HEAT PUMP BEST PRACTICES INSTALLATION GUIDE FOR EXISTING HOMES

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In partnership with:
FRESCo

Foreword

This Guide provides heat pump installation contractors with general information on best practices for the installation of a heat pump system and useful information to help educate and communicate with homeowners. It provides an overview of the key steps involved in heat pump system design and installation, including job-site survey and pre-changeout, system design (sizing and selection), installation, commissioning, and homeowner education and maintenance. In addition, this guide discusses common challenges encountered by heat pump contractors during the installation of heat pump systems and suggested solutions. This guide is not intended to replace residential heat pump installation training materials developed for HVAC contractors.

Acknowledgements

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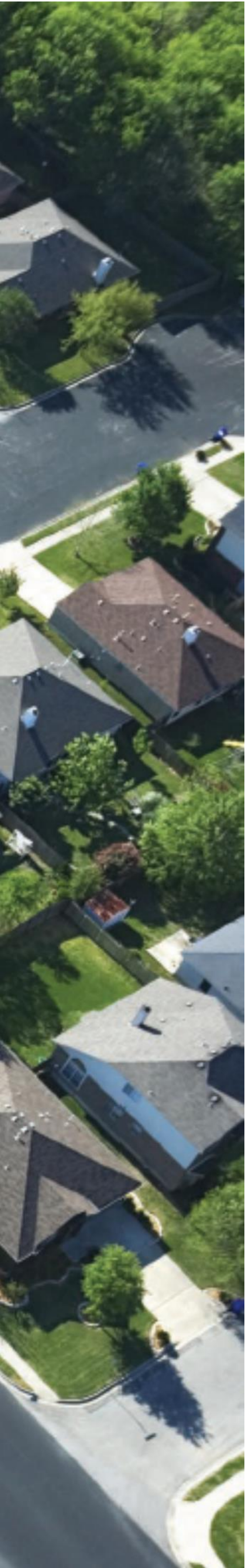
We also gratefully acknowledge the financial support of BC Hydro, FortisBC, the Province of British Columbia, and the City of Vancouver.

BC Hydro Power smart FORTIS BC Energy at work BRITISH COLUMBIA CITY OF VANCOUVER



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1 | HEAT PUMP BASICS

1.1 IMPORTANCE OF GOOD DESIGN AND INSTALLATION

Air-source heat pumps (ASHPs) can often help reduce the energy consumption, operating costs, and environmental impacts associated with heating and cooling homes; this is especially true with homes that are heated by electric baseboards, fuel oil, or propane. Heat pumps can also help improve occupant comfort in many situations. However, poor design and installation practices, such as improper sizing and selection and poor sealing of building envelope penetrations, may reduce these potential benefits.

Various studies have found significant reductions in the overall efficiency of heat pump systems as a result of installation issues.[1, 2] Poor installation practices may also reinforce misperceptions that ASHPs are not well suited to Canadian winters, creating a barrier towards the increased adoption of heat pumps by both homeowner and installers.

A recent study on ASHP installation practices in BC indicated that only 32% of the studied ASHP installations were well-matched with the heating requirement of the homes they were installed in, while the remaining units were either oversized or undersized.[3] The study also found that the savings from the ASHP systems was lower than would be expected in most of the sites. This guide, which is primarily focused on experienced installers of heat pump systems, attempts to address these issues by providing best practice guidelines for the design and installation of common types of residential ASHPs.

Following installation best practices can benefit installation contractors through referrals, increase sales, reduced callbacks, and improved customer comfort and satisfaction. Contractors can also use this guide as a tool to educate homeowners on the advantages of installation best practices. Additional advantages for contractors, homeowners, and the broader public are summarized below.

Contractor Benefits

- Improved client satisfaction, leading to more referrals and fewer callbacks
- Differentiation between high quality and poor, lower cost and quality installations
- Compliance with future codes, regulations, and permits

Homeowner Benefits

- More comfortable indoor environment (e.g. fewer cold spots, more consistent temperature distribution, etc.)
- Increased economic life of ASHP system and reduced
- Improved utility bill savings

Societal Benefits

- Improved province-wide uptake of heat pump systems
- More efficient use of BC's green electricity grid
- Important component to achieve BC's climate change goals

1.2 TYPES OF HEAT PUMPS

Heat pumps are becoming increasingly popular in North America, as they are energy efficient and can provide year-round climate control by supplying heat in the winter and air conditioning during the summer months. Heat pump heating efficiency is commonly defined by the dimensionless unit coefficient of performance (COP), which is the ratio of heat delivered by the heat pump system to the electricity consumed. The efficiency of heat pumps is substantially higher than other types of heating systems like natural gas furnaces or electric baseboards. Heat pumps transfer heat from a source (or sink) including outdoor air, the ground, or a mechanically heated or cooled fluid loop rather than producing it (e.g. via an electric resistance coil or by burning natural gas). In the heating season, heat is extracted from the heat source and supplied to the conditioned space. During the cooling season, heat is extracted from the conditioned space and rejected to the heat sink.

Two common types of heat pumps used for space heating in low-rise residential applications are air-source heat pumps (ASHPs) and ground-source heat pumps (GSHPs). ASHPs absorb heat from the outside air during the heating season and use a refrigeration cycle to transfer that heat indoors. During summer months, they absorb heat from indoor air and reject that heat outdoors. ASHPs are the most common type of heat pump currently installed in Canadian homes. GSHPs transfer heat to and from the ground, which maintains a nearly constant temperature year-round. In British Columbia the ground temperature is generally around 7 to 12°C year-round.[4] Although they are more efficient than ASHPs, GSHPs are also substantially more expensive; as such, they are not widely used.

This guide is focused on ASHPs since they are the most common and most applicable to low-rise residential applications (i.e. single-family homes, townhomes, etc.).

1.3 AIR-SOURCE HEAT PUMPS

ASHPs are the most common type of heat pump system because the atmosphere is readily available as a heat source and they are relatively inexpensive compared with other types of heat pumps. They are used in many applications and are available as central systems or split systems (commonly referred to as mini-splits).[5] The main drawback of ASHPs is that they become less efficient with colder outdoor temperatures. Fortunately, the average winter temperature in most regions of British Columbia is high enough to allow this equipment to operate efficiently. In colder climates, supplementary heat is required when the outdoor temperature drops below around -8°C for most conventional ASHPs.[6] Cold climate ASHPs are a costlier alternate option for colder climates. They include features that allow them to operate in heat pump mode at outdoor temperatures as low as -25ºC,[7] albeit with degraded COP and heating capacity.[a]

Since frost can form on the outdoor coils of ASHPs when the outdoor temperature falls below 7°C, they employ defrost cycles to melt any ice.[8] Frost forms on the outdoor coils because they are colder than the ambient air that they are absorbing heat from. This issue is more pronounced in coastal areas since these locations tend to have higher levels of absolute humidity than inland areas.[b]

[a] Some manufacturers claim that their cold climate heat pumps can operate in heat pump mode down to -30°C.

[b] As such, the dew point in the coastal areas is higher than the interior, causing condensation to form on the outdoor coils at warmer temperatures. In other words, suspended moisture in the air starts to condense on a warmer surface in coastal areas.

Defrost cycles either operate the heat pump in reverse or leverage integrated electric residential coils to produce heat for short periods of time, until any frost on the coils has been melted. This is essential to optimal heat transfer and efficiency of ASHPs in colder temperatures.

ASHPs for residential space heating applications are available in two main configurations; centrally ducted heat pumps and mini-split heat pumps.

In addition, two of these system types are sometimes combined to overcome certain design challenges. For example, if there is limited duct capacity, a ductless heat pump may be used to heat and cool one area of a home that is primarily conditioned by a centrally ducted ASHP. A brief description of the different types of ASHPs is provided below. A more detailed description of cold climate ASHPs is included as well.

CENTRALLY DUCTED HEAT PUMPS

Centrally ducted heat pumps refer to whole-house systems with central air handlers, which are employed in homes with central ducting.

MINI-SPLIT HEAT PUMPS

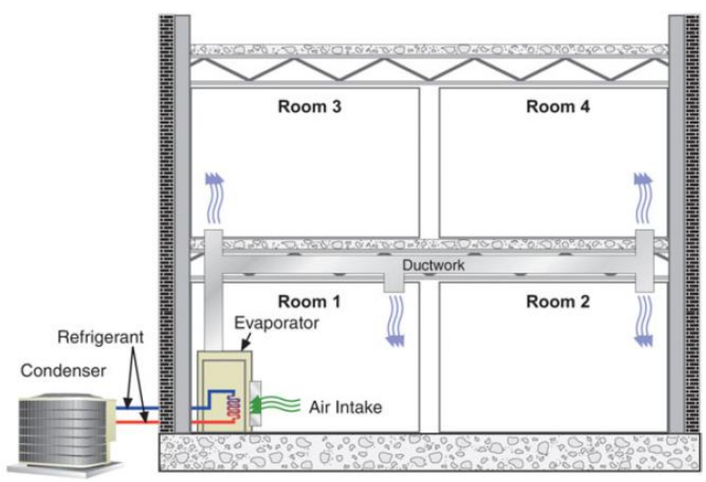
Mini-split heat pumps are generally used in homes without central ducting and can be used to condition either a portion of the home or the entire home.

- **Ductless heat pumps:** Refers to an ASHP with any non-ducted indoor unit, including wall-mount air handlers, floor-mounted consoles, and in-ceiling cassettes.
- **Mini-ducted heat pumps:** A variant of mini-split heat pumps with concealed air handlers and ducting used to distribute the conditioned air to multiple spaces in a home.

CENTRALLY DUCTED HEAT PUMPS

Centrally ducted ASHPs, also known as central ASHPs, consist of an outdoor unit with an integrated compressor, an indoor air handling unit, and refrigerant piping connecting the units. These systems tie in to a home's central ducting, which is used to distribute conditioned air. Centrally ducted ASHPs with single stage compressors are the lowest cost variant but they are also the least efficient. Units with two-stage or variable speed compressors are more costly but they are more efficient and better able to tune their output to the space heating and space cooling requirements.

Exhibit 1: Central ASHP System Operating in Cooling Mode



Source: ACEEE Summer Study on Energy Efficiency in Buildings, 2008

MINI-SPLIT HEAT PUMPS

Mini-split heat pumps are generally used in homes without central ducting. This makes them particularly useful in retrofit scenarios for homes.

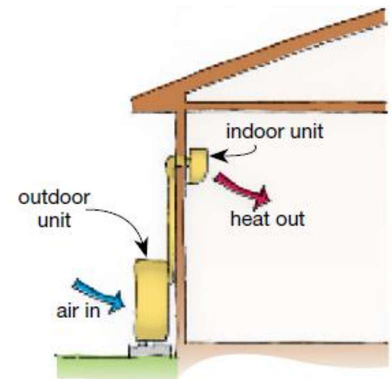
Ductless Heat Pumps

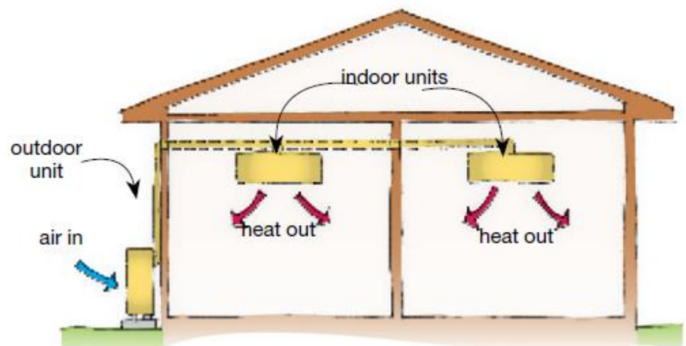
Ductless heat pumps, also commonly referred to as ductless mini-splits, are the most common variant of mini-split heat pumps. They are composed of an outdoor unit and typically one to four indoor units; however, up to eight indoor units (or heads) can be used with a single outdoor unit.[c] The outdoor and indoor units are connected with refrigerant lines. Exhibit 2 depicts the basic setup of single zone and multi-zone ductless heat pump systems operating in heating mode.

Mini-Ducted Heat Pumps

Mini-ducted heat pumps, also known as ducted mini-splits or compact ducted heat pumps) are a relatively new variant of mini-split heat pumps but they are becoming increasingly popular. Their indoor air handler is typically located in a concealed space (e.g. below the floor or above the ceiling), and short runs of ducting are used to distribute conditioned air to a number of spaces in the home. Since it is necessary to install ducting as part of the installation of these systems, they are best suited to larger home retrofit projects or homes with unfinished basements. Ducting can be installed in the unconditioned spaces as well (e.g. attic spaces) but extra care is required to avoid issues in these scenarios (e.g. need to ensure no leakage and insulate ducting to building code requirements for exterior wall/attic).

Exhibit 2: Single Zone (Top) and Multi-Zone (Bottom) Ductless ASHP Operating in Heat Mode





Source: EECA, New Zealand

COLD CLIMATE HEAT PUMPS

The capacity and efficiency of conventional heat pumps drops in colder temperatures. Some conventional units shut down at outdoor temperatures around -8°C and below[9] to protect themselves from damage, while others are rated to operate down to -12°C. However, heat pump technology has evolved to allow operation at outdoor temperatures as low as -25ºC, with some manufacturers claiming that their units can operate in even colder temperatures. These heat pumps are known as cold climate heat pumps (ccASHPs). Cold climate variants of ductless, central, and mini-ducted ASHPs are available.

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[c] As noted in the System Design section, there are several disadvantages to coupling a larger number of indoor units to each outdoor unit. In these cases, a larger number of outdoor units should be considered.

Cold climate ASHPs are generally more efficient at colder temperatures. They also typically offer higher supply air temperatures, which can improve occupant comfort and sometimes eliminate the need for duct improvements. Basic ccASHPs incorporate a larger compressor and a larger outdoor unit, which allows them to operate down to about -15°C. More advanced (and expensive) ccASHPs can operate at colder temperatures.

These units incorporate features such as variable speed fans, higher efficiency compressors, variable speed ECM compressor motors, and communications between the outdoor and indoor units. Some of these features are incorporated into some conventional ASHPs as well.

Northeast Energy Efficiency Partnerships (NEEP) maintains performance requirements for ccASHPs and a list of qualified units that meets these specifications.[10]

1.4 HEAT PUMP SYSTEM COMPARISON

The following table provides an overview of the pros and cons of different types of ASHP systems. In addition, the ideal scenarios for each type of system are highlighted.

Exhibit 3: Pros and Cons of Different ASHP Systems

	Centrally Ducted ASHPs	Ductless ASHPs	Mini-Ducted ASHPs
PROS	+ Effective solution for homes with central ducting + Indoor units can be smaller than many conventional furnaces + Far more energy-efficient and cost-effective than oil or electric resistance heat	+ Easy and quick installation by qualified professionals + Require no ductwork + Cost-effective method to heat individual rooms or zones that are routinely occupied + Using multiple ductless systems improves HVAC system reliability	+ Concealed equipment improves visual appeal + Quieter operation than other ASHP systems + Can be a cheaper alternative to multi-head ductless ASHPs + Effective solution for rooms with smaller heat loads
CONS	- Upgrading of electrical connection may be required to accommodate new system - Existing ducting in older homes may need to be improved/upgraded	- Each indoor unit serves a single zone or room rather than the entire home - Indoor wall units take more space and may look bulky to some	- Lower efficiency than ductless ASHPs - Installation of ducting is challenging in some existing homes
IDEAL FOR	Larger homes with central heating and cooling (forced air system) having existing ductwork in good condition[d]	Small or large homes with baseboard heating and no ductwork	Small or large homes with baseboard heating, no ductwork, and easy access to install ducting

[d] Assessments of existing ducting should always be completed to determine condition, identify any issues, and ensure that it is well-suited to accommodate a new ducted ASHP system.

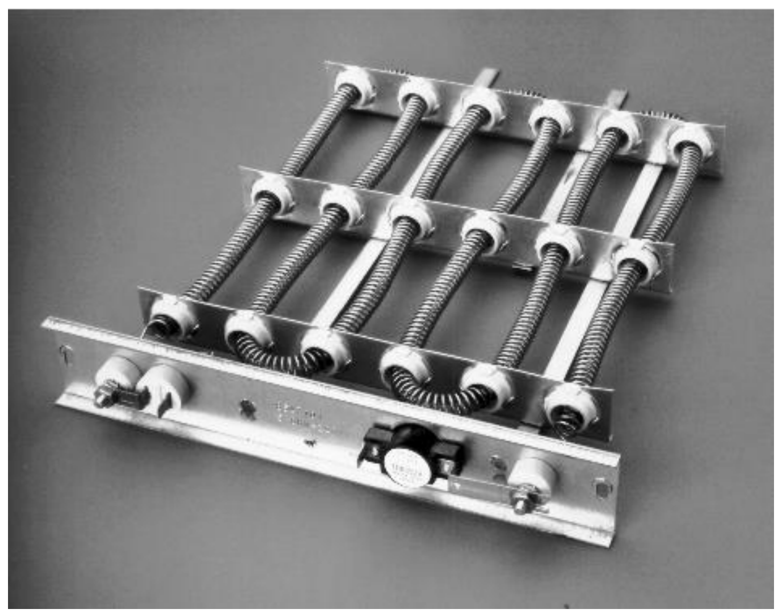
1.5 SUPPLEMENTARY HEATING BASICS

When a heat pump is not sized to meet the design heat load of a home, a supplementary (or auxiliary) heating system is required. The temperature at which an ASHP can no longer meet a given home's heating needs is referred to as the thermal balance point. Most ASHPs switch to a supplementary heating system at temperatures below the thermal balance point. However, some ASHPs may be programmed to switch to their supplementary heating system at a higher temperature, where its more economical to operate the supplementary heating system.[e] Conversely, ASHPs are sometimes designed to operate in conjunction with the supplementary heating system at temperatures lower than the thermal balance point since the ASHP may still be providing some useful heat. ASHPs might also need supplementary heat (e.g. integrated electric resistance coils) during the defrost cycle.

Supplementary heat can be supplied by any type of heating system. Central furnaces (i.e. oil, gas or electricity) are mainly used as supplementary heating systems but electric baseboards/resistance heaters and central boilers can be used as well. Where possible, supplementary heating systems are activated by the ASHP thermostat. Outdoor thermostat should also be used to lock-out the supplementary heat if the outdoor temperature is above the thermal or economic balance point. Thermostat setup and compatibility are very important to efficient use of supplementary heat and occupant comfort; further details on this subject are included in Section 3.5.8.

Although it is not necessary, it is recommended that heat pumps have an emergency (backup) heating system sized to meet the total heating load at design conditions for redundancy. This condition is easily met if existing heating systems are used to provide supplementary heat. In other situations, it may be cost-effective to install a larger bank of supplementary electric resistance heaters if the incremental cost of doing so is limited. To ensure efficient heat pump system operation it is critical to ensure that the system controls only engage any backup heating during a true emergency (i.e. rare system failure)

Exhibit 4: Supplementary Electric Resistance Heating Coil



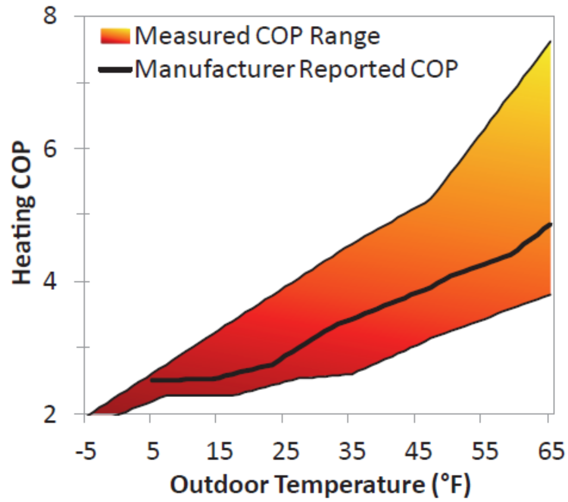
[e] Since the performance of heat pumps declines at lower temperatures, it may be more economical to heat the home with a fossil fuel fired system below a certain temperature. The point at which it is more economical to operate the supplementary

1.6 HEAT PUMP PERFORMANCE

RELEVANT EFFICIENCY METRICS

Proper selection of heat pump systems requires a thorough understanding of their performance at a range of outdoor temperatures. Heat pump efficiency is based on the heating or cooling delivered, compared to the electrical energy required to operate the system. Separate ratios and different terminology are used to characterize heat pump heating and cooling efficiency, both in terms of seasonal efficiency and efficiency at particular operating conditions. The following values are found on the energy rating label or manufacturer's information:

Exhibit 5: Heat Pump Performance at Different Outdoor Temperature



Source: NREL Documents Efficiency of Mini-Split Heat Pumps

HEATING:

- **Coefficient of performance (COP):** The ratio of heating delivered, compared to the electrical energy input. COP varies based on operating conditions (e.g. temperature).

$$\boldsymbol{COP} = \frac{Heating\ delivered\ (kW)}{Electricty\ input\ (kW)}$$

- **Heating seasonal performance factor (HSPF):** Characterizes the average efficiency of an ASHP over a typical heating season. This calculation assumes standard operation, which includes defrost cycles.

$$\boldsymbol{HSPF}\left(\frac{BTU}{W \cdot h}\right) = \frac{Seasonal\ heating\ delivered\ (BTU/h)}{Seasonal\ electricty\ input\ (W)}$$

COOLING:

- **Energy efficiency ratio (EER):** The ratio of cooling delivered, compared to the electrical energy input. EER varies based on operating conditions (e.g. temperature).

$$\boldsymbol{EER}\left(\frac{BTU}{W \cdot h}\right) = \frac{Cooling\ delivered\ (BTU/h)}{Electricty\ input\ (W)}$$

- **Seasonal energy efficiency ratio (SEER):** Characterizes the average efficiency of an ASHP over a typical cooling season. This calculation includes the heat generated by the system components while in operation.

$$\boldsymbol{SEER}\left(\frac{BTU}{W \cdot h}\right) = \frac{Seasonal\ cooling\ delivered\ (BTU/h)}{Seasonal\ electricty\ input\ (W)}$$

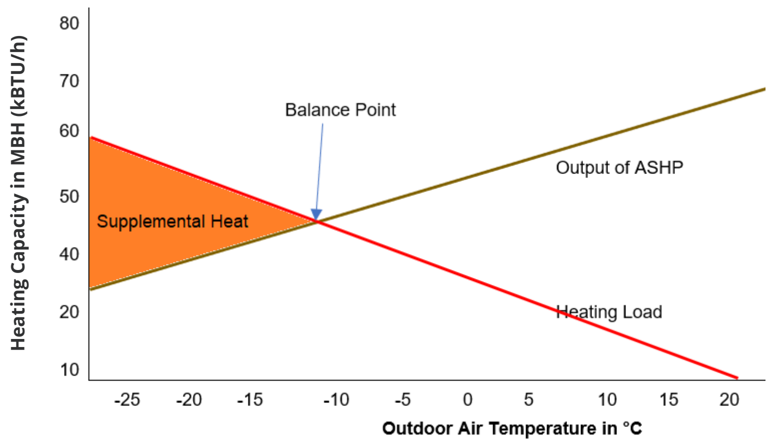
For a variety of reasons, the actual performance of heat pumps differs from their rated efficiency. Factors that influence the actual efficiency of a heat pump include but are not limited to the following:

- Local climate, heating and cooling loads, and source and supply temperatures, which likely differ from the testing conditions
- Local exposure to solar radiation and wind
- Auxiliary energy consumption (e.g. pumps and fans)
- Heat pump sizing relative to heating and cooling loads
- Operating characteristics, including occupancy and setback schedules
- Installation issues and/or poor compatibility with existing systems

THERMAL BALANCE POINT

The thermal balance point is the outdoor temperature at which the amount of heating provided by an ASHP system equals the amount of heat lost from the house. At this point, the heat pump capacity matches the full heating load of the house. When outdoor temperature drops below this point, supplementary heat is required from another source.

Exhibit 6: Thermal Balance Point of Heat Pump



1.7 RELEVANT CODE REFERENCES

There are several codes and standards related to heat pump system design, equipment selection and installation in Canada. A list of relevant codes/standards are shown in below.

Exhibit 7: Codes and Standards related to ASHP Systems

Functional area	Code/Standard	Remarks
Heat loss and heat gain calculation	CSA F280-12	Applicable to any type of HVAC system
Performance standards for air-source heat pump	CSA C656	Applicable to ASHPs
Installation standard for air-source heat pump	CSA C273.5	Applicable to ASHPs
Safety Standard for Electrical Installations	CSA C22.1	Applicable to any type of HVAC system
Natural Gas and Propane installation code	CSA B149.1	Applicable to natural has and propane fueled HVAC systems (supplementary heating systems for some ASHPs)
Installation code for oil-burning equipment	CSA B139	Applicable to oil fueled HVAC systems (supplementary heating systems for some ASHPs)
Mechanical Refrigeration Code	CSA B52	Applicable to any type of HVAC system

2 | HOMEOWNER EDUCATION

This section provides content for contractors to help educate homeowners on why they should choose heat pumps, the importance of quality installation, including hints and tips to ensure a quality installation, pictures to help identify installation issues and higher quality installations, and a sample quotation.

2.1 WHY CHOOSE A HEAT PUMP?

Heat pumps are an increasingly popular option for reliably heating and cooling homes. Heat pump systems that have been designed and installed properly lasts longer, have fewer maintenance issues, and result in improved utility bill savings. They also help contribute to comfortable indoor environments, with fewer cold spots and more consistent temperature distribution. In addition, by making more efficient use of BC's green electricity grid, heat pumps can reduce the environmental impact of heating and cooling homes. In fact, a recent analysis by the Pembina Institute suggests that the costs of heating a home with a natural gas furnace are comparable to heating it with a heat pump, while heat pump option represents a 97.5% reduction in carbon pollution.[11]

2.2 STEPS TO A HIGH-QUALITY INSTALLATION

The following hints and tips for homeowners, including any items that should be considered ahead of an installation, help ensure that they are choosing the right heat pump system for their home and that the equipment is being installed properly.

☑ Building Efficiency

Building enclosure issues should be addressed before installing any new HVAC equipment. This includes but is not limited to issues with poor or inadequate insulation, leakiness of the building envelope, and duct leaks.

Addressing these issues before installing new heat pump equipment reduces a home's heating and cooling costs, improves comfort and heat pump performance, and reduces the required size of any new equipment. Homeowners should discuss any previous or planned changes to their homes with their heat pump contractors. For example, homeowners should mention improved attic insulation, new windows, changes to their homes' ventilation system, and control system improvements.

☑ Correct Equipment Sizing

It is important to ensure that ASHP are properly sized for each application. Oversizing can lead to excessive cycling, lower efficiency, and inadequate dehumidification during summer months. Room-by-room load calculations are preferable to other simplified approaches (e.g. block load calculations). However, room-by-room load calculations may not be necessary for many retrofit applications where existing heating systems will remain in place.

☑ Getting the Right Heat Pump System (Including Supplementary Heating)

There are many different types of heat pump systems. The suitability of each system to different scenarios depends on a variety of factors, including the existing condition of the building, the configuration of the existing HVAC system, any other planned upgrades, occupancy requirements, and local weather conditions.

Some heat pump installations require a supplementary heating system; however, for most of BC, this need can be eliminated by selecting a heat pump that is sized for the home's design heating load. When supplementary heating systems are employed, ASHPs are often set to shut off at a particular temperature and supplementary heating system starts working beyond that point.

Conversely, ASHPs are sometimes designed to operate in conjunction with supplementary heating even at very cold temperatures since the ASHP may still be providing some useful heat. Supplementary heat can be supplied by any type of heating system. It may be incorporated into the heat pump or may be a separate system. Conventional ASHPs also require supplementary heating to prevent cold air from blowing in during defrost cycles.

☑ Key ASHP Installation Criteria[12]

Heat pump contractors should include the following items in their quotations:

- Heat load calculation to size the system
- Thermal balance point temperature calculation, to optimize the design and control of supplementary heating system
- Outdoor unit installed above anticipated snow level with due regard to defrost water drainage, which may otherwise result in slip hazards and damage to walkways
- Line sets have all refrigeration lines insulated, and fully protected from UV
- All penetrations (i.e. floor, wall, ceiling) sealed
- A condensate pipe connected to a drain or pump (for central systems)

Many of the above items can be reviewed visually by homeowners, allowing them to verify the quality of a heat pump installation.

☑ Benefits of Advanced Integrated Controls

Advanced integrated controls help maximize savings from ASHP systems by managing the interaction with a home's existing heating system.[f] Control algorithms of advanced control systems minimize energy consumption and heating costs by prioritizing heat pump operation at appropriate times and ensuring that the supplementary heating system is operating during peak heating loads to ensure comfort.

☑ Operation and Maintenance of Your New Heat Pump[13]

Operation: The energy savings from a heat pump are highly dependent on the operational behavior of a home's occupants. Below are some operational tips to maximize energy savings and ensure comfort:

- Try to keep indoor temperature settings steady and avoid frequently adjusting the thermostat.
- Avoid large temperature setbacks during colder periods since ASHPs can take a long time to recover without supplementary heat.
- Avoid turning heat pumps "on" and "off" to control the temperature, allow the thermostat to control the temperature instead.

Maintenance: Regular maintenance schedules are critical for reliable heat pump operation. Periodic maintenance can increase the service life of your equipment and will save you money on your utility bills. Below are some common maintenance tips:

- Clean filters as recommended by manufacturer and replace as necessary.
- Be sure to keep debris and snow away from outdoor units and ensure that there is sufficient airflow around them.
- Check on your system at least once every season to make sure there's no obvious damage to the outdoor pipe covering, dirt clogging the outdoor coil, or oil drips at or below the piping connections at the unit.
- There may be indicator lights or display icons on the controller or on the indoor unit itself, that can indicate fault conditions. Review your owner's manual to interpret any displays.
- Schedule professional service at the manufacturer's recommended interval (generally annually) or if you see any problems.
- Consider using ultraviolet (UV) light to prevent growth of mold and bacteria on the coil.

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f Where they are compatible. Older existing heating systems are more likely to have compatibility issues.eating system is referred to as the economic balance point

2.3 SYSTEM SELECTION REFERENCE GUIDE

The following table provides general guidelines for suitable heat pump and supplementary heating systems at different conditions.

Exhibit 8: System Selection Reference Guide

Existing Heating System	Region/Local Weather Conditions	Other Considerations	Recommended ASHP Type	Recommended Supplementary Heating System[g]
Electric Baseboards	Lower Mainland and Vancouver Island *(Moderate Winter, Design Temp >-8°C)*	N/A	Ductless or Mini-Ducted	Not required but can use existing heating system
	Southern and Northern Interior *(Cold Winter, Design Temp <-8°C)*	N/A	Cold Climate Ductless or Mini-Ducted	Existing heating system, where necessary
Forced Air Central Heating (Gas/Oil/Electric Furnace)	Lower Mainland and Vancouver Island *(Moderate Winter, Design Temp >-8°C)*	Consider upgrading insulation and/or air sealing, modifications to the ductwork may be necessary	Centrally Ducted	Not required but can use existing heating system or electric resistance coil in air handler
		Existing ductwork does not allow for ideal airflow, and upgrading ducting is cost-prohibitive	Centrally Ducted (combined with Ductless), Ductless (Multi-Head or Multiple Units), or Mini-Ducted	Not required but can use existing heating system or electric resistance (baseboards or coil in air handler)
	Southern and Northern Interior *(Cold Winter, Design Temp <-8°C)*	Consider upgrading insulation and/or air sealing, modifications to the ductwork may be necessary	Cold Climate Centrally Ducted	Existing heating system or electric resistance coil in air handler, where necessary
		Existing ductwork does not allow for ideal airflow, and upgrading ducting is cost-prohibitive	Cold Climate Centrally Ducted (combined with Ductless), Ductless (Multi-Head or Multiple Units), or Mini-Ducted	Existing heating system or electric resistance (baseboards or coil in air handler), where necessary

[g] Recommendations pertain to portion of home heated by heat pump(s). Supplementary heating is only required if heat pumps cannot meet design heating loads but they are recommended to improve comfort in cases where defrost cycles would blow cold air into the conditioned space. If supplementary systems are appropriately sized, they can also be used as emergency heating; this is recommended where the incremental costs are small.

Existing Heating System	Region/Local Weather Conditions	Other Considerations	Recommended ASHP Type	Recommended Supplementary Heating System[g]
Central Hydronic System (Gas/Oil Fired Boiler)	Lower Mainland and Vancouver Island *(Moderate Winter, Design Temp >-8°C)*	If replacing functioning boiler is not economically feasible, use it for the supplementary system	Ductless (Multi-Head or Multiple Units) or Mini-Ducted[h]	Not required but can use existing heating system or electric resistance coil in air handler
	Southern and Northern Interior *(Cold Winter, Design Temp <-8°C)*	If replacing functioning boiler is not economically feasible, use it for the supplementary system.	Cold Climate (Multi-Head or Multiple Units) Ductless or Mini-Ducted[h]	Existing heating system or electric resistance (baseboards or coil in air handler), where necessary

[h] Air-to-water heat pumps are a direct replacement for boiler systems; however, these systems are not very common in residential applications and are not covered by this guide.

2.4 IDENTIFYING QUALITY INSTALLATIONS

Several important ASHP installation best practices can be observed visually. Exhibit 9 below provides a comparison between installation best practices and poor installation practices for reference purposes.

Exhibit 9: Comparison of Poor Installation Practices and Best Practice Installations

POOR INSTALLATION	BEST PRACTICE INSTALLATION
Outdoor Units	

Ground not properly compacted

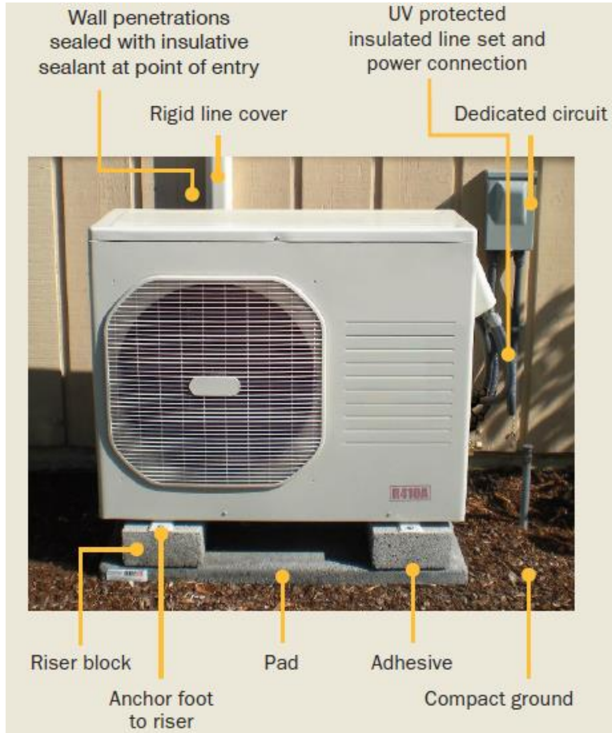
Source: Best Practices Installation Webinar, NEEA

No clearance between ground and base of outdoor unit

Source: Marc R., Minisplit Heat Pump Lessons, South Mountain Company, Martha's Vineyard, MA

Frozen discharge water poses serious safety hazards

Source: Best Practices Installation Webinar, NEEA



Best practices installation of outdoor unit

Source: Best Practices for Installing Ductless Heat and Cooling System, www.GoingDuctless.com

Unit on brackets attached to foundation wall

Source: Marc R., Minisplit Heat Pump Lessons, South Mountain Company, Martha's Vineyard, MA

POOR INSTALLATION | **BEST PRACTICE INSTALLATION**

Line Set and Penetrations

Line set not properly insulated

Source: Best Practices Installation Webinar, NEEA

Line set properly insulated

Source: Best Practices Installation Webinar, NEEA

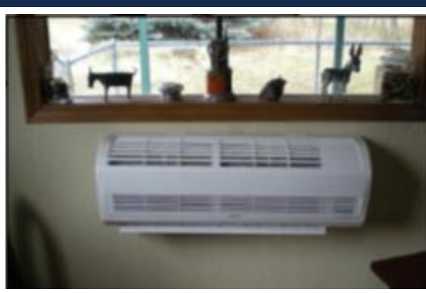
Envelope penetration not sealed properly

Source: Marc R., Minisplit Heat Pump Lessons, South Mountain Company, Martha's Vineyard, MA

Envelope penetration properly sealed

Source: Marc R., Minisplit Heat Pump Lessons, South Mountain Company, Martha's Vineyard, MA

Indoor Units



Indoor units located below window and too close to celling

Source: Best Practices Installation Webinar, NEEA

Indoor units located more than 30 cm below the celling (best practice 30-45 cm from celling)

Source: www.pinterest.es

3 | CONTRACTOR SECTION

Heat pump systems are more efficient than other types of residential HVAC systems. To maximize their effectiveness, efficiency, and economic benefits, good design and proper installation are essential. Heat pumps that are designed and installed properly lead to more comfortable homes and improved customer satisfaction since their equipment lasts longer and has fewer maintenance issues.

Good design and proper installation involve correctly calculating heating and cooling loads (i.e. properly considering the building envelope), understanding the importance of correct sizing for the local conditions, selecting the right equipment for each home, and correctly installing the heat pump system and related components.

This guide provides a list of minimum requirements and the best practices for designing and installing the two most common types of residential air-source heat pump (ASHP) systems into existing homes:

- Centrally ducted ASHPs
- Mini-split ASHPs (both ductless and mini-ducted)

This guide also includes some information related to homeowner education and system setup to help ensure that the heat pump systems are operating efficiently and customers are satisfied.

This guide is mainly targeted at experienced installers of heat pump systems. High-quality installations of heat pump systems can give numerous benefits to the installers, including client referrals, increased sales, reduced call-backs, and improved customer comfort and satisfaction.

Heat pump systems should always be designed and installed by licensed, trained professionals. Installers should always follow the manufacturer's specification and installation instructions, and all applicable standards, codes, and regulations. For instance, Technical Safety BC requires that licensed contractors secure an installation permit for air conditioning systems exceeding 5 kW input capacity (i.e. 17,000 BTU/h).[14]

For clarity, this guide does not cover ground-source or water-source heat pumps.

3.1 HOUSE AS A SYSTEM

A house is considered a multi-component system, where all of the components are interactive. The operation of one system can affect many others and when all systems work together properly, a home is comfortable, safe, efficient, and durable. Conversely, it can lead to issues when systems don't work together properly. If a change is made in one part of the system, other changes will occur in other parts of the system. For example, adding insulation and improving the air tightness of a home reduces its heating and cooling load, which ultimately reduces the required size of any replacement heating and cooling systems.

A building system has two main components: (1) outer layer or envelope; and (2) inner parts or systems. The building envelope, which is comprised of the roof, walls, windows, and foundation, are the outer layer or skin of a building system and act as a barrier between the inside of the home and the outdoors. The heating and cooling equipment, ventilation and exhaust systems, electrical systems, and humidifiers/dehumidifiers are the inner components of a building system. These components operate and control the three main processes inside a house that keep it comfortable, safe, and efficient: (1) heat flow; (2) airflow; and (3) moisture flow.

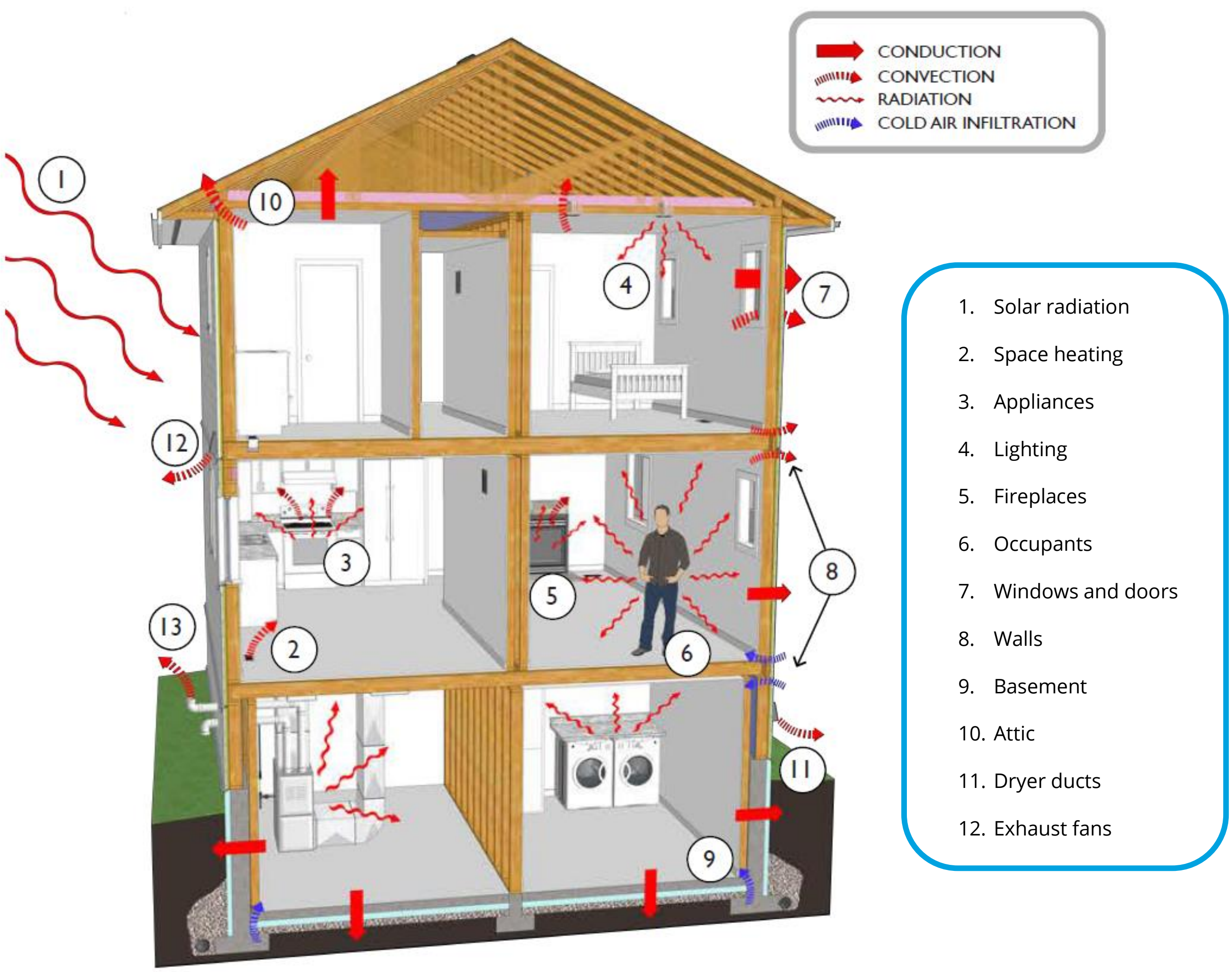
In addition to the inner components, the way a house is laid out and the way that residents live in it impacts the overall system. A house also interacts with the outside environment. Therefore, renovating an existing house to be energy-efficient requires careful planning and attention to detail. A house as a system approach helps homeowners, architects, builders, contractors, and equipment installers develop successful strategies for optimizing home energy efficiency.

Some benefits of using house as a system approach include:

- Increased comfort
- Reduced operation and maintenance costs
- Healthier and safer indoor environment
- Improved building and equipment durability
- Higher home resale value

HVAC system performance is dependent on several interlinked factors. For instance, the building envelope is particularly important. At any given moment, heat is flowing through the building envelope and being generated within it. Exhibit 10 depicts some of the typical heat flows in a home. Any change in the building system that affects any one of these heat flows can influence a home's heating and cooling demand and hence the selection of HVAC equipment such as an ASHP.

Exhibit 10: Heat Loss and Gain within a Building



Source: High-Efficiency Furnace Installation Guide For Existing Houses, FortisBC

3.2 STEPS TO A HIGH-QUALITY INSTALLATION

Before beginning any installation work, contractors should consider the following factors that have significant influence on the viability of air-source heat pumps:

- ☑ **Codes, standards, and regulations:** Relevant codes, standards, and regulations in the local jurisdiction should be reviewed to ensure that all required health and safety considerations are properly addressed. Refer to CSA Standards C2733.5-11 "Installation of air-source heat pumps and air conditioners", the BC Building Code (e.g. Division B, Part 6: Heating, Ventilating and air Conditioning, Part 7: Plumbing Services, Part 10: Energy Efficiency, etc.), and the Technical Safety BC for further information on health and safety regulations related to heat pump installations. WorkSafe BC regulated issues, such as asbestos abatement, should also be reviewed since they can prevent a heat pump installation from occurring if they are not properly mitigated.
- ☑ **Existing heating and cooling system:** Installation contractors should assess the existing heating and cooling system type, location, and layout. It is also important to consider occupancy, usage patterns, and the local climate. Furthermore, consideration should be given towards other equipment that may be dependent on the existing system and might affect the viability of the ASHP installation. In particular, some combustion appliances may be dependent on the existing heating system for venting. This can include hot water tanks and other equipment related to the home HVAC system. In these cases, venting changes may be required.
- ☑ **Supplementary heating options:** Contractors should evaluate whether supplementary heating is required based on local design conditions, heat load calculations, and/or to improve comfort during defrost cycles with some systems. Based on design conditions of the Lower Mainland and Vancouver Island, properly sized conventional ASHPs can meet the heating requirements on the coldest day. Similarly, properly sized cold climate ASHPs can meet the heating requirement of homes located in the Southern Interior without any supplementary heating, while supplementary heating may be required for homes located in the Northern Interior. In cases where homeowners request a supplementary heating system even though it is not required, existing heating systems should be considered first. It is also recommended that supplementary heating systems be sized for emergency heating where incremental cost are small (e.g. additional electric resistance heating in homes not requiring panel upgrades).
- ☑ **Financial support:** Contractors should assess the availability of applicable utility rebates, tax credits, and other financial support available for homeowners in their jurisdiction.

The ASHP installation process can be divided into the following five distinct steps. Generally, a homeowner will be interested in an ASHP retrofit when either an existing heating/cooling system fails or adding air conditioning system or when other upgrades are being completed on the home. The accompanying flowchart depicts the necessary steps that should be followed to ensure installation best practices for an ASHP installation.

Step 1: Job-Site Survey and Pre-Changeout

In existing buildings, an initial assessment of the existing heating and cooling system, ducting system (including duct disconnects /leaks), overall home condition (i.e. existing insulation, air leaks/bypass, etc.), and occupancy should be completed pre-quote. Identified issues should be addressed before installing any new equipment to ensure proper sizing and efficient operation of the ASHP system. This will improve occupants' comfort, reduce heating and cooling costs, reduce the size of equipment required and improves heat pump performance. If any ducting modifications are required in the case of centrally ducted ASHPs, they should also be made prior to installing any new equipment.

Step 2: Design (Sizing and Selection)

Correct sizing is important for the proper operation and economic viability of ASHP system. Oversizing equipment can lead to excessive cycling, reduced equipment life, lower efficiency, and ineffective summer dehumidification. CSA standard CAN/CSA-F280 combined with HRAI's "Residential Heat Loss and Heat Gain Manual" or TECA's Quality First® Heat Loss & Heat Gain software or equivalent are recommended for calculating heating and cooling loads for ASHP systems. For sizing of equipment, CSA standard CAN/CSA-C273.5-11 should be followed.

Step 3: Installation

ASHP installations should be completed by properly trained and qualified contractors. For instance, contractors should be properly training in heat pump systems, including knowledge of refrigeration, sizing, and air distribution. Manufacturer training on specific system is recommended. Installations should also meet CSA standard CAN/CSA-C273.5-11 and all other required codes and standards and should be installed in a manner that optimizes the systems' performance and durability and occupant comfort. Ideally, the installation contractor should be a member of TECA and/or HRAI as well. Among other benefits, this will help reinforce continuing education requirements.

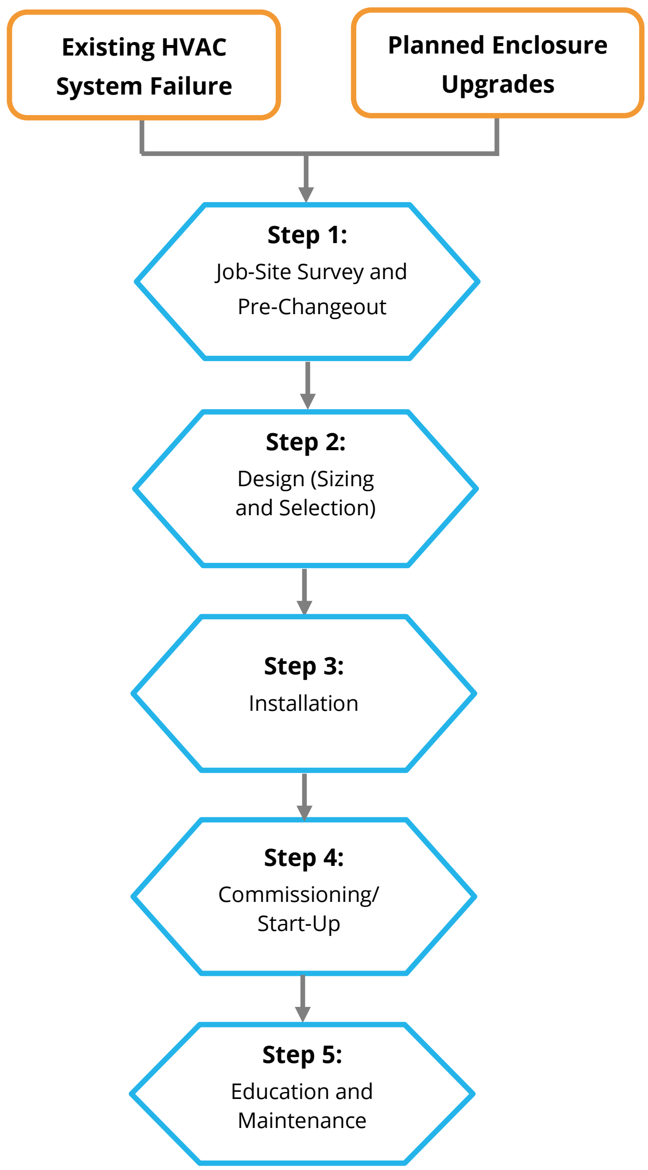
Step 4: Commissioning/Start-Up

Commissioning and start-up of the system must also be performed by appropriately trained and qualified contractors. At ASHP start-up, the necessary commissioning tests should be completed and logged to ensure the heat pump is operating according to the manufacturer's specifications.

Step 5: Education and Maintenance

Contractors should provide the commissioning checklist and manufacturer's information to the homeowner. Contractors should also review warranty information and operation and maintenance procedures for the new ASHP with the homeowner before leaving the site.

Exhibit 11: Steps for Installation Best Practices



3.3 JOB-SITE SURVEY AND PRE-CHANGEOUT

The first step of a best practice installation of ASHPs includes completing a homeowner interview, evaluating the existing HVAC system and the building enclosure, and gathering other site-related information in order to complete load calculations and design an appropriate ASHP system.

INTERVIEWING HOMEOWNERS

Homeowner interviews are an important source of important information for system design. They can help with collecting the following useful information:

- ☑ **Homeowner's expectations, concerns, and needs:** Contractors should discuss the homeowner's needs and any concerns with their existing system. For example, some homeowners may wish to reduce heating and/or cooling costs associated with main living areas of their homes. For them, the main tradeoff is between initial cost and savings, and comfort in the less used or isolated zones. Other homeowners may desire a whole home system or a system for an isolated zone.
- ☑ **Planned and/or recent home retrofits:** Planned or recent home retrofits can have a significant impact on the sizing of an ASHP. New heating and ventilation equipment or building enclosure changes impact the heating and cooling requirements of a building and can result in incorrect heat pump sizing if they are not considered. Contractors should discuss recent or future building changes with homeowners to ensure that any and all modifications will be accounted for in the heating and cooling load calculations.
- ☑ ***Space usage:*** Contactors should discuss the intended space usage (e.g. guest suite, media room, home office), average number of occupants and occupancy patterns, and zoning requirements as these factors may impact the home's heating and cooling loads and the proposed system design.
- ☑ ***Existing comfort and health problems:*** Contractors should also discuss the comfort level provided by the existing HVAC system and if there are any health problems that may require special consideration as part of the design and installation of the ASHP system (e.g. special type of filtration).
- ☑ ***Design conditions and system options:*** Based on the information gathered from discussions of the above-mentioned items, contractors should further discuss design considerations and viable system options to select from.

EVALUATING EXISTING HVAC SYSTEMS

It is critical to thoroughly assess the existing HVAC system before sizing and selecting a new ASHP system that will either replace or work in conjunction with the existing system. To evaluate the condition, it is necessary to complete some tests and calculations and visually inspect the current system arrangement in order to accurately size the new ASHP and consider any changes in configuration. Furthermore, this pre-investigation may determine whether additional work beyond the localized ASHP installation is needed (e.g. ductwork improvements, asbestos abatement). Evaluation of existing systems should include the following items:

- Type of system (space, central, split, package, etc.)
- Age of the existing system
- Existing heating system fuel and type
    - Natural gas, propane, fuel oil, and/or electricity
    - Forced air, hydronic, baseboards, heat pumps, etc.

- Air distribution system capacity and condition, if applicable. Contractors should:
  - Assess the number and size of supply diffusers and return grills for each level and determine their capacity
  - Assess ductwork near indoor equipment to make sure it has been designed for low pressure drop
  - Assess the condition of other visible ductwork
  - Look for poorly designed fittings with mitered inside corners and ensure tapered takeoffs were used
- Ventilation system layout

EVALUATING BUILDING ENCLOSURE

The accuracy of the building heat loss and heat gain assessment is heavily dependent on a thorough evaluation of the condition of building enclosure. The evaluation should include the following items:

- Exposed above grade walls and basement walls (area, type, thickness, insulation, etc.)
- Windows, doors, and skylights (area, type, thickness, air sealing, direction, etc.)
- Ceilings and roof (area, type, thickness, insulation, etc.)
- Foundation type and insulation

GATHERING OTHER SITE INFORMATION

It is also important to gather other site related information to properly design the system and safely completing the installation work. This information includes:

- Existing electrical supply, mains, and control wiring and fuel (e.g. natural gas) piping
- Site hazards (e.g. vermiculite insulation, asbestos, knob and tube wiring)
- Architectural and space constraints, including but not limited to an assessment of the mechanical room and potential sites for outdoor units
- Trees and adjacent structures
- Below grade walls, partitions, and other relevant structures
- Relevant plans, sketches, and notes

A sample checklist for the job-site survey is provided below.

Exhibit 12: Job-Site Survey Checklist

JOB-SITE SURVEY CHECKLIST					
Item	**Description**	**Orientation**			
		North	**South**	**East**	**West**
Homeowner's Requirements					
Homeowner's requirements and reason for replacement	Mainly for heating or cooling				
Indoor unit preference*	Homeowner preference for floor-mounted, high wall-mounted, or ceiling-mounted unit				
Control type preference	Wi-Fi enabled remote control or other				
Location and Home Type					
Outdoor design conditions					
Indoor design conditions					
Home Type	Vintage, single detached, middle-unit townhome, etc.				
Zoning requirements					
Room types	Typical single room or a large or open plan room/hallway, where more than one unit may be required				
Plans, Sketches, Notes					
Measurement, Areas, and Volumes					
Windows					
Doors					
Exposed walls					
Above grade walls					
Partitions					
Daylight-basement floors (wedgies)					
Closets (size matters)					
Halls (size matters)					
Above grade volume (for infiltration)					

JOB-SITE SURVEY CHECKLIST					
Item	**Description**	**Orientation**			
		North	**South**	**East**	**West**
Construction Details					
Walls					
Windows (detail and direction)					
Doors (detail and direction)					
Ceiling					
Roof					
Skylights					
Floors					
Slab on grade (edge insulation?)					
Envelope leakage evaluation					
Internal load survey – Occupants					
Internal load survey – Appliances					
Duct system survey – Location					
Duct system survey – Insulation					
Duct system survey – Sealing					
Air quality survey (ventilation?)					
Garages					
Fireplaces					
Others					
Retrofit Checklist					
Load estimate required					
Comfort, Air-quality and Efficiency – Compliance with BC Building Code					

* A floor-mounted unit may be better for an older user to give more direct heat flow and allow easier access for maintenance. A high wall-mounted or ceiling-mounted unit can provide more effective cooling and allows occupants more flexibility with arranging furniture in the room.

3.4 SYSTEM DESIGN (SIZING AND SELECTION)

ASHP system performance and occupant comfort depend on proper system design. This includes proper system sizing, equipment selection, and consideration of how the system will interact with any existing systems.[15,16]

Correct sizing of the heat pump system is critical to its efficiency and performance. The overall system, including any supplementary heating, needs to be able to provide the required heating and cooling capacity at the local outdoor design conditions. If the heat pump capacity is too low, the system will likely need to defrost more frequently during heating operation, and may rely too much on the supplementary heating system during colder weather, increasing overall operating costs.

The extra running costs of an undersized ASHP system generally outweigh the additional cost of installing a larger unit. However, significant oversizing should be avoided since this can present significant issues as well, such as excessive cycling and poor performance at warmer temperatures. It is recommended that equipment that most closely meets the calculated load be selected. However, in cases where duct capacity is an issue that is not easily addressed through duct improvements, smaller capacity centrally ducted ASHPs can be coupled with mini-split (ductless or mini-duct) systems to provide an effective solution. More details are provided below.

The following four steps should be followed to properly designing an ASHP system:

Step 1: Determine requirements

- Heating (or heating and cooling) displacement
- Full HVAC system replacement
- Isolated zone
- Other

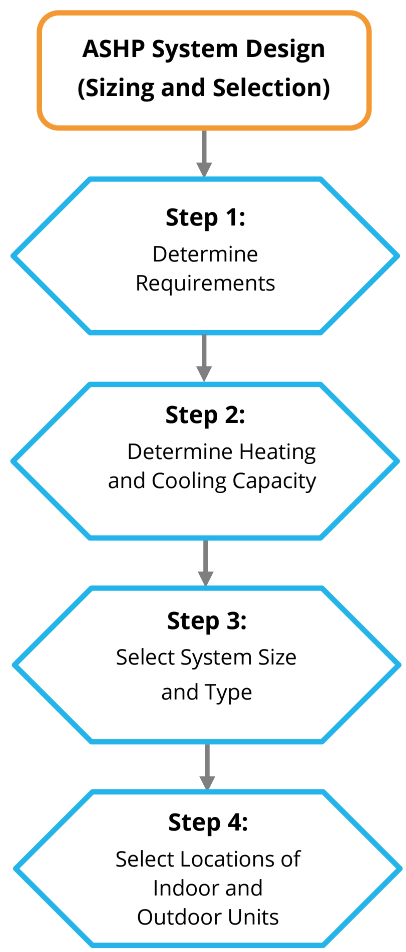
Step 2: Determine heating and cooling capacity requirements (heating and cooling load calculations) at the indoor and outdoor design conditions

Step 3: Select the system size and type/configuration to suit the design requirements and homeowner preferences

Step 4: Select the location of the indoor and outdoor units

Each of the above-mentioned steps are described in more detail below:

Exhibit 13: Steps for Designing of ASHP System



DETERMINING REQUIREMENTS

As a first step, gather the information that is needed to determine what the most appropriate heat pump option is for a particular home. All the required information will be available from the Job-Site Survey and the Pre-Change Out stages.

DETERMINING HEATING AND COOLING CAPACITY

Using the information from Step 1, the required heating capacity can be calculated following CSA standard CAN/CSA F280-12 combined with HRAI's "Residential Heat Loss and Heat Gain Manual" or TECA's Quality First® Heat Loss & Heat Gain software or equivalent. To ensure accurate sizing of heat pumps, the following items must be taken into consideration regardless of the method used:

- The load calculation method must account for:
  - Surface areas and thermal properties of the building enclosure (walls, roof, doors, windows, floors, foundations, etc.)
  - Heat losses of all types, including air leakage in the building, duct losses (where appropriate), and latent loads (i.e. humidity) for cooling
  - Heat gains from all sources, including solar gains from windows and roof, and internal sensible and latent gains for cooling
- Load calculation steps and procedures should be followed closely. Regardless of whether or not safety factors are already built-in to the load calculation software or other methods being employed, the use of additional safety factors is not recommended since this may lead to gross oversizing.
- Appropriate indoor and outdoor design conditions and other climate factors for the location should be used.
- The actual building conditions should be taken into consideration. For example, don't use duct loss factors for ductless systems.
- Caution should be taken when applying infiltration estimates, which are often overstated. Blower door testing is recommended for estimating infiltration.
- Special attention must be given in the following situations, where realistic equipment loads may be surprisingly small:
  - Calculating individual, small block loads (e.g. for a single zone ductless ASHP serving an individual room, or loads for individual heads of a multi-spilt system)
  - Calculating loads for one or several rooms served by a mini-ducted system
- In cases where single zone systems are being installed in an "open floor plan" home, it is acceptable to include connected open spaces (including other floors connected via an open stairway) in the load estimates for that zone.

SELECTING THE SYSTEM SIZE AND TYPE

With the load calculations completed, all required information needed to select the right size of heat pump system is now available. Select the appropriate size of system following Section 5 of CAN/CSA standard C273.5-11. The following items should be considered when selecting an ASHP:

- Most manufacturers provide performance guide charts for selecting a heat pump system, similar to Exhibit 14. Use these charts to determine heating and cooling capacity at the actual design conditions for the local climate.
- Where heating capacity data is not available for the exact external design temperature relevant to the installation site, use the heating capacity information for the nearest outdoor temperature available below the external design temperature. Where cold climate air-source heat pumps are being considered, the information in NEEP's ccASHP specification tables[17] (i.e. maximum heating capacities reported at -15°C or 5°F) may be used to estimate performance near design conditions and help ensure proper equipment selection.

Exhibit 14: Representative Heat Pump Performance Guide Chart

Model A: Capacity (kBTU/h), 12,000 BTU/h Rated Output															
Indoor Temp	Outdoor Temperature														
20°C	-15°C (5°F)			-8.3°C (17°F)			0°C (32°F)			1.7°C (35°F)			8.3°C (47°F)		
	Output	Input	COP	Output	Input	COP	Output	Input	COP	Output	Input	COP	Output	Input	COP
	7.2	2.31	3.12	8.64	2.73	3.15	11.1	3.3	3.31	11.4	3.36	3.4	12.3	3.54	3.5
Model B: Capacity (kBTU/h), 18,000 BTU/h Rated Output															
Indoor Temp	Outdoor Temperature														
20°C	-15°C (5°F)			-8.3°C (17°F)			0°C (32°F)			1.7°C (35°F)			8.3°C (47°F)		
	Output	Input	COP	Output	Input	COP	Output	Input	COP	Output	Input	COP	Output	Input	COP
	10.8	3.9	2.76	12.96	4.62	2.8	15.3	5.13	2.98	15.6	5.25	3.0	18.3	5.7	3.2
Model C: Capacity (kBTU/h), 24,000 BTU/h Rated Output															
Indoor Temp	Outdoor Temperature														
20°C	-15°C (5°F)			-8.3°C (17°F)			0°C (32°F)			1.7°C (35°F)			8.3°C (47°F)		
	Output	Input	COP	Output	Input	COP	Output	Input	COP	Output	Input	COP	Output	Input	COP
	14.4	5.55	2.59	16.95	6.15	2.75	18.6	6.75	2.8	19.2	7.2	2.7	24.3	7.8	3.1

- The minimum capacity of the selected system (i.e. ability to modulate) is as important as the maximum capacity. To ensure heating comfort and efficiency, select equipment with adequate turn-down to perform well during mild weather, low-load conditions. This is an important reason to not to overestimate design loads or oversize equipment and is particularly important for multi-zone systems.
- When installing multi-zone systems, consider using separate single-zone systems or increasing the number of outdoor units, each with lower capacity and with fewer zones. This will make it easier to match minimum capacity requirements and may have only a most impact on the system cost. This is mainly due to the cost associated with running long refrigerant lines to multiple indoor units, which can also have a negative impact on system performance.
- In general, avoid situations where the minimum steady-state capacity of the outdoor unit (rated at 8.3°C or 47°F) is higher than the smallest indoor unit's heating capacity. In these situations, centrally ducted and mini-ducted heat pumps should be considered as well.
- The heating capacity of heat pumps declines with lower outdoor temperatures. As such, the proposed ASHP system must be able to provide the required heating at the relevant outdoor design temperature where the system is being installed. The capacity of heat pump at the outdoor design temperature will likely be different to the rated heating output capacity. For example, Model A in Exhibit 14 has a rated capacity of 12,000 BTU/h but this model can only provide about 8,640 BTU/h (or 72% of its rated heating capacity) at Lower Mainland design temperatures, which are close to -8°C.

- The following is provided as a sizing example:
  - If a contractor were sizing an ASHP system with the performance characteristics noted in Exhibit 14 for a home with a heating load of 14,000 BTU/h at an outdoor design temperature of -11°C, the 24,000 BTU/h rated capacity heat pump (Model C) should be selected as it is able to deliver 14,400 BTU/h output at -15°C (i.e. nearest temperature below -11°C with data available). Model B would only be able to provide a 10,800 BTU/h output at -15°C, which is less than the required 14,000 BTU/h design heating load.
- In retrofit situations with existing duct work, the system size will be limited by the capacity of the existing duct work. In these cases, if the calculated load is larger than the capacity of the existing duct work and there is no scope to upgrade ductwork, select a smaller unit that will work with the existing duct system, and provide adequate supplementary heating.
- Selection of type of ASHP system should be done based on homeowner's requirements, type and condition of existing heating system, and local weather conditions. Exhibit 8 in Section 2 can be used as reference guide to help select the appropriate ASHP system for different situations.
- Supplementary heating will be required for systems with heating loads below the thermal balance point of a given home. Supplementary heating is strongly recommended on any conventional systems that are able to employ it for defrost cycles since this prevents cold air from blowing during defrost cycles, and thus improves occupant comfort. Exhibit 8 in Section 2 can be used as reference guide to select the appropriate supplementary heating system for different situations. The following table provides some high-level guidance for sizing heat pumps and any associated supplementary heating system.

Exhibit 15: Sizing of ASHP and Supplementary Heating System

Climate Zone	Requirement	Sizing Criteria	
		Heat Pump	**Supplementary Heating System***
All	Cooling and partial heating	100-125% of design cooling load	Difference between design heat load and heat output of selected ASHP
Lower Mainland and Vancouver Island (Moderate Winter, Design Temp >-8°C)	Heating 1-2 zones or entire home	*Preferred Approach:* 100% of design heating load	Not required but can use existing system as emergency heating system
		Alternate approach: Slightly undersized vs. design heating load	Difference between design heating load and heat output of selected ASHP at balance point
Southern and Northern Interior (Cold Winter, Design Temp <-8°C)	Heating 1-2 zones or entire home	100% of design heating load or max available capacity (where supplementary heating is required)	Where existing system is not being used: ▪ *Cold regions:* Difference between design heating load and heat output of the selected ASHP (where applicable) ▪ Very cold regions: Entire design heating load

** In addition to any supplementary heating to support defrost cycles*

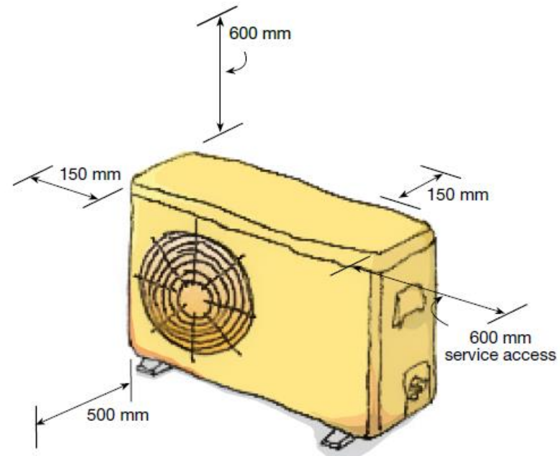
SELECTING LOCATIONS OF INDOOR AND OUTDOOR UNITS[18,19]

To enable optimum performance of an ASHP system, it is important to select appropriate locations for both outdoor and indoor units. Units installed at improper locations can cause poor performance of heat pump system, leading to comfort issues and customer complaints.Locating Outdoor Units

All outdoor units should be located in accordance with the manufacturer's instructions, with consideration given to the following items:

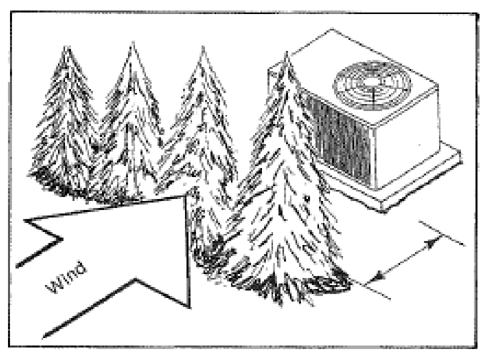
- Keep outdoor units away from fences, walls, and other surfaces to allow unimpeded air flow around the unit (i.e. to avoid the creation of a microclimate that negatively impacts heat pump performance and efficiency)
- Where manufacturer's literature does not provide clearance recommendations, ensure enough clearance based on site and system type. For example, the following minimum distances from obstructions should be maintained in case of mini-split systems:
  - 500 mm between air inlet and outlet faces
  - 600 mm above the unit
  - 600 mm service access
  - 150 mm to other faces
- Positions that gets full sun in the winter are preferable
- Keep refrigerant pipe run lengths and bends at minimum level (follow manufacturer's instructions if given)
- Minimize the length of refrigerant lines outside the conditioned space
- Ensure easy drainage of condensate
- To ensure correct defrost system operation, protect from winter winds using trees or other vegetation, wind baffles, or the positioning relative to the home

Exhibit 16: Example of Outdoor Unit Clearances for Mini-Split System



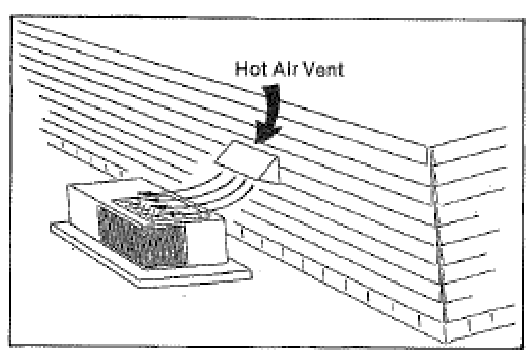
Source: EECA, New Zealand

Exhibit 18: Outdoor Unit – Protect from Wind



Source: ACCA Manual H

Exhibit 17: Outdoor Unit – Avoid Hot Air Vents



Source: ACCA Manual H

- Minimize sound problems (for unit sound rating, the maximum should be 76 dB)
- If mounted on brackets attached to the home, ensure vibration isolators are used to ensure vibrations from the unit are not transferred to the home and avoid sound resonance issues
- Blockages (e.g. from leaves or snow) should be visible so that they can be cleared away quickly
- Units should be protected from the sea spray in coastal areas and sheltered from frost and strong winds. Strong winds can cause the condenser fan to spin in reverse and burn out the motor, which is of particular concern when a unit is located on a roof. Many manufacturers make optional wind block panels that can be installed for outdoor units in areas with excessive wind.
- Outdoor units should be located above anticipated snow levels with due regard to defrost water drainage
- Units should be located at a safe distance from any gas sources or appliances
- If homeowners have pets that may urinate on outdoor units, it is recommended that they be protected with a section of low garden fencing that will not restrict airflow or service access. This issue can also be addressed by elevating the unit above the anticipated snow line

DO NOT LOCATE OUTDOOR UNITS:

- Where operating noise may disturb home occupants or neighbors
- Under the house or a deck, or any location that may impede airflow
- Below a window where the unit has a vertical discharge
- Where multiple outdoor units are competing for airflow
- Close to hot building exhaust air (e.g. clothes dryer vent), or where heat is generated by other equipment, or in locations where pavement or masonry materials produce a high ambient temperature
- Where people pass (i.e. close to an accessway or path) since freezing discharge can pose a slip hazard
- On a balcony or deck that is more than 1 m above a surface below in a way that facilitates climbing over any nearby railings. In addition, any screen around the outdoor unit must not facilitate climbing and must not include toe holes.

Exhibit 19: Bad Practice for Outdoor Unit

Decorative shed over outdoor unit with very little air space to the house wall

Source: FRESCo, ASHP Installation Practices

Exhibit 20: Best Practice for Outdoor Unit

The outdoor unit attached at the top to prevent it from falling over

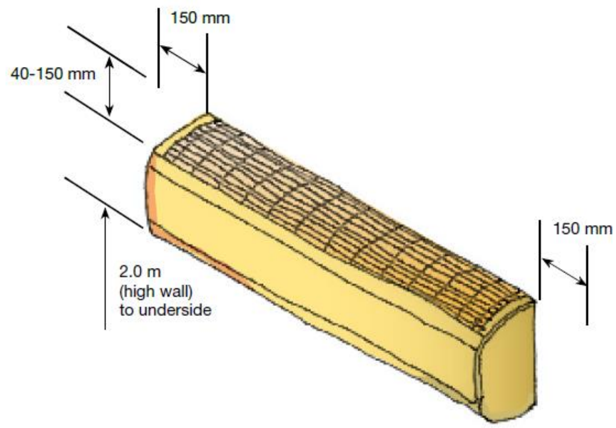
Source: FRESCo, ASHP Installation Practices

Locating Indoor Units

Indoor airside equipment includes the air handler section and, in some cases, a compressor section. All indoor units should be located in accordance with the manufacturer's instructions, with consideration given to the following items:

- According to the type of equipment that can be located in the basement, attic, equipment room, or in a closet;
- Where manufacturer's literature does not provide clearance recommendations, ensure enough clearance based on site and system type. For example, the following minimum distances from obstructions should be maintained in case of mini-split systems:
  - 40-150 mm minimum above and 150 mm minimum on either side of a wall mounted unit
  - 2.0 m minimum (measured to the bottom of the unit) above floor for a high wall or ceiling-mounted unit
  - 50 mm minimum to each side for a floor console (Exhibit 21)
- Direct airflow to the coldest point in the room (but not towards a window)
- Ensure adequate clearances for making all connections and future servicing of the unit
- Ensure that a clear airflow path is maintained
- Minimize refrigerant pipe run lengths and bends (each 90° bend causes approximately 1% reduction of heating/cooling capacity)
- Ensure that the any condensate drainage piping can drain to outside without the need for a condensate pump
  - If ventilation is required, the unit must be located so that outdoor air and exhaust air can be ducted to and from the unit.

Exhibit 21: Example of Indoor Unit Clearances for Mini-Split System



Source: EECA, New Zealand

DO NOT LOCATE INDOOR UNITS:

- In a tight corner or space
- Behind a grille
- Where they direct air to a primary source of heat gain or loss, such as windows, or onto seating locations or electronic equipment
- Where there may be any steam (e.g. kitchen or bathrooms with showers)
- Near an automatic insect repellent dispenser
- Above or close to any heat source, including electrical appliances, which could affect the performance or act as an ignition point

Exhibit 22: Bad Location for Ductless Indoor Unit

Source: NEEA, DHP Best Practices Installation Webinar

3.5 INSTALLATION[20,21,22,23]

REFRIGERANT LINE SET AND TUBING

Refrigerant line set (pipework) can have a significant impact on heat pump performance. A properly sized and installed line set gives a safe, efficient and reliable installation necessary for the heat pump system to perform properly. All refrigerant line set installations should be performed in accordance with the manufacturer recommendations. Follow manufacturer's instruction for pipe sizes, minimum and maximum line set lengths, and height changes, with consideration to the following:

- Follow section 5.12, 6.2 and other relevant sections of CSA C273.5-11
- Design pipelines for the shortest runs and minimum number of joints and bends to limit internal friction and reduce risk of leaks
- Insulation must cover the entire line set length to avoid condensation and decreased efficiency. In addition, both pipes (i.e. supply and return) should be insulated separately to minimize heat transfer between them.
- Glue insulation joints to prevent condensation from dripping inside space
- Protect the outdoor line set from insulation damage with rigid line hide and building code-approved line set protection
- Protect any remaining exposed line set with UV-resistant tape or other mechanical protection
- Protect line set penetration through the building enclosure with rodent-proof insulation (e.g. with PVC sleeve and cap drilled to the size of the refrigerant lines, metal-wool stuffing, or similar)
- Correctly seal all penetrations through the shell of the home with insulating sealant/spray foam. As necessary, use gasket material to properly seal all penetrations.
- Return any insulation disturbed by installed line set to original (or better) condition
- Create new flare fittings (where used), using flaring tool and measurement gauge appropriate to the applicable refrigerant (e.g. old R22 flaring tools should not be used for R410A refrigerant systems) and in accordance with manufacturer's instructions
- Apply refrigerant oil to the end of each flare
- Purge brazed connections with dry nitrogen while brazing to prevent oxidization
- Slope pipes towards the compressor to allow any oil that gets into the pipes to drain back to the compressor sump (some compressor oil will likely get into the pipeline in any system, and if it remains there it will de-rate the system's pressure and hence its efficiency)
- Make tubing connections using gasketed press/crimp designed for the refrigerant and tubing type (e.g. Sporlan Zoom Lock®, Vulkan LokRing®)
- Use factory-supplied flare adapters where necessary to connect to equipment and avoid field-fabricated tubing flares
- Follow the steps given below to perform good-quality refrigerant line set work:

  1. Select suitable pipes and joints (i.e. pipes must be rated for the refrigerant pressure being used in the system)
  2. Ensure pipes are clean and moisture-free
  3. Make bends properly and use proper bending tools to prevent kinking
  4. Create flared joints properly
  5. Ensure pipework is properly-supported or clipped to prevent sagging, excessive movement, or an unsightly installation
  6. Insulate refrigerant pipework
  7. Position and connect the condensate drainage pipe properly

DO NOT:

- Reuse manufacturer provided tubing flares and fittings
- Use an old R22 flaring tool for R410A refrigerant systems (i.e. R410A flaring tools create a larger flare wall to withstand the higher refrigerant pressures of R410A systems)
- Use line sets used for R22 for R410A systems without flushing them with an agent like RX11
- Use a saw blade to cut the pipe
- Mix polyolester oil and mineral-based oil
- Use leak lock or PTFE tape, as these are not plumbing joints
- Cross thread the fittings, as you may damage them

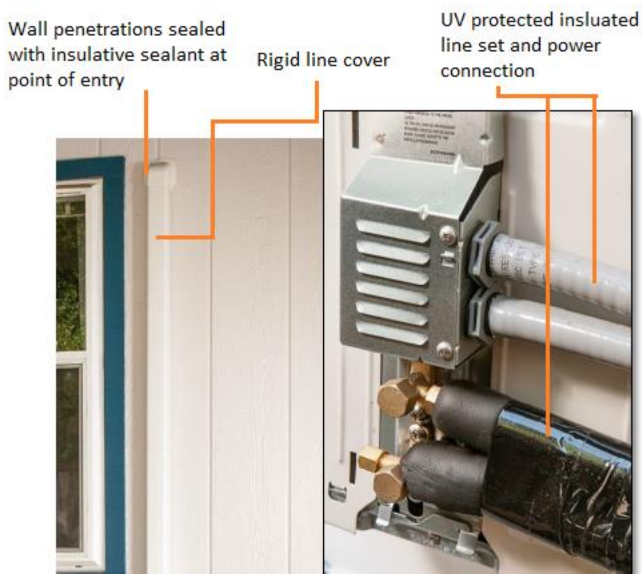
Exhibit 23: Poorly Installed Line Set

Excess line set not removed but coiled up

Envelope penetration and line set are not covered

Source: FRESCo, ASHP Installation Practices

Exhibit 24: Best Practice Line Set Installation



Source: NEEA, Ductless HP Best Practices Installation Webinar

REFRIGERANT CHARGE AND ADJUSTMENT

The outdoor units of heat pump systems are factory-charged with the appropriate quantity of refrigerant to allow for the indoor unit and a specific pipe run. No additional refrigerant charge or adjustment is needed if manufacturer's installation instructions for the pre-charge pipe length is followed. Extra refrigerant may only be needed when pipe runs exceed the manufacturer's parameters. Refrigerant charging must be carried out in accordance with CAN/CSA B52 Section 8: Maintenance of System. The following procedures should be following if extra refrigerant charge/adjustment is needed:

- Work should only be completed by contractors with the appropriate training and certifications
- Only use manufacturer's specified refrigerant
- Pressure test refrigerant line set using dry nitrogen and triple-evacuated with vacuum pump per manufacturer's instructions. Vacuum shall be held at 500 microns or less for a minimum of 15 minutes in each of the three vacuum cycles, and valved off to check for pressure changes that indicate contamination or leaks. Each evacuation shall be alternated with nitrogen under pressure. Pressure test refrigerant lines only at pressures lower than the pressure rating of service valves (typically 300-400 PSI), or per manufacturer's specifications).
- Measure the additional pipe run length and accurately calculate the amount of refrigerant required according to the manufacturer's instructions
- Weigh in the required amount of refrigerant by mass, using electronic scales
- Keep the charge lines as short as possible
- Leak test the pipework before charging, by partially opening, then closing the cylinder valve to pressurize the connecting pipework
- Charge using liquid refrigerant from the cylinder
- Check for leaks using the bubble test solution
- Ensure that the cylinder and unit are at the same height to prevent gravity transfer of the refrigerant

Any system that is charged with refrigerant or lubricant must be labelled appropriately. Labelling must be done in accordance with CAN/CSA B52 clause 5.11: Marking and Labelling and must include the following:

- Refrigerant type
- Date of service
- Lubricant type
- Refrigerant charge (total including any additional charge)

CONDENSATE DRAIN

The condensate that forms on coils of indoor and outdoor units must be collected and disposed of safely. Contractors should follow BC Plumbing Code 2018 and consider the following when installing and/or connecting condensate drainage piping:

- Drains should slope downhill. Drain can be routed with line set and run to a suitable termination point, away from crawl spaces, walkways and outdoor equipment.
- Some units, such as ducted mini-splits and ductless cassette units, have limited vertical lift built in. Do not exceed manufacturer's specifications for the vertical lift allowed before a continuous downward slope, otherwise a condensate pump may be required.
- Wrap the indoor and through wall section of the drainage pipe in polyurethane foam insulation.
- Use smooth, hard PVC-U drainage pipe if drainage pipe runs laterally – flexible, ribbed drainage pipe can be used for vertical drainage
- Where pipe traps are recommended by the manufacturer to reduce negative pressure, install in accordance with the manufacturer's specifications
- Use mechanical connectors (jubilee clips) to connect the hoses
- Locate indoor units suitably to avoid the need for a condensate pump. Where unavoidable, install a condensate pump in accordance with the manufacturer's specifications. Advise the owner of the maintenance requirements of the pump and that it may make noise. In addition, ensure that the pump has a system cut-off switch if it fails or doesn't drain properly.
- Condensate drains should be tied in upstream of a trap and not tied into a vent

DO NOT:

- Allow the condensate outlet pipe to be immersed in water, as this can cause an air lock and prevent water drainage under gravity
- Use flexible drainage piping in internal wall spaces
- Use flexible ribbed drainage piping for lateral pipe runs, as water may sit in the ribs or low points may occur in the pipe
- Use electrical conduit as a drainage pipe
- Discharge where it can run over a footpath as it may become slippery or freeze in winter

OUTDOOR UNIT INSTALLATION

The outdoor unit can be fixed on:

- A concrete pad cast in place or a single piece pre-cast concrete or composite slab
- A concrete patio or balcony
- A timber slatted deck with anti-vibration mounts
- Brackets fixed to a foundation or wall; note that anti-vibration isolators are required in these situations
- A roof where the installation has been specifically designed (engineered) to accommodate live loads and wind forces acting on the roof, and it incorporates anti-vibration mounts
- A specified base in accordance with manufacturer's instructions

Installation of outdoor units must ensure the following:

- Units sit level, both side-to-side and front-to-back and cannot fall over
- Their weight is fully supported to prevent sagging
- Units have an unobstructed gap under them
- Units create no vibration; in cases where vibration is unavoidable, anti-vibration mounts should be used
- There is a suitable clearance underneath to allow for hosing, clearing of leaves and dirt, and clearance for snow
- Components used for fixing are corrosion-resistant (i.e. typically requires stainless steel)
- Any ground mounted units are placed on a pad on soil that is well drained and will not heave with frost
- Use wall brackets designed for attachment to foundation wall, where ground clearance allows
- Use anti-vibration isolators when mounting the outdoor unit to any component in direct contact with the structure (wall brackets, decks, etc.)
- Install surge suppressors at service disconnect to protect sensitive electronics. Alternatively, suppressors may be installed at circuit breaker boxes if devices are approved for such application. Follow device manufacturer's instructions and all applicable codes and standards.

Exhibit 25: Outdoor Unit on Concrete Pad

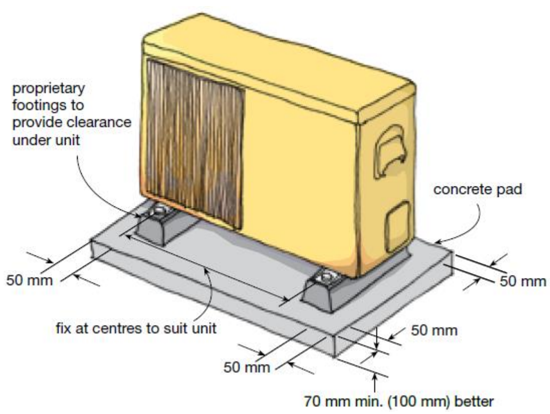
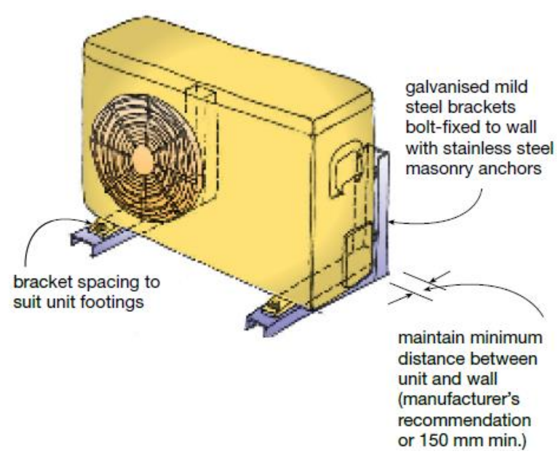


Exhibit 26: Wall Mounted Outdoor Unit on Bracket – Masonry Wall



Source: Good practice guide: Heat pump installation, EECA, New Zealand, June 2019



AVOID:

- Avoid proximity to walkways or other areas where re-freezing defrost meltwater might cause a slip-and-fall hazard and/or damage the surface due to freeze/thaw cycles
- Installing outdoor unit(s) directly under any drip line from the roof or other overhang that would subject them to falling snowmelt, ice, or concentrated rain runoff. When this is unavoidable, and a functioning gutter is not present, outdoor units shall be installed with drip caps or shields approved by the manufacturer.
- Drain pan heaters if drip cap and ground clearance are provided, except in extreme (e.g. marine) environments

DO NOT:

- Fix the unit onto a waterproof deck or a membrane roofing system, as the fixings will penetrate and compromise the waterproofing
- Mount units on concrete or clay tile roofs (i.e. tiles are not strong enough to allow mounting and the weight of the installers working on the roof)
- Mount directly onto metal roofing, as roofing can act as a sound amplifier and direct fixing may cause corrosion of the roofing
- Place multiple units above each other, or with outdoor fan outlet flow pointing directly at another unit, except when explicitly recommended by manufacturer

INDOOR UNIT INSTALLATION

Ductless Heat Pumps

Install wall mounted indoor units with adequate clearance from the ceiling for making all connections, for servicing the unit, and for replacing the components contained (if necessary). The top clearance should be at least equal to the manufacturer's instructions. If possible, units shall be installed with minimum additional clearance of 300 mm from the ceiling in the case of ceiling heights up to 2.5 m from the floor. In rooms with higher or vaulted ceilings, units shall be installed at such a height (where possible) so that the air discharge is no higher than 2.5 m from the floor.

Besides the above, consideration must be given to the following:

- Ensure that the wall is structurally strong enough to carry the load of the unit
- Ensure that wall space where the unit is being installed is free from electrical cables, plumbing and cross bracings
- Ensure that the unit is securely seated
- If space allows, install floor-mounted units in larger living areas and lower levels of 2-story homes

Centrally Ducted Heat Pumps

The following considerations apply to centrally ducted ASHP systems:

- If possible, position the air handler in such a location so that the duct system doesn't have unusually long runs or inefficient fittings

If ventilation is required, the unit must be located so that outdoor air and exhaust air can be ducted to and from the unit

Exhibit 27: Properly Installed Ductless Indoor Unit

Good choice of location, easy access for maintenance

Source: NEEA, Ductless HP Best Practices Installation Webinar

DUCTING CONSIDERATIONS

Consideration must be given to the following during the installation of duct systems for centrally ducted or compact-ducted ASHPs:

- Duct system design must follow NBC (Section 9.33.6) and the TECA Forced Air Guideline, HRAI Residential Air System Design manual (SAR-R2), or ACCA Manual D
- Ducts systems should be designed to minimize friction losses
- Pay close attention to available static pressure, especially with mini-ducted air handlers
- New supply and return ducts must be sealed with suitable long-life material to minimize air leakage
- Duct sealing materials should be rated to UL181A or UL181B specifications and used in accordance with the manufacturer's instructions
- Avoid ducts in unconditioned spaces when possible
- If ducts and/or air handlers in unconditioned space can't be avoided, all joints and seams in duct should be thoroughly sealed with duct mastic and all components should be insulated to a minimum of above grade wall building code requirements
- When installing central ASHP systems using existing ducts, always ensure that ductwork is adequately sized for the heat pump air flow requirements and available static pressure. The TECA, HRAI, and ACCA documents noted above are useful references to assess duct capacity.

ELECTRICAL WIRING

Registered electricians should assess the building's existing electrical installation and the existing electrical load to determine whether the existing electrical installation has sufficient spare capacity to support the requirements of the heat pump system, including any supplementary heating. In cases where additional capacity is required, separate dedicated circuits (i.e. wired back to the main switchboard) should be used. New electrical wiring should be installed following all codes and standards, including CSA Standard C22.1 and manufacturers' recommendations. All electrical work must be carried out by a registered electrician. An Electrical Certificate of Compliance (CoC) must be issued on completion.

Registered electricians should ensure that:

- Each piece of equipment is supplied with correct voltage
- Overcurrent protection is properly sized to protect the load and the circuit (i.e. circuit breaker or fuse) and the mains wiring is sized correctly (i.e. minimum circuit ampacity)
- There is phase balance on three phase circuits (where applicable)
- The electrical service entrance can supply all of the power requirements of the system
- A lockable isolating switch for outdoor unit is installed and attached to the house (not the outdoor unit)
- Waterproof protection to the electric connection is installed as required

DO NOT:

- Connect the isolating switch to the outdoor unit (i.e. unit cannot be isolated from power)
- Allow contact between wiring and refrigerant pipework
- Run the main power cable and heat pump system power cable together

THERMOSTAT AND CONTROL SETTINGS SETUP

Different types of thermostats are available on the market to control heat pumps. A brief description of the different types is presented below:

Conventional Thermostats:

- Thermostats with basic functionality
- Turn heat pumps on or off to meet desired heating or cooling setpoints
- Where applicable, can also control supplementary heating
- May also communicate with one of two types of outdoor thermostats: 1) First type selects the appropriate heating based on outdoor temperature; 2) Second type shuts off the heat pump when the outdoor temperature falls below a specified level.

Exhibit 28: Conventional Thermostat

Programmable Thermostats:

- Proprietary thermostats that offer improved temperature control
- Set temperature schedules
- Eliminate the need for outdoor thermostats for heat pump systems
- Can lead to energy savings when used properly
- Many are difficult to program, so they're often used in manual mode, negating any potential energy savings
- Newer models include some of the features of smart thermostats (e.g. control via smartphones)

Exhibit 29: Programable Thermostat

Smart Thermostats:

- Advanced form of programmable thermostat
- Algorithm-based software establishes heating and cooling schedules, which are easy to temporarily override if desired but challenging to override permanently
- Occupancy sensors and/or geofencing capabilities detect when occupants are away from home and set-back temperatures accordingly
- Homeowners can interact with them remotely via their smartphones, laptops, etc.
- The majority of models are designed to be used with central forced air systems but they may not be compatible with variable speed systems
- Many smart thermostats rely on weather stations for outdoor weather conditions. This may be different from the weather the outdoor unit is experiencing.

ASHP Thermostat Selection

When selecting a thermostat for an ASHP, consideration should be given to the following:

- **Compatibility:** Not all thermostat models are compatible with heat pump system. For instance, most smart thermostats can only be used with centrally ducted ASHPs. In addition, some thermostats may not be able to properly control heat pumps with variable speed compressors. Thermostat specifications should be reviewed to assess compatibility.
- **Wiring:** The wiring required for a heat pump system is different from other HVAC systems. Hence, contractors should ensure that the thermostat under consideration supports the wiring required for heat pumps. Thermostat specifications should be reviewed to assess this aspect of compatibility as well.
- **Supplementary Heating:** Some thermostats support heat pumps but are not compatible with certain types of supplementary heating. Where possible, a thermostat that supports both the heat pump and the supplementary heating system should be selected.

Exhibit 30: Smart Thermostats[i]

[i] Source: How-To-Geek, Nest vs. Ecobee3 vs. Honeywell Lyric: Which Smart Thermostat Should You Buy?, http://www.howtogeek.com/259644/nest-vs.-ecobee3-vs.-honeywell-lyric-which-smart-thermostat-should-you-buy/

Control System Installation

When installing a control system for an ASHP, consideration should be given to the following:

- Place thermostats on interior wall (about 1.5 m high), away from direct sunlight, appliances, or drafts
- Locate any outdoor thermostats in shady protected areas
- In larger spaces (>300 ft^2), a fixed, wall-mounted control should be installed in a location that will be representative of the space the unit is serving.
- For smaller rooms or isolated zones that have no significant thermal/comfort problems, return-air temperature sensing with a handheld remote is acceptable
- Temperature sensing may need adjustment, especially for wall-mounted indoor units. Adjust sensing offset settings for 2-4ºC ("more heating" and "less cooling") for high-wall installations and other situations where air distribution to the space may be compromised. Further adjustments might be required based on occupant feedback.
- Use an integrated multi-stage control for systems that include a central HVAC system as the supplementary heat source. If integrated multi-stage control is not available, use two thermostats.
- Check installer settings as needed. They should include the following, as applicable:
- Retain installer settings during power outage
- Use "efficient home" settings when available to improve cycling behavior in low load situations
- Some compact-ducted air handlers require adjustment for static pressure on duct systems
- When available and not required due to ventilation requirements, installer settings shall be set to avoid continuous fan operation, even at low speeds

Control of Supplementary Heating

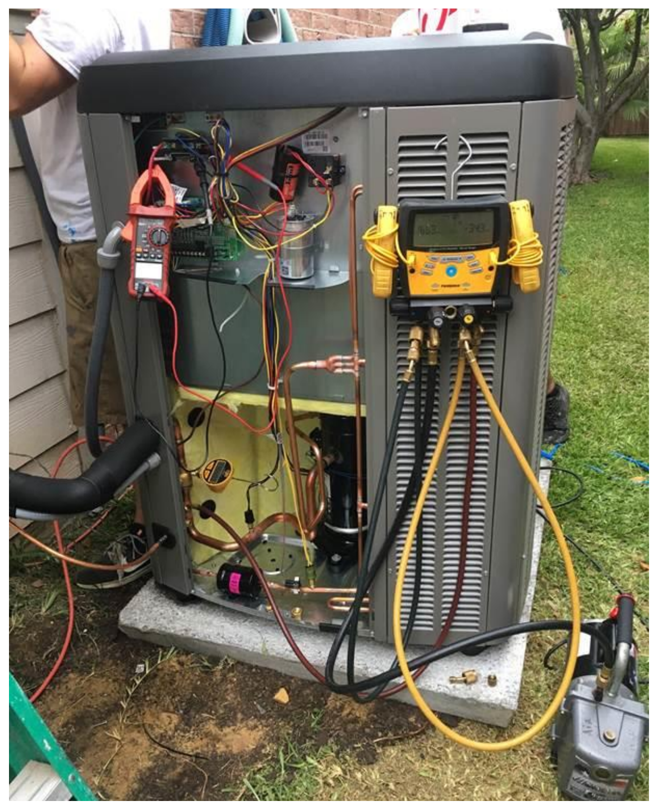
- Supplementary heat must be controlled in such a manner that it does not engage when the outdoor air temperature is above the balance point temperature of the heat pump, except when supplementary heating is required during a defrost cycle or when emergency heating is required during a refrigeration cycle failure.
    - If a low ambient temperature compressor cutout option is installed, it must not cut out the compressor at temperatures above -8°C (17°F) in the case of standard ASHPs and -15°C (5°F) in case of cold climate ASHPs.
    - If thermal balance point used for sizing ASHP, it must not cut out the compressor at temperatures above the thermal balance point temperature.
    - Any independent thermostats for supplementary heating systems (e.g. baseboards) should be turned down 3-5°C lower than the usual to ensure that the heat pump is the primary heating source.
- For constant speed systems with multiple stages of compression and supply air temperature sensor control, supplementary heat shall be controlled in such a manner that it does not engage when the supply air temperature is above 25°C.
- If the supplementary heat is provided by a furnace in the case of centrally ducted ASHP systems, the control system should be setup in such a way that both the systems cannot operate simultaneously.

New York State Energy Research and Development Authority (NYSERDA) and Mass Save (Massachusetts) maintain a list of controllers that are compatible with centrally ducted heat pumps and supplementary heating systems, including systems that are compatible with dual fuel heat pump systems.[24]

EQUIPMENT COMMISSIONING[25]

Once the installation is complete, the system should be commissioned. If instructions are provided by the manufacturer, they must be followed; otherwise, testing and commissioning must comply with the Section 6.3 of CSA Standard C273.5-11 with consideration to the following:

- Confirm that all control settings are done as per manufacturer's specifications taking the economic cut-off and thermal balance point setting into consideration
- Check all control and electrical wiring connections before starting the system
- Clean all ductwork (where requested by homeowners), accessories, and existing air handlers and install a clean filter as per design before start-up
- At a minimum, the following operational checks and measurements should be completed:
    - **Refrigerant charge:** Refrigerant charge evaluation relies on measurement of operating pressures and comparison to pressures specified by the manufacturer. The specified pressures correspond to measured ambient (and perhaps indoor) temperatures. Record refrigerant line set length and any adjustments thereof. Sometimes, the outdoor unit might be improperly charged, which can be checked by measuring the operating pressures. Use the method approved and specifically stated by the manufacturer to measure operating pressure and ensure proper refrigerant charge.
    - **Airflow:** The airflow across indoor coils shall be as per manufacturer's specifications. Take airflow readings when the system is believed to be in full heating capacity flow. For multiple-stage systems, it may be necessary to test in partial capacity depending on various factors. For major renovations with newly designed and installed central ductwork, the airflow to individual rooms should be balanced to the designed duct system flow.
    - **Power inputs:** Power inputs of the circulating fan motor and compressor motor should be as per manufacturer's specification. Ensure that all electrical components are operating below their maximum amperage rating (RLA).



3.6 HOMEOWNER EDUCATION AND MAINTENANCE

One of the biggest factors in a homeowner satisfaction with their new ASHP system is their understanding of how to operate and maintain the system. The contractor should facilitate this understanding and should clarify any owner responsibilities once the installation is complete. This also provides an opportunity for contractors to propose a service plan for new ASHP systems, which is beneficial to the continued optimal performance of the equipment and future contractor business.

Contractors should always provide the homeowner with all heat pump related documentation. They should also demonstrate basic ASHP operation and maintenance procedures in order to ensure that the homeowner is comfortable operating their new equipment. The following list provides a summary of documentation that should be provided and topics that should be discussed and/or demonstrated with the homeowner before leaving the site:[26,27]

- Original equipment manufacturer (OEM) equipment performance information and Owner’s Manual
- Model and serial numbers of all equipment
- Proper operation of the system, including operation and programming of the indoor temperature controller (i.e. thermostat)
- Explanation of the proper service and maintenance requirements, which should include the following types of maintenance:
    - Filter replacement – what products are acceptable (size, efficiency, etc.)
    - Annual equipment servicing requirements
    - Establishing a maintenance schedule
    - Benefits of a maintenance contract versus callouts as required
- A discussion of other common maintenance concerns. For example:
    - Watch for snow buildup that blocks the outdoor unit
    - The cloud of water vapor that looks like smoke upon defrost termination and indications of improper defrost cycling (buildup of frost on the outdoor unit coils)
- Warranty coverage of the ASHP system and control system including servicing requirements for compliance with warranty policy
- Copy of installation record and commissioning checklist
- Proper labeling of switches
- Information on the following heat pump heating characteristics:
    - Longer runtimes
    - Lower supply air temperature
    - Implications of using setback
    - Where applicable, additional details on how heat pumps are different from the combustion appliances (e.g. furnaces) being replaced

3.7 COMMON CHALLENGES AND SOLUTIONS

There are a variety of challenges that can lead to poor performance of ASHP installations. If not addressed, these challenges can result in higher energy consumption, decreased equipment longevity, and sub-optimal occupant comfort. Some common challenges encountered by ASHP installation contractors and the suggested solutions for overcoming these barriers are summarized below. At a high level, it is recommended that contractors attend factory-sponsored training and keep current with evolving technology on an ongoing basis (i.e. continuing education).

Exhibit 31: Summary of Common Challenges and Solutions

Issue/Challenge	Solution
System requires more control wires	Implement one of the following solutions: • Rough in 18-8 or 18-10 thermostat wire • Employ wireless thermostats or thermostats that use only two wires • Use existing thermostat location and wiring for a temperature sensor and install a new thermostat in an alternate location
ASHP controls (i.e. thermostats and control panels) have more connections	Read and follow field wiring diagrams
Higher level of snow accumulations	Use risers or "pump-ups" to get outdoor units high enough off the ground
Water runs out of the outdoor unit during defrost and can re-freeze on the ground	Provide a safe, suitable drainage plane for the water and ice
Heating capacity drops with the outdoor temperature	Ensure adequate supplementary heat or use cold climate heat pumps
Defrost controls and reversing valves have unique service and repair considerations	Attend factory-sponsored training and keep current with evolving technology (i.e. continuing education)
Installations or repairs may have to be done outdoors in the winter	Maintain a portable heat source (radiant propane or kerosene "torpedo" heater) for field use in the winter. A more comfortable technician is more likely to do high quality work.
Excessive number of call-backs related to installs	Properly educate homeowners (refer to Homeowner Education and Maintenance section)
Excessive use of supplementary heating system	Ensure that lockout temperature is appropriate and that the control system is programmed properly to operate in conjunction with the supplementary heating system. Homeowner education is also very important to ensure optimal performance of the ASHP.
Capacity of existing duct system insufficient for centrally ducted ASHP system	Complete duct system improvements (e.g. adding turning vanes, replacing square elbows, etc.) to improve the capacity of the duct system. Building envelope upgrades that reduce the heat load can also help to solve this issue.
Misconceptions about heat pump sizing limitations (e.g. heat pump can't be primary heater as it can't be sized for >125% of cooling load)	Multi-stage or variable capacity ASHP and cold climate system (ccASHP) can be designed/sized for >125% of cooling load.

4 | GLOSSARY

ASHP: Air-source heat pump.

Block Load: Heating and cooling load for entire conditioned space.

BTU/h: British Thermal Units per hour. Rate of energy use or transfer equivalent to 0.293 Watts.

ccASHP: Cold climate air-source heat pump. ccASHPs have improved performance in colder weather, including a lower thermal balance point temperature than standard air-source heat pumps.

Climate zones: Regions of Canada that have a similar number of heating degree days (HDD) in the heating season. Canada is subdivided into six climate zones (i.e. Zones 4, 5, 6, 7A, 7B and 8), ranging from <3000 HDD (Zone 4) to ≥7,000 HDD (Zone 8).

COP: Coefficient of performance is a dimensionless ratio used to indicate heating or cooling efficiency of a heat pump at a specific outdoor temperature. The COP of a heat pump is the rate of heat (or cooling) delivered divided by rate of electricity used by the heat pump. Higher COP ratings indicate higher efficiencies. The COP of a heat pump in heating mode declines with decreasing outdoor air temperature, and in cooling mode the COP declines with increasing outdoor air temperature. A heat pump operating with a COP of 3.0 at a particular outdoor temperature will deliver 3 kW of heat (equivalent to 10,250 BTU/h) for each kW of electricity consumption.

CSA: Canadian Standards Association

Cut-off control: A control device that restricts the operation of a heat pump or backup heating system to a predetermined range of outdoor temperatures.

Cut-off temperature: The outdoor temperature, below which the operation of an air-source heat pump is restricted by an outdoor control, and full back-up heating is used for heat the building or target. The cut-off temperature value can be determined by either a “low-temperature cut-off limit” of the heat pump equipment, or by an “economic cut-off temperature” that is determined by equipment efficiencies.

EER: Energy efficiency ratio. Used to indicate the cooling efficiency of a heat pump or air-conditioner at a particular operating point, expressed in BTU/h of cooling energy per Watt of electricity consumption. EERs vary with outdoor temperature.

EEV: Electronic expansion valve.

GSHP: Ground-source heat pumps also know as geothermal heat pump (GHP)

HDD: Heating degree day (HDD) is a measurement designed to quantify and compare the heating needs of buildings in different geographical areas. The HDDs for a location are calculated based on a comparison of the outdoor temperature for every hour in the heating season compared to a reference temperature above which heating is not required (generally 18°C in Canada).

HSPF: Heating Seasonal Performance Factor characterizes the average efficiency of an ASHP over a typical heating season. The HSPF is the ratio of BTUs of heating delivered to watt-hours of electricity consumed over the heating season. A higher HSPF rating indicates a higher efficiency. HSPF ratings for ASHPs vary by “Climate Zone”.

HRAI: The Heating, Refrigeration and Air Conditioning Institute

HVAC: Heating, Ventilation and Air Conditioning.

kW: kilowatts, rate of energy use or transfer. Is used to rate electric power consumption of equipment, or the output capacity of heating or cooling equipment. One kW is equivalent to 3,412 BTU/h.

kWh: Energy consumption or thermal energy expressed in kilowatt-hours, equivalent to the amount of electricity consumed by a 1 kW load running continuously for one hour. One kWh is equivalent to 3,412 BTU.

SEER: Seasonal Energy Efficiency Ratio for electric cooling equipment over a typical cooling season. The SEER rating is the ratio of BTUs of cooling delivered to watt-hours of electricity consumed over the cooling season. A higher SEER rating indicates a higher efficiency.

Supplementary heating system: Heating system needed when the heat pump cannot provide enough heat to meet a building's heating load (e.g. furnace, electric baseboard, electric resistance heater, etc.)

TECA: Thermal Environmental Comfort Association

Thermal balance point: Outdoor temperature at which the heating load of the home just matches the heat pump's output capacity. Below the thermal balance point, the building heating load grows and the heat pump output declines sufficiently that the heat pump cannot meet the heating load without any support from a supplementary heating system.

5 | ADDITIONAL RESOURCES

- ACCA Manual H, Heat Pump Systems: Principles and Applications, Second Edition. ISBN 978-1-892765-07-9
- Air-Source Heat Pump, National Renewable Energy Laboratory, U.S. Department of Energy (DOE), June 2001. Available at: https://www.nrel.gov/docs/fy01osti/28037.pdf
- Air-Source Heating Pump Installation Commissioning Procedure, Performance Tested Comfort Systems®, BPA, February 2006. Available at: https://www.bpa.gov/EE/Sectors/Residential/Documents/Heat_Pump_Commissioning_procedure_2007.pdf
- Assessment of Residential and Small Commercial Air-Source Heat pump (ASHP) Installation Practices in Cold-Climates, NEEP. Available at: https://neep.org/sites/default/files/AssessmentofResandSmallComm ASHPInstallationPracticesinCold-Climates.pdf
- Best Practices For Installing Ductless Heating And Cooling Systems, DoingDuctless.com. Available at: https://goingductless.com/assets/documents/uploads/DHP_BP-Guide.pdf
- Cold Climate Air-Source Heat Pump Demonstration, Natural Resources Canada (NRCan), Nov. 23, 2006. Available at: https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/current-investments/cold-climate-air-source-heat-pump-demonstration/4965
- Cold Climate DHP Specification and Recommendations, Guidance for Northwest IECC Climate Zones 5 and 6, Version 1.01-April 2019. Available at: https://neea.org/img/documents/NEEA-Cold-Climate-DHP-Spec-and-Recommendations.pdf
- Getting The Most Out of Your Heat Pump, Northeast Energy Efficiency Partnership (NEEP). Available at: https://neep.org/sites/default/files/GettingTheMostFromYourHeatPumpConsumerGuideFINAL.pdf
- Good practice guide: Heat pump installation, New Zealand Energy Efficiency and Conservation Authority, June 2019. Available at: https://consumer-nz-assets.s3.amazonaws.com/assets/2065/Good_practice_heat_pump_installation.pdf
- Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates, NEEP. Available at: https://neep.org/sites/default/files/Sizing%20%26%20Selecting%20ASHPs %20In%20Cold%20Climates.pdf
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- Heating and Cooling with a Heat Pump, Natural Resources Canada (NRCan), December 2004. Available at: https://www.nrcan.gc.ca/energy/publications/efficiency/residential/heating-heat-pump/6817
- Installation of air-source heat pumps and air conditioners, CSA Standard C273.5-11 (reaffirmed 2015).

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[2] Erin Kruse and Larry Palmiter, Ecotope, Inc, *"Measured Effect of Air Flow and Refrigerant Charge on Heat Pump Performance in Heating Mode"*, ACEEE Summer Study on Energy Efficiency in Buildings, 2006. Available online at: https://aceee.org/files/proceedings/2006/data/papers/SS06_Panel1_Paper14.pdf

[3] Air-Source Heat Pump (ASHP) Installation Practice: Final Report, October 15, 2018, FortisBC

[4] British Columbia Water Temperature, https://www.seatemperature.org/north-america/canada/british-columbia/

[5] Guide to Installing Air-Source Heat Pumps in Cold Climates, Northeast Energy Efficiency Partnership (NEEP). Available online at: https://neep.org/sites/default/files/Installing%20Air-Source%20Heat%20Pumps%20in%20Cold%20Climates.pdf

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[19] CAN/CSA C273.5-11: Installation of air-source heat pumps and air conditioners

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