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Electrifying Building Heating with Heat Pumps in Residential Sector

Shahriar Ghahremanian, PhD, PMP, PEng, CEM, GBE, CEA, CMVP

Agenda

- An overview of heat pump technology and its application in the Ontario market
- Typical retrofit opportunities for multi-unit residential housing including single family/townhouse style for social housing
- Full fuel switch versus hybrid solutions
- Overview of the business case - what variables to factor in life cycle cost analysis using capital repair plans and building condition assessments for planning
- Tips on finding and working with contractors

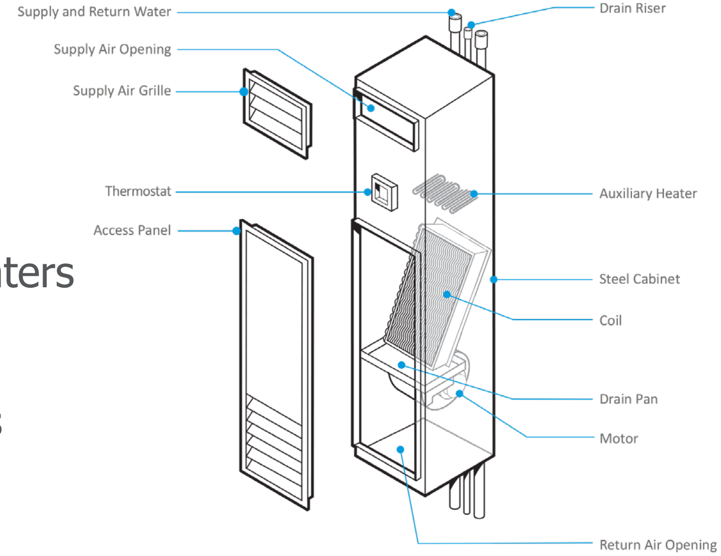
Typical space conditioning systems for residential buildings

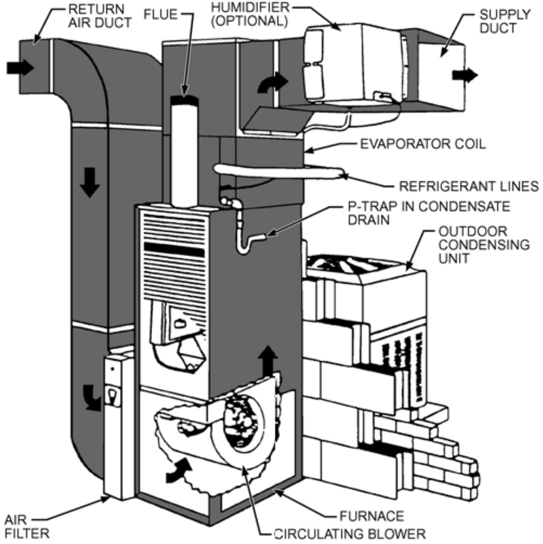
Heating

- Furnaces
- Boilers
- Heat pumps
- Electric Baseboard Heaters

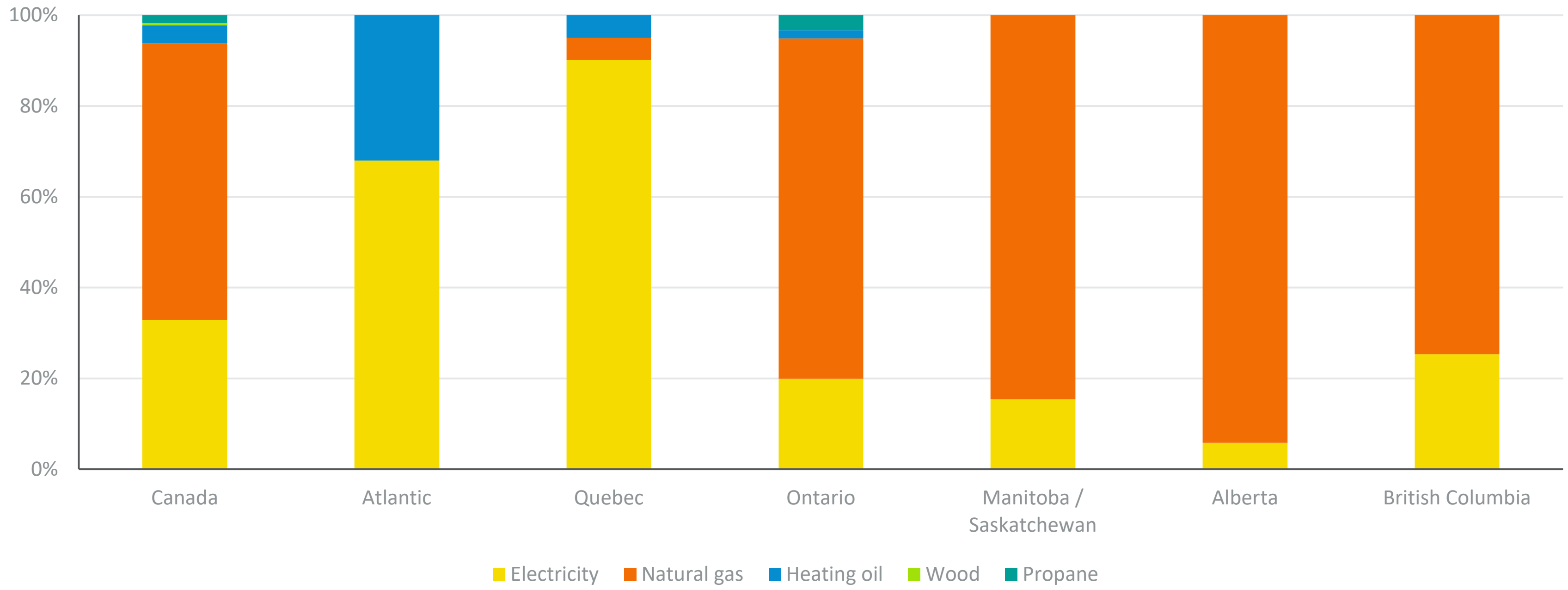
Cooling

- Central Air Conditioners
- Ductless Mini-Split Air Conditioners
- Combined/Hybrid Systems: Heat Pump





Regional residential heating system energy source



Source: Natural Resources Canada

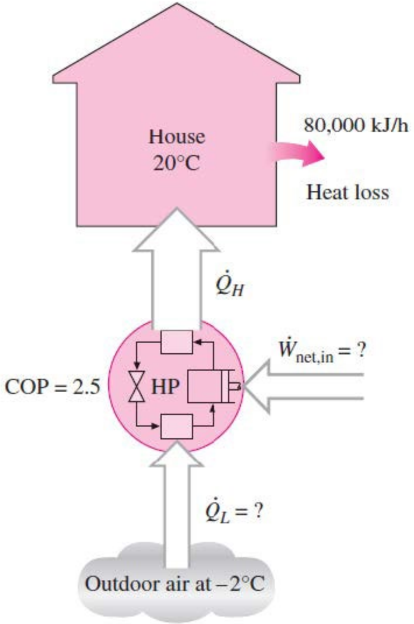
Why choose a heat pump system?

Heat pumps offer several advantages over other traditional heating and cooling systems

- Energy efficiency
- Versatility
- Environmental benefits
- Improved safety
- Improved comfort
- Longer Lifespan
- Zone control

Why heat pumps are more efficient

A heat pump is used to meet the heating requirements of a building and maintain it at 20°C. On a day when the outdoor air temperature drops to -2°C, the building is estimated to lose heat at a rate of 80,000 kJ/hr = 75,000 Btu/hr = 22 kW = 6.3 ton).



Why heat pumps are more efficient

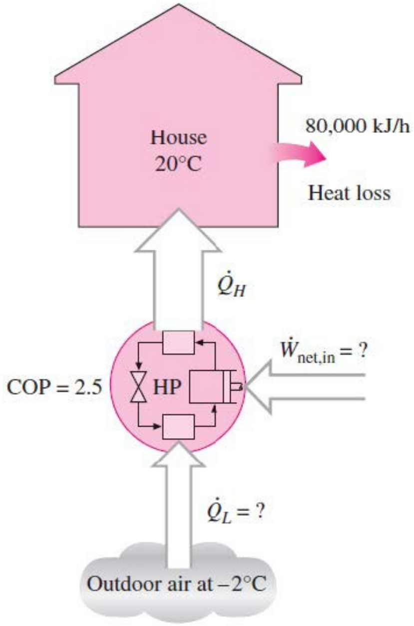
If the heat pump under these conditions has a COP of 2.5:

Power Consumption by heat pump:

$$W_{net,in} = \frac{Q_H}{COP_{Heat\ Pump}} = \frac{80{,}000\ kJ/hr}{2.5} = 32{,}000\ kJ/hr = 8.9\ kW$$

Rate of heat transfer from outdoor:

$$Q_L = Q_H - W_{net,in} = (80{,}000 - 32{,}000)\ kJ/hr = 48{,}000\ kJ/hr = 13.3\ kW$$

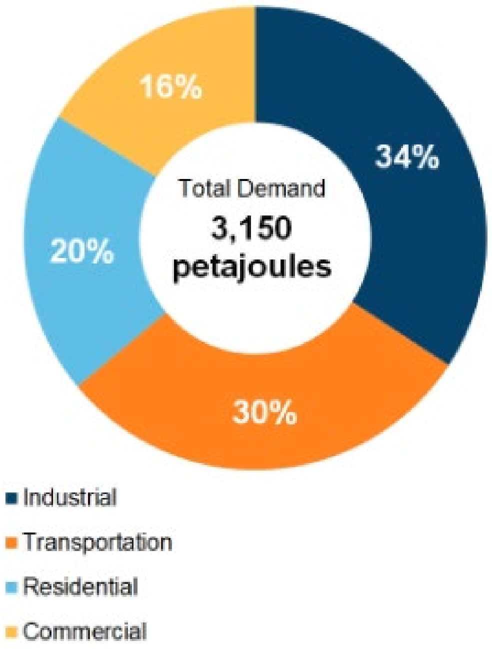


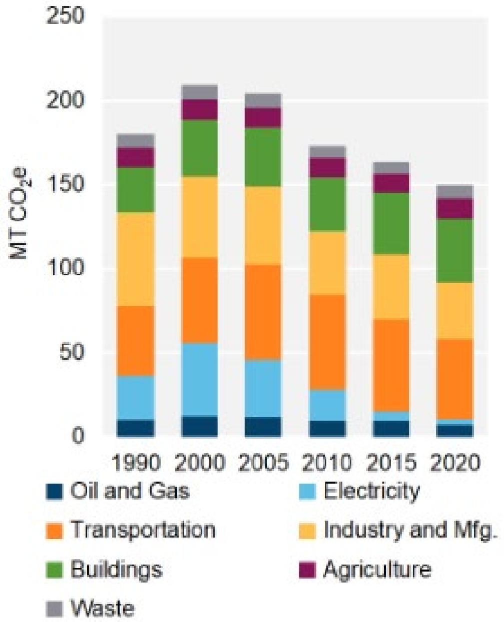
Where heat pumps fit in today and in the future

- Energy used for heating residential and commercial/institutional buildings combined currently accounts for 16% of all energy used in Canada and 13% of energy related GHG emissions.
- Electricity used to heat homes in Canada has increased from 21% of the total in 2000 to 31% by 2020, mostly from the installation of electric baseboard heating systems – which are only half as efficient as heat pumps.By 2021, heat pumps were the primary heating systems in two per cent of those in Ontario households.
- Ontario’s low emissions electricity means less greenhouse gases (GHGs) emitted per unit of energy generated when compared to other home-heating fuels like heating oil, propane, or natural gas.

Source: Net Zero by 2050 – A Roadmap for the Global Energy Sector, IEA
Canadian Climate Institute

End-use demand & GHG emissions by sector





Source: Canada Energy Regulator, Provincial and Territorial Energy Profiles – Ontario

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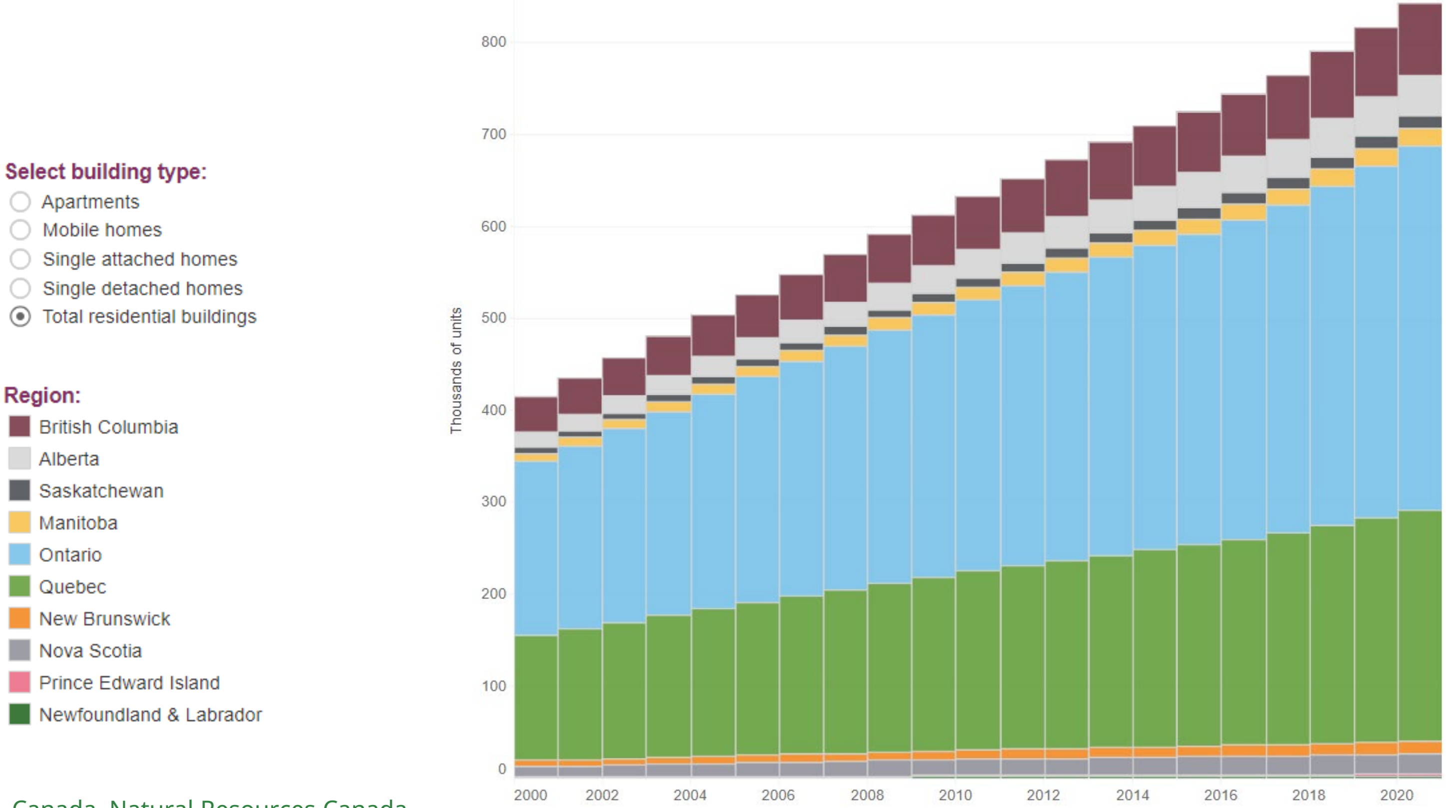
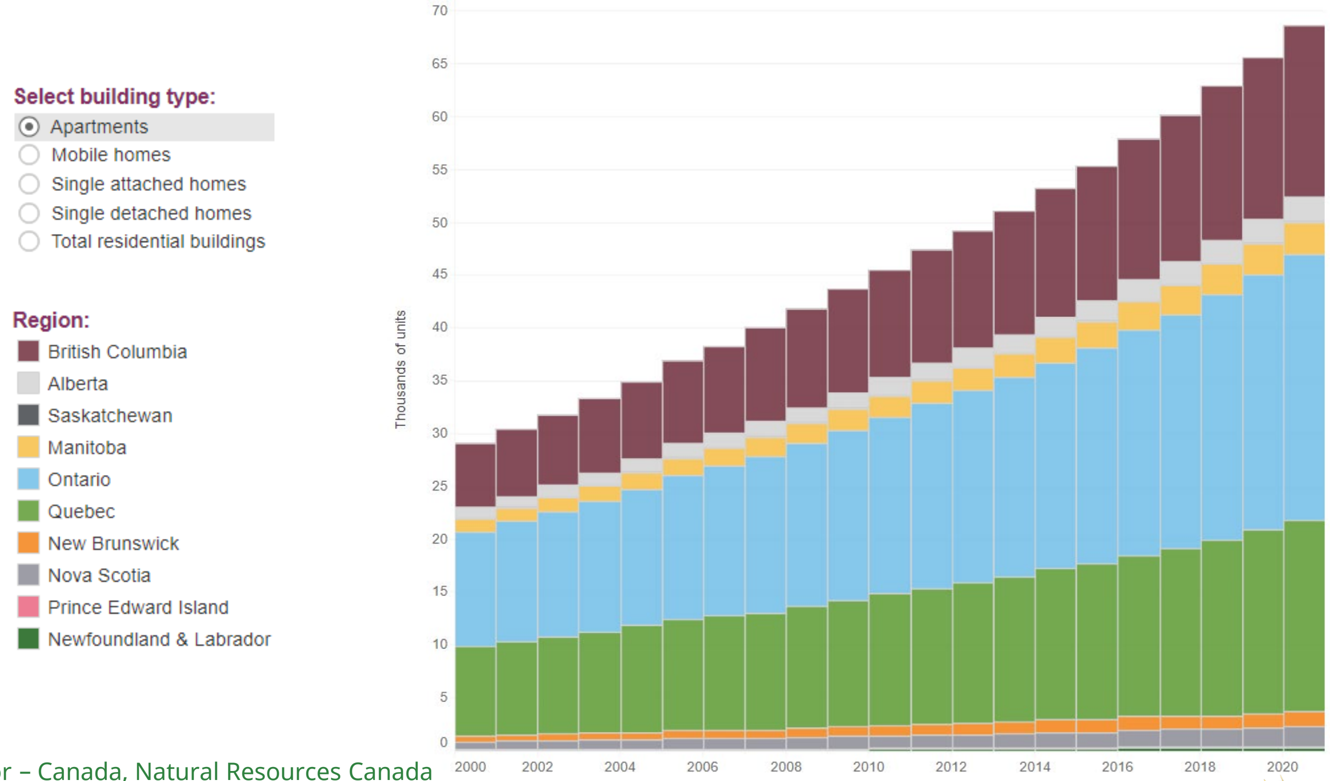
Total residential heat pumps installed in Canada



Residential Sector – Canada, Natural Resources Canada

Residential heat pumps installed in Canada - apartments



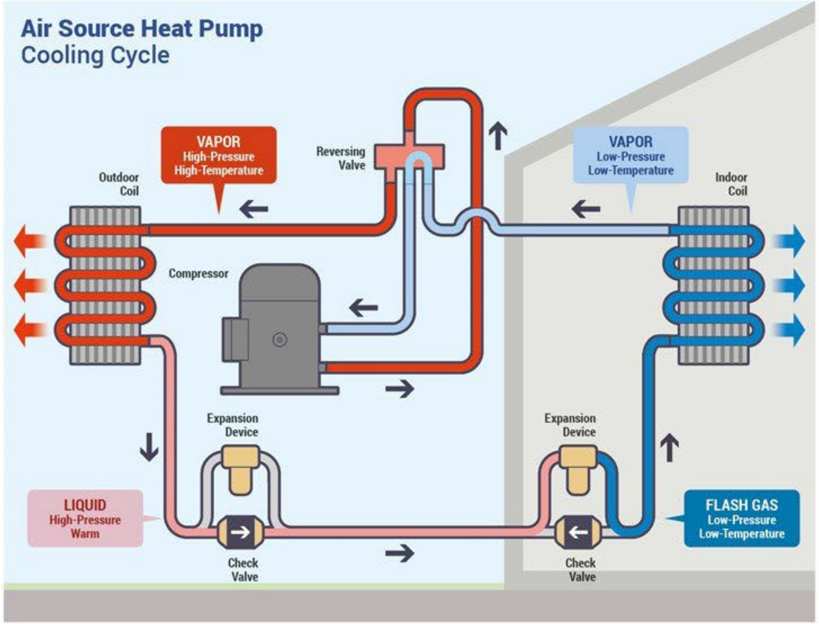
Residential Sector – Canada, Natural Resources Canada

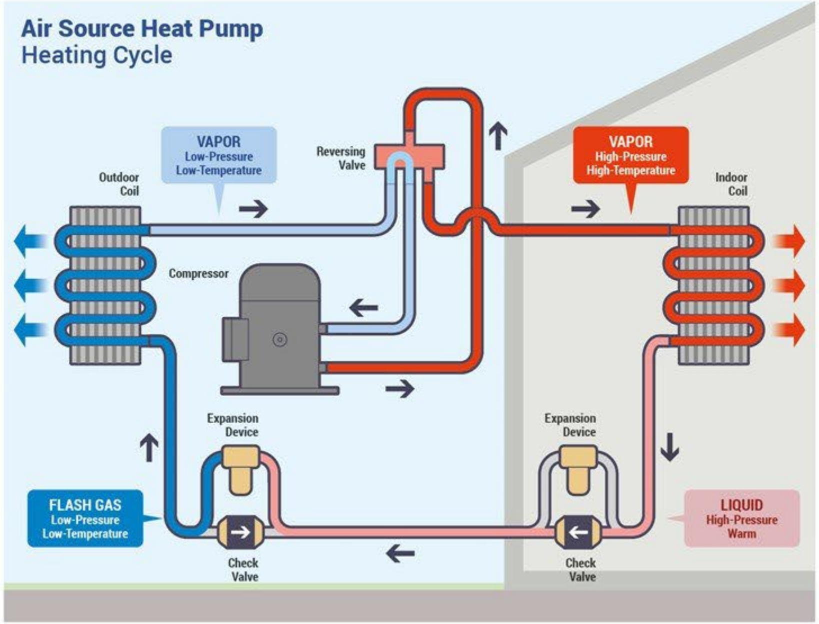
Heat pump technology

What is a heat pump?

- A mechanical device in the house that can move warmth around.
- When it's cold outside, this device can take warmth from the air, ground, or water outside and bring it inside to make the house warmer.
- And when it's hot outside, it can take warmth from inside the house and move it outside to cool the space.

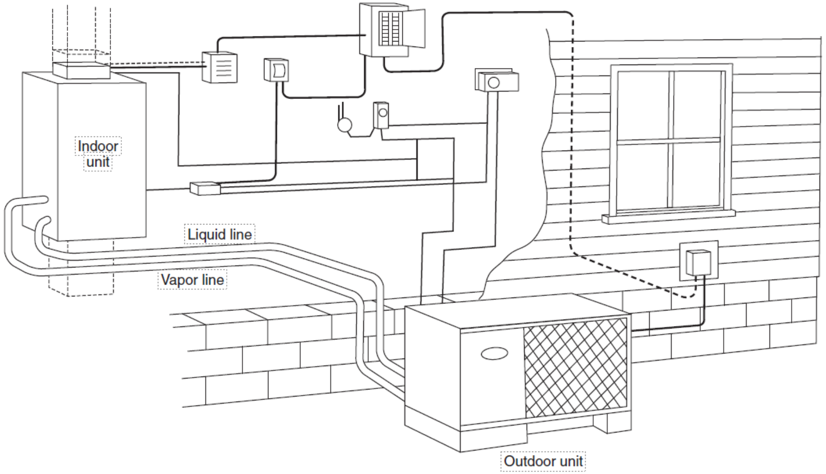
The refrigeration cycle





Air-to-air split systems

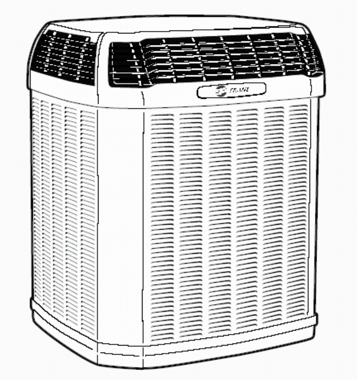
- Air-to-air split-systems are the most common type of heat pump.
- Favorable installation, operation, and maintenance costs.
- System manufacturing is completed in the field by the installing contractor using ductwork, refrigerant piping, and wiring.



Air-to-air split systems cont’d

Major components in the outdoor unit are:

- Heat exchanger coil
- Fan and motor
- Metering device
- Check valve
- Reversing valve
- Defrost controls
- Compressor



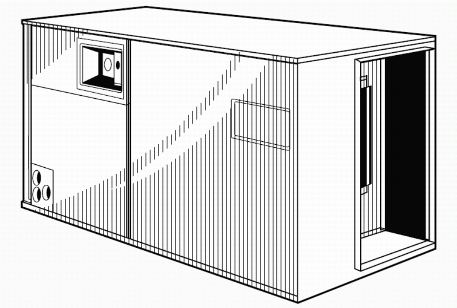
Outdoor unit functions

- The outdoor section serves as the *condenser* in the summer:
  - It rejects indoor heat to the outdoor air
- The outdoor section serves as the *evaporator* in the winter:
  - It extracts heat from outdoor air for rejection to the indoor air

Air-to-air split systems cont'd

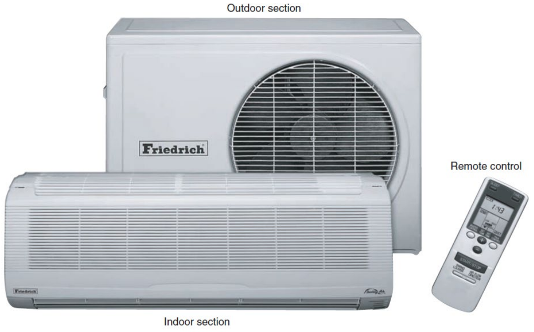
Major components in the indoor unit are:

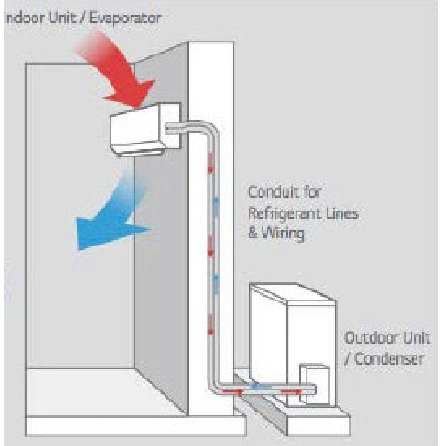
- Indoor heat exchanger
- Fan and motor
- Supplemental heat source



Mini-split heat pumps

- Mini-split or ductless heat pumps lend themselves to applications where ductwork can not be conveniently installed.
- Indoor sections may be wall-mounted, floor-mounted, or cassettes for use in a drop ceiling.
- Provide zone control without ductwork.

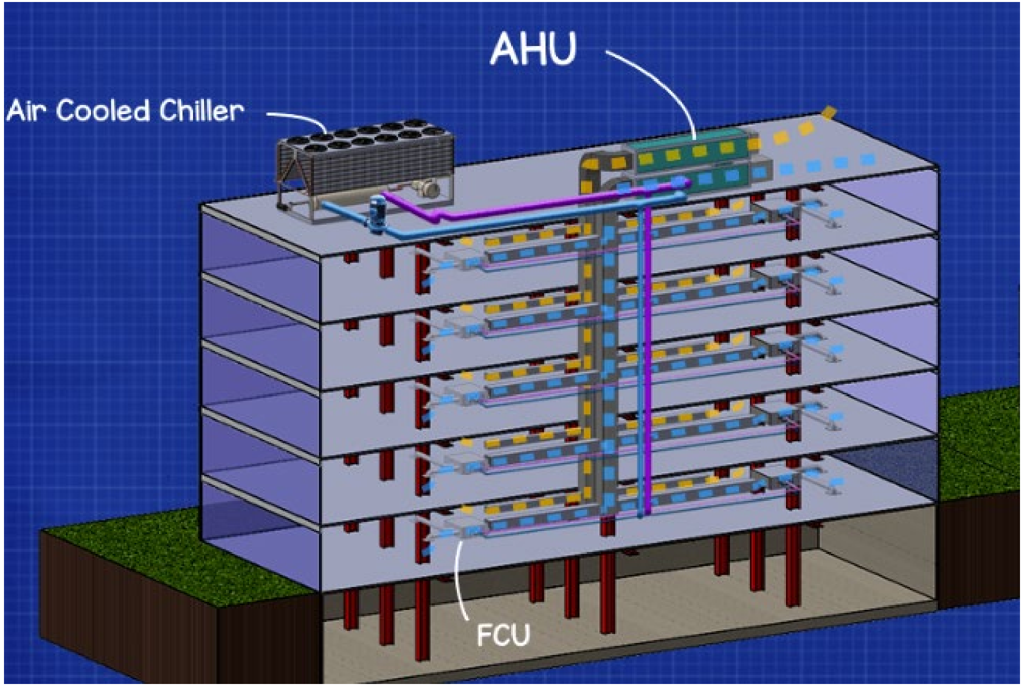


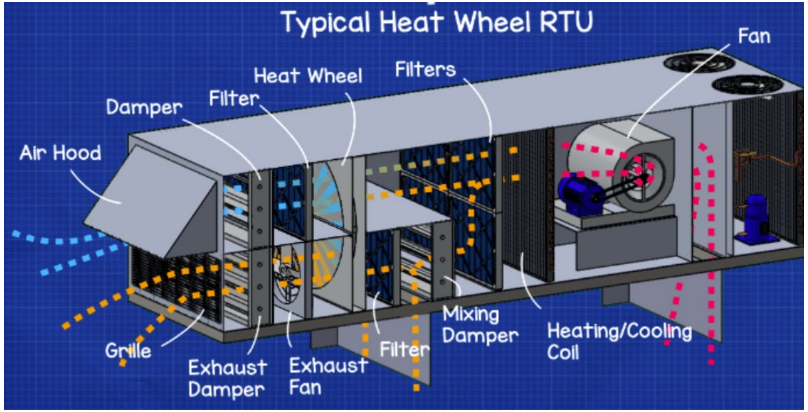


Packaged heat pumps

- Packaged, or self-contained heat pumps have all indoor and outdoor components located in a single cabinet.
- Rooftop units may be set on roof curb with ductwork connecting horizontally or vertically.
- May be set at ground level on a concrete pad.

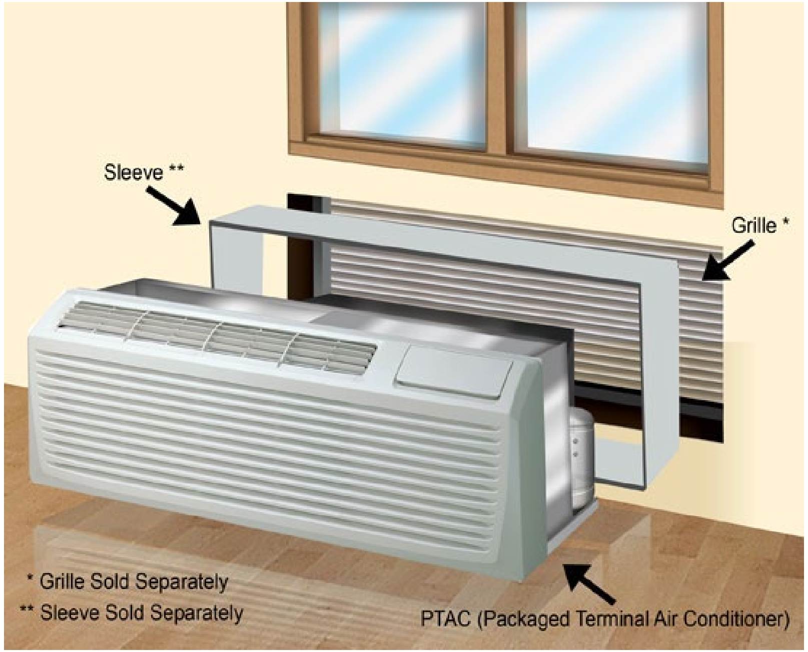
Roof Top Units





Packaged terminal heat pumps

Packaged terminal heat pumps are self-contained, through-the-wall units of the kind commonly used in some residential buildings.



Water-source heat pumps

Water source heat pumps are preferred as they are independent of the Outdoor Air Temperature!

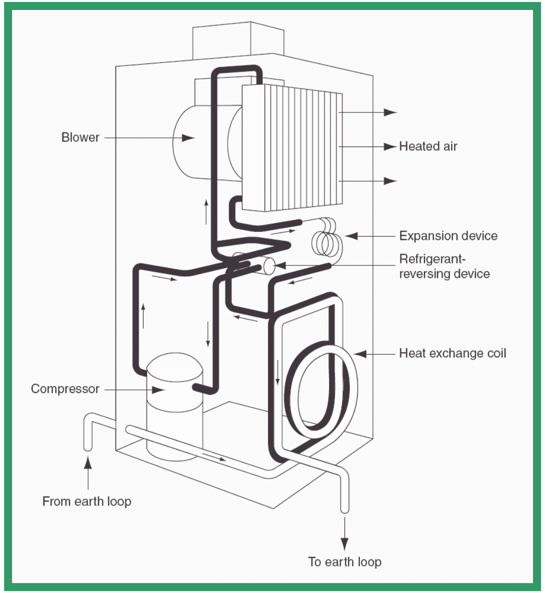
- No defrost cycle is needed with water-source heat pumps
- Provides excellent efficiency
- Compressor life benefits
- Widely popular in residential applications

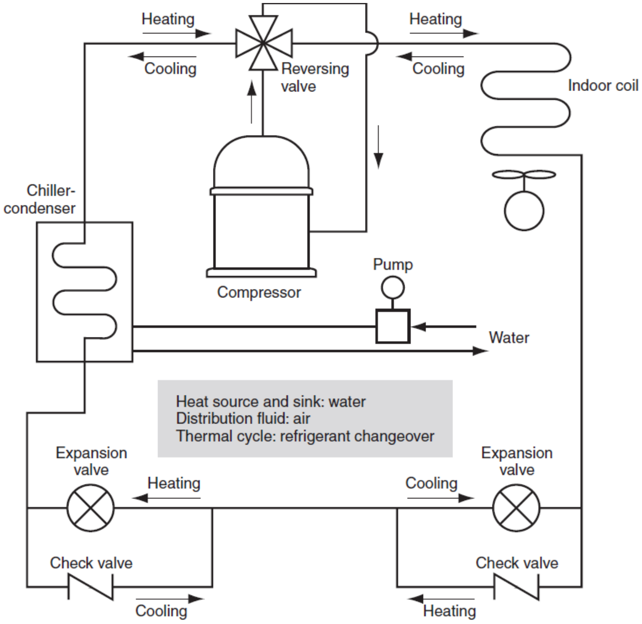
Water-source equipment is available based on several different design strategies. These units may be separated into two broad categories: open-loop systems and closed-loop systems.

Water source or water-to-water heat pumps

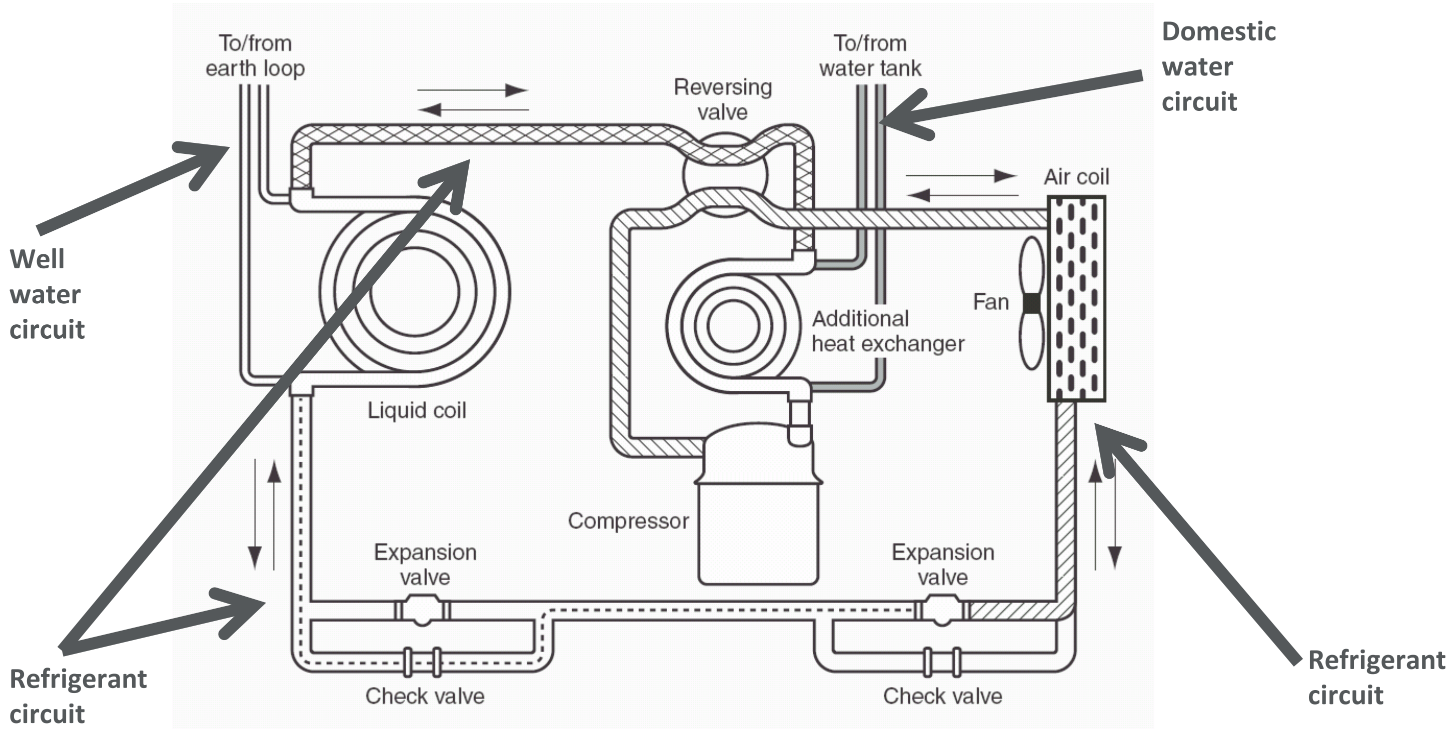
Use water as both a source and a sink.

Typical Single-Package WSHP





Basic water source heat pumps (WSHP) fluid circuits



Open-loop ground water

Ground water must usually exceed 4°C (40°F) for use in the heating mode of operation

- Lower water temperatures could freeze the evaporator

Ground water must be 32°C (90°F) or less for use in the cooling mode of operation

- Heat extracted from indoor air is rejected into the ground water

Closed-loop systems

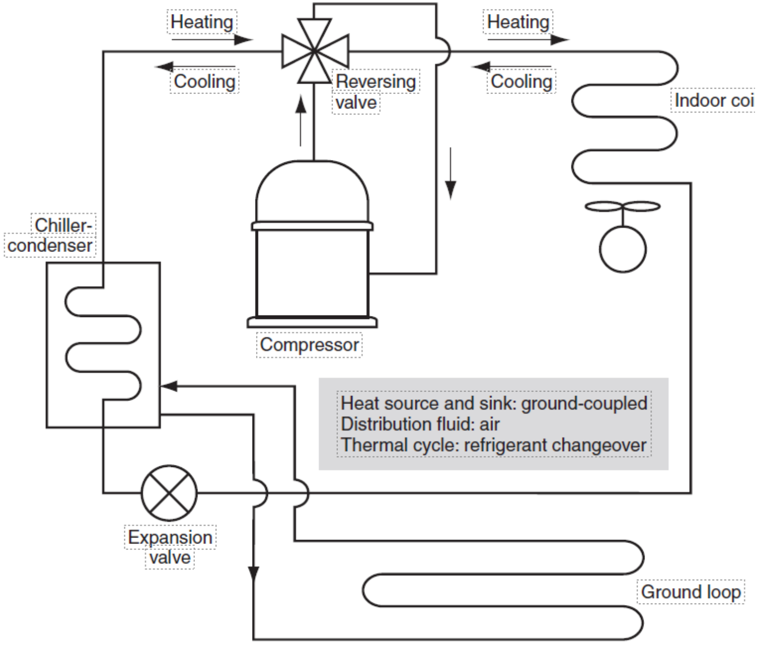
- Tubing loops may be installed in either vertical or horizontal configurations
- The soil is used as both a source and a sink

  More accurately referred to as “ground-source”
- Adequate distance must be maintained between tubing loops to use the soil effectively as a heat exchange medium

Closed-loop water-source heat pumps

No defrost cycle is needed with water-source heat pumps

- Provides excellent efficiency
- Compressor life benefits



Large buildings

Ground coupled or closed-loop heat pumps can be used to transfer heat from zone to zone within a large building. Cooling and heating can be done simultaneously.

- Cooling towers and plate frame heat exchangers may be added to the water loop to serve as the sink during the cooling season.
- Boilers can be added to the water loop for heating in extreme weather to maintain a 16°C (60°F) loop temperature is desired.

Water-to-water heat pumps

Capable of producing from 1.7 to 54 °C (35 to 130°F) water temperatures for commercial, industrial, and residential applications.

Applications include:

- Hydronic baseboard heating
- Radiant slab heating
- Space heating or cooling utilizing fan coils
- Ice and snow removal

Hydronic heat pump

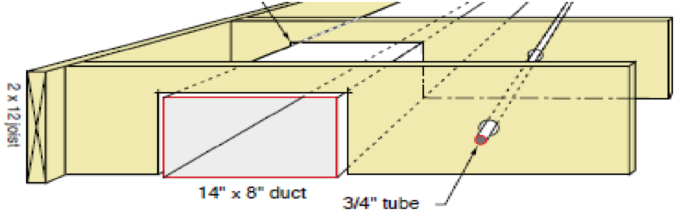
Hydronic systems use water or water-based solutions to move thermal energy from where it is produced to where it is needed.

Why Hydronic Systems?

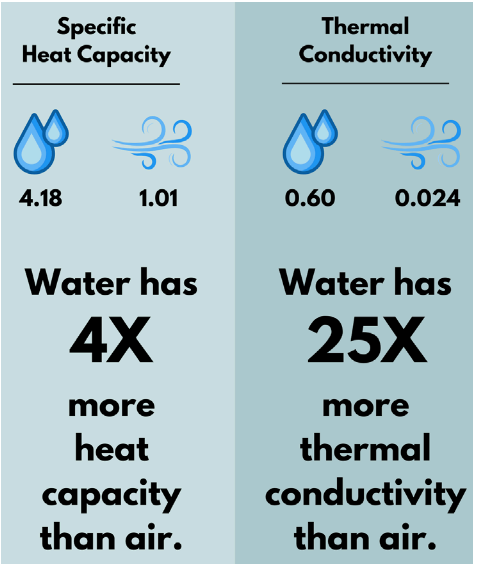
- **Comfort**: Control air and surface temperature.
- **Energy savings**: Very high distribution efficiency.
- **Design flexibility**: Easy to adapt to a wide range of renewable heat sources.
- **Clean and quiet operation** compared to forced air systems.
- **Lower temperature operation**.
- **Easy to zone** to reduce loads.
- **Versatility**: A single heat source can supply heating and DHW.
- **Aesthetics**: No building filled with refrigerant tubing.
- **Less maintenance** compared to forced air systems.
- **Intelligence**: Potential for thermal metering.

Water vs. air

- Water is vastly superior to air for conveying heat.
- Due to the high heat capacity of water, the heat conduits are much smaller than air heating systems.
- Less material is required to insulate the tubing compared to ducting



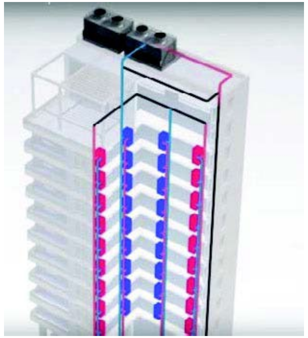
For 80 kW heating/cooling with temperature difference of 2°C, we need: 33,000 lit/s of Air 11 lit/s of Water

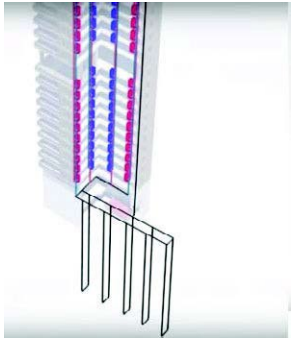


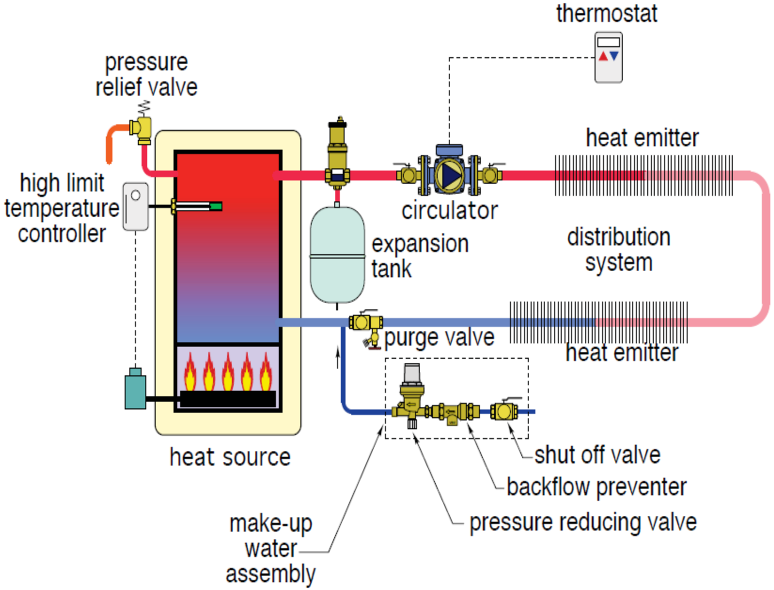
Hydronic heating system components

The overall hydronic system consists of four inter-related subsystems:

- Heat source
- Distribution system
- Heat emitters
- Control system







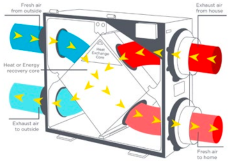
Classification of heat sources

Hydronic heat sources are classified as follows:

- Fossil-fuel boilers
- Electric thermal storage (ETS) equipment
- Hydronic heat pumps
- Renewable heat sources:
    - Solar thermal collectors
    - Solid-fuel boilers

Electrification of heating systems: typical retrofit opportunities for residential and multi-unit residential buildings

Energy hierarchy



Study: Audit and Analysis

Avoid and Reduce Waste: Energy Conservation

Unplug Appliances When Not in Use

2

Use Natural Lighting

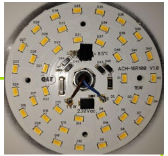
3

Close Blinds and Curtains

Reuse/Recover Waste Energy

Improve:

- Energy Efficiency
- Energy Management
- Demand Management



Onsite Switch:

- Renewable Energy Sources
- Low Emission Energy Sources

Offset

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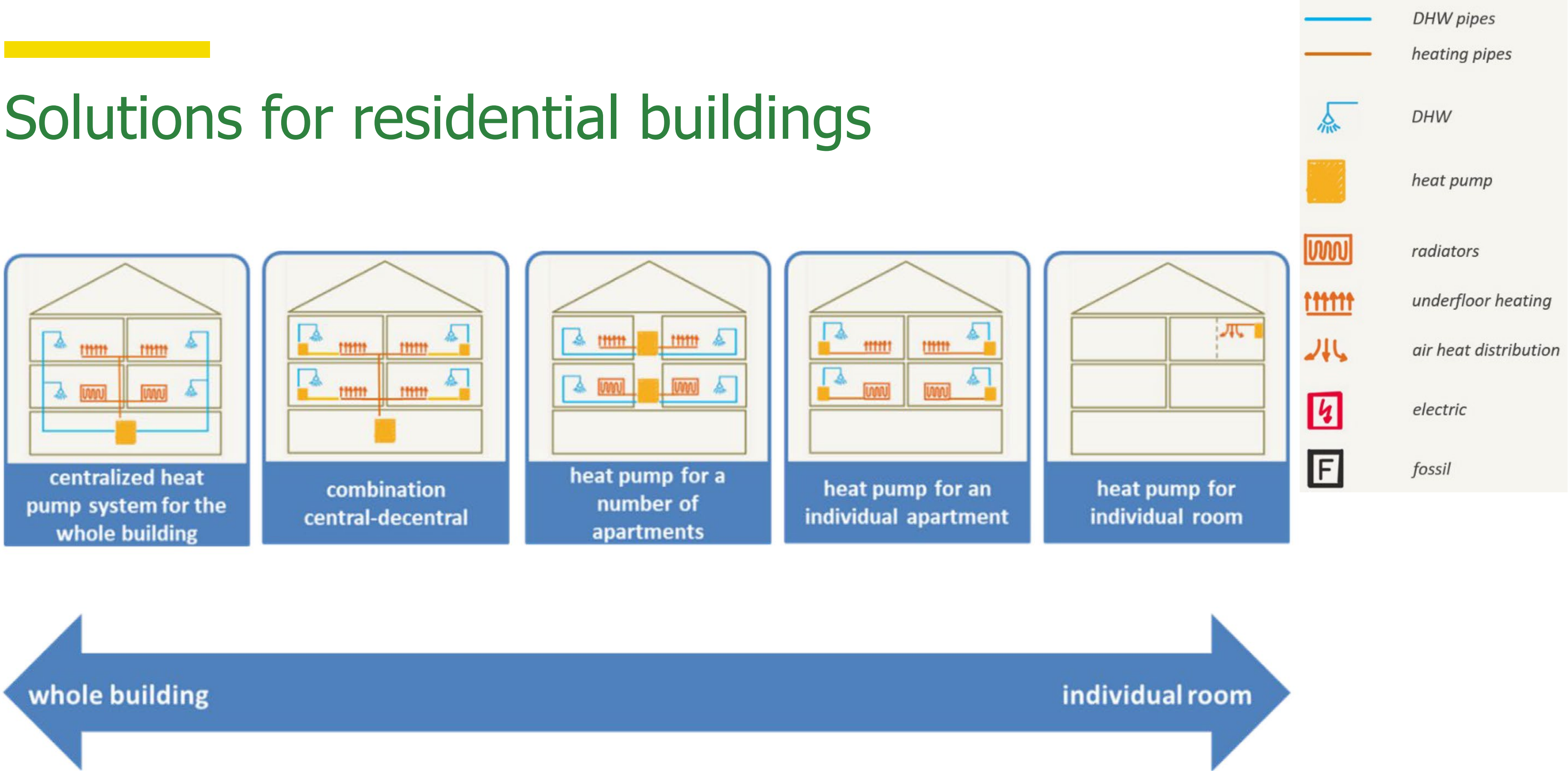
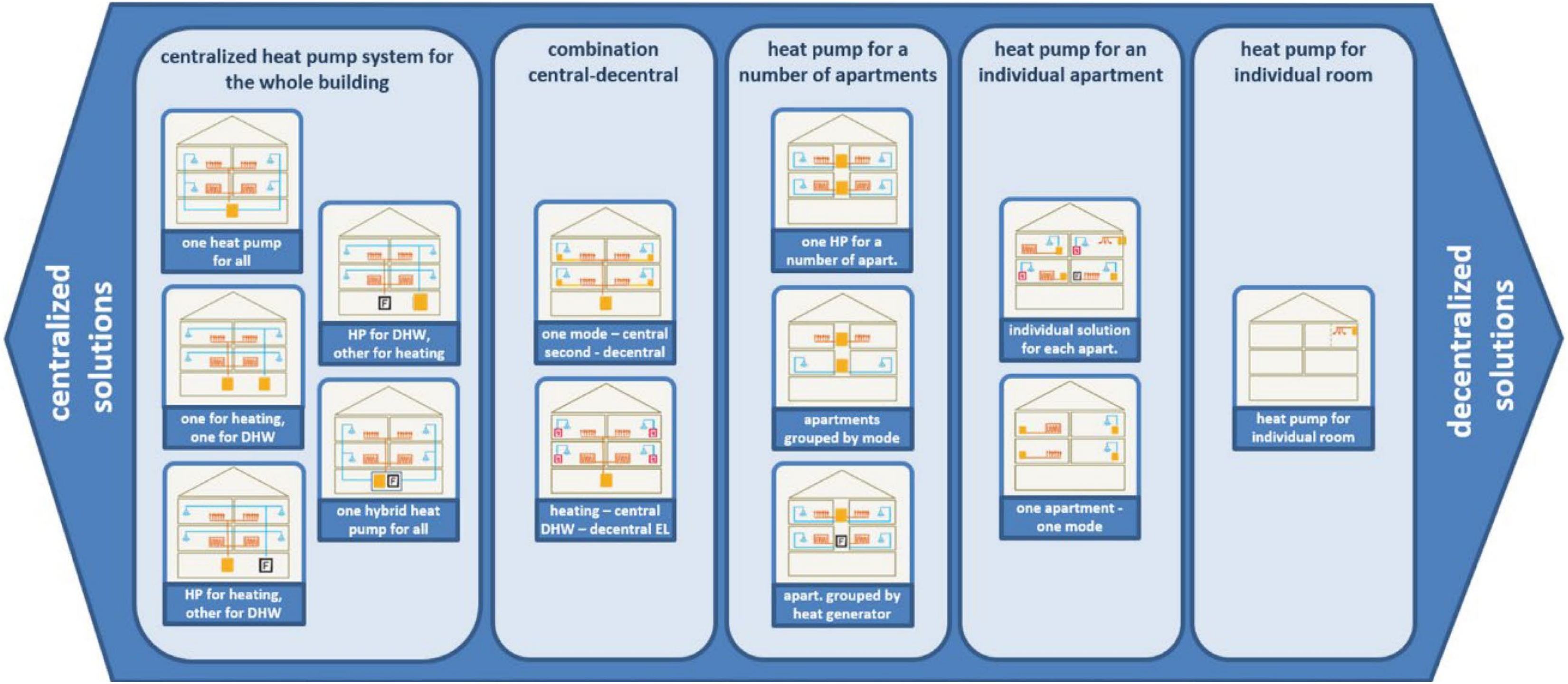
Solutions for residential buildings



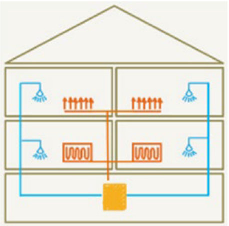
https://heatpumpingtechnologies.org/annex50/

Overview of the solutions

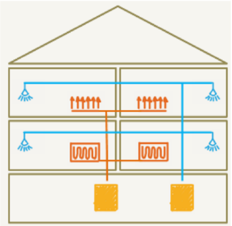


IEA HPT Annex 50 Final Report – Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water, 2022

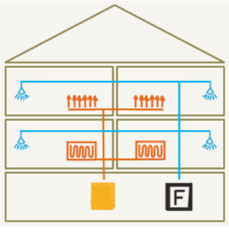
Solutions



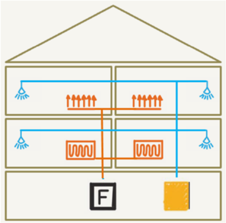
Solution 1.1 „one heat pump for all“
One central heat pump system for the whole building, both for space heating and DHW.



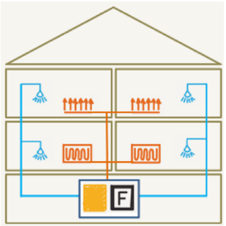
Solution 1.2 „one for heating, one for DHW “
One heat pump system for each mode. One for space heating, separate one for DHW.



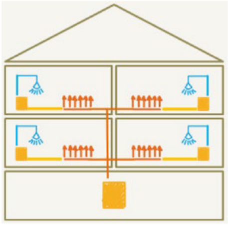
Solution 1.3 „ HP for heating, other device for DHW “
One heat pump system for the space heating, separate heat generator (fossil, biomass, electric, …) for DHW.



Solution 1.4 „HP for DHW, other device for heating “
One HP system for DHW, separate heat generator (fossil, biomass, electric, …) for space heating.



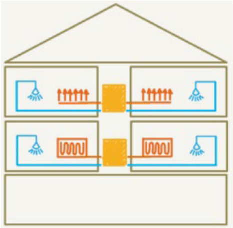
Solution 1.5 „one hybrid heat pump for all “
One hybrid heat pump system for space heating and DHW for the whole building



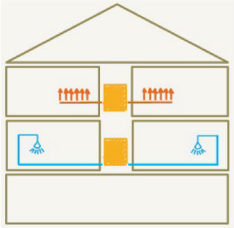
Solution 2.1 „ one mode – central, second - decentral “
One central heat pump system for one mode (for example space heating). Decentral heat pumps for the second mode (for example DHW).

Source: IEA HPT Annex 50 Final Report – Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water, 2022

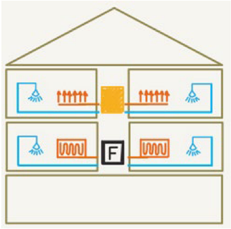
Solutions cont'd



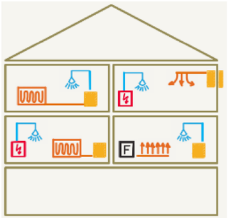
Solution 3.1 „one HP for a number of apartments “
One heat pump system for space heating and DHW for several apartments (usually grouped by levels or staircases).



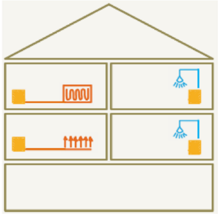
Solution 3.2 „apartments grouped by mode “
One heat pump system provides one mode (space heating or DHW) for several apartments (usually grouped by levels or staircases).



Solution 3.3 „ apartments grouped by heat generator “
The apartments are grouped by heat generators (usually grouped by levels or staircases).

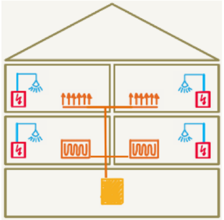


Solution 4.1 „ individual solution for each apartment “
Each apartment has individual concept of space heating and DHW.



Solution 4.2 „ one apartment - one mode “
Decentral heat pump for one mode for one apartment.

Solution 5.1 „ heat pump for individual room “
One heat pump for space heating (or cooling) for one room of the apartment.



Solution 2.2 „ heating – central, DHW – decentral EL “
One central heat pump system for space heating. Decentral direct electrical heaters for DHW.

Source: IEA HPT Annex 50 Final Report – Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water, 2022

Step by step for heat pump retrofits

1. Preliminary Assessment
2. Investigation
3. Financing & procurement
4. Implementation
5. Post Retrofit

Step by step for multifamily building retrofit

Preliminary Assessment

- Pre- qualify your building based on property characteristics
- Assess the business case assessment tool, for example TAF

Investigation

- Financial feasibility of retrofitting with heat pumps.

Financing & procurement

- Select project delivery approach
- Apply for incentives
- Procurement
- Developing your Measurement & Verification plan

Step by step for multifamily building retrofit cont’d

Implementation

- Design
- Construction
- Verify project completion
- Commissioning

Post Retrofit

- Measuring the benefits
- Report back to stakeholders

ASHP Key Specification Summary Worksheet

Project or Client Name: ____ Date Completed: ____

COMPLETION INSTRUCTIONS: Select Required Option(s) in each STEP. Provide information in shaded boxes as necessary

Key ASHP Requirements	Option A	Option B	Option C	Option D	NOTES
1 **Define ASHP Configuration**	**1A: Centrally Ducted:**	**1B: Ductless Mini-split, Single-Zone** No. of outdoor units: ____	**1C: Ductless Mini-split, Multi-Zone** No. of outdoor units: ____		☐ New Home Install ☐ Full System Replacement ☐ Add-on ASHP
2 **Choose Mini-split Indoor Unit Type(s)**	**2A: Wall-Mounted:** No. of units required: ____	**2B: Floor Mounted:** No. of units required: ____	**2C: Ceiling Mounted:** No. of units required: ____	**2D: Ducted (concealed):** No. of units required: ____	**NOTE: ONLY COMPLETE STEP 2 if using Option 1B or 1C**
3 **Determine Design Heating Load (DHL) and Design Cooling Load (DCL) Estimates**	**F280-12 Design values** **DHL:** ____ Btu/h **DCL:** ____ Btu/h	**Energy Audit Report Estimates** **Reported DHL:** ____ Btu/h **Adjusted DHL:** ____ Btu/h **Reported DCL:** ____ Btu/h **Adjusted DCL:** ____ Btu/h	**Energy Model Estimates of Design Loads** **DHL:** ____ Btu/h **DCL:** ____ Btu/h	**Existing Equipment Capacities:** **Heating (output):** ____ **Btu/h** **DHL estimate:** ____ **Btu/h** **Cooling (output):** ____ **Btu/h** **DCL estimate:** ____ **Btu/h**	**F280 Design temperatures for house location** **Heating:** ____ **°F** **Cooling:** ____ **°F**
4 **Determine Sizing Approach and Capacity Requirements of ASHP**	**4A: Emphasis on Cooling** **Target:** 80% DCL: ____ Btu/h to to 125% DCL: ____ Btu/h **Single-stage:** Match output to target **Multi-stage:** Match maximum output to target	**4B: Balanced Heating & Cooling** **Target:** 80% DCL: ____ Btu/h to to 125% DCL: ____ Btu/h **Single-stage:** Match output to high end of target **Multi-stage:** Match minimum output to target	**4C: Emphasis on Heating** **Target:** **Heating Load at:** 17°F : ____ Btu/h	**4D: Sized on Design Heating Load:** **Target:** DHL: ____ Btu/h at ____°F (Design Temperature)	**For FULL SYSTEM Replacements** - Maximum Airflow capacity of existing ducting: ____ CFM
Identify & Select ASHP	**Candidate #1**	**Candidate #2**	**Candidate #3**	**Candidate #4**	**Final Choice:** ____
5 **Identify candidate ASHP models matching Key Requirements**	Model #: ____ Stages: ____; Cut-off: ____°F Nominal Cap: ____ Heat-output: ____ Btu/h at 17°F ☐ , or at ____°F Cool-output at 95°F: ____ Btu/h	Model #: ____ Stages: ____; Cut-off: ____°F Nominal Cap: ____ Heat-output: ____ Btu/h at 17°F ☐ , or at ____°F Cool-output at 95°F: ____ Btu/h	Model #: ____ Stages: ____; Cut-off: ____°F Nominal Cap: ____ Heat-output: ____ Btu/h at 17°F ☐ , or at ____°F Cool-output at 95°F: ____ Btu/h	Model #: ____ Stages: ____; Cut-off: ____°F Nominal Cap: ____ Heat-output: ____ Btu/h at 17°F ☐ , or at ____°F Cool-output at 95°F: ____ Btu/h	Heat-output: ____ Btu/h at 17°F ☐ , or at ____°F Low Temp. Cut-off: ____°F Cooling at design: ____ Btu/h BP Temperature: ____°F %Total Heating above BPT: ____ % of total
Control Strategy	**Option A (ASHP cut-off above design T)**	**Option B (ASHP cut-off below design T)**	**Option C (ASHP cut-off below design T)**		**NOTES**
6 **Define Control Strategy**	**ASHP Cut-off Control required** **6A1:** Low-Temp cut-off at: ____°F **6A2:** Economic cut-off at: ____°F	**No ASHP Cut-off Control required** **6B1:** Heat pump may operate over full outdoor temperature range **ASHP Cut-off Control required:** **6B2:** Economic cut-off at: ____°F	**No Backup Heat** **6C: Heat pump is Sole Heat Source** (No ASHP Cut-off Control required)		
Back-up Heating	**Option A**	**Option B**	**Option C**	**Option D**	**NOTES**
7 **Define Backup Heating Requirements**	**7A - New required at > 100% DHL** Minimum of: ____ Btu/h	**7B - New required < 100% DHL** Minimum of: ____ Btu/h	**7C - No new Backup required** (use existing heating system for backup heating)	**7D - No Backup Required** (ASHP output is greater than the design heating load at the design temperature)	**NEW Backup Type:** ☐ Fuel: ____ ☐ Electric: ____

Motivations and barriers for building owners

Motivations

1. Energy efficiency
2. Environmental sustainability
3. Government incentives
4. Cost savings
5. Energy independence
6. Long-term investment
7. Reduced maintenance
8. Increased asset values

Barriers

1. High initial costs
2. Lack of awareness
3. Perceived reliability issues
4. Technical challenges
5. Space requirements
6. Access to financing
7. Split incentives

Additional barriers – building owners

High upfront and operational costs	• Operating costs have been noted as both a motivator and a barrier, indicating an opportunity for better awareness.
Functionality Concerns	• Cold weather performance, incompatibility with existing systems, operating noise levels, aesthetics and curb appeal.
Complex customer journey and the status quo bias	• From awareness to installation, the customer journey can span several months and require substantial effort • Inertia versus urgency – unless a heating systems requires urgent repair or replacement, many won't consider a change. The urgency then creates a need for a solution quickly, which is not always possible with heat pumps.
Tenant considerations	• Tenants may have concerns about disruptions during installation, changes to utility bills, or the impact on indoor comfort levels.

Additional barriers – building owners

(In)compatibility with current heating systems	• Fears or misconceptions about the integration of heat pumps into existing heating systems may prevent some installers from promoting heat pumps.
Difficulty estimating energy efficiency	• Calculating the energy efficiently correctly is difficult and time consuming, with several inconsistent variables
Time-consuming quotations	• Proper sizing and selection can be difficult and more time consuming than methods used to produce quotes for more traditional systems
Rapid advancements in technology	• It can be difficult and overwhelming to keep up with the pace of change.

Heat pump sizing

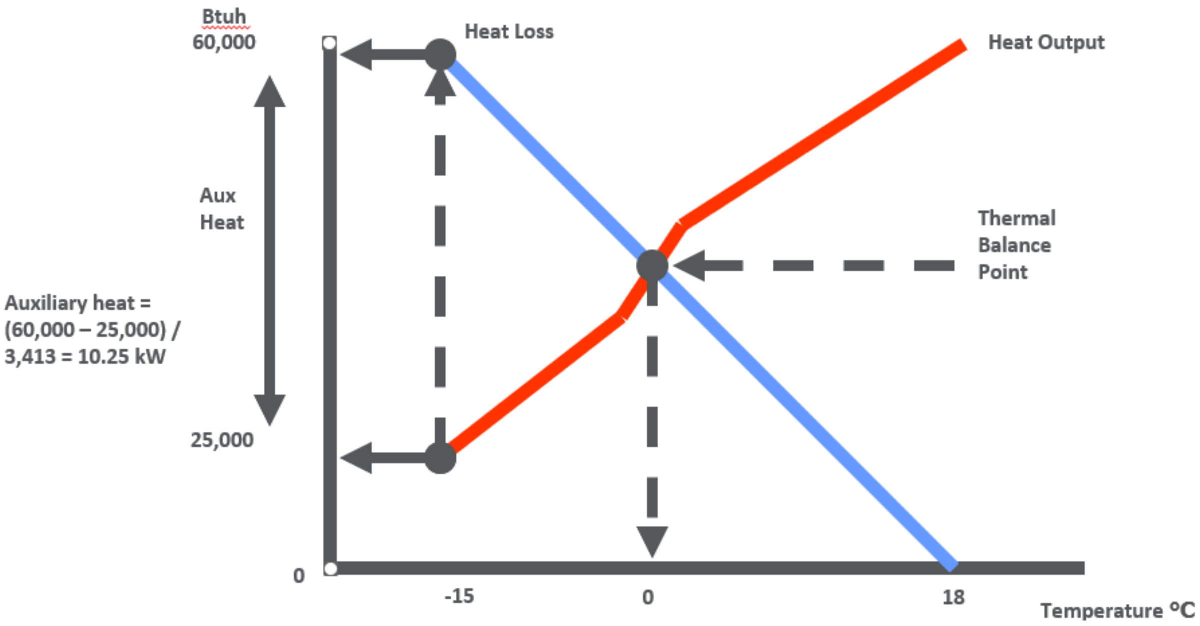
When it comes to sizing a heat pump, one of the most critical concepts is that of the **thermal balance point**.

Thermal balance point is that condition where the heating output of the heat pump is equal to the heat loss rate of the home.

The thermal balance point can be plotted on a graph.

Supplemental heat is needed for periods when the outdoor air temperature is below the thermal balance point.

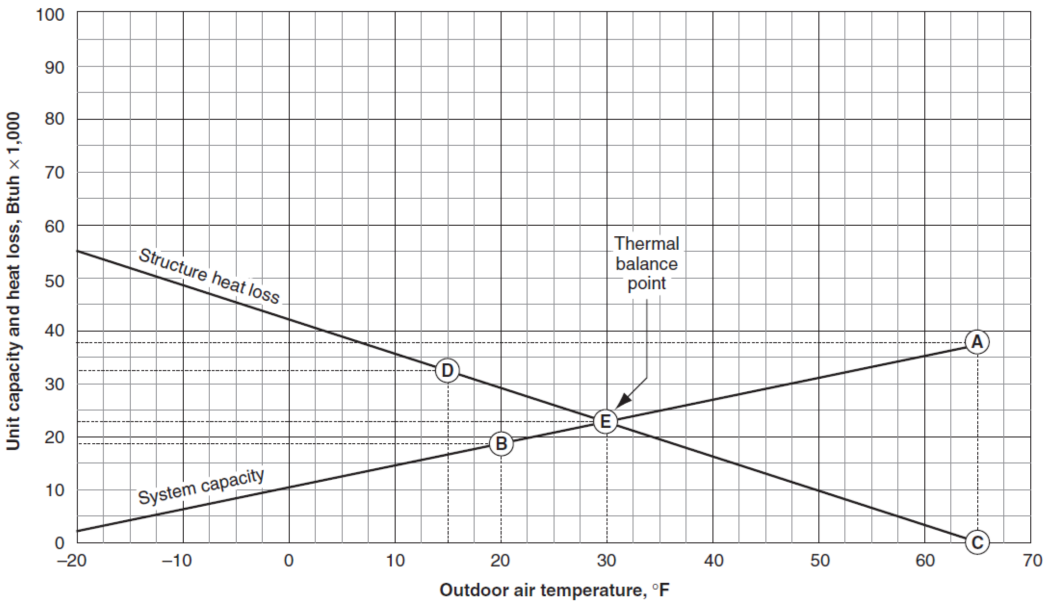
Plotting the balance point



Typical manufacturer data for air-to-air heat pump

Heating performance at 1,000-cfm indoor air volume		
Outdoor air temperature (°F)	**Compressor motor input (W)**	**Total output (Btuh)**
65	2,425	37,800
60	2,365	35,900
55	2,300	34,000
50	2,235	32,100
45	2,160	29,900
40	2,060	27,300
35	1,960	24,600
30	1,920	23,200
25	1,885	21,800
20	1,845	20,400
15	1,785	18,800
10	1,685	16,900
5	1,585	15,100
0	1,490	13,200
–5	1,390	11,400
–10	1,290	9,500
–15	1,190	7,700
–20	1,095	5,900

(Outdoor air temperature at 70% relative humidity, indoor temperature at 70°F)



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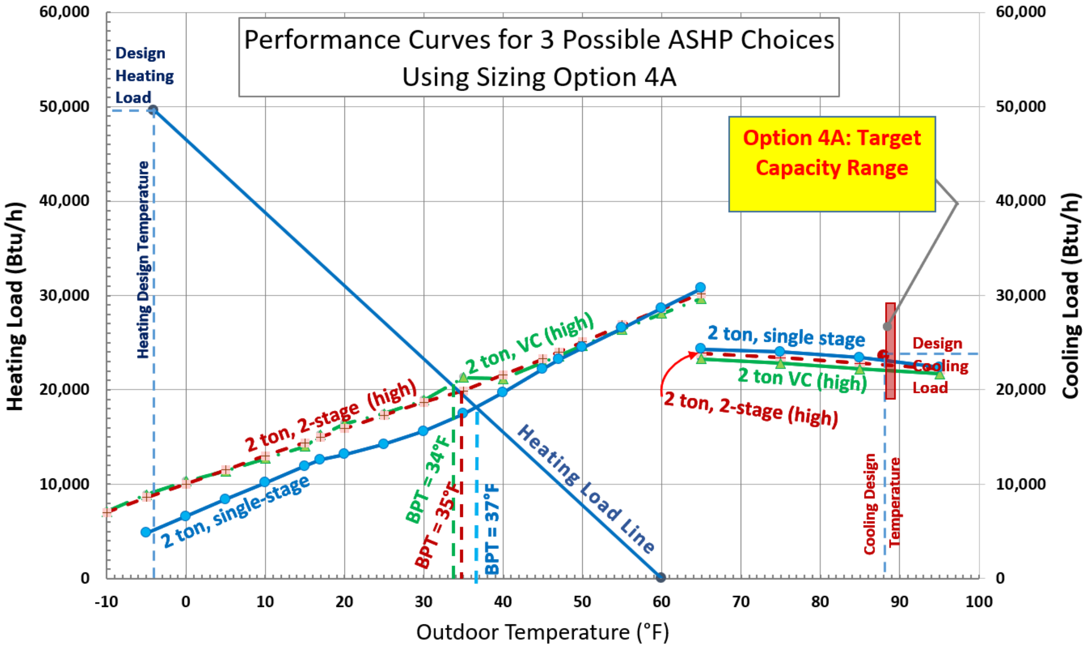
POWER WHAT'S NEXT

Heat Pump Capacity



Source: Natural Resources Canada Air-source Heat Pump Sizing and Selection Guide.

Heat pump capacity

Heat Pump capacity is often chosen according to the summer heat gain to ensure humidity control.

Where winters are less extreme, cooling capacity may be oversized no more than 15%.

Where winters are extreme, cooling capacity may be oversized no more than 25% to reduce the amount of supplemental heat required.

High efficiency air-to-air heat pumps

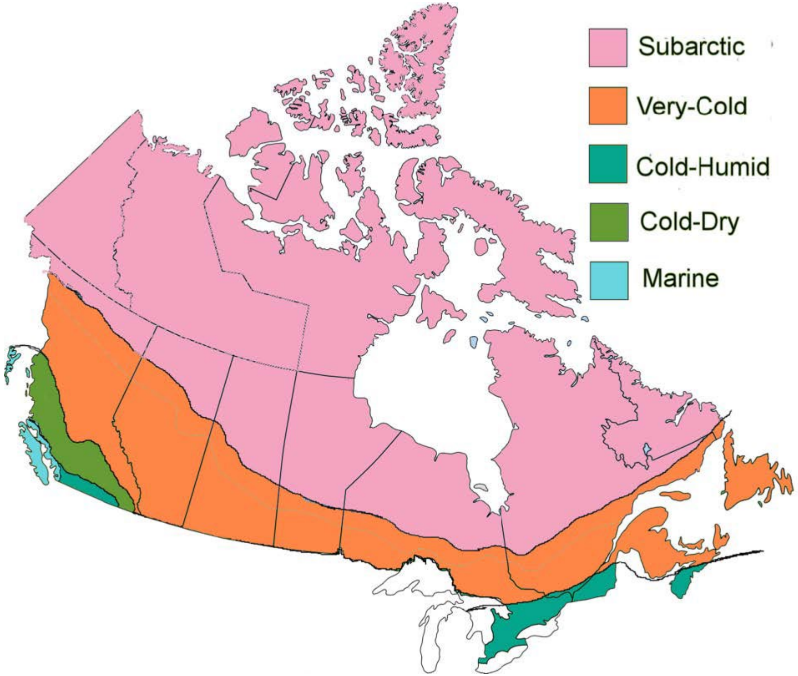
Capacity Unloading

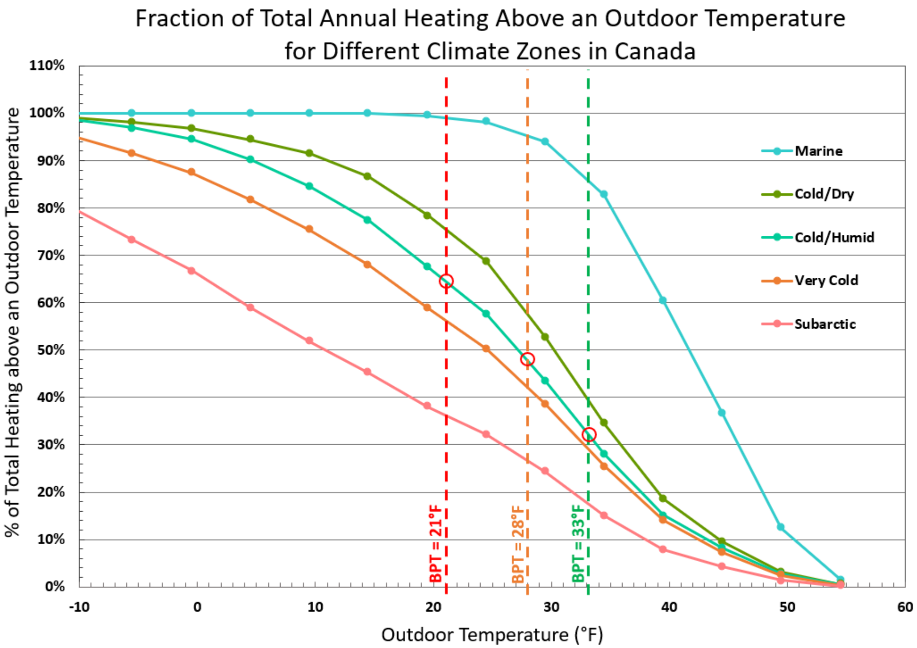
A variety of approaches have been taken to provide variable capacity including the use of:

- Multiple compressors
- Two-speed compressors
- Variable speed compressors and fan motors
- Unloading devices

Heat pumps vary greatly in their design and application. Air-to-air heat pumps are the most numerous type. Water source units offer advantages, but their use can be limited by water supply.

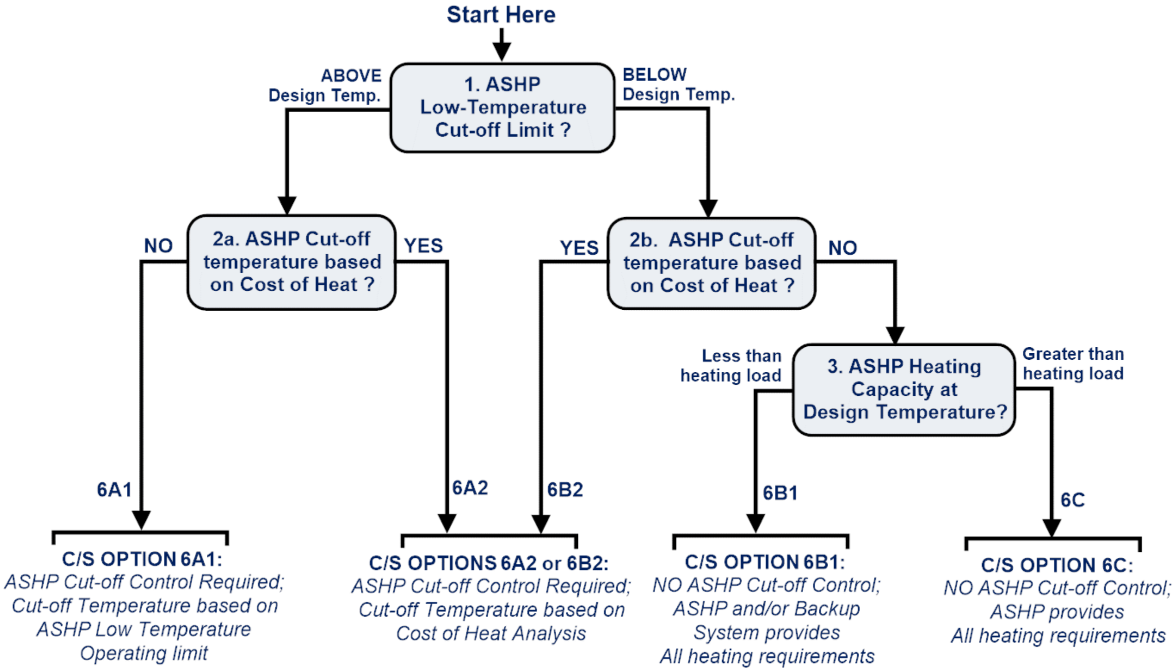
Selecting Supplemental Heat





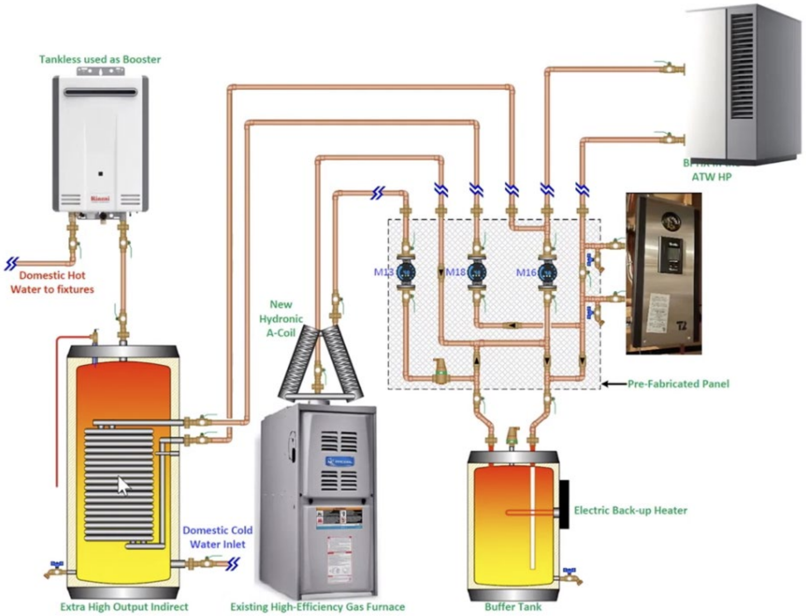
Source: NRCAN: Air-Source Heat Pump Sizing and Selection Guide

Control strategy

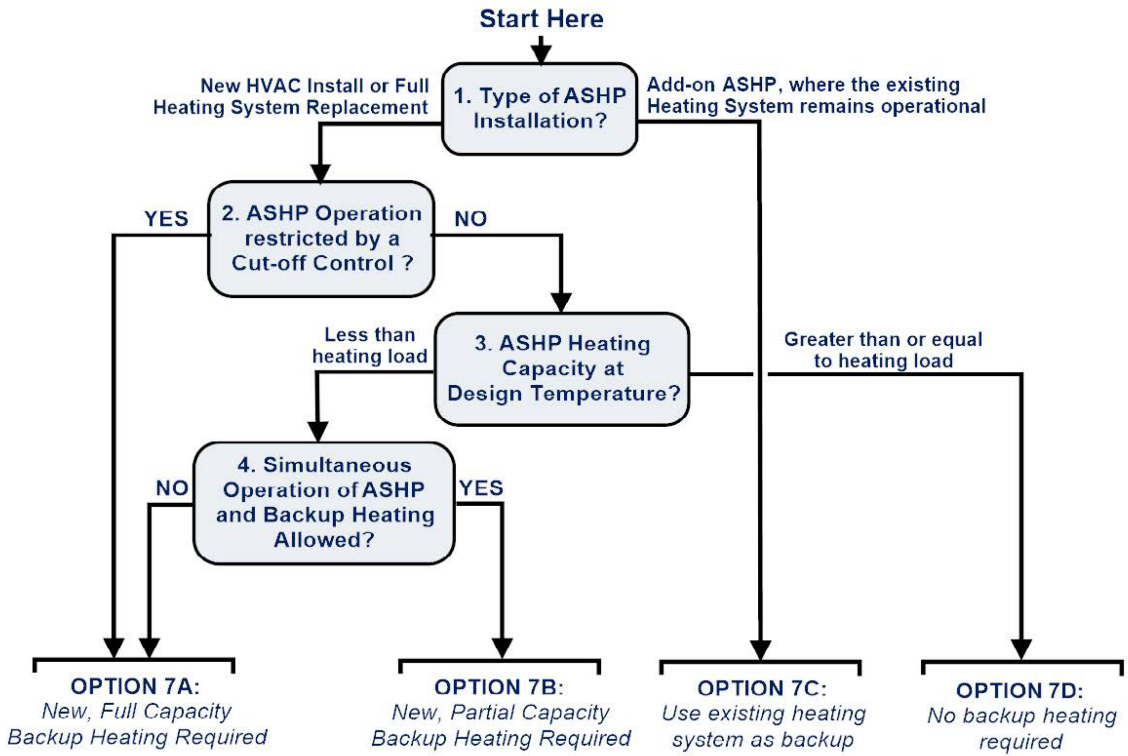


Supplemental heat capacity

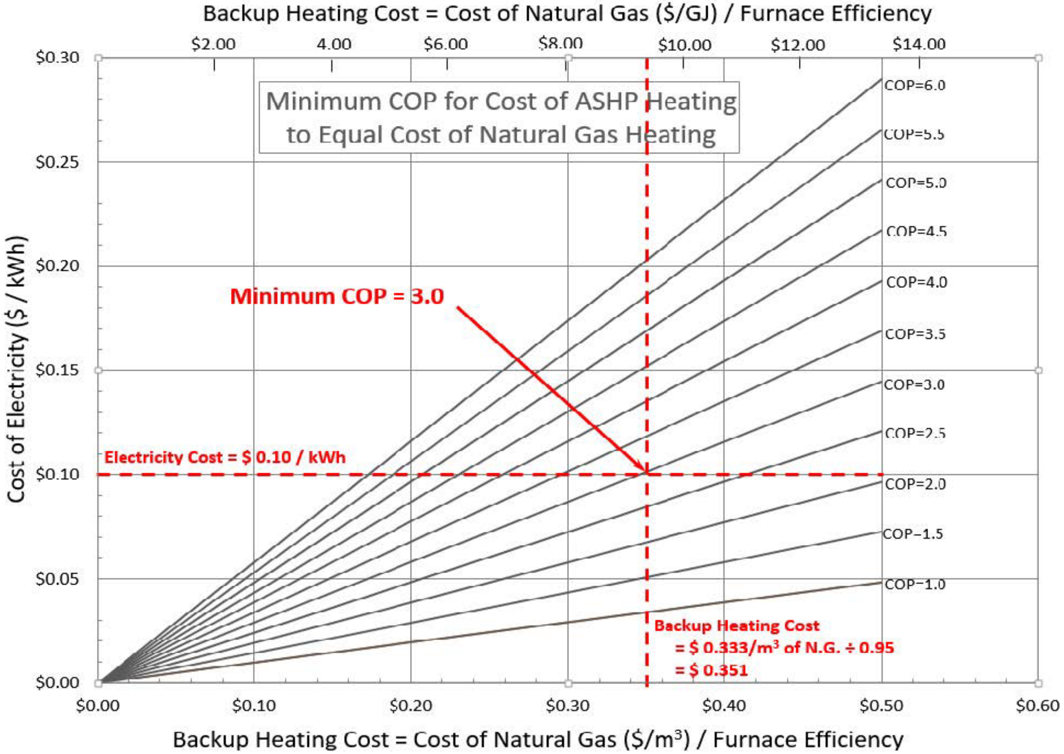
- **The total supplemental heating capacity should not exceed the home's heat loss at design conditions by more than 15%.**
  - It is more often recommended that the total heat pump heating capacity be equal to 75 to 80% of the heat loss at design conditions.



Backup Heating Decision Matrix



Backup Heating Decision Matrix



Outdoor Thermostat

The outdoor thermostat setting should be-17 or -16°C (2 or 3°F) higher for summer and lower for winter than the calculated thermal balance point.

This practice provides a safety margin for error that could exist in the load calculation and the balance point plot.

Coefficient of Performance

Coefficient of performance is the ratio of the heat delivered by the heat pump to the energy input to the heat pump.

COP is published by Air Conditioning, Heating, and Refrigeration Institute (AHRI) at two points:

High-temp COP at 8°C (47°F) outdoor air temperature.

Low-temp COP at -8 °C (17°F) outdoor air temperature.

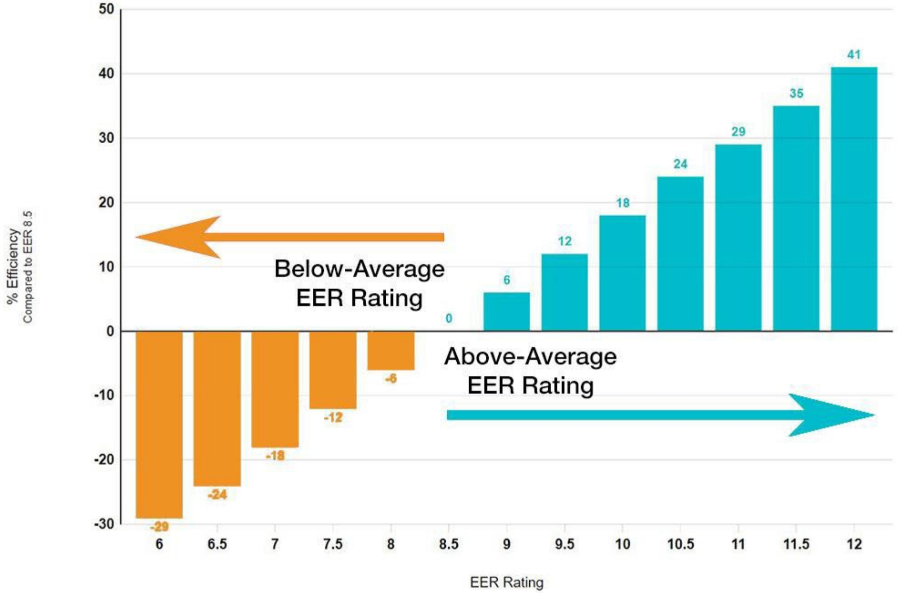
$$COP = \frac{heat\ delivered\ by\ the\ heat\ pump\ (Btuh)}{energy\ supplied\ to\ the\ heat\ pump\ (Btuh)}$$

Energy Efficiency Ratio (EER)

$$EER = \frac{\text{Cooling Capacity (Btu)}}{\text{Electrical Input (W)}}$$

The **EER** of a system is a ratio of the cooling output over the electrical power input.

Like COP, also a steady state measurement at a fixed operating condition.

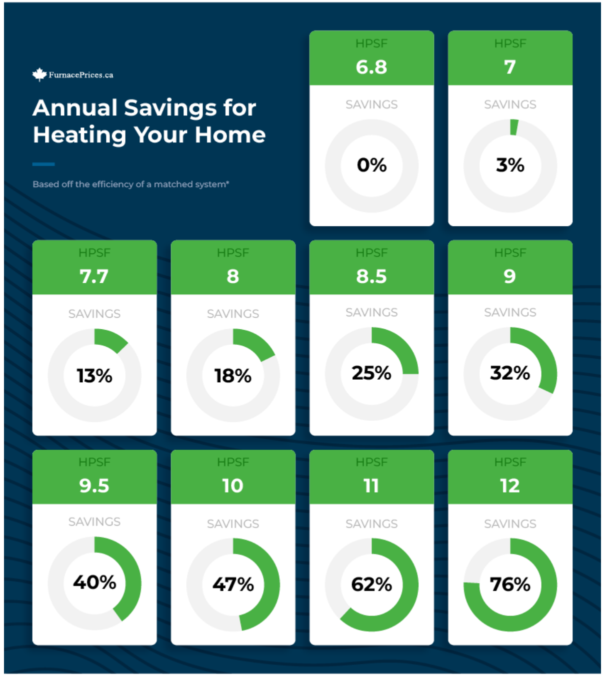


Heating Seasonal Performance Factor (HSPF)

$$\textbf{HSPF} = \frac{\textbf{Total Heating Output (Btu)}}{\textbf{Total Electrical Input (Wh)}}$$

The **HSPF** measures a heat pump's heating efficiency over an entire heating season.

HSPF is calculated by dividing the total heating output over the season by the total energy input for the same period.



Seasonal Energy Efficiency Ratio (SEER)

$$\text{SEER} = \frac{\text{Total Cooling Output (Btu)}}{\text{Total Electrical Input (Wh)}}$$

The **SEER** measures a heat pump's cooling efficiency over an entire cooling season.

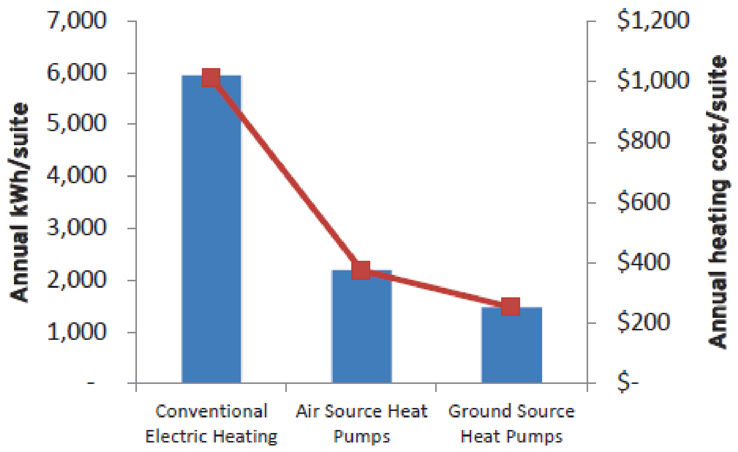
SEER is calculated by dividing the total cooling output over the season by the total energy input for the same period.

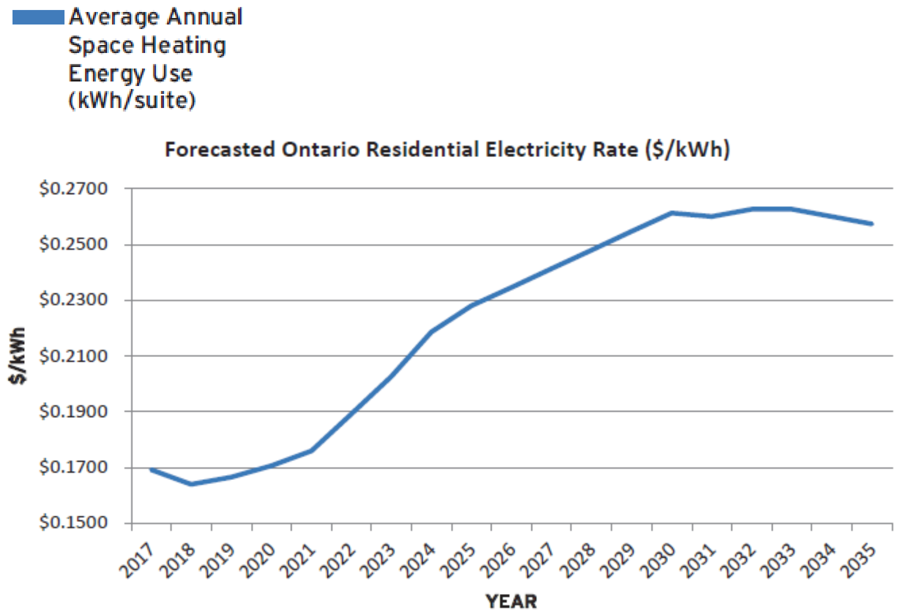
Operating Parameters

Work done by a heat pump requires that:

- The indoor coil must be larger
- Indoor air volume (cfm) will typically be greater
- Greater care must be taken to manage flood back
- Defrost controls are used for the heating cycle
- Supplemental heat may be required

Case Study 1





TAF: Harvesting heat with heat pumps_ a guide to retrofitting electrically-heated multi-family dwellings in Ontario with heat pumps

Heating Systems

Combustion Heating

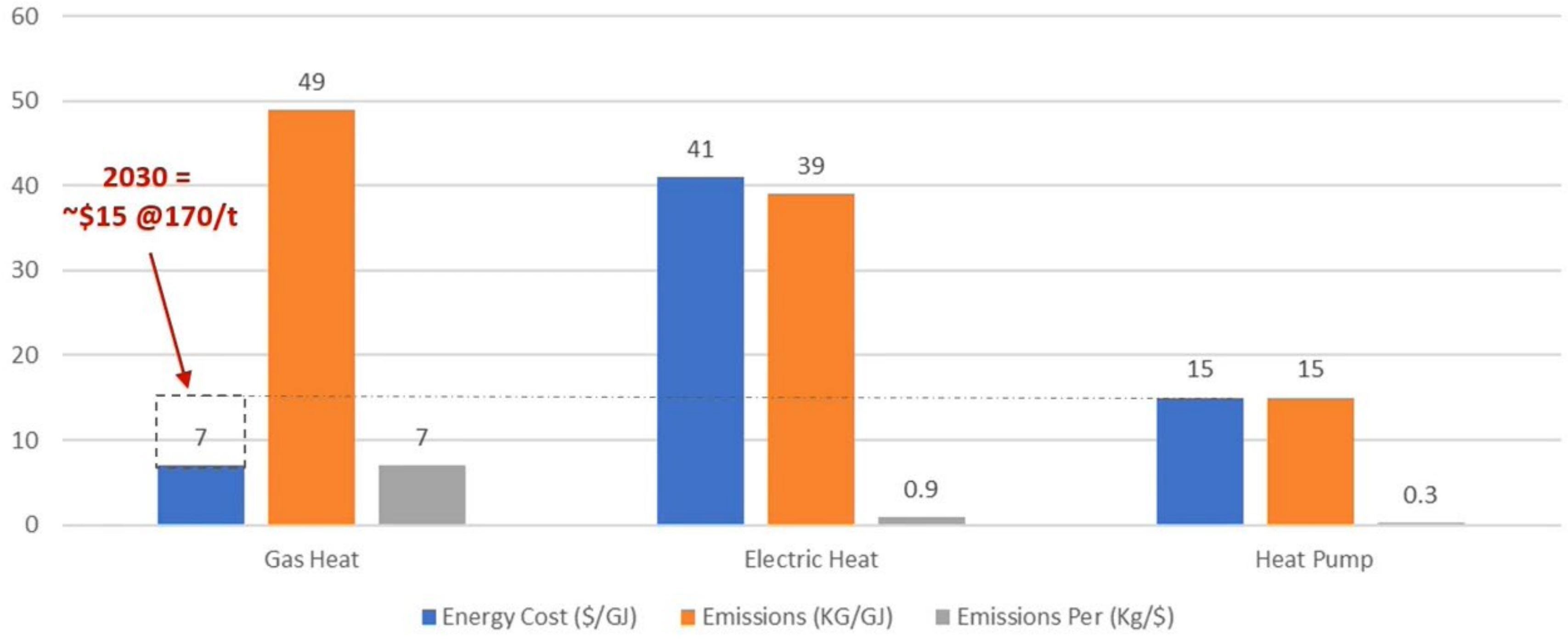
Resistance Heating

Heat Pump Heating/Cooling

Efficiency	80% – 98%	Close to 100%	250 - 400% or 2.5 - 4.0 Coefficient of Performance (COP)
Energy Cost	$0.45/m^3$	$0.15/kWh	$10/GJ - $20/GJ
Energy Cost	$15/GJ ($20.5/GJ by 2030 @$170/t)	$41/GJ	$10/GJ - $20/GJ
Emissions	49 kg CO_{2eq}/GJ	8 kg CO_{2eq}/GJ (Margin)	2 – 4 kg CO_{2eq}/GJ

All values are approximate for illustrative purposes

Heating Systems cont'd



Example - Heat Pumps in Residential Buildings

An older home heated with an 80,000-Btuh (output) fossil fuel furnace, sized correctly.

Acceptable heat rise across the heat exchanger ranges from 50 to 85°F (10 to 30°C). 70°F (21°C) return air heated to a supply air temperature ranging from 120°F (70°F + 50°F) to 155°F (70°F + 85°F).

Air volume needed to operate heating equipment correctly, the sensible heat equation may be expressed as: $cfm = \frac{Btuh\ output}{1.08 \times TD}$

A heat rise (TD) = 68°F, Air volume as follows: $\frac{80{,}000\ Btuh}{1.08 \times 68°F} = 1{,}089\ cfm$

Heat pump acceptable heat rise of 40°F, the air volume needed for successful operation of new equipment with equal output capacity will be: $\frac{80{,}000\ Btuh}{1.08 \times 40°\mathrm{F}} = 1{,}852\ cfm$

Efficiency and GHG emissions of air source heat pumps under future climate scenarios

- Air source heat pumps (ASHPs) in detached residential homes
- Study ASHPs as reliable heating responses in mild, cold, and very cold climate zones across Canada
- Different systems are compared under current and future climate scenarios

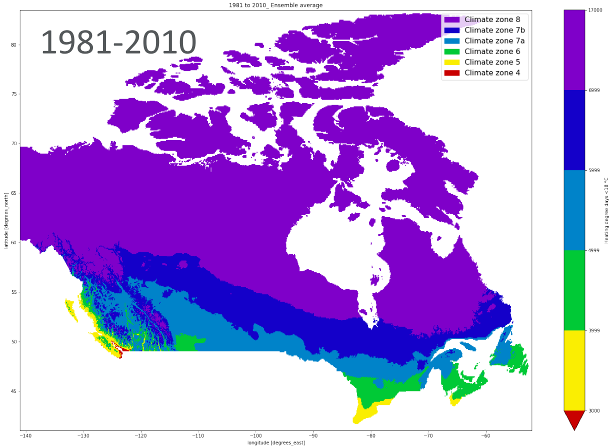
The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

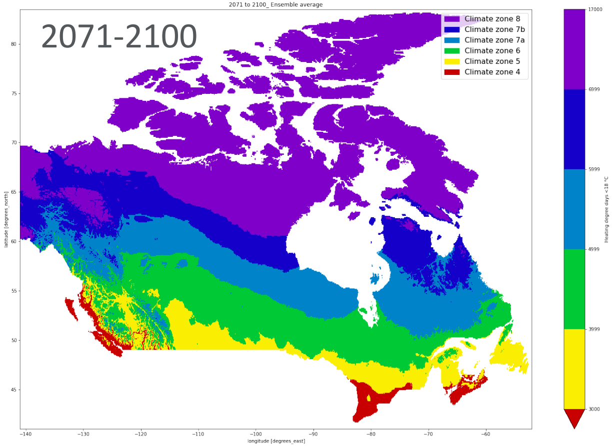
Climate changeD!

Across Canada, residential buildings have historically been designed with heating systems only.

Climate change projections show that:

- The number of cooling degree days (CDD) are set to increase at a rate of 13 CDD per year.
- The heating degree days (HDD) are decreasing at 12.8 HDD per year.





The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

Case Study 1

- The use of ASHP in domestic buildings is not uncommon, especially in locations where the cost and supply of electricity are cheaper and cleaner than a fossil fuel-powered ASHP.
- Historically some concerns regarding the performance in cold temperatures exist, specifically with regards to compressor performance.
- Another method to improve the COP of an ASHP is to use a refrigerant with a lower boiling point that will allow for more efficient heat transfer throughout the system.

Source: The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

Case Study 1- Methodology

Dynamic energy simulations of a detached residential home in Toronto, Vancouver and Quebec City were realized. The methodology consisted of four steps:

- EnergyPlus weather files for 1998 to 2014, 2030 to 2041 and 2056 to 2075
- Current and future electricity generation data for Ontario, British Columbia, and Quebec were recorded and modelled to find the emission factors of the different fuels
- Simulations in EnergyPlus of a single-family residential building for both current and future weather
- Seasonal COPs of the ASHPs were calculated together with the GHG impact of the energy demand

Source: The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

Single family detached house characteristics

Parameter	Assumption
Conditioned floor area	188 m^2
Footprint and height	10.1 m by 9.3 m, two-storey
Perimeter length	55.8 m
Gross exterior wall area	290.16 m^2
Window to wall ratio	15% in each direction
Door area	3.9 m^2
Internal gains (appliances + lighting)	25.43 kW (86,761 Btu/day)
Heating system	natural gas furnace (92% AFUE)

Thermal resistance value, air infiltration, and occupancy rate for the modelled building.

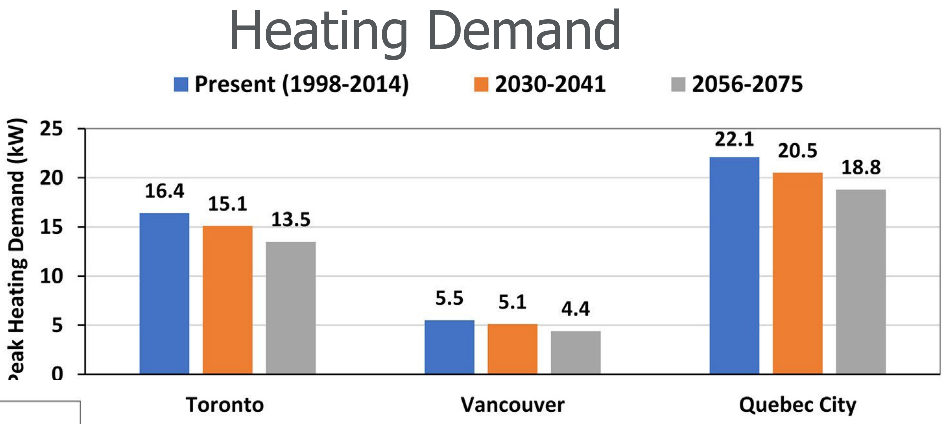
City	Climate Zone	RSI value (m^2·K/W)				ACH per Hour at 50 Pa	Number of people
		window	roof	wall	slab		
Toronto	6A	0.5	12.3	8.8	7.0	0.7	4
Vancouver	5A	0.5	10.6	8.8	7.0		
Quebec City	7	0.5	15.8	10.6	8.8		

Technical specifications of the ASHP used in this study .

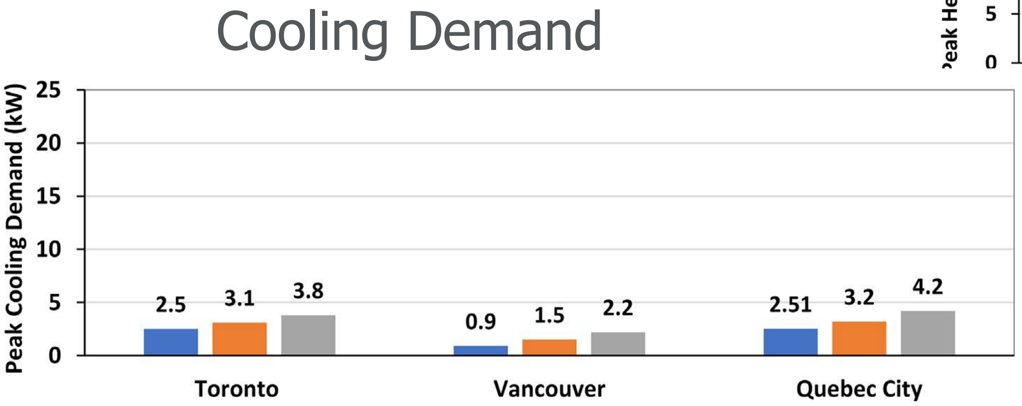
Manufacturer	Model	Cooling capacity (kW) at 31 °C	Heating capacity (kW) at −8.3 °C	COP (cooling)	COP (heating)	Air flow rate (m^3/s)	Compressor Type
Goodman	GSZ160211	7.03	5.3	3.75	2.78	0.24	Single Stage
Carrier	25VNA8	7.03	5.3	4.12	3.22	0.28	Five Stage
Trane	4TWR5024G	6.98	5.2	3.89	2.78	0.22	Single Stage
Daikin	DZ14SA	7.03	5.3	3.60	2.78	0.2	Two Stage
Bryant	284ANV	6.79	5.1	4.54	3.81	0.28	Five Stage

The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

Comparison of cooling and heating demand

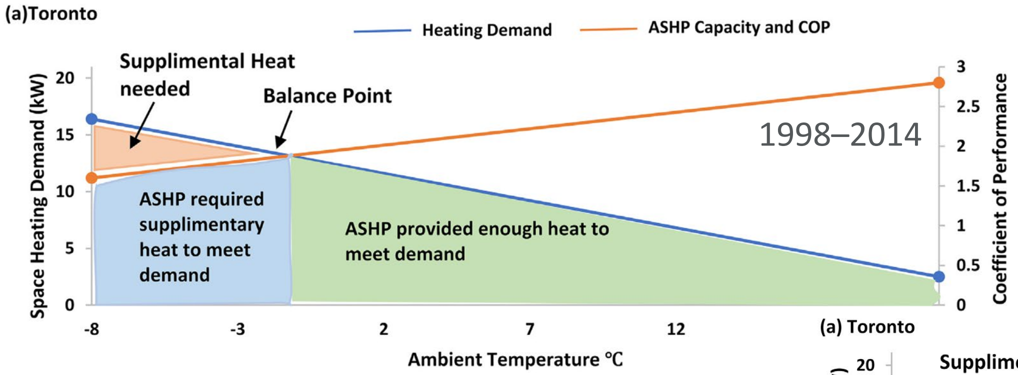


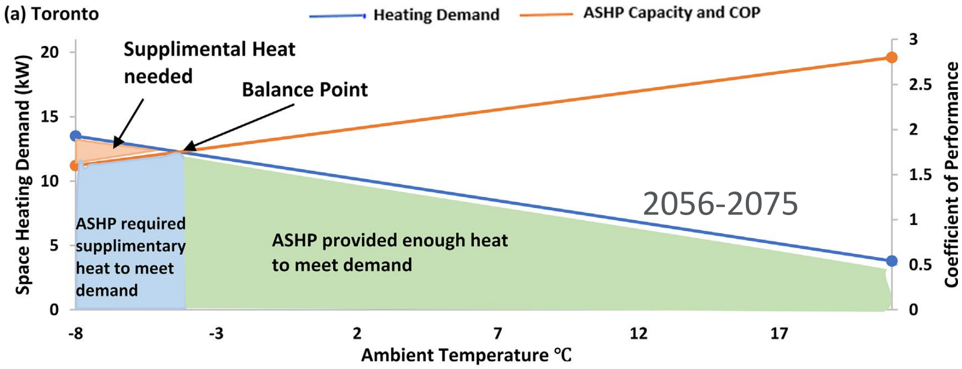
Toronto peak heating demand: 16.4 kW



The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

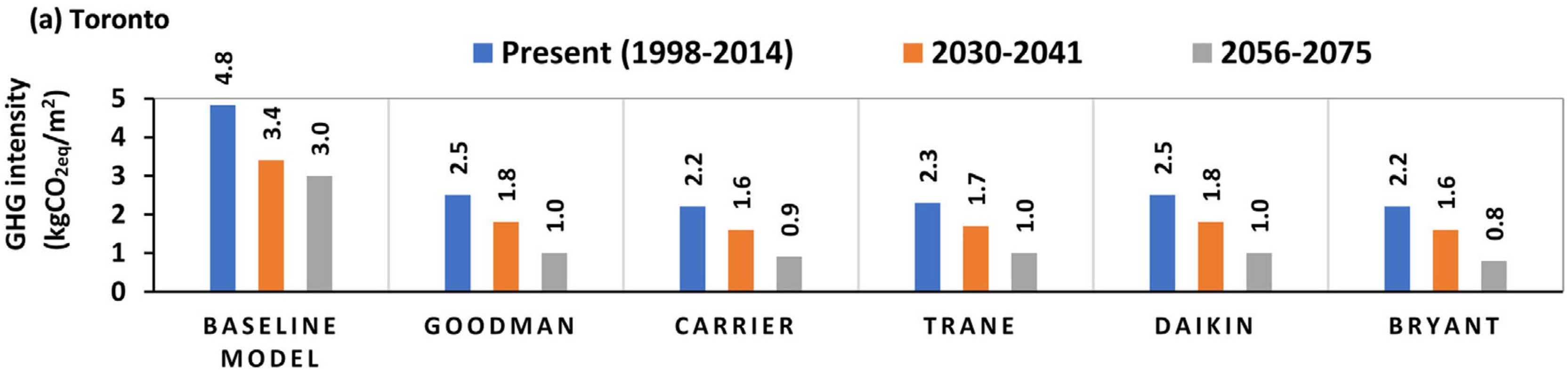
ASHP capacity and COP versus the heating needs





The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

GHG emissions intensity of natural gas furnace and ASHP



The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

Economic Analysis, Hybrid System with Heat Pumps

Canadian Climate Institute, September 2023 - Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute

Cost of Heat Pumps

- Cost is one of the most important factors, but it is not the only factor.
- The initial cost of heat pumps compared to alternative heating and cooling technologies is an important factor.
- Consumers often don't know what energy costs will be years or decades into the future.
- Climate conditions of different Canadian cities need to be considered.
- Different types of residential houses (e.g. single-detached, townhouse, etc.). Equipment configurations (e.g. heat pump with gas or electric backup).

Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute

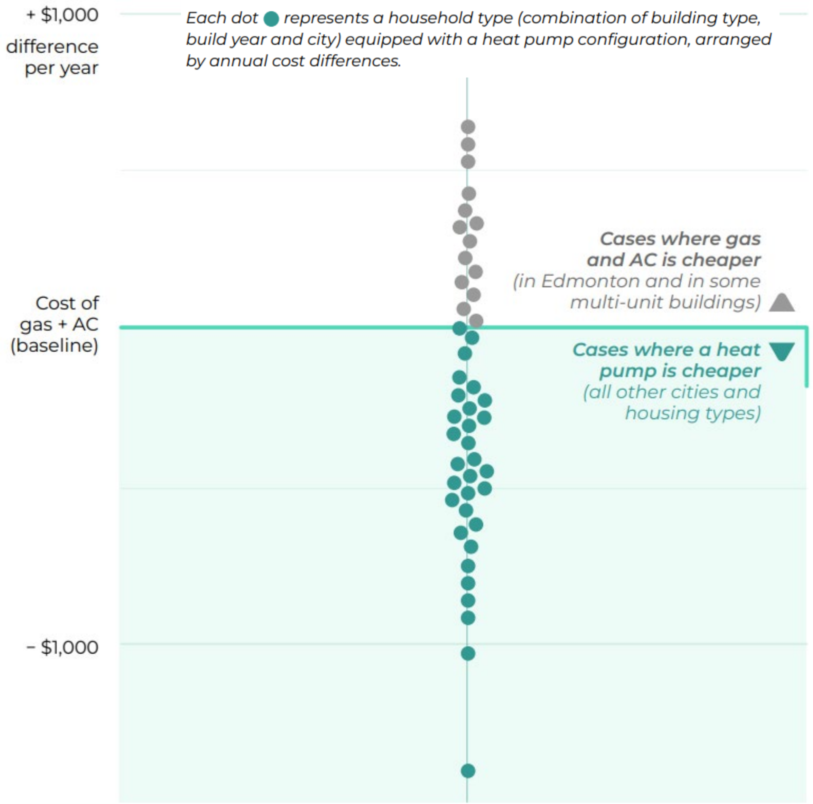
Case Study 4

- Four residential building archetypes: Single-detached (1,770 sq ft), townhouses (1,450 sq. ft.), multi-unit residential buildings with in-unit HVAC systems, and multi-unit residential buildings with central HVAC systems (both with 20 units at 1,040 sq. ft. per unit).
- Three building vintages: 1940, 1980, and new construction (2023).
- Four equipment configurations, including four different types of space heating and cooling equipment:
    - Gas heating with air conditioning;
    - Standard heat pump with gas backup;
    - Standard heat pump with electric backup;
    - Cold climate heat pump with electric backup.

Canadian Climate Institute, September 2023 - Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute

Heat Pumps are more Cost Competitive

- Standard heat pumps are the lowest cost heating and cooling option for most households, lower than gas-fired heating with air conditioning.
- The payback period — the time it will take for lower operating costs to make up for higher upfront costs — is between two and seven years, depending on the city.



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Annualized Cost of Space Heating and Cooling for Homes Built in 1980

Annualized cost of space heating and cooling with various heat pump configurations for homes built in 1980

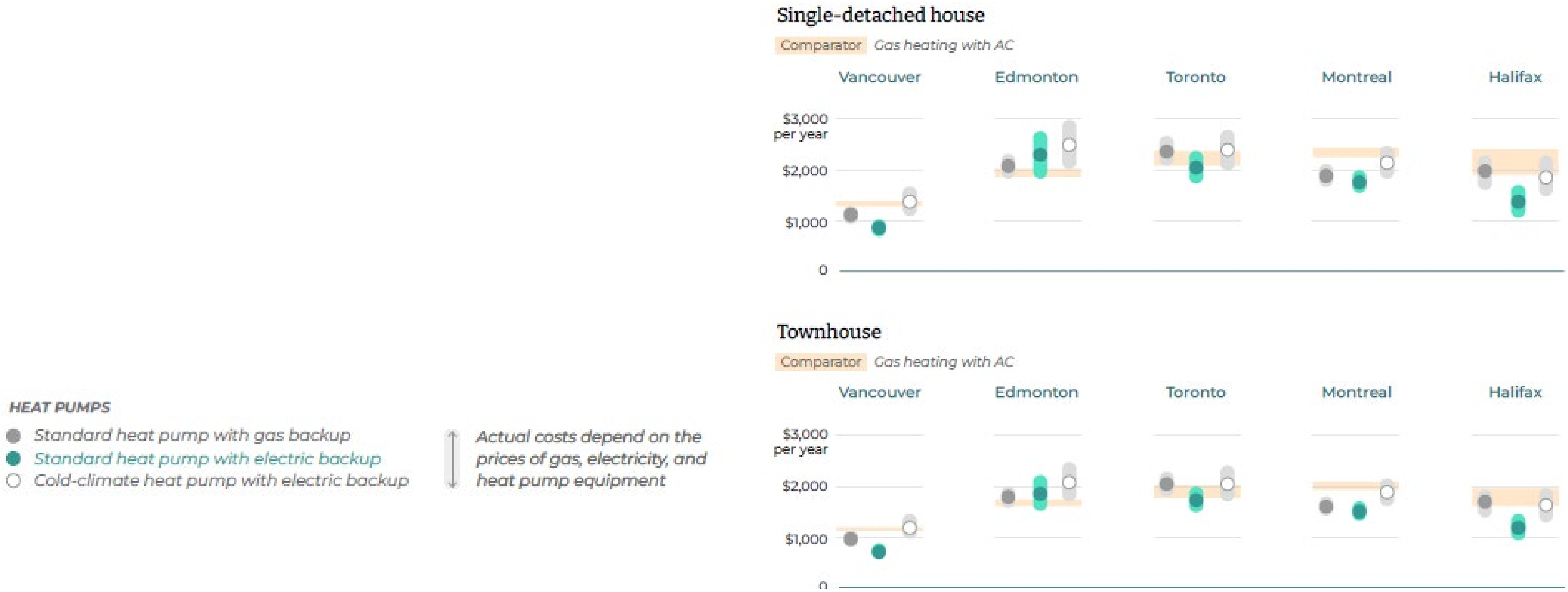
HEAT PUMPS

- *Standard heat pump with gas backup*
- *Standard heat pump with electric backup*
- *Cold-climate heat pump with electric backup*

Actual costs depend on the prices of gas, electricity, and heat pump equipment

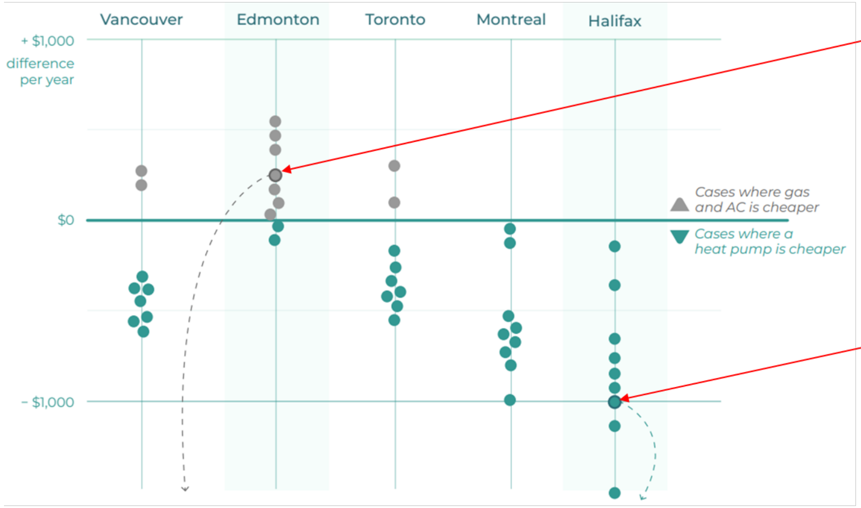
Canadian Climate Institute, September 2023 - Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute

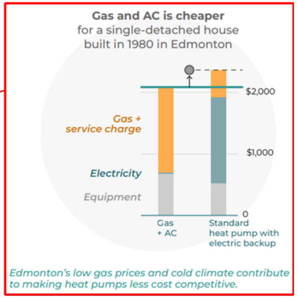
Annualized Cost of Space Heating and Cooling for Homes Built in 2023

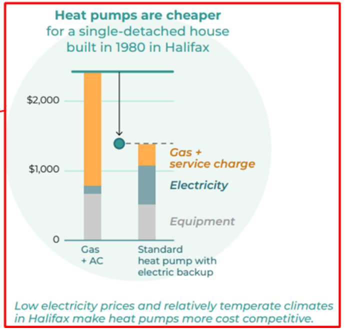


Canadian Climate Institute, September 2023 - Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute

Annualized Cost Difference between a Heat Pump and Gas Heating with Air Conditioning







Each dot ● represents a household type (building, build year, city) equipped with a heat pump configuration, arranged by annual cost differences.

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Canadian Climate Institute, September 2023 - Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute

Equipment Cost

The figure shows the capital cost assumptions for different heating and cooling technologies for a single-detached home.

Single detached - 1,770 sq ft

	Low equipment cost assumption			High equipment cost assumption		
Building vintage	1940	1980	2023	1940	1980	2023
Gas-fired ducted heating system (Primary and secondary heating system)[19]	$3,902 to $4,687	$3,720 to $4,265	$3,680 to $4,171	Did not model higher equipment costs		
Electric duct-heater element for ducted system	$512 to $990	$376 to $676	$311 to $523	$768 to $1,485	$564 to $1,014	$467 to $785
Ducted air-source heat pump	$6,175	$6,175	$5,740	$9,263	$9,263	$8,610
Cold climate ducted air-source heat pump	$12,723	$12,723	$11,761	$19,085	$19,085	$17,642
Panel upgrade	$3,403	$3,403	$0	$5,105	$5,105	$0
Ducted central air-conditioner	$4,987	$4,987	$4,765	Did not model higher equipment costs		

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Tips on Finding and Working with Contractors

Tips on finding and working with contractors

- Installation: Your heat pump must be installed by a licensed and trained professional. Before accepting the quote from a licensed professional, it is highly recommended that to obtain proof of their licence to install equipment in your province or territory:

https://natural-resources.canada.ca/sites/nrcan/files/science-and-data/funding-and-partnerships/greener-homes/MechanicalSystem-Contractorqualification_Final.pdf

- Communication, Preliminary investigative interview

Installation

- It is a best practice to follow all manufacturer recommendations when installing new heat pump equipment.
- All local, provincial, and national codes must be met.
- Equipment performance must be verified using published product data.
- The jobsite must be clean and presentable when the installation is finished.

Questions?

Thank you!

[SaveOnEnergy.ca](#)

[trainingandsupport@ieso.ca](#)

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