressors

   The Variable-speed compressor allows the system to continuously adjust compressor speed based on real-time heating demand. This results in more stable performance and higher seasonal efficiency. This feature is widely adopted in cold-climate models such Mitsubishi Hyper-Heating INVERTER (H2i), Daikin Aurora, and Fujitsu Halcyon XLTH (Mitsubishi Electric Trane HVAC US, n.d.; Daikin Comfort, 2021; Fujitsu General America, n.d.).

2) Two-stage compression and vapor-injection

   By injecting additional refrigerant vapor during compression, this technique increases mass flow and boosts pressure, allowing the system to produce more heat without straining the compressor. It helps maintain full heating capacity and stable COP even at –20 °C or below. This technology is used in cold-climate models from Mitsubishi and Daikin to ensure reliable performance in sub-zero conditions（Mitsubishi Electric Canada, n.d.; Daikin, 2023).

3) Optimized refrigerants and coil designs

   The next-generation refrigerants such as R-32 and R-454B which offer lower boiling points, higher heat transfer efficiency, and significantly lower Global Warming Potential (GWP) compared to traditional R-410A. These refrigerants evaporate more readily in cold outdoor air, enhancing heat absorption and maintaining higher COP at sub-zero temperatures.

   Manufacturers pair these refrigerants with advanced coil/heat-exchanger designs to further strengthen low-temperature performance. Representative product lines include Daikin R-32 systems, LG Therma V (R-32), and Trane R-454B–based systems (Daikin Comfort, n.d.; LG Electronics, 2023; Trane Residential, n.d).

These advancements expand the applicability of heat pumps across British Columbia's colder climate zones. In this study, several evaluated models incorporate one or more of these features, which explains their superior performance at cold design temperatures and supports their viability for standalone heating in high-performance homes.

3. Methodology

This study followed a structured methodology to evaluate the suitability of heat pumps for Part 9 residential homes across British Columbia's climate zones. The process involved four main steps, as shown in Figure 6.s

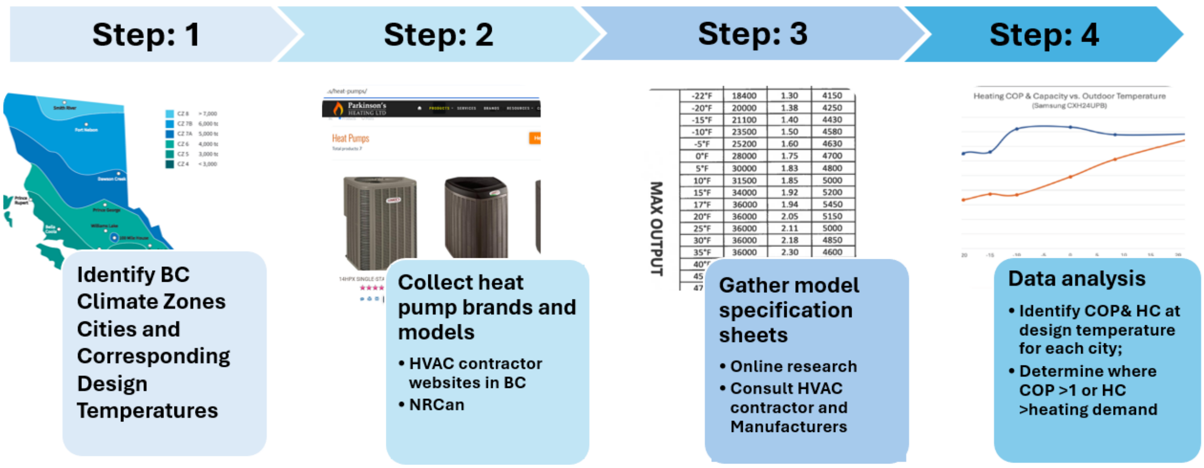


Figure 6. Study Methodology

3.1 Selection of Cities across Climate Zones

A list of representative cities across BC's six major climate zones (CZ4 - CZ8) was compiled using winter design temperatures specified in the BC Building Code. For each climate zone—except CZ 8, which includes only one recorded location, two cities were selected to reflect the coldest and warmest winter design temperatures within the zone.

Although Climate Zone 7B was not listed separately, its temperature range is fully captured by the selected cities in Zone 7A and is therefore considered indirectly represented. Preference was given to larger population centers to improve representativeness and ensure practical relevance for residential heat pump deployment. The final selected cities are listed in Table 1.

Table 1. The Selected Cities for study

Climate zone	City	Winter Design Temperature (˚C)
CZ 4	Agassiz	-9

CZ 4	Langley	-8
CZ 4	Sooke	-1
CZ 5	Bamfield	-2
CZ 5	Kamloops	-23
CZ 5	Kelowna	-17
CZ 6	Prince George	-32
CZ 6	Whistler	-17
CZ 7A	Glacier	-27
CZ 7A	Smithers	-45
CZ 8	Smith River	-47

3.2 Identification of Available Heat Pumps in BC

To identify available heat pumps in BC, two methods were used.

Method 1: Contractor-Based Brand Survey
Major HVAC contractors across the selected cities were reviewed to identify brands and models commonly installed in Part 9 residential homes. Key sources included contractor websites, CleanBC Better Homes program resource, and HRAI Canada contractor directory.

Method 2: Public Market & Registry Data
Market reports and manufacturer listings were reviewed alongside the NRCan product directory, which catalogs heat pump models registered for use in Canada.

These two methods were cross-referenced to verify model availability, minimize gaps, and ensure the accuracy of the final inventory.

3.3 Collection of Technical Specifications

Once the initial list of brands and models was compiled, the following three-step strategy was used to gather performance data.

Method 1: Publicly Available Data

Manufacturer websites and product catalogs were reviewed to obtain specification sheets and performance data, including heating capacity at multiple outdoor temperatures and COP values at those temperatures.

Method 2: Direct Manufacturer Outreach

When online data was insufficient, manufacturers were contacted directly via email, contact forms or phone calls to local distributors or representatives.

Method 3: Industry Databases as Backup

If specifications were still unavailable, reputable third-party resources were used, including NEEP (Northeast Energy Efficiency Partnerships) Cold Climate Heat Pump List and NRCan tested performance data. These sources provide verified COP and heating capacity data at standardized temperatures.

3.4 Perform Data Analysis

The final dataset was analyzed to assess each heat pump's ability to operate independently—without backup heating—at each city's winter design temperature. The following criteria were considered:

1) Whether the model maintains COP ≥ 1.0 at the winter design temperature.
2) Whether heating capacity meets or exceeds building load requirements at the winter design temperature.

4. Findings and Discussion

This section presents a comprehensive analysis of 84 heat pump models from 10 manufacturers, assessed across 11 representative cities in BC's six climate zones. The evaluation focuses on three aspects:

1) Heat pump performance trends (COP and heating capacity vs. temperature)
2) Potential for meeting heating demand across cities and climate zones
3) Impact of Step Code level and building type on heat pump feasibility

4.1 Brands and Models Selected for Analysis

A total of 84 heat pump models from 10 brands (as shown in Table 2 and Figure 7) were selected for analysis. These models were chosen based on the following criteria:

1) Air source systems – only air-to-air heat pumps were considered.
2) Heating capacity between 1.5 and 5 Tons (approximately 18 to 60 MBH), typical of Part 9 residential loads.
3) Centrally ducted or multi-zone systems, ensuring applicability across a wide range of housing types.
4) Residential use only, excluding large-scale commercial equipment.

Table 2. The Heat Pump Brands in the Study

NO.	BRAND	COUNTRY
1	DAIKIN	JAPAN
2	CARRIER	USA
3	GREE	CHINA
4	GOOD MAN	USA
5	SAMSUNG	SOUTH KOREA
6	YORK	USA

7	MOOVAIRE	CANADA
8	TOSOT	CHINA
9	MITSUBISHI	JAPAN
10	FUJITSU	JAPAN

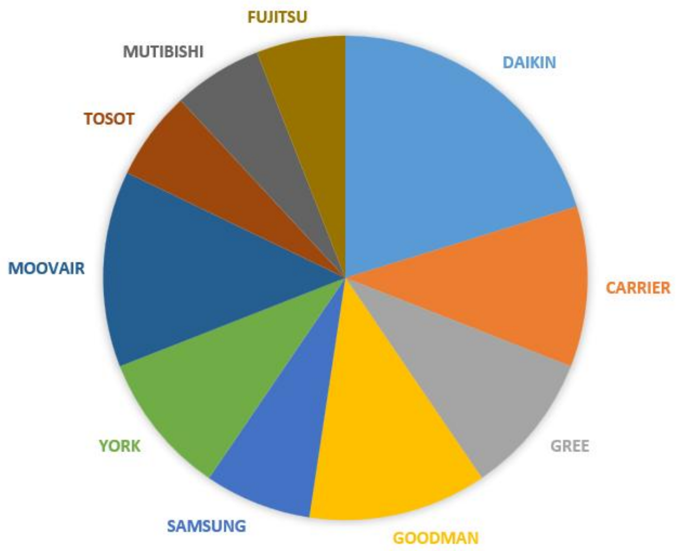


Figure 7. Distribution of Heat Pump Models by Brand

Figure 7 illustrates the distribution of the 84 heat pump models analyzed in this study, categorized by manufacturers. It highlights the relative contribution of each brand to the total number of models selected for evaluation.

Note: This chart reflects only the models for analysis for this project. It does not represent the actual market share or sales volume of each brand in British Columbia.

4.2 Performance Variation with Outdoor Temperature

4.2.1 The COP Curves

Figure 8 illustrates how the Coefficient of Performance (COP) of various heat pump models changes with outdoor temperature. Each color represents a unique model, and each colored dot corresponds to one performance data point at a specific temperature. The thick black line indicates the average COP trend across all models at each temperature.

From the plot, several key observations can be made:

1) Modern heat pumps demonstrate a wide operational range, maintaining functionality between -35 °C and 24 °C in heating mode.
2) COP values range from approximately 1.0 to 5.3, depending on the temperature and model, indicating significant performance variation across the market.

3) COP declines substantially as outdoor temperature drops. At extremely low temperatures (e.g., -35 °C), only a limited number of models remain operational with COPs around 1.2 to 1.5, while many standard models fail to operate effectively.

4) At any given temperature, COP varies considerably across models, highlighting the importance of careful model selection to ensure energy efficiency and suitability for local climate conditions.

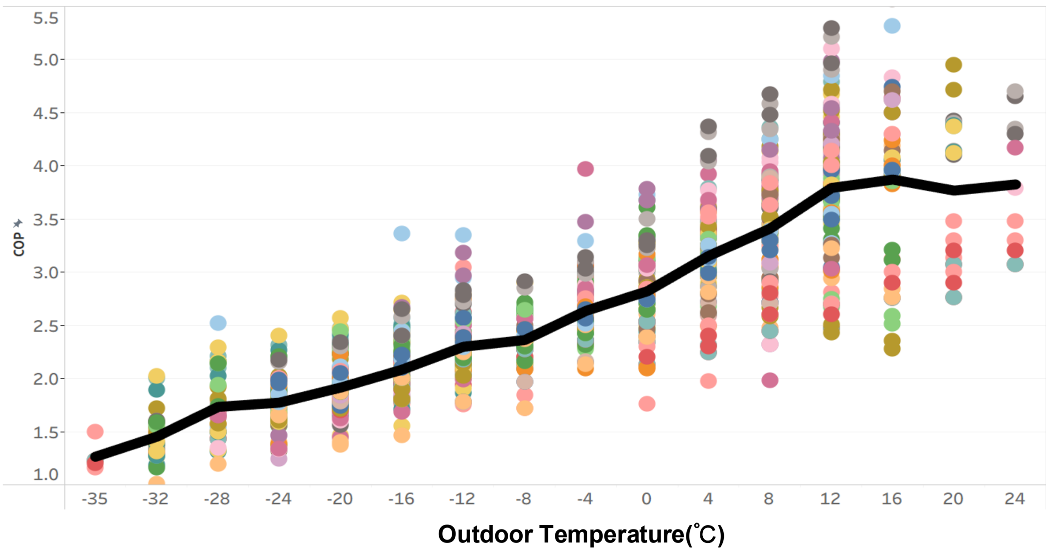


Figure 8. The COP Variation with Outdoor Temperature

4.2.2 The Heating Capacity Curves

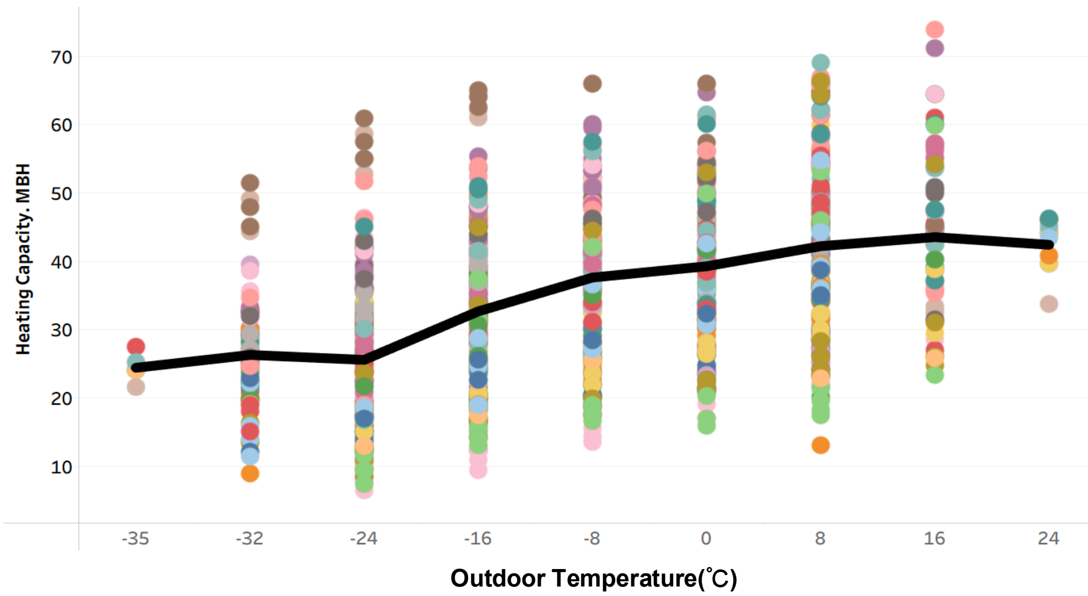


Figure 9. The Heating Capacity Variation with Outdoor Temperature

A similar trend is observed in the heating capacity plot Figure 9. The chart illustrates how the heating output of various heat pump models changes with outdoor temperature. Each colored dot represents a specific model's capacity at a given temperature, while the thick black line shows the average capacity trend across all models.

Key observations include:

1) Heat pump models remain operational across a broad temperature range, from -35 °C to 24 °C, similar to the COP performance range.
2) Heating capacity generally decreases as outdoor temperatures drop. At extremely low temperatures (e.g., -35 °C), only a limited number of cold-climate models are able to maintain sufficient output, albeit at reduced capacity levels. In contrast, many standard models experience significant capacity degradation or fail to operate altogether.
3) Capacity variation across models becomes more pronounced in colder conditions, indicating that some models are significantly better equipped to handle cold-climate demands. This underlines the necessity of selecting systems based not only on rated capacity at mild temperatures, but also on verified performance at design temperatures relevant to local climate zones.

4.2.3 The Performance Contrast Between Cold Climate Heat Pump and Normal Heat Pump

Figure 10 compares the average heating capacity and COP between cold-climate and non-cold-climate (standard) heat pump models across a range of outdoor temperatures. The datasets are grouped based on classification listed by NEEP.

The data reveals the following insights:

1) Heating capacity retention is the key advantage of cold-climate heat pumps. At very low outdoor temperatures (around –20 ℃ and below), most standard models reach or exceed their operational limits and may no longer provide adequate heating. In contrast, cold-climate units are designed with wider operating ranges (often down to –25 ℃ to –35 ℃), enabling them to sustain substantial output even under extreme conditions and ensuring reliable performance in colder regions.
2) COP performance does not show a universal advantage for cold-climate models. While they maintain stable efficiency at sub-zero temperatures, standard units achieve higher average COP values under mild to moderate conditions (above –5 ℃) reflecting their optimization for temperate climates rather than extreme cold.
3) Both heating capacity and COP follow the same general pattern with outdoor temperature—decreasing as temperature drops and increasing as it rises.
4) In relatively mild climate zones, standard models may already provide adequate performance with higher efficiency at moderate temperatures, offering a cost-effective solution. In colder regions, however, only cold-climate models can

ensure reliable heating throughout the winter season, making them the preferred option.

5) In addition, the heating capacity curve suggests that when heating demand is low—such as in high-performance homes designed to Step 4 or Step 5 of the BC Energy Step Code—standard heat pumps become a more viable option. This highlights the importance of integrating building envelope performance with equipment selection in achieving cost-effective decarbonization.

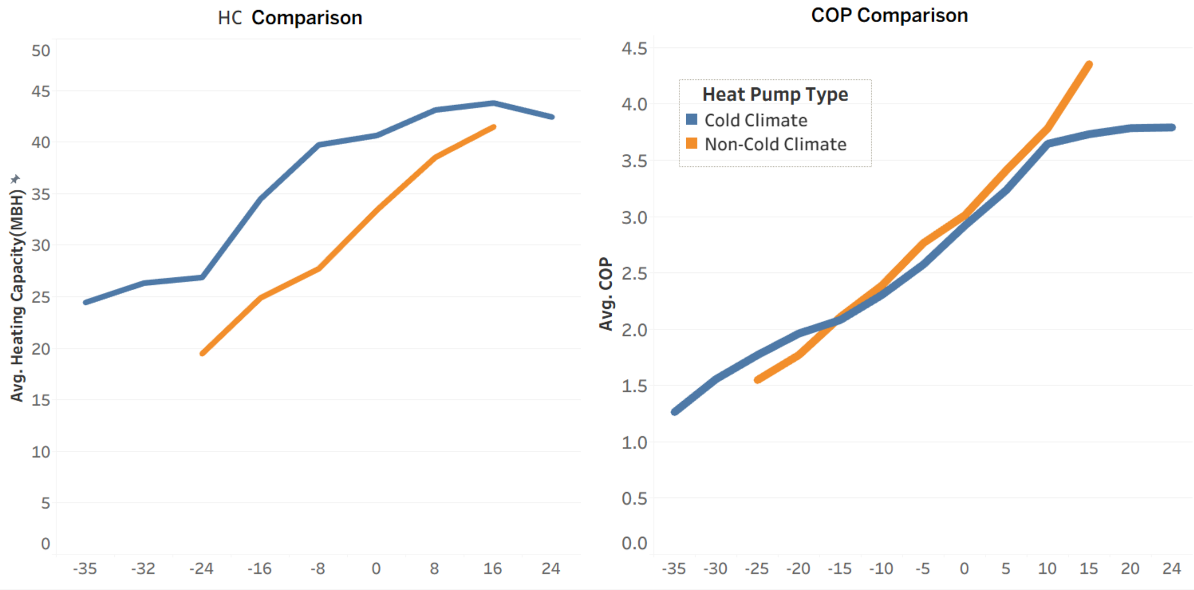


Figure 10. The Performance Contrast Between Cold Climate Heat Pump and Standard Heat Pump

4.2 Performance-Based Screening of Heat Pumps Across Climate Zone Cities

To evaluate which heat pump models are capable of meeting heating requirements under different climate conditions, a screening process was applied based on two minimum performance thresholds at each city's winter design temperature:

1) Minimum Heating Capacity: The unit must deliver at least the required heating output to meet 100% of the building's design load.

2) Minimum Operational Efficiency: The unit must maintain a COP ≥ 1.0 to ensure basic operational efficiency and functionality.

This screening was conducted under two demand scenarios to reflect different building energy needs and levels of thermal performance.

4.2.1 Low-Demand Scenario

Under the low-demand condition—defined as a building heating load requirement of at least 20 MBH at local winter design temperature and a minimum COP of 1.0 —a performance screening was conducted across cities representing different BC climate zones. Figure 11 illustrates the percentage of heat pump models that met both the heating capacity and COP thresholds in each representative city.

From the analysis, the following observations can be made:

1) In Climate Zone 4 and the warmer parts of Zone 5, most heat pump models passed the screening. For example, Sooke (CZ4) achieved a 96.4% pass rate, Langley (CZ4) and Agassiz (CZ4) both reached 89.3%, and Bamfield (CZ5) reached 95.2%.
2) In Climate Zone 6 and the colder portions of Zone 5, the pass rates dropped significantly. Whistler (CZ6) and Kelowna (CZ5) had 71.4%, Kamloops (CZ5) had 40.5%, and Prince George (CZ6) had only 4.8%.
3) In the coldest zones, CZ7 and CZ8, very few models passed. Glacier (CZ7A) had a pass rate of 25.0%, Smithers (CZ7A) had 0%, and Smith River (CZ8) also had 0%, indicating the technical limitations of many standard systems in extreme cold conditions.

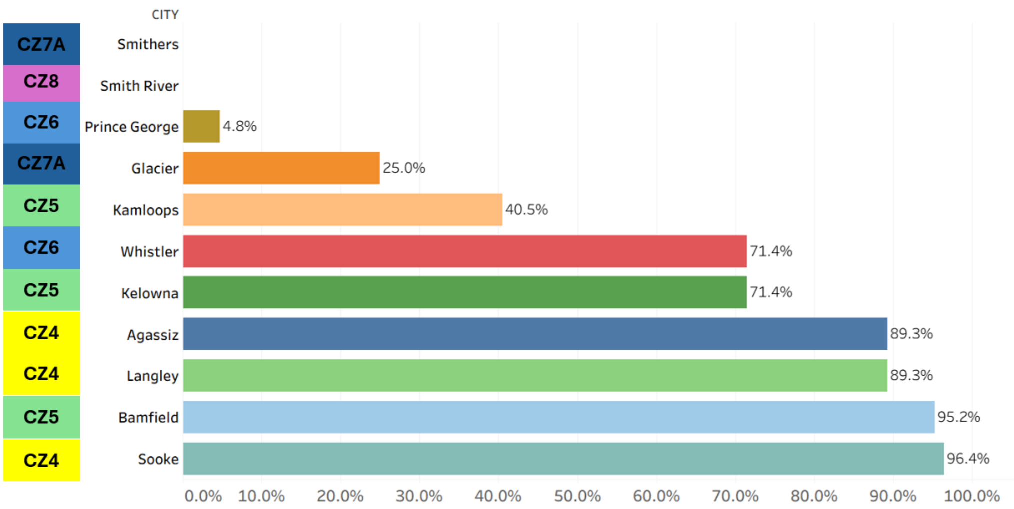


Figure 11. Low-Heating Demand applicability analysis across climate zone cities

4.2.2 Higher-Demand Scenario

To evaluate system performance under a higher building load condition, a second screening was conducted using stricter criteria: heating capacity ≥ 30 MBH and COP ≥ 1.0. This reflects the requirements of larger or less energy-efficient residential buildings, or those located in colder regions. Figure 12 depicts the percentage of heat pump models that achieved the required heating capacity and COP in each representative city.

1) A notable portion of heat pump models met the 30 MBH / COP ≥ 1.0 thresholds in Climate Zone 4 and the warmer parts of Zone 5, but the percentage was lower than in the low-demand case.

2) In Climate Zone 6, the percentage of models meeting both performance criteria declined sharply, indicating fewer viable options for high-load applications in colder regions.
3) In Climate Zones 7 and 8, only a negligible fraction was capable of meeting both thresholds, pointing to the need for dual fuel systems in these locations.
4) As the heating demand increased from 20 MBH to 30 MBH, the share of qualifying models dropped significantly across all cities—e.g., from 89.3% to 63.1% in Langley, and from 71.4% to 39.3% in Kelowna—highlighting the reduced feasibility of standard heat pumps under higher load requirements.

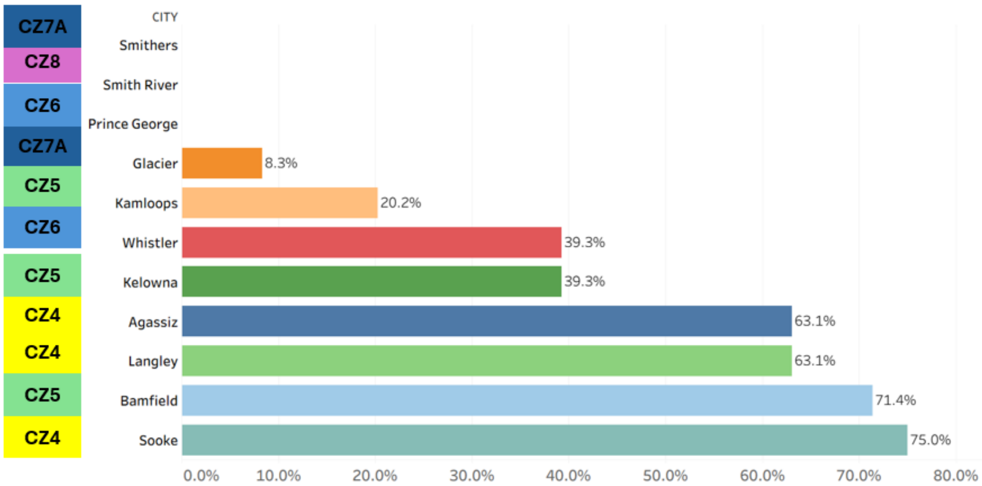


Figure 12. Higher-Heating Demand Applicability Analysis Across Climate Zone Cities

4.3 Impact of Step Code Levels on Heat Pump Compatibility

To assess how BC Energy Step Code affects heat pump applicability, building energy models were developed using HOT2000 software for both single-family dwellings (SFDs) and townhouses located in three climate zones: Langley (CZ 4), Kamloops (CZ 5), and Prince George (CZ 6). All models share the same archetype within each building type to ensure comparability.

For SFDs, the model represents a 260 m², 3-storey home with a secondary suite. For townhouses, a 3-storey, 5-unit row building with 170 m² per unit was used.

The following analysis compares the percentage of heat pump models capable of meeting the full heating demand (based on local winter design temperatures) under each scenario.

4.3.1 Single-Family Dwellings

Table 3 presents the heating demand for Single-Family Dwellings(SFDs) across Step Code levels in three representative cities. In all cases, heating demand decreases steadily from Step 3 to Step 5 due to improved building envelope performance, with total reductions of 38.9% in Langley (CZ 4), 33.9% in Kamloops (CZ 5), and 41.2% in

Prince George (CZ 6). The decline is slightly more pronounced in colder climates, where enhanced insulation and airtightness deliver greater absolute savings.

Table 3. The Heating demand for SFDs across Step Code levels

Location	Step 3 (MBH)	Step 4 (MBH)	Step 5 (MBH)
Langley (CZ 4)	36	29	22
Kamloops (CZ 5)	56	40	37
Prince George (CZ 6)	68	54	40

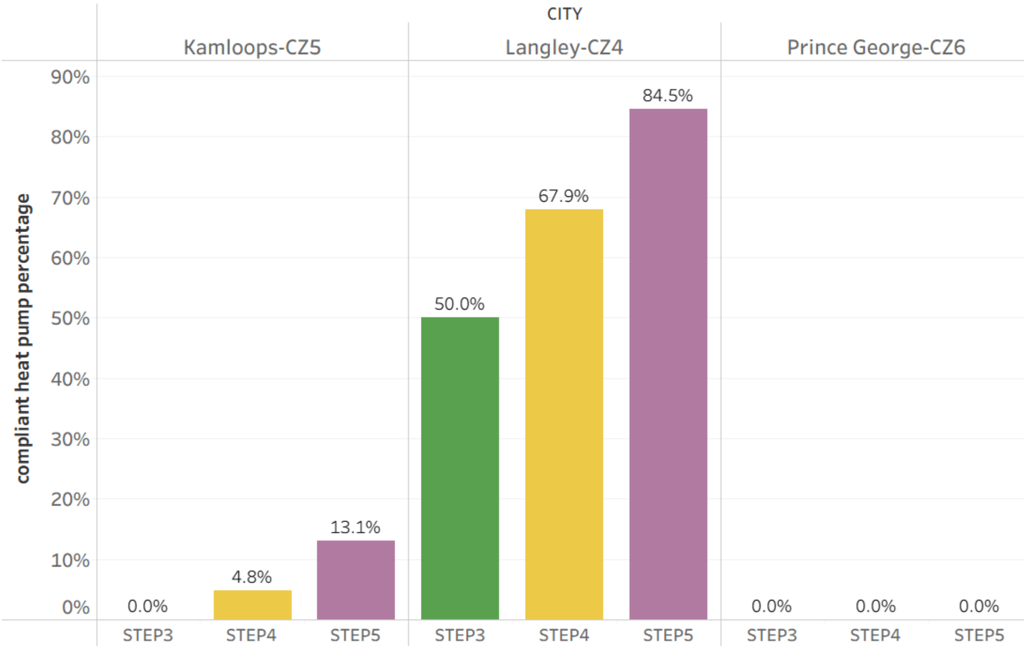


Figure 13. Step Code Level vs. Heat Pump Compatibility Across Cities

Figure 13 illustrates the proportion of heat pump models that can meet the calculated heating loads for Step 3 to Step 5 homes in three representative cities (Kamloops–CZ5, Langley–CZ4, and Prince George–CZ6). Based on this comparison, the following patterns were identified:

1) In Langley, the percentage of heat pump models meeting the full heating demand increased from 50.0% at Step 3 to 67.9% at Step 4 to 84.5% at Step 5, This indicates that homes built to Step 4—and especially Step 5—standards have many more viable heat pump options capable of meeting the heating load without supplementary systems.
2) In Kamloops, no heat pump model was able to meet the 56 MBH load at Step 3. However, when the same home was upgraded to Step 4 and Step 5, 4.8% and 13.1% of models became viable respectively, highlighting the importance of envelope efficiency improvements in colder zones.

3) In Prince George, none of the heat pump models were able to meet the heating demand at any Step level for single-family dwellings. The city's very low design temperature significantly reduces the heating output of all models.

4.3.2 Townhouses

Table 4 shows the heating demand for townhouse units across Step Code levels in the three representative cities. Demand decreases from Step 3 to Step 5 by 30.0% in Langley (CZ 4), 39.4% in Kamloops (CZ 5), and 37.5% in Prince George (CZ 6). Compared with the SFD homes in Table 3, townhouses exhibit significantly lower absolute heating demand at each Step Code level, owing to reduced envelope surface area and shared walls.

Table 4. The Heating demand for Townhouses across Step Code levels

Location	Step 3 (MBH)	Step 4 (MBH)	Step 5 (MBH)
Langley (CZ 4)	20	17	14
Kamloops (CZ 5)	33	27	20
Prince George (CZ 6)	40	33	25

Figure 14 illustrates the percentage of heat pump models capable of meeting the full heating demand for Step 3 to Step 5 townhouses in each city, based on the performance data and local design temperatures. The following patterns were observed:

1) In Langley, 98.8% of heat pump models were able to meet the heating demand for Step 5 townhouses, compared to 84.5% for Step 5 SFDs—demonstrating the advantage of attached housing types.

2) In Kamloops, 13.1% of heat pump models met the Step 3 townhouse demand, increasing to 41.7% at Step 5. In contrast, no model met the Step 3 SFD demand, and only 13.1% met the Step 5 SFD requirement—highlighting the benefit of lower unit load.

3) Even in Prince George, while no heat pump model met the full demand for SFDs under any Step level, a small number of models became feasible for Step 5 townhouses, as the heating load dropped to 25 MBH.

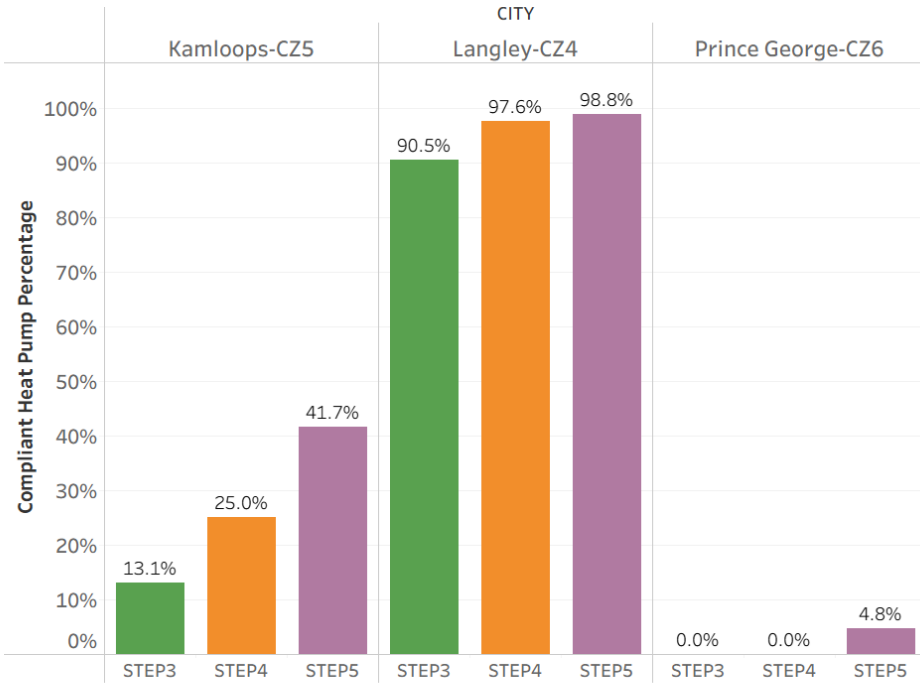


Figure 14. Step Code Level vs. Heat Pump Compatibility Across Cities

4.3.2 Overall Implication

The results from both SFDs and townhouse models highlight three key insights:

1) Higher Step Code levels effectively reduce heating demand, making it possible for more heat pump models to meet performance requirements, especially in milder climates.
2) Building type has a clear impact: townhouses, with smaller unit areas and shared walls, experience lower heat loss and therefore offer greater flexibility in heat pump selection.
3) Climate zone remains the most limiting factor. In colder regions like Prince George, even energy-efficient homes may not be compatible with current air-source heat pump models due to significant capacity loss at low design temperatures.

4.4 Conclusion

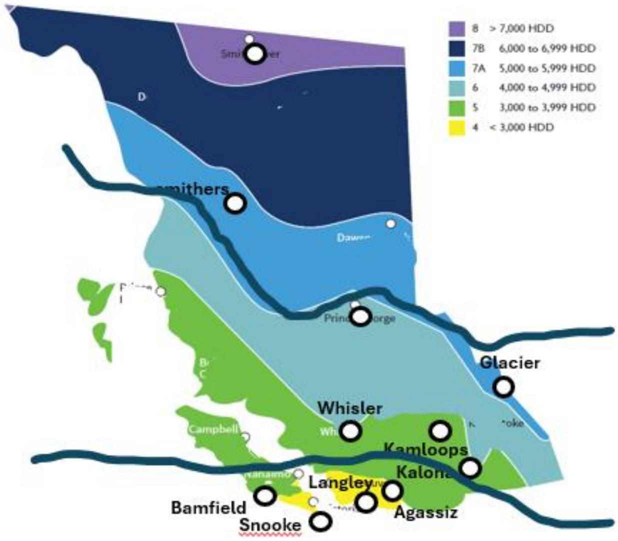


Figure 15. The Heat Pump Applicability in Different Climate Zone

Based on the above analysis, we can draw several important insights:

Firstly, heat pump performance—including COP and heating capacity—declines as outdoor temperature decreases, meaning that heat pumps generally perform better in warmer cities.

Secondly, buildings in warmer zones—whether single-family homes or townhouses—have lower heating demand compared to those in colder regions.

Thirdly, Step Code improvements reduce heating demand within the same building type and location, thereby increasing the proportion of heat pump models able to meet the load. This positive effect is observed across all climate zones.

Considering the variation across BC's climate zones and integrating all the performance and load data analyzed in Sections 4.1 to 4.3, the following conclusions can be made(as shown in Figure 15):

a) For Climate Zone 4 and the warmer parts of Zone 5:

Most heat pump models can meet the heating demand without supplementary systems, even for SFDs at Step 3. Higher Step Code levels further improve the feasibility of using heat pumps as the sole heating source. This trend also applies to other climate zones, though the magnitude of benefit varies with local winter design temperatures.

b) For the colder parts of Zone 5 and most of Zone 6:

In higher Step Code homes (e.g., Step 4 and Step 5), heat pumps may still meet the full load without supplementary heating, but the percentage of viable models drops substantially. The Step Code effect remains significant, but equipment selection is more constrained than in warmer regions.

c) For Zones 7A, 7B, and 8:

Supplementary heating systems are generally required during peak winter periods, and in some cases may be the only practical option. While higher Step Code levels reduce demand, the extremely low ambient temperatures limit the ability of most heat pumps to operate effectively. Specialized cold-climate models may still function, but the range of options is very limited.

5. Opportunities For Future Analysis

5.1 Existing Home Retrofit

To better understand how energy retrofits affect heat pump feasibility in existing homes, a series of simulations were conducted based on data provided by TECA. The modeling examined the same house upgraded across four retrofit levels: from its original 1960 condition to versions meeting 1980, 2010, and Net Zero performance standards.

At each retrofit stage, building envelope improvements significantly reduced the heating demand(as shown in Table 5), making it easier for more heat pump models to meet the full load requirement.

This decline in heating load directly increases the percentage of heat pump models that can be applied without the need for supplementary systems. As shown in Figure 16, the percentage of heat pumps capable of meeting the demand rises dramatically as the retrofit level improves—especially in warmer cities. Even in colder regions, deeper retrofits (such as Net Zero) can create viable pathways for standalone heat pump applications.

Table 5. The Heating demand for retrofit homes

Retrofit Level	Heating demand(MBH)
1960	56
1980	45
2010	29
Net zero	16

Figure 16. Retrofit Level vs. Heat Pump Compatibility Across Cities

This preliminary analysis demonstrates the potential of building envelope retrofits to significantly improve the feasibility of using heat pumps in existing homes. By reducing heating demand through upgrades, retrofitted homes that were once unsuitable for standalone heat pump systems may now be served without backup heating.

However, this is only an initial exploration. Further research is needed to quantify the relationship between specific retrofit measures and their impact on heating demand reduction. Additionally, evaluating the cost-effectiveness, energy savings, and carbon reduction potential of various retrofit strategies will be essential for supporting retrofit decisions and incentive program design.

5.2 Cooling Capability Analysis

An important point to consider is that the outdoor design temperatures used in this study are based on the 2024 BC Building Code (BCBC), which relies on historical weather data averaged over the 25-year period from 1981 to 2006. However, since 2006, average summer temperatures across BC have already increased by approximately 2 °C, and this warming trend is expected to continue due to ongoing climate change(Environment and Climate Change Canada,2025). According to projections from the Climate Explorer (Pacific Climate Impacts Consortium), average temperatures are expected to rise by an additional 1.6 °C between 2024 and 2055.

This has important implications for cooling performance analysis. Many heat pump systems are currently selected to meet today’s heating/cooling loads based on past design conditions. If outdoor temperatures continue to rise, homes that are compliant with current overheating limits may no longer meet those requirements in future climates.

Therefore, a logical extension of this study is to conduct future-oriented cooling analysis, using climate data to test whether today's heat pump systems still:

1) Deliver sufficient cooling under higher ambient conditions, and
2) Prevent indoor overheating as defined by updated thermal comfort and code requirements.

This type of analysis is essential to ensure that climate-resilient building designs and equipment choices remain effective not just today, but over the expected lifespan of the building and mechanical systems.

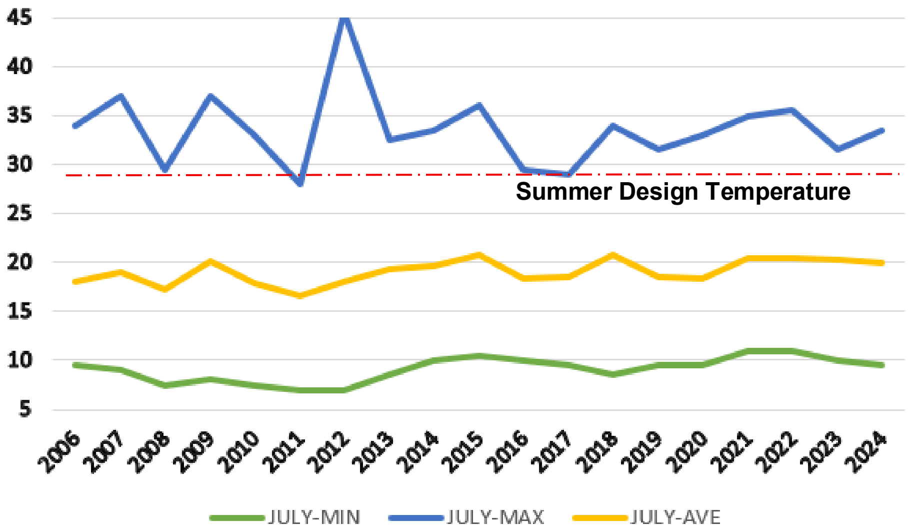


Figure 17. The Temperature Change from 2006-2024 at Langley

(Environment and Climate Change Canada)

6. Challenges and Limitations

6.1 Challenges and Mitigation Measures

This study faced several challenges and limitations related to data availability, performance comparability, and validation across heat pump models. The following subsections summarize the key issues encountered during the research and the measures taken to address them.

Challenge 1: Limited Availability of Model-Specific Data in BC

A major challenge encountered in this study was the difficulty in obtaining reliable, model-specific performance data for heat pumps currently available in the BC market.

1) Most HVAC contractor and distributor websites only list the brands they carry, without providing specific model-level information or access to specification sheets.
2) Although the NRCan product registry includes over 10,000 heat pump models, it is extremely difficult to determine which of these are available in BC. Moreover,

the registry only provides limited average performance metrics, without the detailed performance curves (heating capacity and COP variation with outdoor temperatures) required for this study.

3) To clarify which models are marketed in BC and to obtain the corresponding specification sheets, multiple inquiries were sent through emails, web forms, and phone calls to HVAC contractors and manufacturers. However, only a few responses were provided, even after repeated follow-up attempts.

Mitigation Measures:

1) To support the continuation of this research, performance data were obtained through extensive manual searches of each model's manufacturer specification sheets, engineering data tables, technical manuals, and other related submittals.
2) Among the 84 models analyzed, 10 models were supplemented with data from the NEEP database to broaden coverage and improve the representativeness of the dataset, particularly for cold-climate-certified products.
3) Additional effort was made to identify the model's year of release, its availability in Canada (especially in BC), and whether it was intended for residential or commercial use. This process was highly time-consuming and involved cross-referencing multiple sources, including manufacturer websites, third-party databases, archived documentation, and marketing materials.

Challenge 2: Mixed System Types and Non-Uniform Test Conditions

Another major challenge was that the dataset combined different system types and manufacturers' non-uniform test setups, which hindered fair comparison of performance data:

1) The sample includes single-zone centrally ducted and multi-zone heat pumps. The performance was reported under inconsistent test conditions (e.g., indoor setpoints, connected-capacity ratio), making direct comparison difficult.
2) Many manufacturer documents provide only graphs (COP or capacity vs. outdoor temperature) without tabulated values or a common temperature grid, limiting consistent numerical analysis.

Mitigation Measures:

1) To improve comparability, performance data used in this study were restricted to indoor setpoints within ±2 °C of 21 °C (70–72°F). For multi-zone systems, only 100% connected-capacity-ratio, full-load points were used; for single-zone centrally ducted systems, only full-load points with all zones fully open were used.
2) Relevant data points were extracted manually and standardized as much as possible to allow comparison across models. In cases where only graphical

data (curves) was available, visual extraction tools were used when feasible, though with recognized limitations.

6.2 Limitations

The conclusion presented in this study is based on the performance data of 84 heat pump models across 10 brands. This dataset does not represent the full range of products currently available on the market.

Within the scope of the collected data, the findings are intended to serve as a reference to explore whether heat pumps have the potential to independently meet residential heating demands rather than recommending specific heat pump models.

It is acknowledged that further research is needed to provide a more comprehensive and detailed conclusion. This should include but not limited to cooling capacity, heating demand buffers, weather variations, cost and other influencing factors.

7. Conclusion

This study assessed the potential suitability of air-source heat pumps for residential applications across BC’s six climate zones. By analyzing 84 heat pump models and evaluating their COP and heating capacity under various climate and building conditions, several key conclusions were drawn:

1) Climate Dependency: Heat pump performance is highly sensitive to outdoor temperature. Warmer zones (CZ 4 and warmer parts of CZ 5) offer favorable conditions where most models can meet heating demands without backup systems.
2) Step Code Impact: Building efficiency significantly influences feasibility. Homes built to higher Step Code levels require less heating capacity, expanding the pool of compatible heat pump models.
3) Building Type Matters: Townhouses, due to smaller thermal loads and shared envelope surfaces, have better compatibility with heat pump than single-family dwellings in all climate zones.

These findings align directly with the project’s objective: to evaluate the technical feasibility of using heat pumps in BC's diverse climate context and to inform decisions regarding energy-efficient residential retrofits and new construction. The analysis provides a strong foundation for municipalities and utility partners to prioritize policy support, technology selection, and building design strategies.

References

Government of British Columbia. (2021). CleanBC Roadmap to 2030. Ministry of Environment and Climate Change Strategy. https://www2.gov.bc.ca/assets/gov/environment/climate-change/action/cleanbc/cleanbc_roadmap_2030.pdf

Government of British Columbia. (2025, March). BC Energy Step Code and Zero Carbon Step Code Handbook for Building Officials.

U.S. Department of Energy. (n.d.). Heat pump systems. EnergySaver (U.S. Department of Energy). from https://www.energy.gov/energysaver/heat-pump-systems

Government of British Columbia. (2024). British Columbia building code 2024: Book I – General (Revision 1). Ministry of Housing.

BC Housing Research Centre. (2018). BC Energy Step Code: Builder guide (Version 1.0, Lower Steps). Government of British Columbia.

Northeast Energy Efficiency Partnerships. (2023). Cold Climate Air Source Heat Pump Specification (Version 4.0). https://ashp.neep.org

LearnMetrics. (n.d.). Air source heat pumps: Heating cycle [Illustration], from https://learnmetrics.com/how-do-heat-pumps-work/

International Energy Agency. (2022). The future of heat pumps: How a heat pump works. https://www.iea.org/reports/the-future-of-heat-pumps/how-a-heat-pump-works

Government of British Columbia. (2025). *Population estimates.* BC Stats. https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/population

Grasby, S. E., Allen, D. M., Bell, S., Chen, Z., Ferguson, G., Jessop, A., Kelman, M., Ko, M., Majorowicz, J., Moore, M., Raymond, J., & Therrien, R. (2012). Geothermal energy resource potential of Canada (Open File 6914). Geological Survey of Canada.

Environment and Climate Change Canada. (2022). Canadian Climate Normals. Government of Canada.

Natural Resources Canada. (2023). HVAC: Heating, ventilation and air conditioning. https://natural-resources.canada.ca

Daikin. (2023). VRV AURORA heat recovery brochure (PB-CB-VRVAURORA). Daikin North America LLC. from https://daikincomfort.com/docs/default-source/vrv-aurora-heat-recovery/pb-cb-vrvaurora.pdf

Daikin Comfort. (2021). Multi-zone Daikin AURORA brochure (2–4 zones). Daikin North America LLC. Retrieved August 17, 2025, from https://daikincomfort.com/docs/default-source/multi-zone-daikin-aurora-%282-3-and-4-zones%29/cb-aurmzsth.pdf

Daikin Comfort. (n.d.). FIT AURORA inverter heat pump—product sheet (SS-DH9VS-R32). Daikin North America LLC. Retrieved August 17, 2025, from https://daikincomfort.com/docs/default-source/fit-aurora-heat-pump-dh9vs/ss-dh9vs-r32.pdf

Fujitsu General America. (n.d.). Extra Low Temperature Heating (XLTH) technology overview. Retrieved August 17, 2025, from https://www.fujitsugeneral.com/us/residential/technology/xlth-low-temp-heating.html

LG Electronics. (2023). THERMA V (AWHP) R32 Monobloc S leaflet [Brochure]. LG Electronics Inc. fromhttps://www.lg.com/global/business/download/airsolution/2023%20LG%20THERMA%20V%20%2

8AWHP%29%20R32%20Monobloc%20S%20Leaflet_%28for%20End-user%29%5B20250804_191833184%5D.pdf

Mitsubishi Electric Canada. (n.d.). Heating & cooling—Hyper-Heat (H2i) flash-injection and inverter technologies. from https://www.mitsubishielectric.ca/hvac

Mitsubishi Electric Trane HVAC US. (n.d.). Outdoor heat pumps—Hyper-Heating INVERTER® (H2i) overview. from https://www.mitsubishicomfort.com/products/heat-pumps

Trane Residential. (n.d.). Next-generation refrigerant (R-454B) overview, Trane Technologies plc. from https://www.trane.com/residential/en/learning-hvac/next-generation-refrigerant/

Pacific Climate Impacts Consortium. (n.d.). *Climate Explorer*. University of Victoria from https://www.uvic.ca/pcic/data-analysis-tools/analysis-tools/climate-explorer/index.php

Appendix A: Design Temperatures for Cities Across Climate Zones

No	Climate Zone	Heating Degree Days (HDD)	Location	Heating design temperature	Summer design temperature
1	CZ 4	< 3,000 HDD	Abbotsford	-8	29
2	CZ 4	< 3,000 HDD	Agassiz	-9	31
3	CZ 4	< 3,000 HDD	Burnaby	-7	25
4	CZ 4	< 3,000 HDD	Chilliwack	-9	30
5	CZ 4	< 3,000 HDD	Crofton	-4	28
6	CZ 4	< 3,000 HDD	Duncan	-6	28
9	CZ 4	< 3,000 HDD	Jordan River	-1	22
10	CZ 4	< 3,000 HDD	Langford	-4	27
11	CZ 4	< 3,000 HDD	Langley	-8	29
12	CZ 4	< 3,000 HDD	Mission	-9	30
13	CZ 4	< 3,000 HDD	New Westminster	-8	29
14	CZ 4	< 3,000 HDD	North Vancouver	-7	26
15	CZ 4	< 3,000 HDD	Port Renfrew	-3	24
16	CZ 4	< 3,000 HDD	Richmond	-7	27
17	CZ 4	< 3,000 HDD	Sechelt	-6	27
18	CZ 4	< 3,000 HDD	Sidney	-4	26
19	CZ 4	< 3,000 HDD	Sooke	-1	21
20	CZ 4	< 3,000 HDD	Squamish	-9	29
21	CZ 4	< 3,000 HDD	Surrey	-8	29
22	CZ 4	< 3,000 HDD	Vancouver	-7	28
23	CZ 4	< 3,000 HDD	Victoria	-4	24
24	CZ 4	< 3,000 HDD	West Vancouver	-7	28
25	CZ 4	< 3,000 HDD	White Rock	-5	25
26	CZ 5	3,000 to 3,999 HDD	Alberni	-5	31
27	CZ 5	3,000 to 3,999 HDD	Ashcroft	-24	34
28	CZ 5	3,000 to 3,999 HDD	Bamfield	-2	23
29	CZ 5	3,000 to 3,999 HDD	Bella Bella	-5	23
30	CZ 5	3,000 to 3,999 HDD	Bella Coola	-14	27
31	CZ 5	3,000 to 3,999 HDD	Burnaby (SFU)	-7	25
32	CZ 5	3,000 to 3,999 HDD	Cache Creek	-24	34
33	CZ 5	3,000 to 3,999 HDD	Campbell River	-5	26
34	CZ 5	3,000 to 3,999 HDD	Castlegar	-18	32
35	CZ 5	3,000 to 3,999 HDD	Comox	-7	27
36	CZ 5	3,000 to 3,999 HDD	Courtenay	-7	28
37	CZ 5	3,000 to 3,999 HDD	Crescent Valley	-18	31
38	CZ 5	3,000 to 3,999 HDD	Gold River	-8	31
39	CZ 5	3,000 to 3,999 HDD	Grand Forks	-19	34

40	CZ 5	3,000 to 3,999 HDD	Hope	-13	31
41	CZ 5	3,000 to 3,999 HDD	Kamloops	-23	34
42	CZ 5	3,000 to 3,999 HDD	Kaslo	-17	30
43	CZ 5	3,000 to 3,999 HDD	Kelowna	-17	33
44	CZ 5	3,000 to 3,999 HDD	Kitimat Plant	-16	25
45	CZ 5	3,000 to 3,999 HDD	Kitimat Townsite	-16	24
46	CZ 5	3,000 to 3,999 HDD	Ladysmith	-7	27
47	CZ 5	3,000 to 3,999 HDD	Lillooet	-21	34
48	CZ 5	3,000 to 3,999 HDD	Lytton	-17	35
49	CZ 5	3,000 to 3,999 HDD	Masset	-5	17
50	CZ 5	3,000 to 3,999 HDD	Merritt	-24	34
51	CZ 5	3,000 to 3,999 HDD	Montrose	-16	32
52	CZ 5	3,000 to 3,999 HDD	Nakusp	-20	31
53	CZ 5	3,000 to 3,999 HDD	Nanaimo	-6	27
54	CZ 5	3,000 to 3,999 HDD	Nelson	-18	31
55	CZ 5	3,000 to 3,999 HDD	Ocean Falls	-10	23
56	CZ 5	3,000 to 3,999 HDD	Osoyoos	-14	35
57	CZ 5	3,000 to 3,999 HDD	Parksville	-6	26
58	CZ 5	3,000 to 3,999 HDD	Penticton	-15	33
59	CZ 5	3,000 to 3,999 HDD	Port Alberni	-5	31
60	CZ 5	3,000 to 3,999 HDD	Port Alice	-3	26
61	CZ 5	3,000 to 3,999 HDD	Port Hardy	-5	20
62	CZ 5	3,000 to 3,999 HDD	Port McNeill	-5	22
63	CZ 5	3,000 to 3,999 HDD	Powell River	-7	26
64	CZ 5	3,000 to 3,999 HDD	Prince Rupert	-13	19
65	CZ 5	3,000 to 3,999 HDD	Qualicum Beach	-7	27
66	CZ 5	3,000 to 3,999 HDD	Queen Charlotte City	-6	21
67	CZ 5	3,000 to 3,999 HDD	Salmon Arm	-19	33
68	CZ 5	3,000 to 3,999 HDD	Sandspit	-4	18
69	CZ 5	3,000 to 3,999 HDD	Tahsis	-4	26
70	CZ 5	3,000 to 3,999 HDD	Tofino	-2	20
71	CZ 5	3,000 to 3,999 HDD	Trail	-14	33
72	CZ 5	3,000 to 3,999 HDD	Ucluelet	-2	18
73	CZ 5	3,000 to 3,999 HDD	Vernon	-20	33
74	CZ 5	3,000 to 3,999 HDD	Youbou	-5	31
75	CZ 6	4,000 to 4,999 HDD	Carmi	-24	31
76	CZ 6	4,000 to 4,999 HDD	Cranbrook	-26	32
77	CZ 6	4,000 to 4,999 HDD	Dog Creek	-28	29
78	CZ 6	4,000 to 4,999 HDD	Elko	-28	30
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81	CZ 6	4,000 to 4,999 HDD	Greenwood	-20	34
82	CZ 6	4,000 to 4,999 HDD	Kimberley	-25	31

83	CZ 6	4,000 to 4,999 HDD	McBride	-29	29
84	CZ 6	4,000 to 4,999 HDD	Prince George	-32	28
85	CZ 6	4,000 to 4,999 HDD	Princeton	-24	33
86	CZ 6	4,000 to 4,999 HDD	Quesnel	-31	30
87	CZ 6	4,000 to 4,999 HDD	Revelstoke	-20	31
88	CZ 6	4,000 to 4,999 HDD	Stewart	-17	25
89	CZ 6	4,000 to 4,999 HDD	Terrace	-19	27
90	CZ 6	4,000 to 4,999 HDD	Whistler	-17	30
91	CZ 6	4,000 to 4,999 HDD	Williams Lake	-30	29
92	CZ 7A	5,000 to 5,999 HDD	100 Mile House	-30	29
93	CZ 7A	5,000 to 5,999 HDD	Burns Lake	-31	26
94	CZ 7A	5,000 to 5,999 HDD	Chetwynd	-35	27
95	CZ 7A	5,000 to 5,999 HDD	Dawson Creek	-38	27
96	CZ 7A	5,000 to 5,999 HDD	Fort St. John	-35	26
97	CZ 7A	5,000 to 5,999 HDD	Glacier	-27	27
98	CZ 7A	5,000 to 5,999 HDD	Mackenzie	-34	27
99	CZ 7A	5,000 to 5,999 HDD	McLeod Lake	-35	27
100	CZ 7A	5,000 to 5,999 HDD	Smithers	-45	26
101	CZ 7A	5,000 to 5,999 HDD	Taylor	-35	26
102	CZ 7B	6,000 to 6,999 HDD	Beatton River	-37	26
103	CZ 7B	6,000 to 6,999 HDD	Dease Lake	-37	24
104	CZ 7B	6,000 to 6,999 HDD	Fort Nelson	-39	28
105	CZ 8	> 7,000 HDD	Smith River	-47	26

Appendix B: Heat Pump Operating Principles

Normally ,The heat pump has five main components, a compressor, a reversing valve which can switch between heating and cooling mode, expansion device, and two heat exchangers, one associated with the external heat source/sink and the other with the interior.

In heating mode, the outdoor heat exchanger functions as the evaporator, while the indoor unit serves as the condenser. In cooling mode, the roles are reversed.

The following section explains the operating process, as illustrated in Figure 18.

The heating cycle

During the heating cycle, heat is extracted from the outdoor air and “pumped” indoors to warm the building.

1) Compression
   Low-pressure, low-temperature refrigerant vapor enters the compressor. The compressor—powered by electricity—increases both the pressure and temperature of the vapor, converting it into high-pressure, high-temperature superheated vapor. This step injects energy into the refrigerant and drives the cycle forward.
2) Condensation
   The superheated vapor flows into the indoor heat exchanger (condenser), where it releases heat to the indoor air. As it gives off thermal energy, the refrigerant condenses into a high-pressure liquid, undergoing an isothermal phase change and releasing latent heat of vaporization into the space.
3) Expansion
   The high-pressure liquid refrigerant then passes through an expansion valve, which reduces its pressure and temperature. This process creates a low-pressure, low-temperature liquid–vapor mixture, ready to absorb heat.
4) Evaporation process
   The cooled refrigerant enters the outdoor exchanger(evaporator), where it absorbs heat from the ambient air—even in cold conditions. As it gains energy, the refrigerant evaporates into vapor, completing the cycle.

The overall efficiency of the heat pump—measured by its Coefficient of Performance (COP)—depends heavily on the outdoor air temperature. As the ambient temperature drops, the amount of usable heat in the air decreases, reducing the system’s ability to extract energy and lowering its COP.

This temperature-dependent performance is a key factor in evaluating the suitability of different heat pump models across BC’s diverse climate zones.

The Cooling cycle

In cooling mode, the reversing valve changes the refrigerant flow direction, allowing the heat pump to remove indoor heat and release it outdoors. While the system components remain the same, their roles switch.

1) The indoor exchanger becomes the evaporator, absorbing heat from the indoor air.
2) The outdoor exchanger becomes the condenser, releasing heat to the outdoor environment.
3) The compressor and expansion valve perform the same functions as in heating mode, but with reversed heat flow.

This cycle provides indoor cooling by transferring thermal energy out of the building.

Unlike heating mode, cooling performance is generally more consistent across regions, since summer outdoor temperatures in BC rarely reach extreme levels. As a result, heat rejection to the outside air is typically not a limiting factor.

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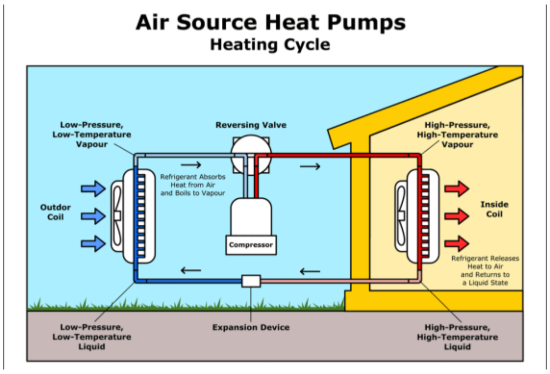
<td>
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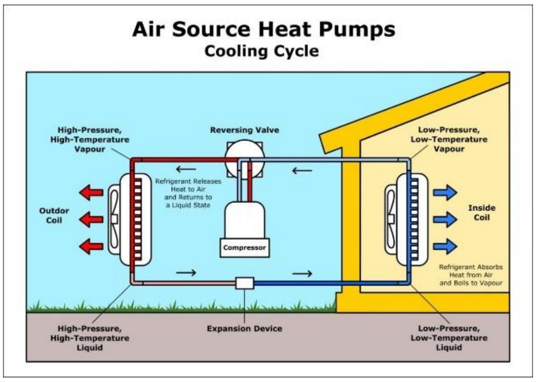
<td>
</td>
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<tr>
<td>Heating cycle</td>
<td>Cooling cycle</td>
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Figure 18. Air source heat pumps (LearnMetrics).

Appendix C: Heat Pump types and Suitability for BC

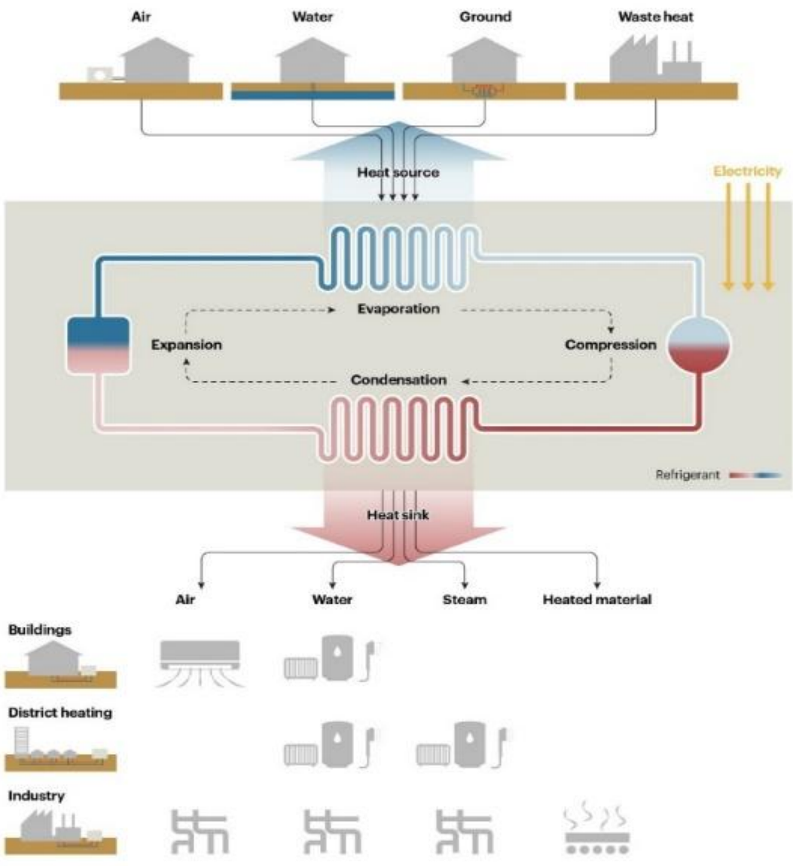


Figure 19. Heat pump Types (International Energy Agency, 2022).

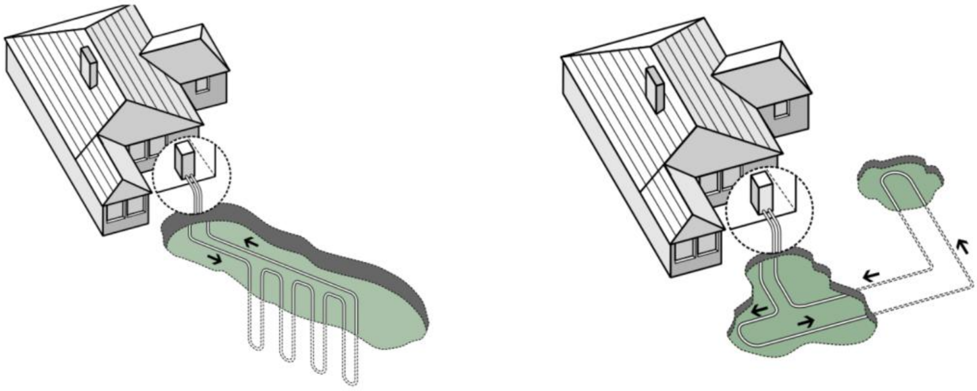
As shown in Figure 19, Heat pumps are generally classified by the source of thermal energy used to drive the refrigeration cycle:

a) **Air-Source Heat Pumps (ASHPs)**

Air-source heat pumps were discussed in Section 2.3.1.

b) **Ground-Source Heat Pumps (GSHPs)**

Ground-Source Heat Pumps or geothermal systems, draw heat from the ground via buried piping loops. These systems rely on relatively stable underground temperatures for consistent year-round performance. In Canada, where air temperatures can go below –30°C, ground-source systems are able to operate more efficiently because they take advantage of warmer and more stable ground temperatures.



Vertical closed-loop GSHPs Horizontal GSHPs

Figure 20. Ground-Source Heat Pumps Configuration

(Natural Resources Canada, 2023)

As shown in Figure 20, the system requires extensive excavation or vertical drilling to install the underground loop, resulting in higher installation complexity and significantly greater upfront costs compared to air-source heat pumps. Its performance depends heavily on local subsurface conditions such as soil conductivity, moisture content, and thermal stability, which means it is not universally applicable. Moreover, system design and installation must comply with local codes and environmental regulations, including specific requirements for borehole depth, pipe material, spacing, and sealing (e.g., CSA C448 in Canada). While the installation is more demanding, ground-source systems offer higher efficiency and more stable performance year-round, particularly in cold climates where air-source systems tend to lose capacity.

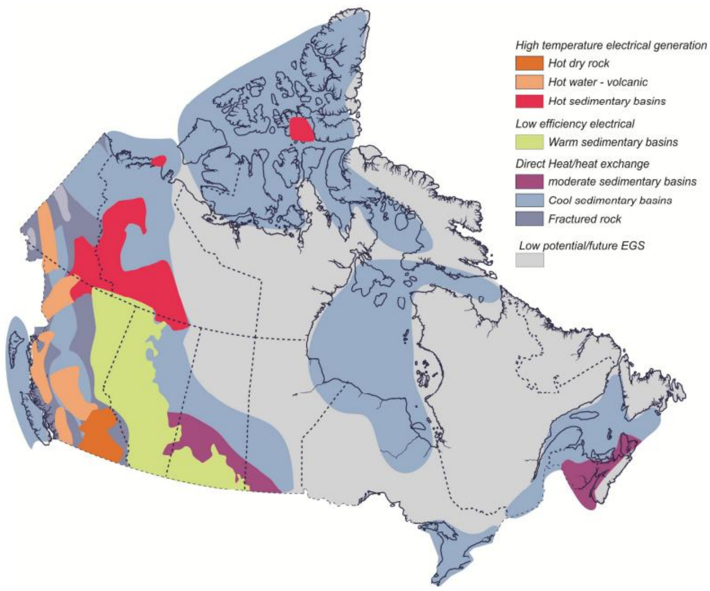


Figure 21. Distribution of Geothermal Potential in Canada
(Geological Survey of Canada,2012)

Figure 21 shows the distribution of geothermal potential in Canada. As displayed, British Columbia has diverse geothermal resources, including hot dry rock, volcanic hot water, and warm sedimentary basins, particularly in the southern and coastal regions. These areas show strong potential for both direct heating applications and future enhanced geothermal systems (EGS). However, in BC, especially in densely populated urban areas such as Metro Vancouver, the installation of GSHP is constrained by factors such as:

1) Limited land availability for trenching or borehole drilling,
2) Higher capital and labour costs for ground loop construction,
3) More complex permitting and environmental review processes.

While GSHPs are technically viable and are included in energy efficiency incentive programs (e.g., CleanBC), they are typically deployed only in rural, large-lot, or institutional projects where land, drilling access, and long-term performance justify the initial investment.

c) **Water-Source Heat Pumps (WSHPs)**

Water-source heat pumps extract thermal energy from surface water bodies such as lakes or rivers. Their application requires access to stable, high-volume water sources and may involve complex environmental permitting processes. Due to these site-specific and regulatory constraints, their use is generally limited in British Columbia.

Given site-constrained and complexity limitations to GSHPs and WSHPs, air-source systems remain the most common choice for residential applications in British Columbia, particularly in Part 9 homes, due to their lower installation cost, widespread availability, and improved cold-climate performance. This study focuses exclusively on air-source heat pumps, including both standard and cold-climate models.

Appendix D: Performance for Heat Pump

The Coefficient of Performance (COP) is a measure of heat pump efficiency, defined as the ratio of heating output to electrical energy input:

$$\text{COP} = \frac{\text{Heating output}}{\text{Electrical Input}}$$

For example, a COP of 3 means the system delivers 3 units of heat for every unit of electricity consumed. A higher COP indicates greater efficiency, meaning less electricity is required to produce the same amount of heat, which in turn results in lower energy bills.

However, COP is not fixed. It varies significantly with outdoor temperature: At mild conditions, COP can exceed 4.0, as temperatures drop below freezing, COP declines sharply.

In addition to COP, heating capacity—the total amount of heat a unit can deliver, typically measured in kW or MBH—also is an important performance indicator, it dictates the size of the heat pump needed to maintain the indoor temperature. Same to COP, the heating capacity also decreases at lower ambient temperatures.

These two performance indicators are crucial for assessing whether a given heat pump model can reliably meet heating demand at the specified winter design temperature for each BC climate zone.