Heat Pump Characterization Study

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Preface

This background paper is intended to be a brief overview that covers air-source heat pump topics of particular relevance to the Yukon. These topics include a summary of recent technology developments, economic estimates of the cost of heating with air source heat pumps in the Yukon compared to oil and electric heat, a recommended sizing approach for cold climates, recommended efficiency specifications for the Yukon, and other cold climate specific topics.

Caneta has prepared booklets or guides for other organizations and it is intended that the reader look to these for more details on definitions, benefits, service and maintenance, advantages and disadvantages, and information on other heat pump system types. In particular, the reader is directed to the Natural Resources Canada booklet Heating and Cooling with a Heat Pump and the Centre for Energy Advancement through Technological Innovation (CEATI) publication Heat Pump Efficiency Guide.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

Recent improvements in air-source heat pump technology and associated improved efficiency have increased interest in this alternative heating source in the Yukon. The use of heat pumps has the potential to reduce building heating cost, reduce the use of non-renewable heating fuels, and reduce greenhouse gas emissions in the Yukon. The intent of this background paper is to provide information on air-source heat pumps that will assist those interested in purchasing an air-source heat pump to make an informed decision. Below is a summary of the main conclusions in this background paper:

Sizing and economics

- A reasonable sizing approach is to select a heat pump with a heating capacity at 0 °F of 25-35 percent of the house design heating load. A heat pump of this size would supply 60 to 75 percent of the annual heating load and can be economical.
- Air source heat pumps tend to be most economic when the existing heating cost is over $4,000 per year.
- As a rule of thumb, a heat pump will usually have a payback of under six years, if the cost of installation is less than three times the annual heating cost at current electricity and heating prices in the Yukon. This rule could change as energy prices change.
- Payback periods look attractive at higher levels of heating use, but heat pumps can be economic even in SuperGreen insulated homes.

Recommended efficiency specifications for the Yukon

- Generally, only a heat pump that has a coefficient of performance (COP) of 2 or better at -18 °C (0 °F) should be considered to have good energy efficiency.

Summary of recent technology developments

- Three different types of air-source heat pumps (conventional, cold climate and mini-split) have different advantages and disadvantages. The type selected will depend on the user's needs, and all can be suitable in different situations.
- Scroll compressors are becoming more common in heat pumps, and have some advantages over reciprocating compressors.
- Air-source heat pumps on heat recovery ventilators show promise of being economic, but are not currently readily available.

Cold Climate Considerations

- An air-source heat pump can supply the heating requirements for a house or building for a significant portion of the heating season in the Yukon.
- Cold climate designs provide more heating capacity and higher efficiency at lower outdoor temperatures.
- There are a limited number of cold climate heat pump designs available at present.
- Longer hours of heat pump operation may impact on reliability and compressor life. More operating experience is needed.
- Installation of properly-sized start up and running capacitors on a heat pump compressor motor is recommended. Some heat pumps come with these already installed. This will improve operation of the heat pump and also help to extend the compressor motor life.

1. Introduction

1.1 How Air Source Heat Pumps Work

An air-source heat pump works the same way as a refrigerator or an air conditioner. Heat pumps, however, are designed so that they can provide both heating and cooling. Also, an air-source heat pump should not be confused with a ground-source or "geothermal" heat pump.

When an air-source heat pump is used for heating a building, heat from the outdoor air is absorbed at the evaporator. This heat causes the refrigerant in the evaporator to change from a low-pressure liquid to a low-pressure gas. This low-pressure gas is compressed in the compressor into a high-pressure, and hot, gas. This heat is released in the indoor coil or condenser and picked up by the indoor air. The vapour condenses to a high-pressure liquid as it gives up heat. This high-pressure liquid is expanded through the expansion valve to become a low pressure cool liquid which is pumped to an evaporator and the cycle is repeated.

An air source heat pump actually delivers more heat output than the amount of the electric input it uses. An air source heat pump can deliver 200% to 400% more heat than you would obtain from an equivalent electric resistance heating system. The amount of heat delivered depends on the outdoor temperature. This is because a heat pump transfers heat from the outside air. It is not using electricity to create the heat directly as happens in an electric element.

1.2 Benefits and Drawbacks of Air Source Heat Pumps

The energy costs for an air source heat pump can be lower than those of other heating systems, particularly electric or oil heating systems. They can provide heating and cooling from the same machine. Unlike oil and electric heating systems, air source heat pumps have a variable heating output that declines with decreasing outdoor temperature. They therefore require a back up heating system. Air source heat pumps are generally more expensive to purchase and install than oil or electric heating systems.

2. Summary of Recent Developments and Important Considerations

This section provides information on more recent heat pump technology developments and other important considerations for heat pump installation.

2.1 Reciprocating and Scroll Compressors

Reciprocating compressors are a type of positive displacement compressor that uses pistons driven by a crankshaft to compress the refrigerant to a higher pressure.

Scroll compressors operate by using two mating parts that literally "scroll" together. The first scroll is fixed or stationary, and the second scroll orbits in a path defined by the fixed scroll. As the refrigerant enters the space between the two scrolls as a gas, one scroll revolves around the stationary scroll to form a sealed chamber. As the scroll revolves, the refrigerant gas is gradually moved and compressed into the center of the scroll, increasing the temperature and pressure of the refrigerant.

Reciprocating compressors have been commonly used in heat pumps for years. Their efficiency is lower than that of a typical scroll compressor [1]. The scroll compressor exhibits almost 100% efficiency, since all of the refrigerant will be compressed during the scroll movement. In the case of a reciprocating compressor, there is always a small amount of refrigerant left uncompressed, because it is not practical for the piston to touch the valve plate.

In terms of reliability, a scroll compressor is generally much more reliable than a reciprocating compressor. A scroll compressor has a relatively high tolerance for liquid refrigerant because of its construction. There are also fewer moving parts in the scroll compressor's operating mechanism, which tends to improve its reliability. Generally, a scroll compressor vibrates less and is less noisy than a reciprocating compressor.

The scroll compressor's fewer parts make it much lighter than an equivalent reciprocating compressor. This is important to contractors because it helps make installation easier.[2]

The use of scroll compressors in heat pumps can provide 5 °C to 8 °C (10 °F to 15 °F) warmer air when in the heating mode, compared to existing heat pumps with reciprocating compressors. [3] That is, air-source heat pumps at the lower end of the efficiency range use single-speed reciprocating compressors, while higher efficiency units generally use two-stage reciprocating or multiple speed scroll compressors. [4] Nonetheless, many of today's two-stage capacity heat pumps still use a reciprocating compressor, including both the Acadia and York YKH heat pumps described later in section five.

2.2 Digital Scroll Compressors

Conventional scroll compressors have only two capacity settings -- "on" and "off". It is impossible to effectively vary the output of the compressor. Varying the output is known as "operating at part load".

In recent years, a new innovation has been developed to vary the compressor capacity. It is called a digital scroll compressor and was developed by Emerson Technologies. The engineers at Emerson found that if they quickly turn on and off the compression cycle, without having to turn on and off the compressor motor, they could modulate the output very closely to meet the needed capacity. A solenoid valve is installed to make a passage between the upper part of the fixed scroll and the suction pipe. When the solenoid valve is closed, the digital scroll operates like a standard scroll operating at full capacity. When the solenoid valve is open, no refrigerant flows through the compressor. By varying the fraction of time that this happens, the compressor capacity can be modulated between 10% to 100% [5].

Being able to vary the output of the compressor not only greatly improves the compressor efficiency, but also provides precise control over the amount of heating done.

2.3 Electronically Commutated Motors (ECM)

ECM stands for electronically commutated motors. They are ultra-high-efficiency programmable brush-less DC motors utilizing a permanent magnet motor and a built-in inverter [6]. Unlike the typical permanent-split capacitor (PSC) motors, where efficiency is low under part load conditions, ECM motors maintain a high efficiency at all speeds and loads. The ECM motor's efficiency can be as high as 82% which is a 20% greater efficiency at full load and 30% better efficiency at part load conditions than a PSC motor [7]. The microprocessor and electronic controls in the ECM motor provide the ability to program and control the speed of the motor, allowing for advanced operating characteristics that are impossible to replicate using conventional motor technologies. ECM motors greatly reduce the energy consumption and noise level compared to PSC motors. As an example, one ECM motor will use approximately 80% of the energy of a typical PSC motor [8]. Use of such motors helps improve the Seasonal Energy Efficiency Ratio (SEER) and Heating Season Performance Factor (HSPF) ratings of the heat pumps they are used in.

SEER and HSPF are ratings used to compare the efficiency of heat pumps. The SEER rating of a unit is the cooling output in Btu (British thermal unit) during a typical cooling-season divided by the total electric energy input in watt-hours during the same period. The higher the SEER rating the more energy-efficient the heat pump is while cooling.

HSPF is a ratio of BTU heat output over the heating season to Watt-hours of electricity used. It has units of BTU/watt-hr. The higher the HSPF rating, the more efficient the heat pump is while heating.

Another common measure is the coefficient of performance or COP. The COP is the ratio of useful heat produced to the work input, that is, the amount of electricity used. It is given for a specific outdoor temperature, usually -18 °C (0 °F) as it varies with temperature.

ECM motors also having a longer operational life than PSC motors due to their lower operating temperature, robust electronics, and pre-lubricated ball bearing design that requires little or no maintenance. For these reasons, the use of ECM motors is becoming popular in heat pumps.

2.4 Modulating Drives

The use of modulating motors in compressors is certainly not new. They have been quite commonly used in air conditioning applications. In air conditioners and heat pumps, the compressor is the main energy consumer. Modulating the capacities of the compressors represents a major opportunity to improve efficiency, save energy, and reduce compressor cycling [9]. One of the most common ways to modulate the compressor is to use “inverter” systems. A control system adjusts the drive frequency to control the speed of the motor and vary the capacity of the compressor. This technology is quite common in Japan and other far-eastern countries, and is widely used on ductless heat pumps (see the next section) [10].

2.5 Mini-Split or Ductless Heat Pumps

Mini-split or ductless heat pumps are a type of air source heat pump that can be used to provide air conditioning or heating to the interior of a house or building without using any ductwork. They are widely used in Europe and Asia today and are getting more popular in North America. In typical air source heat pumps, air is cooled or heated at the outdoor evaporator coil and distributed around the house through ductwork. However in mini-split systems, no ductwork is involved and refrigerant is compressed at the outdoor compressor/condenser, then delivered to the indoor air-handling unit through insulated liquid and vapour refrigerant lines. The indoor unit delivers the conditioned air to the room or space where it is located.

For years, several manufacturers have been developing and adding new features to the mini-splits, thus making mini-splits more desirable for consumers. New innovations in compressors, controls, and motors, have been increasing the efficiency of these units making them an attractive option.

2.6 Use of Synthetic Oil in Compressors

Synthetic oil is a type of lubricant that is created from compounds other than petroleum. All of the components are high in purity with strong molecular bonds. As a result, synthetic oil has a uniform molecular size, and is less vulnerable to oxidation[11]. Synthetic oil generally outperforms the mineral oils typically used for lubrication due to its superior mechanical and chemical properties. For example, its low viscosity at low temperatures helps make start up and operation of a heat pump easier in cold weather. Synthetic oil is commonly used in automobile engines to improve starting in cold weather, to reduce engine wear, and to improve fuel efficiency.

Synthetic oil has low friction properties, and resists viscosity increases due to oxidation. It helps improve operating efficiency and saves electrical energy consumption. The use of synthetic oil also reduces heat, oxidation and wear within the compressor, thus increasing the compressor life as well [12] [13]. Furthermore, synthetic oil resists water contamination. Water from condensation can build up in compressors and can cause unwanted oil/water emulsions, and rust. It is now becoming popular in compressor applications, too, such as in heat pumps, which are located and operated outside where they are exposed to cold winter temperatures and use of synthetic oils is advantageous. In fact, most heat pumps now use synthetic oil, since it yields better performance ratings than the conventional oils.

2.7 Air Source Heat Pumps On Heat Recovery Ventilators (HRVs)

The use of air-to-air heat pumps on heat recovery ventilators (HRVs) is currently popular in Europe. Two separate air streams pass through the heat exchanger within the heat pump. The heat exchanger extracts heat from the warm exhaust air to heat the incoming fresh air. The heat pump heats the supply air using heat extracted from the warm exhaust air thus raising the overall efficiency of the air source heat pump.

Another type of air source heat pump on HRVs is the air-to-water type. With the same principle, the HRV recovers the warm exhaust air in the building and the heat pump then uses the energy extracted from the exhaust air to generate hot water. The hot water can then be used for domestic hot water or radiant in-floor heating.

Most manufacturers of these types of heat pumps are located in Europe. NIBE, Paul Heat Recovery and Genvex are three major manufacturers.

Due to lack of operating experience with these types of heat pumps in North America, we do not currently have good information on the expected operating savings and payback.

2.8 Pros and Cons of Different Heat Pump Types

There are three basic types of heat pumps: conventional or dual capacity (low and high speed) heat pumps, multi-capacity (variable-speed) heat pumps, and mini-split or ductless heat pumps. Below is a summary of the pros and cons of these types of heat pumps.

Conventional or Dual Capacity Air Source Heat Pumps:

Pros:
- High efficiency in mild climates.
- Familiar to contractors and installers.
- Many residential applications use conventional dual capacity splits.
- High heating capacities available.
- Lower initial installation cost per ton than the other two heat pump technologies.
- Can be used with existing ductwork.

Cons:
- Do not perform well in colder weather (below -20 °C (-4 °F)).
- Leaky airflow in ducts can cause efficiency to decrease.
- Additional cost of installing ducting in homes with no ductwork.

Multi-Capacity or Variable-Speed Air Source Heat Pumps:

Pros:

- Provide high capacity at lower outdoor temperatures where more conventional air source heat pumps do not.
- Provide adequate capacity in cold climates.
- Less back-up electrical resistance heating needed thus reducing winter electrical peak loads.
- Can be economical in cold weather conditions in Yukon.

Cons:
- High first costs as much as twice that of dual capacity air source heat pumps.
- Few companies have experience with this type of unit. Installers will charge more to recover training and possible call-back costs.
- Manufacturers generally have only published ratings for Climate Zone IV Heating Season Performance Factor (HSPF). Information for Climate Zone V (cold) is usually not available for comparison. In addition, there are no certified COP ratings at temperatures below 8 °C (47 °F). In northern locations, much of the heating is done below this temperature. This makes it more difficult to evaluate the benefits of installing a multi-capacity heat pump in northern locations.
- Problems, (such as high bills associated with electric resistance backup heating, and low supply-air delivery temperatures) have been experienced by some heat pump users.
- Limited selection, with only one manufacturer and three sizes available at the present time.

Mini-Split or Ductless Heat Pumps:

Pros:
- Good for room retrofits where extending or installing distribution ductwork is not feasible.
- Small size and flexibility for heating and cooling individual rooms. Can have multiple indoor units providing individual zone control.
- Easier to install than other heating/air conditioning systems.
- No energy loss associated with ductwork, making them more energy efficient.
- Flexible design options for the indoor unit allow for mounting on the wall, ceiling, or the floor depending on homeowner's choice and circumstances.
- No ductwork required, which makes the unit ideal for homes with no ductwork, such as those with existing hydronic or electric baseboard heating systems.
- Integral thermostat allows for different room temperatures in different rooms.

Cons:
- High initial cost, often $1,500-$2,000 per ton of cooling capacity. This is about 30% more than other heat pump systems.
- Location of the indoor unit is very important. Oversized or incorrectly located air handlers result in short-cycling which wastes energy and does not provide proper temperature or humidity control.
- It may be difficult to find qualified installers for mini-split heat pumps.
- Single zone systems have low heating capacities, and multi zone systems, although having higher heating capacities, may require extensive refrigerant piping within the home. Mini-splits are most often used to heat and cool only a portion of a house.

2.9 Other Important Considerations

Harmonics and Other Electrical Effects

Harmonics are variations in the voltage and current in the electrical system as a result of certain kinds of electrical loads, such as motors.

During heat pump start-up, the compressor motor draws a high current. This high current draw causes a voltage drop, which in turn can have undesirable effects on other electrical equipment. One such effect is the flickering of lights in the home served by the heat pump. Using "soft start" (sometimes called "hard start") devices on the compressor motor can mitigate this. [EPRI]. The most common soft start device is the addition of a properly-sized capacitor to the compressor motor. A "start up" and a "running" capacitor are sometimes offered as part of the original equipment. This device will improve the "power factor" of the heat pump. The power factor is an electrical term and is defined as the ratio of the real power flowing to the heat pump and the apparent power.

There is a large variation in the harmonics produced by heat pumps. Some heat pump models produce less harmonics than do others. Harmonics are dependent on ambient indoor and outdoor conditions, and whether a heat pump is in heating or cooling mode. [24]

In some cases, distribution lines and transformers may need upsizing to handle these non-power-producing loads.

Some heat pumps achieve efficient operation by using variable frequency drives (VFDs). These VFDs convert alternating current to direct current, and then direct current back to alternating current with a frequency different from the original alternating current.

Potential problems with electrical harmonics are not common with most heat pumps and can generally be avoided by purchasing a heat pump from a reputable company. Installation of a properly-sized start-up ("soft start") capacitor and a "running capacitor" are recommended, if they are not provided with the heat pump by the manufacturer. These will improve operation of the heat pump and also help to extend the compressor motor life.

Typical Heat Pump Noise Levels

Heat pumps typically have noise ratings between 80 to 90 decibels (dB) [17] with some quiet enough to rate at 61 decibels or lower [Friedrich] depending on the type of heat pump.

Literature obtained from four manufacturers (Lennox, Hallowell, York, and Friedrich) indicates that outdoor unit noise levels are mostly dependent on compressor capacity. The ductless systems have the lowest noise ratings because they have the lowest capacity, and therefore use smaller, and thus quieter, compressors.

Reciprocating compressors produce the most noise of any compressor type. Scroll and rotary compressors produce roughly the same noise levels for outdoor units. The cold climate heat pump, that has reciprocating multi stage compressors, has noise dampening features which keep the noise rating at 61 to 62 dB.

How a compressor is installed in its cabinet affects the amount of noise produced by a compressor. Efforts are normally made to route refrigerant lines and use grommets to reduce noise transmission to the cabinet. For instance, the manufacturer of the cold climate heat pump uses a noise insulating interior cabinet around the compressor to reduce the nose produced by the outdoor unit of the heat pump. Other manufacturers use a special sound wrap on the compressor shell.

3. Recommended HSPF and COP Specification for Yukon

A recommendation for a Minimum Heating Seasonal Performance Factor (HSPF) or coefficient of performance (COP) should be based on local market cost-benefit considerations. Figure 1 shows how the simple payback period changes over a range of oil heating energy costs for a Yukon location. This is for the multi-capacity Acadia cold climate heat pump. It has an HSPF of 9.33, a COP @ -8°C (17 °F) of 2.5 and a COP @ -18 °C (0 °F) of 2.3 and it has almost two-times the heating capacity of conventional heat pumps at lower outdoor temperatures. See appendix 1 for a graph showing the Acadia's COP and heating capacity for a range of outdoor temperatures.

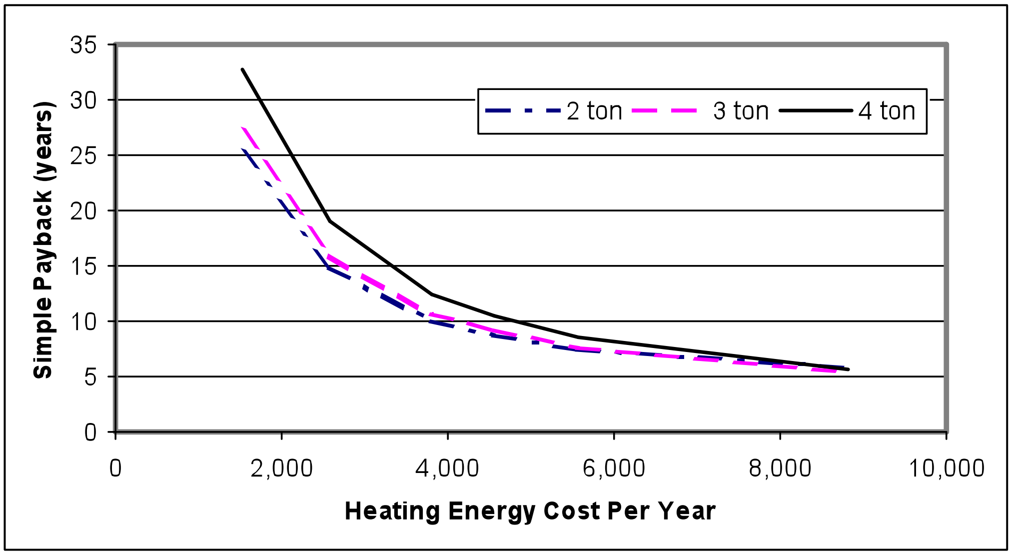

Figure 1: Simple Payback for Range of Annual Heating Costs for Acadia Heat Pump

The figure below shows the simple payback period over the same range of oil heating costs for a Yukon location for the York YZH two stage heat pump. It has an HSPF of 10.0, a COP @ -8°C (17 °F) of 3.0 and a COP @ -18 °C (0 °F) of 2.4. See appendix 1 for a graph showing the York's COP and heating capacity for a range of outdoor temperatures. The York heat pump has half the heating capacity of the Acadia at low temperatures. However, it has a much shorter payback period over the full range of annual oil heating cost.

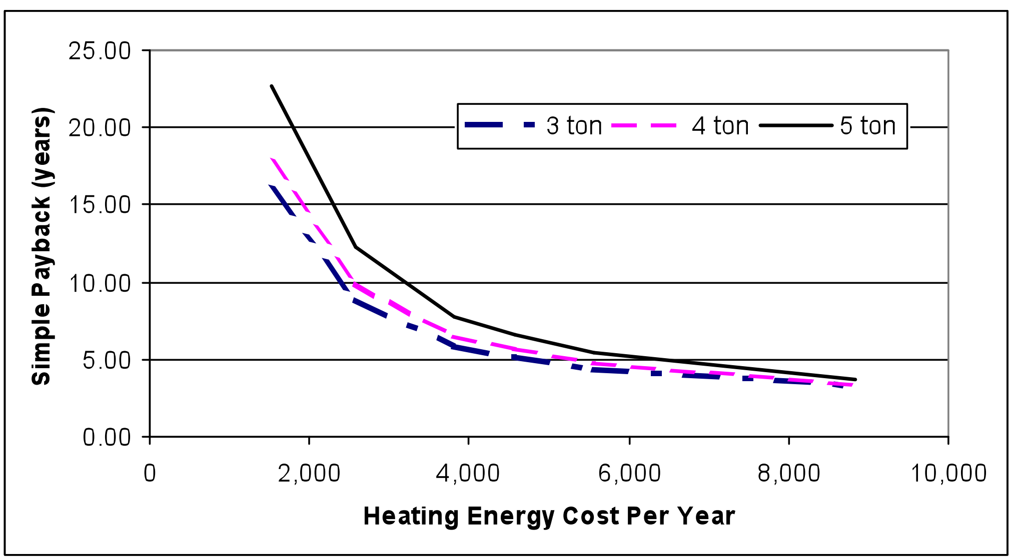

Figure 2: Simple Payback for Range of Annual Heating Costs for York YZH Heat Pump

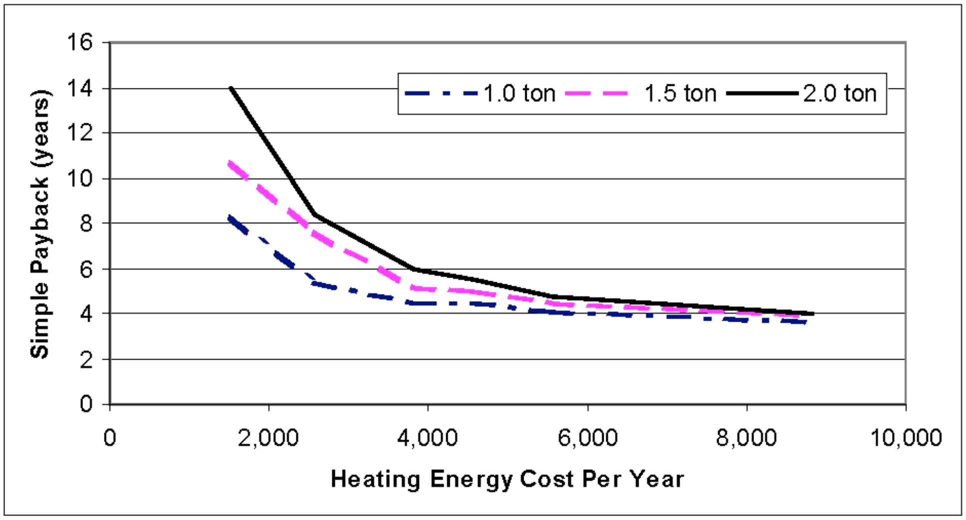

Figure 3: Simple Payback for Range of Annual Heating Costs for Mitsubishi Heat Pump

Finally, the figure above shows the simple payback period over the same range of oil heating costs at a Yukon location for the Mitsubishi heat pump. It has a COP @ -8 °C (17 °F) of 2.4 and a COP @ -18 °C (0 °F) of 2.0. See appendix 1 for a graph showing the York's COP and heating capacity for a range of outdoor temperatures.

The Mitsubishi heat pump has the lowest heating capacity of the three units looked at. However, its pay back period is generally mid-way between that of the other two types of heat pumps over the full range of annual oil heating cost, and was sometimes the best choice.

The Acadia equipment and labour cost is about double that of the York YZH. This cost has a far greater impact on the payback than the HSPF or COP. The additional cost of the Acadia is directly related to the heating capacity difference. This fact makes it difficult to recommend a minimum HSPF or COP specification for the Yukon. However, with a minimum COP of 2.0 @ -18 °C (0 °F) for the heat pumps analysed in Section 5 it was possible to achieve a payback of under four years. A look at the payback figures also shows that where there is a price premium for a cold climate air-source heat pump, the payback will be longer.

4. Equipment Sizing Approach for the Yukon

In climate regions where cooling is a desirable feature of a heat pump, it is customary to size a single capacity heat pump to provide no more than 125 percent of the estimated design cooling load. For a 2-stage compressor heat pump (York YZH), the low capacity compressor stage would be sized to no more than 125 percent of the estimated design-cooling load. In the case of a multi-stage, compressor heat pump (Acadia), the lowest capacity stage would be sized to provide no more than 125 percent of the estimated design-cooling load. In the case of a variable speed compressor, the lowest "turned down" capacity in cooling would not exceed 125 percent of the design-cooling load. When sizing is done in this way, the 2-stage, multi-stage and variable speed heat pumps will provide additional heating capacity in winter and lower heating costs compared to a single capacity heat pump. It is important in these applications not to oversize the cooling capacity to the point where humidity control is compromised in summer.

In the Yukon, summer cooling is not important. Sizing will therefore depend on the reason for installing a heat pump. Is the goal to save as much heating energy as is possible? Is the goal to meet as much of the heating load as is economically practical? As we have demonstrated in Section 3, heat pump capacity does not come cheap. Saving the most heating energy would suggest a much larger heat pump than one to achieve the shortest payback period. A reasonable sizing approach would be to select a heat pump with a heating capacity at -18 °C (0 °F) of 25-35 percent of the house design heating load for a Yukon location. A unit of this size would supply 60 to 75 percent of the annual heating load and be economical.

It is also worth comparing the weather data for Whitehorse with that of a more southern city.

Figure 4 below shows clearly that very little cooling is required in Whitehorse compared to Ottawa as the number of hours the outdoor temperature is above normal room temperature (20 °C (72 °F)) is very low. Similarly, the number of hours below -18 °C (0 °F) is a relatively small portion of the heating season in the Yukon. Thus, the installation of a heat pump has the potential to provide all the home or building heating requirements for a significant portion of the heating season in the Yukon.

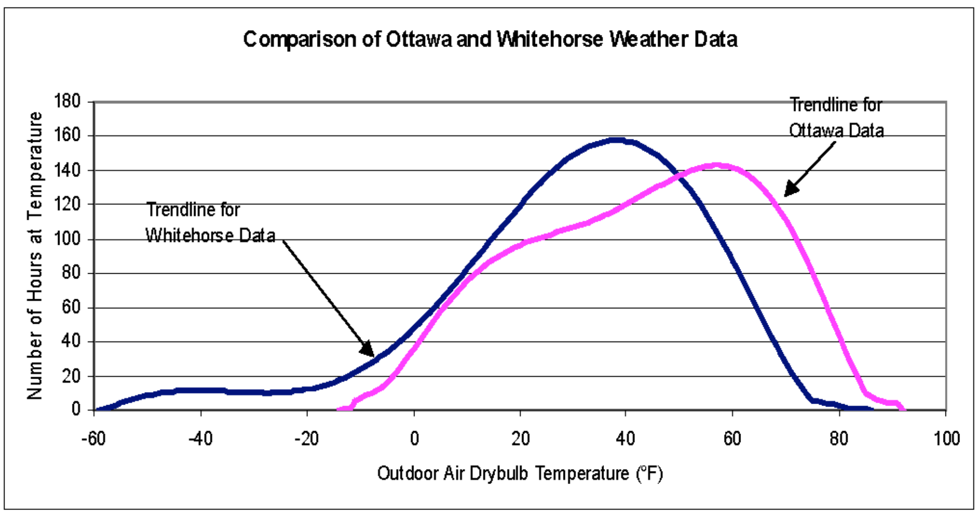

Figure 4: Comparison of Ottawa and Whitehorse Weather Data

5. Heating Cost Comparison: Heat Pump, Electric and Oil Heating Systems

Table 1 shows estimated heating energy costs for three different heat pumps, an electric furnace, and an oil furnace. The heat pumps were assumed to have oil and electric back up. The two Yukon locations for the heating cost comparison are Whitehorse and Dawson. The same weather file was used for both cities. The cost of electricity in Whitehorse and Dawson is identical. Arctic stove oil, which is a common fuel oil used to heat homes in the Yukon, was used for the price of heating oil. It is more expensive in Dawson than in Whitehorse.

According to the energy analysis results, cold climate heat pumps have the lowest operating cost of the three heat pump types analyzed. For all of the cases, heat pump systems have lower annual heating energy costs than electric or oil furnaces. Conventional and mini-split heat pumps can offer reasonable payback periods in homes with poor insulation levels.

In houses insulated to SuperGreen standards, there is less potential for savings simply because the amount of heat needed is lower. However, in these circumstances, a conventional heat pump, while providing a longer payback (over five years) can still be an economic choice provided the installed cost is at the low end of the estimated installation cost.

The comparisons shown in Table 1 include only energy costs for space (room) heating. That is, domestic hot water heating was not included.

Table 1: Heating Energy Cost and Payback Comparison: Air source Heat Pumps, Oil and Electric Heating Systems
(Simple payback period ranges in years shown in italics below energy cost ranges)

Location	**Construction Type**	**Typical Furnace** Oil (80% AFUE)	**Typical Furnace** Electric (100% AFUE)	**Conventional Air-Source Heat Pump Add-on to** Oil Furnace	**Conventional Air-Source Heat Pump Add-on to** Electric Furnace	**Cold Climate Air-Source Heat Pump Add-on to** Oil Furnace	**Cold Climate Air-Source Heat Pump Add-on to** Electric Furnace	**Mini-Split Air-Source Heat Pump Add-on to** Oil Furnace	**Mini-Split Air-Source Heat Pump Add-on to** Electric Furnace
Whitehorse	**2x4**	$3824 - $8745	$3811 - $8827	$2095 - $5682 3.3 - 7.8	$2092 - $5496 3.1 - 7.9	$1945 - $5622 5.3 - 12.4	$1912 - $5322 4.9 - 12.4	$2704 - $7539 3.6 - 5.9	$2675 - $7426 3.1 - 5.9
	SuperGreen	$1573 - $4553	$1534 - $4565	$936 - $2779 5.2 - 22.7	$938 - $2782 5.1 - 24.7	$832 - $2463 8.8 - 32.8	$825 - $2423 8.4 - 34.6	$1045 - $3562 4.4 - 13.9	$1032 - $3492 4.1 - 15.1
Dawson	**2x4**	$4047 - $9255	$3799 - $8799	$2139 - $5906 3.4 - 7.7	$2085 - $5478 3.4 - 8.8	$1964 - $5822 5.1 - 11.8	$1906 - $5305 5.2 - 13.1	$2785 - $7933 4.2 - 6.2	$2666 - $7402 4 - 6.9
	SuperGreen	$1664 - $4816	$1529 - $4550	$952 - $2831 5.3 - 22	$935 - $2773 5.8 - 27.3	$834 - $2509 8.5 - 30.5	$822 - $2415 9 - 36.6	$1072 - $3726 5.1 - 14.4	$1028 - $3481 5.2 - 17.9

1. Electricity prices are based on residential rates as of January 2010, as supplied by local utilities. Electricity rates are tiered, but only the higher tier price of 12.44 ¢/kwh was used for this analysis.

2. Oil prices are 101 ¢/L in Whitehorse and 107 ¢/L in Dawson. These prices exclude taxes.

3. Two levels of house insulation were used for the analysis. The low insulation level represents an older 2x4 framed home which was modeled as having a wall RSI-value of 1.9 (R-10.6), a Roof RSI-value of 2.6 (R-14.7), window RSI value of 0.32 (R-1.8), and a basement RSI-value of 0.65 (R-3.7). The high insulation level is that of a SuperGreen home. It was modeled as having a wall RSI-value of 8.3 (R-47), a Roof RSI-value of 14.1 (R-80), window RSI value of 0.51 (R-2.9), and a basement RSI-value of 8.3 (R-47). All wall R-values include the effects of framing.

4. The energy analysis is of a high performance conventional heat pump (a York YZH) and high performance ductless heat pump (Mitsubishi Mr.Slim). The cold climate heat pump performance characteristics are based on those of the only cold climate air to air heat pump currently on the market (Acadia).

5. The cost of equipment was derived from estimates from a consultant, as well as a pricing catalogue for an HVAC dealer in western Canada. The cost of the cold climate heat pump is based on two estimates from HVAC contractors in the Yukon. Shipping costs are included in the payback analysis. Labour cost estimates are based on an hourly rate of $105/hr, and a consultant estimated the amount of time required for an installation.

6. Houses modeled range in floor area from 111m^2 to 279 m^2(1,200 ft^2 to 3,000 ft^2). This explains the range in annual operating cost and payback period for each construction type.

6. References For Further Reading

Heating and Cooling with a Heat Pump. Natural Resources Canada. Office of Energy Efficiency. Revised December 2004. (**see link in Preface**).

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Appendix A: COP and Heating Capacity of Selected Heat Pumps

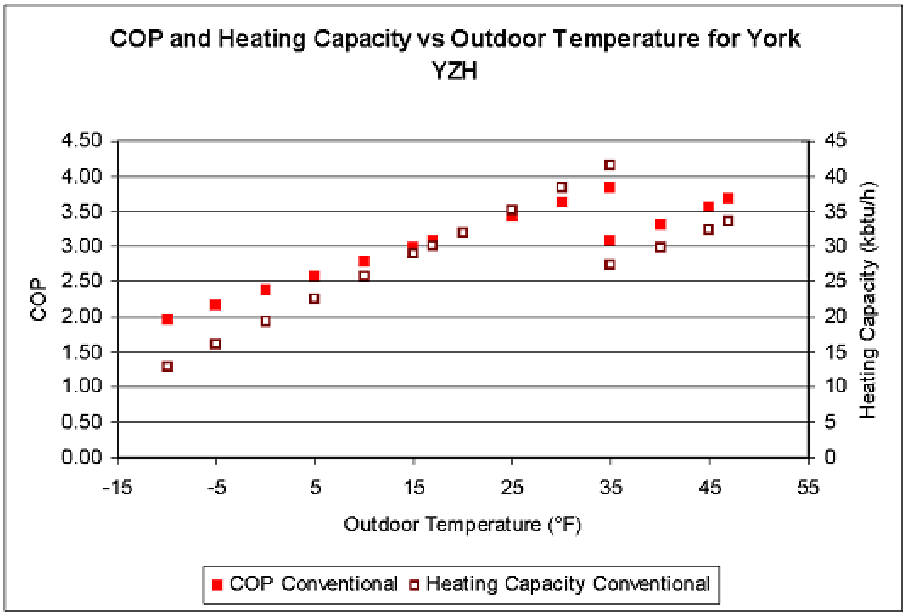


Figure A 1: COP and Heating Capacity vs. Outdoor Temperature for York YZH

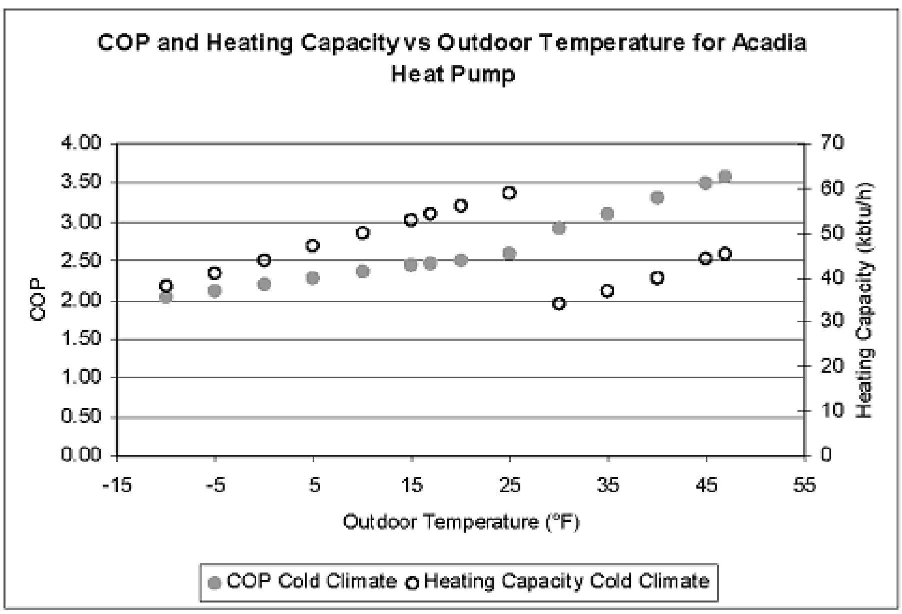


Figure A 2: COP and Heating Capacity vs Outdoor Temperature for Acadia Heat Pump

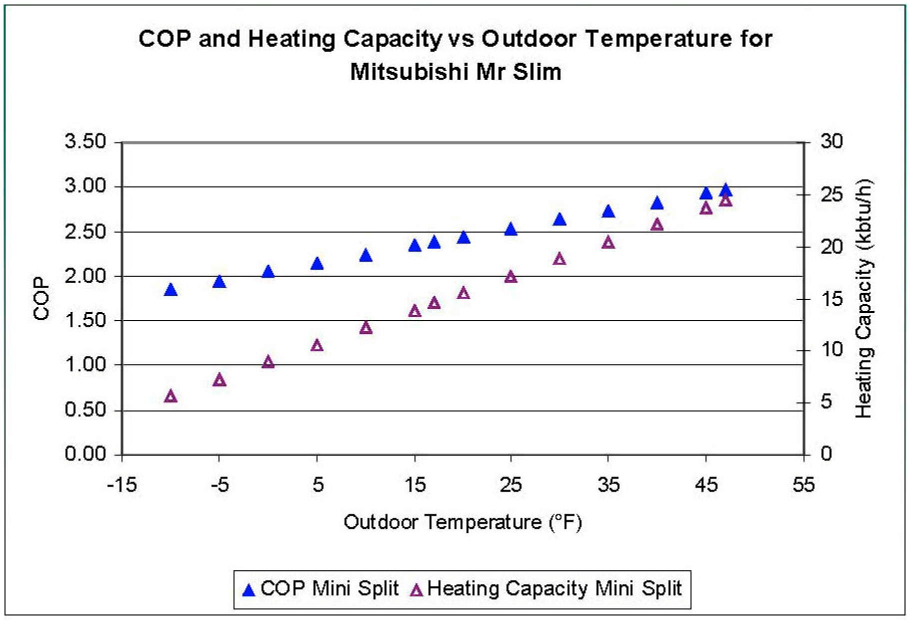


Figure A 3: COP and Heating Capacity vs Outdoor Temperature for Mitsubishi Heat Pump

Appendix B: Installation Tips

Location of Outdoor Unit:

- site unit where prevailing winds will not cause snow drifts or interfere with defrosting.
- avoid locations between houses - snow drifting and noise can be problems.
- locate unit to ensure good service access.
- don't locate under roof drip lines or where two roof slopes create a gutter, unless eave-troughs are used
- elevate above expected snow accumulations on suitably constructed frame with due regard to defrost water drainage.
- keep outside unit away from walls, fences, other surfaces which could reduce airflow or cause recirculation.

Indoor Unit Installation

- use indoor coil that matches outdoor unit and furnace blower CFM capability.
- set airflow to 400 CFM per rated ton.
- install condensate drain for indoor coil that complies with manufacturer and local codes.
- ensure air filter is installed and clean.
- tape or seal all exposed plenum, air duct joints, seams and any penetrations to minimize supply air leakage.

System Start-up and Turnover

- system start-up shall be done in strict accordance with procedures recommended by manufacturer.
- heat pump should have comprehensive instructions, and documentation on equipment installation, electrical requirements, troubleshooting, O&M requirements, warranty (duration, parts and labour coverage).
- contractor should keep installation records to facilitate future servicing; respond to warranty claims and rectify problems without delay.

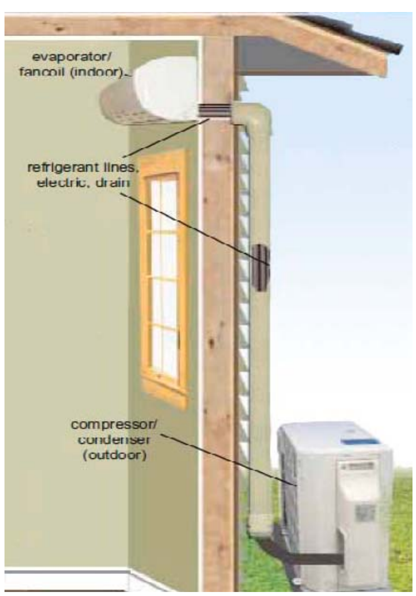
Homeowner Tips

- be aware of benefits of upgrading building insulation/windows etc. to meet or exceed current Yukon requirements and recommendations.
- keep documentation and instructions on differences from other heating systems, settings of thermostats, proper service and maintenance, and how to operate thermostats (including programming where applicable).

Appendix C: Pictures and Conceptual Drawings of the Heat Pumps Studied

Acadia Heat Pump

York YZH



Mitsubishi Mr. Slim