Cold Climate Air Source Heat Pumps

Edmonton, 13 Jan 2024, -33C.

One of the challenges when building net-zero energy is to find a way to electrically heat your home. Since the energy we generate will be electric (from solar) our heat will need to be electric.

How much heat you need to heat your home comes down to two things, how cold it is where you live and how well your home is insulated.

One measure of climate is Heating Degree Days. This is a calculation of the temperature needed to warm your home up to 18C times the number of days needed to maintain that temperature.

So how much heating is needed in your area? Edmonton (where I live) requires 5,439 heating degree days* a year. The warmest city in Canada is Vancouver with 2,776 heating degree days a year while the coldest is Resolute (Qausuittuq) at 12,339 heating degree days a year. Alberta has a high of 6,914 heating degree days a year in High Level and a low of 4,574 heating degree days a year in Lethbridge. Calgary has 5,110 heating degree days a year and Ft McMurray is at 6,276.

The second aspect is how well your home is insulated and sealed. We measure this by calculating a design heating load for the home. This is then used to specify the heating equipment that will heat the home. Ideally, you will have a professional prepare a heating model that will accurately show the heating load you need to heat your home in your climate zone. Natural Resources Canada has a software modeling program called Hot 2000 which is commonly used to evaluate the energy needs of a home.

We can measure the energy efficiency of a home by how much energy is needed to heat it over a year. A typical new home in Alberta will use 120 kWh of energy per year for each square meter of living space (120 kWh/m^2 year). One design standard for energy-efficient homes is Passive House. To meet the Passive House design standard your energy-efficient home must consume less than 15 kWh/m^2 year. Getting to 15 kWh/m^2 year is very challenging in our cold climate but is possible with careful design. Most new net-zero energy homes would target an energy-efficiency of 30 kWh/m^2 year or less. https://www.passivehousealberta.com/

From your heating model your designer will specify the size of the heating unit you will need. In North America this is usually specified in British Thermal Units per hour (BTU/hr). My home requires a heating unit with a capacity of 48,000 BTU/hr (14,000 watts per hour) to maintain heat in our home at the design low temperature (which in our case is -30C). You will also hear heating people talk about a “ton” of heating which is 12,000 BTU/hr (ex. With 48,000 BTU/hr we have a 4-ton unit).

There are three ways to heat a home electrically. The first is to use electric resistance heating. This can be baseboard heaters or small unit heaters with resistance coils and fans. The little space heaters that you plug in to heat cold spots in your house are a type of resistance heater. Electric resistance heat is 100% efficient; that is, for every 1 kWh of electricity you consume you will receive 1 kWh of heat (1/1 = 100%). Resistance heating is used in climates that are not too cold

(Vancouver) and/or where the price of electricity is very low (parts of Quebec). The advantage of resistance heating is that the equipment (such as baseboard heaters) is inexpensive.

We have seen net-zero energy homes that use electric resistance heating in Alberta. These net-zero energy homes have added so much insulation (walls with R40 or better) that their heating requirements are very modest (less than 3,000 watts per hour or 10,000 BTU/hr). These homes would typically be very close to, or better than, the 15 kWh/m^2 year Passive House standard.

When you live in a cold climate electric resistance heating can become very expensive. There are 278 kWh in a Gigajoule (GJ) of energy. Today a typical contract price for electricity in Alberta is 12.85 cents/kWh and the price for gas is $4.85/GJ (camroseenergy.com 13 Jan 2024). If we calculate the price of 278 kWh of electricity (1 GJ) it would be $36 which is 7 times higher than the equivalent price for 1 GJ of gas.

Our point in electrifying our heating is so that we can generate offsetting energy with solar. It is rarely economical to electrify heating in a cold climate without solar. With electric heating and the right amount of solar, however, you can reduce your annual heating bill to nearly zero.

The amount of solar you can put on your home will be limited to the size and shape of your available roof space. The more energy-efficient you make your home the lower the lower your design heating load and the less heat you need to generate in a year. The trick is to balance your home's efficiency so that you can fit enough solar on the available roof space to offset your annual energy needs. You need to keep your heating unit small or get a bigger roof!

A more efficient electric heating method is to use a heat pump. A heat pump uses a refrigeration cycle to extract heat for heating your home. Your refrigerator is a heat pump. Your fridge moves heat from the cold interior of the fridge and expels that heat to the outside of the fridge. You will notice heat coming from your fridge when it is working (typically from the bottom). A home heating heat pump extracts heat from outside the house (chills the outside) and then expels the heat inside the house. There are two basic types of heat pump for home heating; one that extracts heat from liquid-filled pipes in the ground (ground source), and one that extracts its heat from the air (air source).

A Ground Source Heat Pump (GSHP, sometimes called geothermal) extracts heat from liquid-filled pipes in the ground outside of your home and delivers the heat to the inside of your home. Essentially you are cooling the ground outside and warming your home inside. There are a couple of ways to circulate the liquid in the ground, but they all work the same way. Ground source heat pumps are fairly expensive as placing the liquid-filled pipes usually requires significant drilling or trenching during installation.

My ground source heat pump extracts heat from an array of liquid-filled pipes buried in my front yard (4 boreholes 60 m deep) and then blows hot air through the house using my home's original duct work. At capacity my heat pump draws 3,300 watts of electricity and produces 14,000 watts (48,000 BTU/hr) of heat. The heat pump is providing 4.24 times more heat than the electricity used to make the heat (the rest of the heat is extracted from the ground). We say that this heat pump is 424% efficient which is referred to as a Coefficient of Performance (COP) of 4.24.

The other major types of heat pump are those that extract their heat from the air outside your home. Air Source Heat Pumps (ASHP) extract heat, chilling the air outside your home and then bringing that heat inside to provide heat. Air source heat pumps are very common. When you stay in a hotel the unit you see under the window is an air source heat pump. It provides both heating and air conditioning. There are millions of air source heat pumps used worldwide in hotels and in homes in temperate climates. The problem with older types of heat pumps is that they typically can't extract heat from air that is colder than about -10C. Most of these standard heat pumps will have an electric resistance heater that will come on if the outside temperature drops below -10C.

Heat pumps (ground or air source) can be connected to hot air or hydronic heating systems. All heat pumps will provide air conditioning, and some units can also provide domestic hot water.

In the past few years, new Cold Climate air source Heat Pumps (CCHP) have been developed that can extract heat from outside air as cold as -25C to -30C (-13F to -22F). These Cold Climate Heat Pumps (CCHP) are now a viable alternative for heating homes in most of Canada. Initially there were only a few manufacturers that made CCHPs such as Mitsubishi, Tosot, Daikin, Arctic, and Nordic. Other manufacturers are now working on CCHPs in response to the US department of energy's residential heat pump challenge.

The problem right now is that you will still hear heating contractors claim that air source heat pumps are not suitable for cold climates. They are referring to the older style heat pumps and not Cold Climate heat pumps. You will need to seek out the heating contractors that are specifically working with Cold Climate Heat Pumps. They are available, but not yet common.

The COP of an air source CCHP will vary depending on the outside air temperature. The COP will vary from a high of 5 at warmer temperatures to a low of 1 at the design low temperature. There will be an electric resistance heater included in the CCHP to make sure there is sufficient heat at the design low temperature. Overall, throughout the year the COP of a CCHPs will be somewhere around 4.

CCHPs will have a supplementary source of heat which is typically an electric resistance heater. This heater will come on when the heat pump it below its design cold temperature. It is also available as backup heat should there be a problem with the heat pump. On ground source heat pumps an electric resistance heater can be purchased as an emergency heat option.

Note that some air source heat pumps come with gas furnace supplementary heat. This is sometimes done with an older style heat pump (not cold climate) and are sometimes referred to as dual-fuel, or hybrid heat pumps. There are two issues with using gas for supplementary heat. First, you don't get to disconnect from the gas utility which would save utility service charges. Second, you cannot achieve net-zero energy as you can't generate more solar energy than you consume electrically (Alberta microgen guidelines).

So which electrical heating system is right for you as you work toward net-zero energy? If you are building a new home then you may be able to make the building envelope efficient enough so

that you can use electric resistance heat, or perhaps a modestly sized CCHP. To build a new net-zero energy home we would suggest you find a builder that has experience with this type of building.

If you are renovating, then a deep energy retrofit can dramatically reduce the energy demands of your home. Once you add insulation and air-seal your home a bit better then a smaller electric heating unit should meet your needs.

The goal is to match the energy-efficiency of your home and heating system to the amount of solar you can reasonably install on your roof.

So what are your next steps? We would recommend that you visit the Eco-Solar Home Tour each year in June. The tour lets you meet with the homeowners who have installed and are living with these types of heat pump systems. They can let you know what their experience has been with their heat pump and how they have achieved net-zero energy in their home.

**This heating degree data is taken from an online atlas prepared by the Prairie Climate Centre in Winnipeg. Their numbers are based on data collected from 1976 to 2005. You can find this map at https://climateatlas.ca/map/canada/hdd_2060_85#*