# Overview Of Heat Pump Technology

## Types of heat pumps

Our program focuses on residential air source heat pumps- Specifically, air-to-air heat pumps. There are other types of heat pumps. The main types of heat pumps for residential applications are reviewed in this section, including how they work, their distribution types, and possible configurations.

### Air-to-air heat pumps

Air-to-air heat pumps exchange heat between the outdoor and indoor air. The indoor heat exchanger can either be configured in ducted or ductless applications. The outdoor unit exchanges heat with the outdoor air. The efficiency of air-to-air heat pumps varies greatly depending on the outdoor air temperature. Air-to-air heat pumps have more flexible and affordable installation options than the other main types of heat pump applications. Throughout the rest of the document, use of the generic “heat pump” or more specific “air source heat pump” refer to air-to-air heat pumps.

### Ground-source heat pumps

Ground source heat pumps, also called geothermal heat pumps, use buried pipes to extract heating or cooling from below ground. The ground loops can be configured in either narrow and deep vertical wells or shallow and wide horizontal fields. The type and size of the ground loop can depend on the available land area, type of rock or soil, and the heating and cooling needs of the home. The indoor heat exchanger is usually configured in a ducted application. Compared to air-to-air heat pumps, ground source heat pumps have greater energy efficiency, no outdoor unit, and a more expensive and time-intensive installation.

### Water-source heat pumps

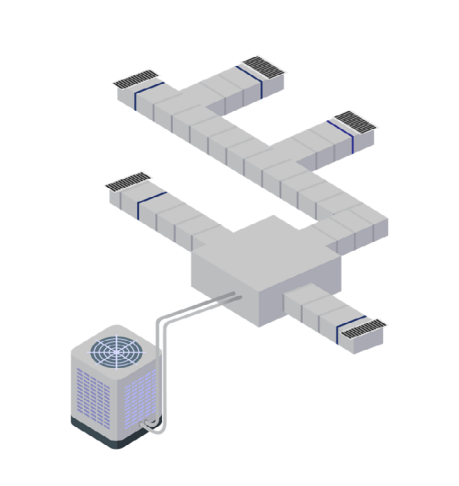
Water source use buried pipes to extract heating or cooling from a water source. The location and size of the water loop depends on the body of water at the site. In cold climates, the coils are placed at least eight feet under the surface to prevent freezing. The indoor heat exchanger is mostly configured in ducted applications. Compared to air-to-air heat pumps, water source heat pumps have greater energy efficiency, no outdoor unit, and a more expensive and time-intensive installation.

## Air-to-water heat pumps

Air-to-water heat pumps are air source heat pumps that use hydronic indoor distribution. An air-to-water heat pump has an extra set of heat exchangers than an air-to-air heat pump which transfer heat from the outdoor unit into a hydronic distribution system. Air-to-water heat pumps can be configured in monobloc or split systems. In a monobloc system, the hydronic lines cross the building envelope. In a split system, refrigerant lines cross the building envelope. Air-to-water heat pumps primarily provide heat but may also be configured to provide cooling. Some air-to-water heat pumps can also provide domestic hot water. Compared to air-to-air heat pumps, air-to-water heat pumps have a more expensive and time-intensive installation.

## Types of distribution

Air source heat pumps have multiple options to distribute heated or cooled air.



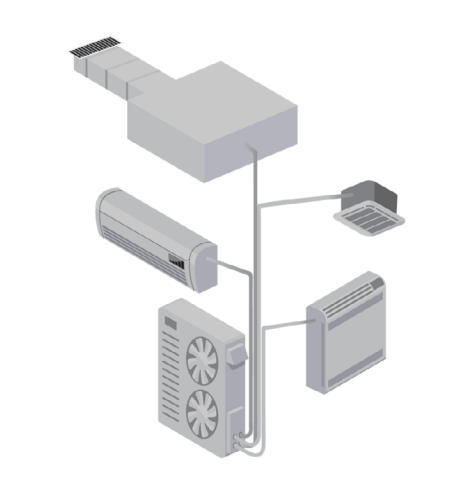
### Centrally ducted and short ducted

Most homes in Minnesota have ductwork and are good candidates for centrally ducted or short ducted heat pump systems.

### Ductless

Homes with hydronic heat or only electric baseboards are good candidates for ductless (“mini-split”) heat pump systems.

Homes with ductwork may still benefit from adding a ductless heat pump for supplemental conditioning.



### Multi-split

A multi-split system can leverage both ducted and ductless delivery but tend to have more complicated installations and controls.

# Definitions

## Cold-climate heat pumps

A cold-climate heat pump generally refers to a heat pump that is efficient at low ambient temperatures and meets certain capacity performance and maintenance requirements. However, there is not a standardized definition of a cold-climate heat pump. The definition can change based on particular program requirements, such as the Consortium for Energy Efficiency  tiers for the federal tax credit and ENERGY STAR v6.1 Cold-Climate.

## Hybrid

Hybrid, also referred to as “dual fuel”, is another term that has multiple definitions. Dual fuel can refer to equipment compatibility, thermostat controls compatibility, and utility program descriptions. It is important to clarify which definition is being used based on your audience.

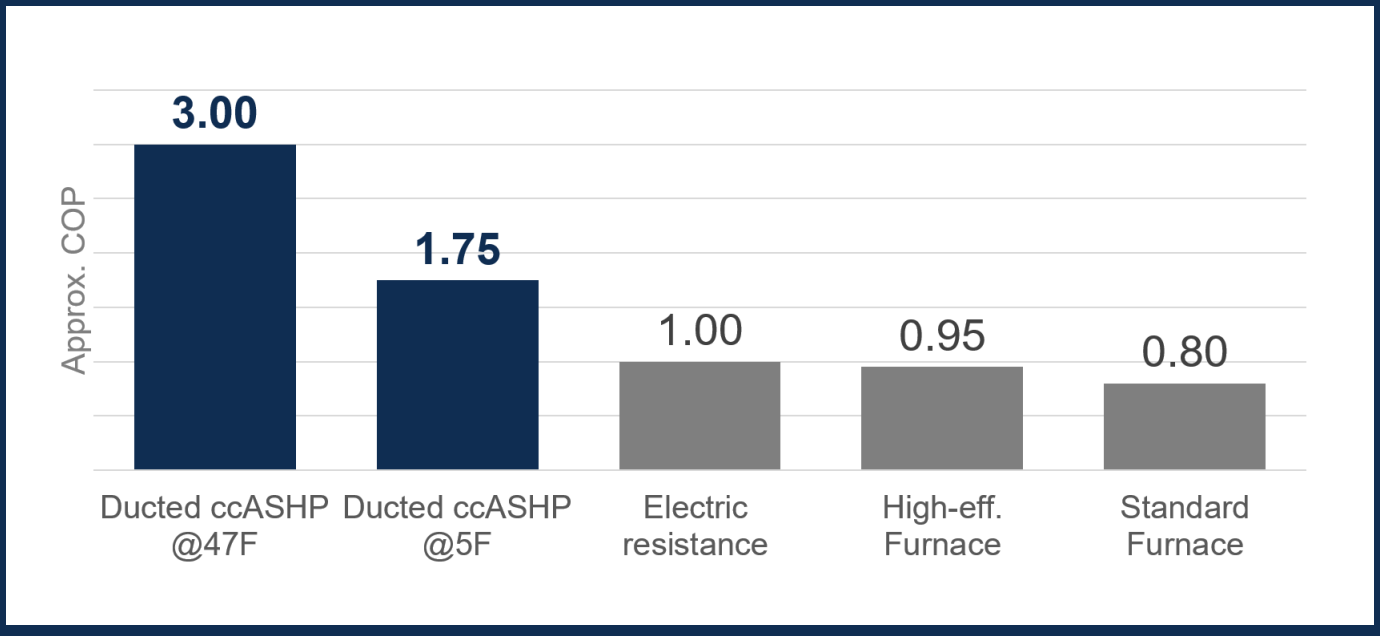
## Coefficient of Performance

Coefficient of Performance (COP) measures how much energy is put into a system versus how much energy the system puts out.

Electric resistance heat is a good baseline example. For every unit of energy put in, the electric resistance puts out one unit of heat, making for a COP of 1. Combustion systems are typically given Annual Fuel Utilization Efficiency (AFUE) ratings, but AFUE can be expressed as COP (AFUE = COP x 100). Combustion systems put out less than one unit of heat for every unit of energy put in. Expressed as a COP, combustion systems have COPs of less than 1.

Heat pumps are highly energy efficient and can put out up to 3.5 units of energy for every unit of energy put in, translating to COPs of up to 3.5. The graph below shows a comparison of COPs for  different equipment types versus a model cold-climate air source heat pump (ccASHP). The COP of the ccASHP is shown at two outdoor air temperatures to demonstrate the COP decrease as the outdoor air temperature decreases.

**Coefficients of Performance (COP) by system type**



# Performance categories

## Single and two-stage heat pumps

Single and two-stage heat pumps have more limited performance than variable-speed heat pumps. Some newer single and two-stage heat pumps may qualify for incentives. However, they do not qualify for cold-climate listing.

## Variable-speed heat pumps

Variable speed heat pumps are ideal for cold-climate applications because of their greater flexibility, modulation, and efficiency. Variable-speed heat pumps are also more likely to qualify for incentives and may be cold-climate listed.

There are key component differences of variable speed heat pumps.

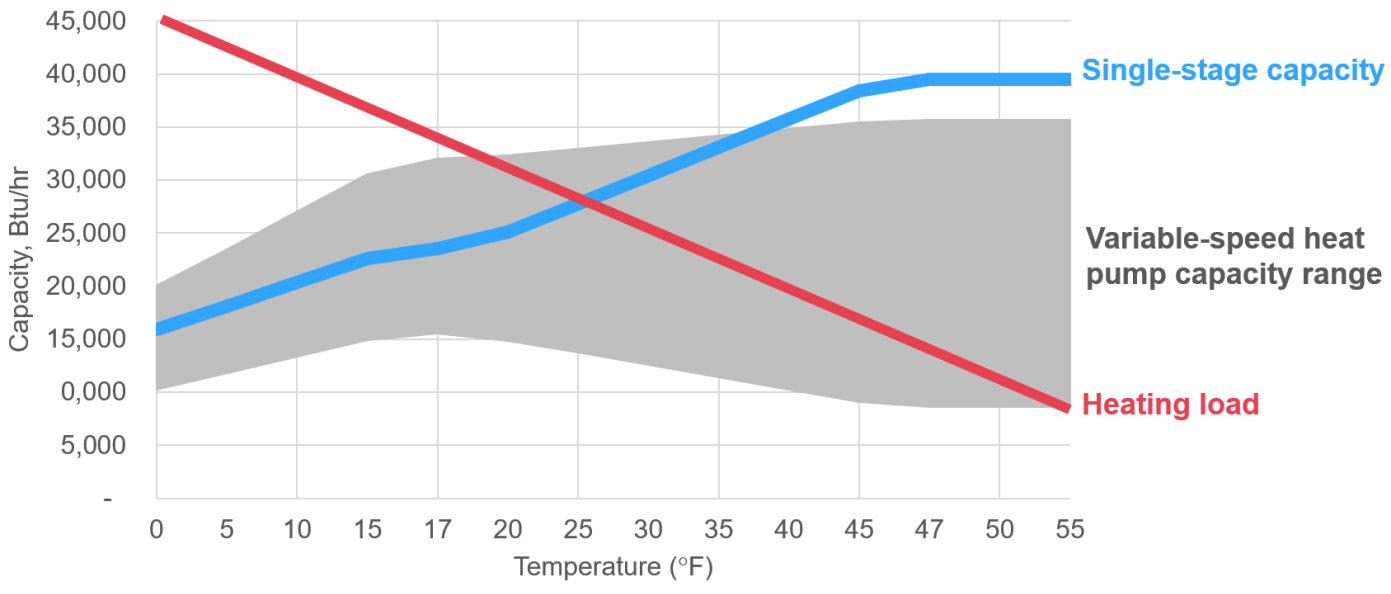
- **Compressor-** The compressor motor is inverter-driven, which gives it the ability to have variance in capacity.
- **Fan-** The fan is controlled by an electrically commuted motor for variable speeds.
- **Expansion valve-** The electronic expansion valve is controlled by an electromagnetic piston to vary the firing rate.

These three components are controlled by finely tuned algorithms. The algorithms adjust the flow of refrigerant and air to deliver the optimal amount of heat for the current need and conditions. Manufacturers have several different sensor and control strategies to inform the algorithms, but they all serve the same purpose.

There are additional advantages to variable-speed heat pumps. Variable-speed heat pumps can operate at higher speeds for quicker recovery. They can also operate at lower speed for steady operation and tighter control around the set point. Comparatively, one or two-stage heat pumps have lower, slower recovery and have a larger deadband.

The chart below shows the modulation and cold weather performance of a variable-speed heat pump compared to a single-stage heat pump. The single-stage heat pump can only operate at one speed, which is shown with the red line. The variable-speed heat pump can modulate between its maximum and minimum capacities, which allows it flexibility to meet the home's heating need. The gray shaded area shows the variable-speed heat pump's operational range.

## Performance of single-stage versus variable-speed heat pumps



At 37°, the maximum capacity of variable-speed heat pump is about the same as the capacity of the single-stage heat pump. Once the outdoor temperature drops to 17°, the capacities diverge significantly. The variable-speed heat pump then achieves about one ton of additional heating capacity compared to the single-stage heat pump, reflecting the greatly improved capacity maintenance of variable speed systems.

## What this means for customers

Variable-speed heat pumps are ideal for customers interested in increasing their comfort, displacing expensive heating fuel, and reducing their carbon impact. Variable-speed heat pumps have more performance benefits than single or two-stage heat pumps, including more consistent temperatures through the home, quieter operation, and better dehumidification. Variable-speed heat pumps are more energy efficient and can operate to lower temperatures. Additionally, variable-speed heat pumps are more likely to qualify for rebates and incentives.

Single and two-stage heat pumps can be good fits for customers who do not mind forgoing the performance benefits of variable-speed systems for a lower upfront cost. Additionally, single and two-stage heat pumps can be good fits for customers who are only interested in using their heat pump for a minimal amount of heating hours.

## Sources:

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