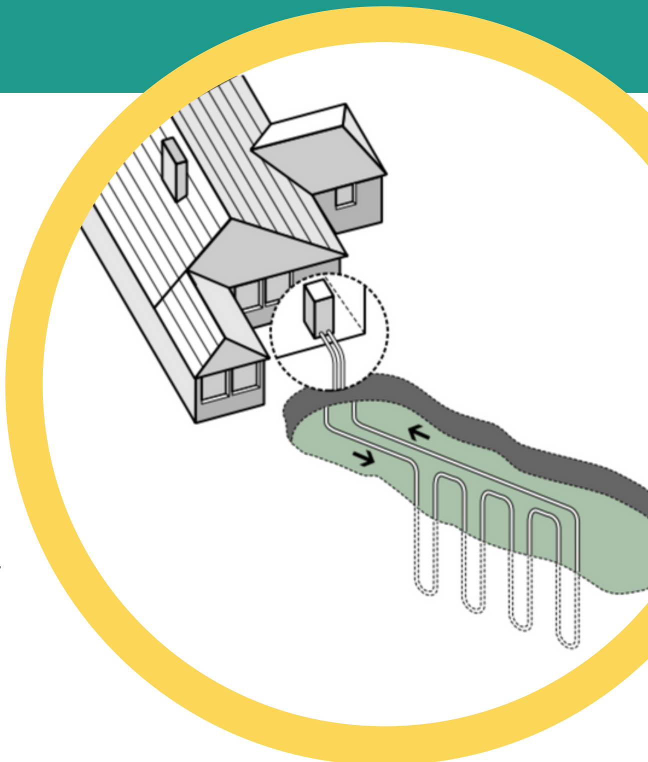
Heat Pumps



Cozying up with Heat Pumps

What's your favourite season? Whether you love the crunch of falling leaves or fresh air of spring, many of us can agree that it's great to have the option to head indoors to cool off in a heat wave (or to keep cozy during cold weather)!

To help manage the temperature of a building, our indoor spaces can depend on a variety of technologies like air conditioners, heat pumps or furnaces. However, not all options are the same, especially when it comes to their functionality and environmental impacts. In this backgrounder, learners will learn about heat pumps, one of the greener technologies for climate control in our buildings.

What is a heat pump?

A heat pump is a heating and cooling system that uses electricity to move thermal energy from one place to another. During the chill of winter, the heat pump can scavenge heat from outside and transfer it into a building to keep us warm. Then, in summer, the heat pump works in the opposite manner and collects heat from the inside of a building and sends it outside to cool down the building. Simply speaking, the heat pump plays the role of a furnace during wintertime and an air conditioner during summertime.

Heat Pumps

- Use electricity to move thermal energy from one location to another. The area where the thermal energy is gathered from is called a **source**, and the area where the energy is delivered is a **sink**. With most heat pumps, the source and sink can be switched as needed.
  - If thermal energy is moved indoors by a heat pump, the room gets warmer.
  - If thermal energy is removed from the indoors by a heat pump, the room gets cooler.
  - This means that heat pumps that can cycle in both directions are able to warm up and cool down the temperature indoors, as needed.
- Are filled with refrigerant - a fluids that boils at low temperature, making it easy to move thermal energy around, even at chilly temperatures.

Two types of heat pumps are commonly used in Canada; air-source heat pumps and geothermal heat pumps.

Air-Source Heat Pumps

The **air-source heat pump** uses a refrigeration system (Figure 1) to transfer heat between the building and outdoor air. The refrigeration system is composed of **a compressor** and **two metal coils** (one indoors and one outside), with refrigerant inside.

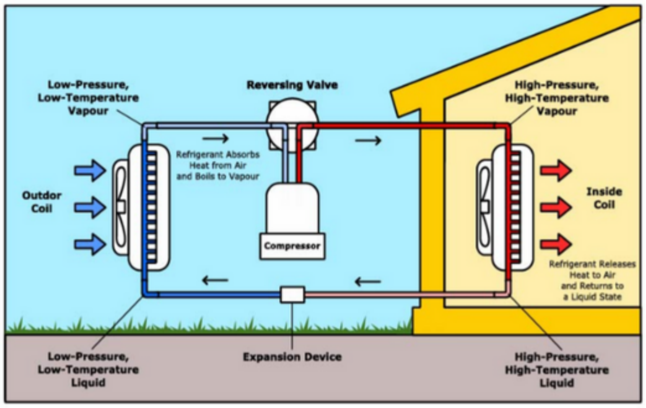


Figure 1 Scheme of an air-source heat pump [1] on a heating cycle

What is refrigerant?

The refrigerant used in refrigeration systems is a liquid that usually has a very low boiling point (as low as -60°C) . This low boiling point allows refrigerant to absorb heat from the environment even at low temperature (e.g. 0°C) and boil into a low-temperature vapour state. As it is cycled through the system, the refrigerant undergoes a phase transition back to liquid from gas as thermal energy is released, and is ready to be cycled through the heat pump again.

Heating Cycle

(warming up the inside)

1. In the **heating cycle**, liquid refrigerant passes through the outside coil and absorbs thermal energy from the outdoor air (*source*), and begins to boil into a vapour state as it heats up.
2. When refrigerant reaches the compressor, it gets compressed into a smaller volume and further heated up before entering the indoor coil.
3. Once refrigerant reaches the indoor coil, the heat from the hot vapour is transferred to the indoor air (*sink*), warming up that space.
4. As the heat leaves the indoor coil, the refrigerant cools and condenses into a liquid again on its way back outside to continue the cycle again. It gets further cooled during expansion in the expansion device, which allows it to absorb more heat from the environment.

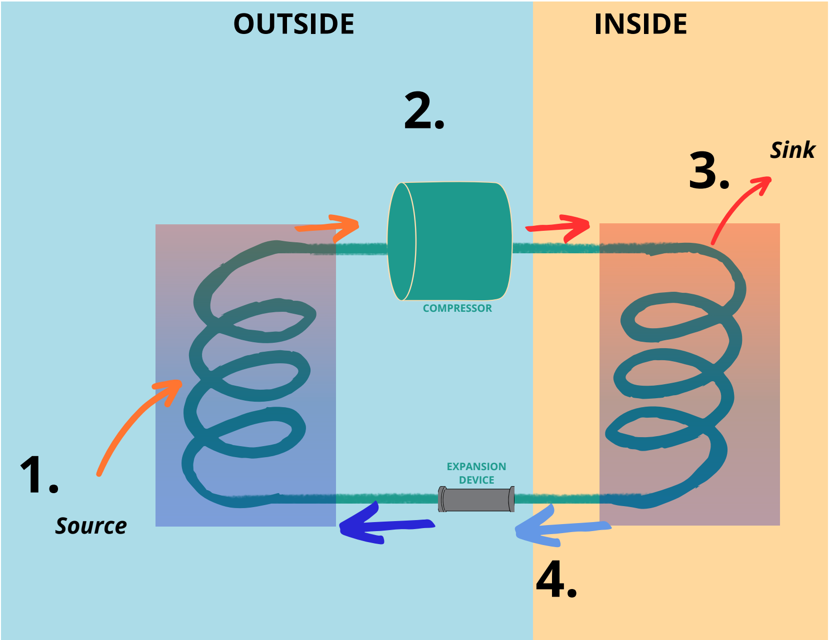


Figure 2 Heating cycle flow of thermal energy in an air-source heat pump

Cooling Cycle

(cooling down the inside)

In the **cooling cycle**, the heat pump works in a similar way - but this time in reverse - moving the heat from indoors to outside.

1. The liquid refrigerant absorbs heat from the indoor air (*source*), boils, and turns to vapour.
2. The vapour is then compressed by the compressor, reducing its volume and causing it to heat up.
3. Finally, the hot vapour will pass through the outdoor coil and transfer heat to the outdoor air (*sink*), resulting in the re-condensation of refrigerant.
4. The cooled refrigerant is chilled even more by the expansion device, and sent inside to begin the cycle again.

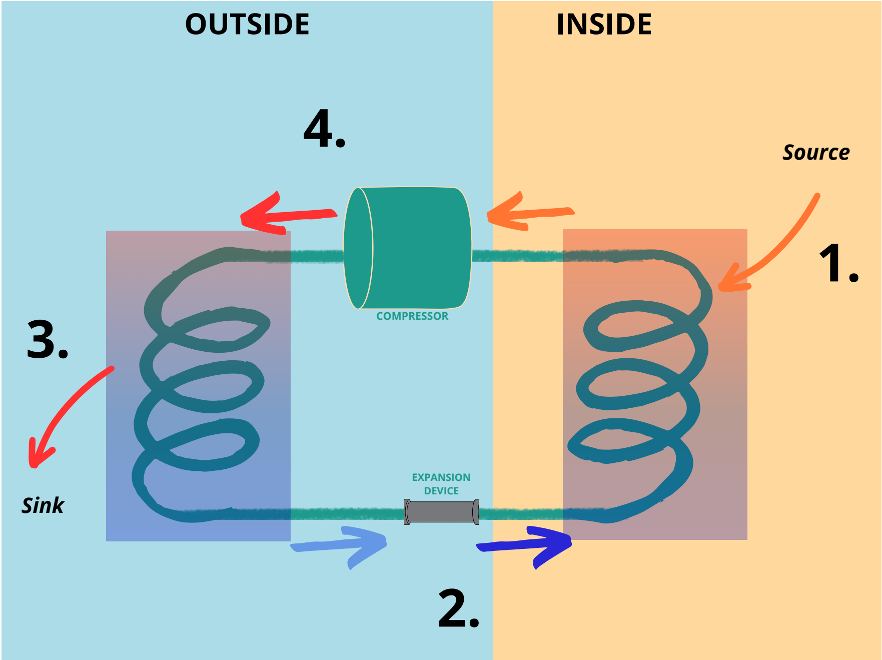


Figure 3 Cooling cycle flow of thermal energy in an air-source heat pump

Geothermal Heat Pumps

The **geothermal heat pump** (Figure 4) transfers heat between the house and either soil or water outside. This type of heat pump contains two key components: **an underground heat collector** and **a heat pump**. The underground heat collector is composed of a series of continuous loops of piping buried underground or submerged in water. The heat pump in the building uses an antifreeze fluid or refrigerant flowing through the ground heat collector which facilitates the heat exchange between the house and soil/water.

Unlike the air temperature which varies significantly across the year in Canada, the temperature underneath the surface is relatively constant. At depths of 5 to 6 m below surface, the ground temperatures are essentially constant throughout the year at about 10 °C.[3] This temperature is warmer than the air in winter and cooler than the air in summer. Therefore, geothermal heat pumps can take advantage of these more favorable temperatures to warm up the house in cold weather and reduce indoor temperature in hot weather.

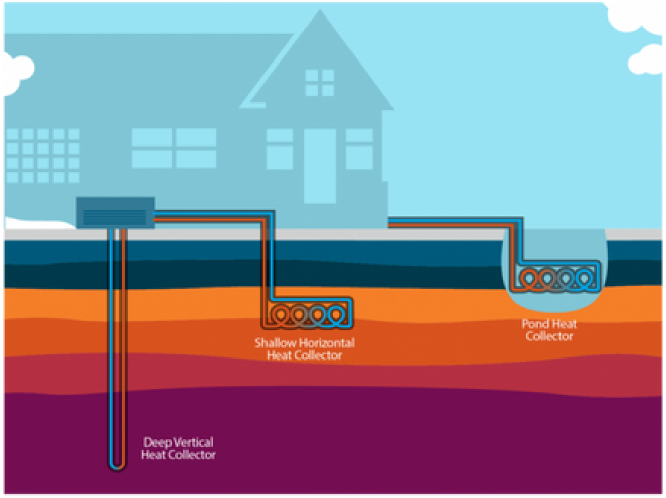


Figure 4 Scheme of a geothermal heat pump [2] on the heating cycle

Advantages of Heat Pumps:

2-for-1! Heat pumps can provide both heating and cooling options to a building - most can do both jobs! This makes them a great option compared to air conditioners, electric baseboard heaters and furnaces can only perform one function for the building (either cool or heat).

Long life! Heat pumps usually require less maintenance and have better reliability than furnaces. Replacing air conditioners and heating units with heat pumps can save time and money on maintenance in the future. Heat pumps also have a long service life; you can expect them to last you as long or much longer than many other common options.

- The service life of air-source heat pumps is about 15 years, which is comparable or longer than a conventional natural gas furnace.
- Geothermal heat pumps last significantly longer than air-source heat pumps; the heat pumps in have an average life expectancy over 20 years and the underground infrastructure like loops and pipes last for 25 to 50 years.[4]

Energy efficient! Heat pumps are very energy efficient. Instead of generating heat, they simply move heat from one space to another using small amounts of electricity. Electric furnaces and baseboard heaters also use electricity, but this electricity is used to generate heat through electric resistance. This takes much more electricity to do, compared to heat pumps.

Lower GHGs! Gas furnaces burn natural gas to heat the air; this burning directly produces greenhouse gases. Heat pumps only require electricity to work, no greenhouse gases are directly produced here! However, the electricity has to come from somewhere - this can vary from province to province, and many local power plants use fossil fuels for electricity production. However, heat pumps are still much more environmentally friendly than furnaces. A recent study published by the University of California conducted carbon dioxide emissions forecasts (this is a prediction based on past and present data) for operating either a heat pump or gas furnace for residential heating over a 15-year period (2022 to 2036) across the US and found that residential heat pumps reduce carbon dioxide emissions by 38-53% over a gas furnace [6]. Similarly, the International Energy Agency predicted that total greenhouse gas emissions for heating in Canada could decrease over 4 times if households switch from gas furnaces to heat pumps.[7]

Safety! Heat pumps are safer than gas furnaces. The natural gas that a furnace burns to produce heat runs the risk of leaking, which can cause dangerous accidents like fires and explosions. Additionally, when natural gas is burned, it produces toxic and harmful substances like carbon monoxide, polycyclic aromatic hydrocarbons, aldehydes, unburnt hydrocarbons, sulphur oxides, and nitrogen oxides. The leakage of these gases in a building can cause health issues ranging from headaches to serious illness, carbon monoxide poisoning, and even death. [8]

Disadvantages of Heat Pumps:

$$$! Heat pumps are generally more expensive to install than other alternatives. Air-source heat pumps in general come at a higher cost compared to other systems such as furnaces or electric baseboards due the number of components in the system. However, it is important to keep in mind that the incremental cost of such a system can be recovered through energy cost savings over a period as low as 5 years.[9] A geothermal heat pump typically has a much higher upfront cost than air-source heat pump and furnace. The drilling and installation of a heat pump could cost about $15,000 to $25,000 CAD and the heat pump itself will cost between $4,000 to $9,000 CAD. Although a geothermal heat pump significantly reduces the monthly utility bills of a building, it will typically take over ten years to have the initial cost recovered through energy cost saving.[10] Also, installation may require some research into municipal regulations. In some areas the installation of geothermal heat pumps will require special permission. The underground work for the drilling process and installation of underground pipes may have negative impacts on municipal infrastructures or aquifers below ground.

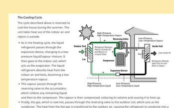
Cold Weather! While geothermal heat pumps can rely on the consistent temperatures below ground all year round, air-source heat pumps become less energy efficient when the weather becomes colder. Air-source heat pump systems have to work much harder to extract heat from the cold environment to warm the building. At the minimum outdoor operating temperature (from -15°C to -25°C for the latest models [9]), air-source heat pumps are unable to operate. In many parts of Canada, especially the interior and prairie provinces, temperatures in the winter are usually close to or lower than the minimum outdoor operation temperature. Therefore, in these areas, supplemental heat sources are required to keep the building warm.

Heat Pump Trends

Today, many of us still heat our houses, schools and offices with fossil fuels, particularly natural gas. This contributes to significant greenhouse gas emissions. Current global energy crisis experts [11] also urge us to move to clean and renewable energies to boost energy security. Therefore, heat pumps, especially when powered by low-emissions electricity, will be an important technology to make heating more secure and sustainable. The International Energy Agency predicted that heat pumps have the potential to reduce global carbon dioxide by at least 500 million tonnes in 2030 - equal to the annual CO2 emissions of all cars in Europe today.[7]

Looking for more information on heat pumps?

If you're looking to dive deeper, Natural Resources Canada has a great explanation of how heat pumps work, in more detail! Check out the following links to learn more about air-source and ground-source heat pumps:



NRCan Heat Pump Resource: **https://natural-resources.canada.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817#b**

Video on heat pumps in Canada: **https://www.youtube.com/watch?v=-wTRGbDY7Kk**

Heat pumps have become more and more popular in the past years. In 2021, heat pump sales increased by more than 13% globally. In some European countries like France, Italy, and Germany, sales grew by around 35% year-on-year, exceeding 2.2 million units. Air-source heat pumps account for the majority of sales globally, with a market share of more than 60% in 2021. Not as many geothermal heat pumps were installed, due to their higher upfront cost.[12] Over 30 countries in the world have announced plans to address the high upfront cost of heat pumps.[7] In Canada, both federal and provincial governments [13, 14, 15] have offered incentives which can save home owners up to several thousand dollars when converting from other heating utilities to a heat pump.

When faced with a climate crisis and financial support from the government, heat pumps are a great climate control system to keep us cool or cozy in the future!

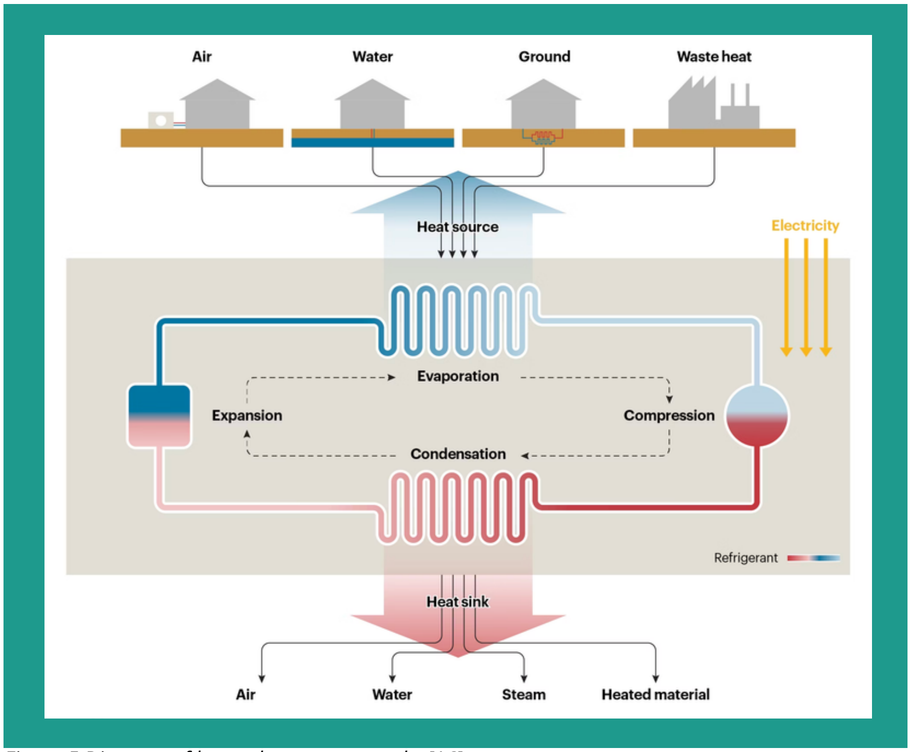


Figure 5 Diagram of how a heat pump works [16]

Reflection Questions:

- How do heat pumps work?
- What are the fundamental differences between heat pumps and natural gas furnaces?
- What are the advantages and disadvantages of air-source heat pumps?
- What are the advantages and disadvantages of geothermal heat pumps?
- How can heat pumps help with the move towards the energy transition?

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