Information Sheet: Heat Pumps

THE AGENCY FOR CO-OPERATIVE HOUSING

L'AGENCE DES COOPÉRATIVES D'HABITATION

Climate change is influencing the timing of our choice to heat or cool our living quarters throughout the year. Comfort in our homes and relief from extreme temperatures becomes a higher priority during these heating and cooling seasons.

When exploring options to heat and cool your home or to reduce your consumption and energy bills, you may want to consider using a heat pump system.

What is a heat pump?

A heat pump is an electrically driven device that extracts heat from a place of low temperature and delivers it to a place with a higher temperature.

How does a heat pump system work?

A heat pump system is fully reversible, meaning that it can both heat and cool your home.

- The system consists of an indoor fan coil unit, an outdoor condensing unit and refrigerant piping that connects the two.
- During the winter, heat from the outdoor air is absorbed and transferred through a refrigerant circuit to heat up an indoor space.
- In the warmer months, heat is absorbed from within the indoor space and is rejected to the outdoors.
- It is important to note that the efficiency of the heat pump depends greatly on the outdoor temperature. Therefore, determining the right size and design of the heat pump is important to maximize seasonal efficiencies.
- Typically, a heat pump can operate at full capacity down to -17°C, while still providing heat at a reduced capacity down to -30°C.

Advantages and Disadvantages of a Heat Pump System

The advantages to a heat pump system are that it is energy efficient, reduces your carbon footprint and can perform at a relatively high level throughout the year. The disadvantages are that it will be less efficient on very cold days and may be more expensive than electric baseboard heating.

Sources and Sinks for Heat Pumps

Selecting the **source** and **sink** for your heat pump system goes a long way to determine the performance, capital costs and operating costs of your system.

In Canada two sources of thermal energy are used most often for heating homes with heat pumps:

- **Air-Source:** In Canada, air-source systems are the most common. In an air-source system, the heat pump draws heat from the outside air during the heating season and rejects heat outside during the summer cooling season.
- **Ground-Source:** A ground-source heat pump uses the earth, ground water or both as the source of heat in the winter and as a sponge that absorbs heat removed from the home in the summer. The primary advantage of a ground-source heat pump is that it is not subject to extreme temperature fluctuations. With the ground as a constant temperature source, this is the most energy- efficient type of heat pump system.

Two sinks for thermal energy are most used for heating homes with heat pumps in Canada:

- Indoor air is heated by the heat pump. This can be done through
  - a centrally ducted system or
  - a ductless indoor unit, such as a wall mounted unit.
- Water inside the building is heated. This water can then be used to serve terminal systems like radiators, a radiant floor, or fan coil units via a hydronic system.

Air-Source Heat Pumps

Air-source heat pumps use the outdoor air as a source of thermal energy in heating mode, and as a sink to contain energy in cooling mode. This type of system generally falls into two categories:

Air-Air Heat Pumps. These units heat or cool the air inside your home and are standard for integrations of air-source heat pumps in Canada. They can be further classified according to the type of installation:

- **Ducted:** The indoor coil of the heat pump is in a duct. Air is heated or cooled by passing over the coil, before being distributed via the ductwork to different locations in the home.
- **Ductless:** The indoor coil of the heat pump is in an indoor unit. Generally located on the floor or wall of an occupied space, these indoor units heat or cool the air in that space directly. Among these units, you may see the terms mini- and multi-split:
  - **Mini-Split:** A single indoor unit is located inside the home, served by a single outdoor unit.
  - **Multi-Split:** Multiple indoor units are in the home and are served by a single outdoor unit.

Air-Water Heat Pumps: Less common in Canada, air-water heat pumps heat or cool water and are used in homes with hydronic (water-based) distribution systems such as low temperature radiators, radiant floors or fan coil units. In heating mode, the heat pump provides thermal energy to the hydronic system. This process is reversed in cooling mode, as thermal energy is extracted from the hydronic system and rejected to the outdoor air.

So how does an air-source heat pump work?

An air-source heat pump has three cycles:

1. The Heating Cycle: Providing thermal energy to the building

During the heating cycle, heat is taken from outdoor air and pumped indoors.

- First, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the outdoor coil, which acts as the evaporator coil. The liquid refrigerant absorbs heat from the outdoor air and boils, becoming a low-temperature vapour.
- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid before the vapour enters the compressor. The vapour is then compressed, reducing its volume, and causing it to heat up.
- Finally, the reversing valve sends the gas, which is now hot, to the indoor coil, which is the condenser. The heat from the hot gas is transferred to the indoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device and the cycle recurs. The indoor coil is in the ductwork, close to the furnace.

The ability of the heat pump to transfer heat from the outside air to the house depends on the outdoor temperature. As this temperature drops, the ability of the heat pump to absorb heat also drops. For many air-source heat-pump installations, this means that there is a temperature (called the thermal balance point) when the heat pump's heating capacity is equal to the heat loss of the house. Below this outdoor ambient temperature, the heat pump can supply only part of the heat required to keep the living space comfortable, and supplementary heat is required.

It is important to note that most air-source heat pumps have a minimum operating temperature, below which they are unable to function. For newer models, this can range from between -15°C to -25°C. Below this temperature, **a supplemental system must be used** to provide heating to the building.

2. The Cooling Cycle: Removing thermal energy from the building

The unit takes heat out of the indoor air and rejects it outside.

- As in the heating cycle, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the indoor coil, which acts as the evaporator. The liquid refrigerant absorbs heat from the indoor air and boils, becoming a low-temperature vapour.
- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid, and then to the compressor. The vapour is then compressed, reducing its volume, and causing it to heat up.
- Finally, the gas, which is now hot, passes through the reversing valve to the outdoor coil, which acts as the condenser. The heat from the hot gas is transferred to the outdoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device, and the cycle is repeated.

During the cooling cycle, the heat pump also dehumidifies the indoor air. Moisture in the air passing over the indoor coil condenses on the coil's surface and is collected in a pan at the bottom of the coil. A condensate drain connects this pan to the house drain.

3. The Defrost Cycle: Removing frost build-up on outdoor coils

If the outdoor temperature falls to near or below freezing when the heat pump is operating in the heating mode, moisture in the air passing over the outside coil will condense and freeze on it. The amount of frost buildup depends on the outdoor temperature and the amount of moisture in the air.

This frost buildup decreases the efficiency of the coil by reducing its ability to transfer heat to the refrigerant. At some point, the frost must be removed. To do this, the heat pump switches into defrost mode. The most common approach is as follows:

- First, the reversing valve switches the device to the cooling mode. This sends hot gas to the outdoor coil to melt the frost. At the same time the system shuts off the outdoor fan, which normally blows cold air over the coil, reducing the amount of heat needed to melt the frost.
- While this is happening, the heat pump is cooling the air in the ductwork. The heating system would normally warm this air as it is distributed throughout the house.

One of two methods determines when the unit goes into defrost mode:

- **Demand-frost controls** monitor airflow, refrigerant pressure, air or coil temperature and pressure differential across the outdoor coil to detect frost accumulation.
- **Time-temperature defrost controls** are activated by a pre-set interval timer or a temperature sensor located on the outside coil. The cycle can be initiated every 30, 60 or 90 minutes, depending on the climate and the design of the system.

Unnecessary defrost cycles reduce the seasonal performance of the heat pump. As a result, the demand-frost method is generally more efficient since it starts the defrost cycle only as required.

Supplementary Heat Sources

Air-source heat pumps have a minimum outdoor operating temperature of between -15°C to -25°C and reduced heating capacity at very cold temperatures. As a result, supplemental heating is essential wherever air-source heat pumps are used. Supplementary heating may also be required when the heat pump is defrosting. Different options are available:

- **All Electric:** In this configuration, heat-pump operations are supplemented with electric baseboards or with electric resistance elements located in the ductwork. These resistance elements are less efficient than the heat pump but can provide heating independent of outdoor temperature.
- **Hybrid System:** In a hybrid system, the air-source heat pump uses a supplemental system such as a furnace or boiler. This is an option in new installations and where a heat pump is being added to an existing system, for example, when a heat pump is installed as a replacement for a central air-conditioner.

Reference for the Heat Pump Information Sheet

The information provided in the Agency Information Sheet is from the Natural Resources Canada's 'Heating and Cooling with a Heat Pump' page - https://natural-resources.canada.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817.