My Heat Pump Story

Homes have been heated over the years by wood, coal, oil, natural gas, electricity, and other fuels. In the 1970's and 1980's, with rising natural gas prices, builders improved home insulation and air-sealing, and manufacturers developed more efficient furnaces. But today, with the advent of climate change, there is a need to further reduce and eventually eliminate fossil fuels used in home heating. For the most part, this is being achieved by using electric heat pumps powered from a less carbon-intensive grid. It will require a massive effort to create a nearly carbon-free grid, powered by some mix of nuclear, hydro, solar, wind, geothermal, and other energy sources.

Heat pump performance has improved in recent years, and they are now used in cold climates. And with efficiency of over 200%, a heat pump will reduce carbon dioxide (CO_2) emissions relative to a furnace, even if the electricity grid relies mostly on fossil fuels [1].

I replaced the gas furnace in my central-Ohio home with a heat pump in March of 2024. In many states, running a heat pump is cheaper than running a gas furnace [2], but Ohio is not one of them. However, in my case, the variable cost of electricity for a heart pump is comparable to the *total* cost of gas for a furnace (variable cost plus monthly fees over a year). To minimize cost, I disconnected gas service, which required converting from a gas water heater to electric (heat pump water heaters are also available). Going all-electric has a safety advantage: it removes all sources of carbon monoxide leakage.

After a winter which included some very cold days, I am pleased with the performance of my heat pump. This performance depended not only on the heat pump model, but also on climate, house size, and other house characteristics. In this article, I'll share what I have learned about heat pumps after a year's experience.

Heat Pump Basics

An air conditioner extracts heat from a home's indoor air and expels it outside. A heat pump is an air conditioner operating in reverse: it extracts heat from the outdoors and moves it inside. Some heat pumps use the ground as the heat source, but most existing ones use the air, and are thus called air-source heat pumps (ASHP).

There are two types of ASHP's: centrally-ducted and ductless (also called mini-split). The centrally-ducted type feeds a warm refrigerant through a tube to a condenser coil and blower in a central location, which then uses ducts to send warm air throughout the house in the same way as a conventional furnace. Ductless systems connect the refrigerant tube directly to one or more condenser/blowers mounted on the indoor walls or ceilings of the home. There is a brand of ductless heat pumps that can be installed by the advanced do-it-yourselfer [3].

Air-source heat pumps transfer heat from the cold outdoor air into a home by using phase changes of a refrigerant in a closed-loop system, as shown in Figure 1 [4]. Liquid from the indoor unit is applied to an expansion valve, which lowers the pressure and temperature. The refrigerant is then warmed by the outdoor air flowing over the evaporator coils. The resulting vapor is then compressed, raising its temperature. The warm vapor is condensed in the indoor unit, releasing heat, and the cycle repeats. For efficiency, the temperature of the warm air generated by the heat pump is as low as practical, with temperature at the indoor registers in the 90’s F/30’s C. The outdoor air is cooled by the evaporator, so the temperature of the air exiting the outdoor unit is quite cold.

The amount of heat energy transferred can be up to 4 times the energy expended, depending on the outdoor temperature. A peculiar feature of the system is that the main energy consumption occurs outside the home, in the compressor.

In warm weather, the heat pump also functions as an air conditioner. A device called a reversing valve in the outdoor unit reverses the functions of the indoor and outdoor coils. The outdoor coil becomes the condenser, and the indoor coil becomes the evaporator.

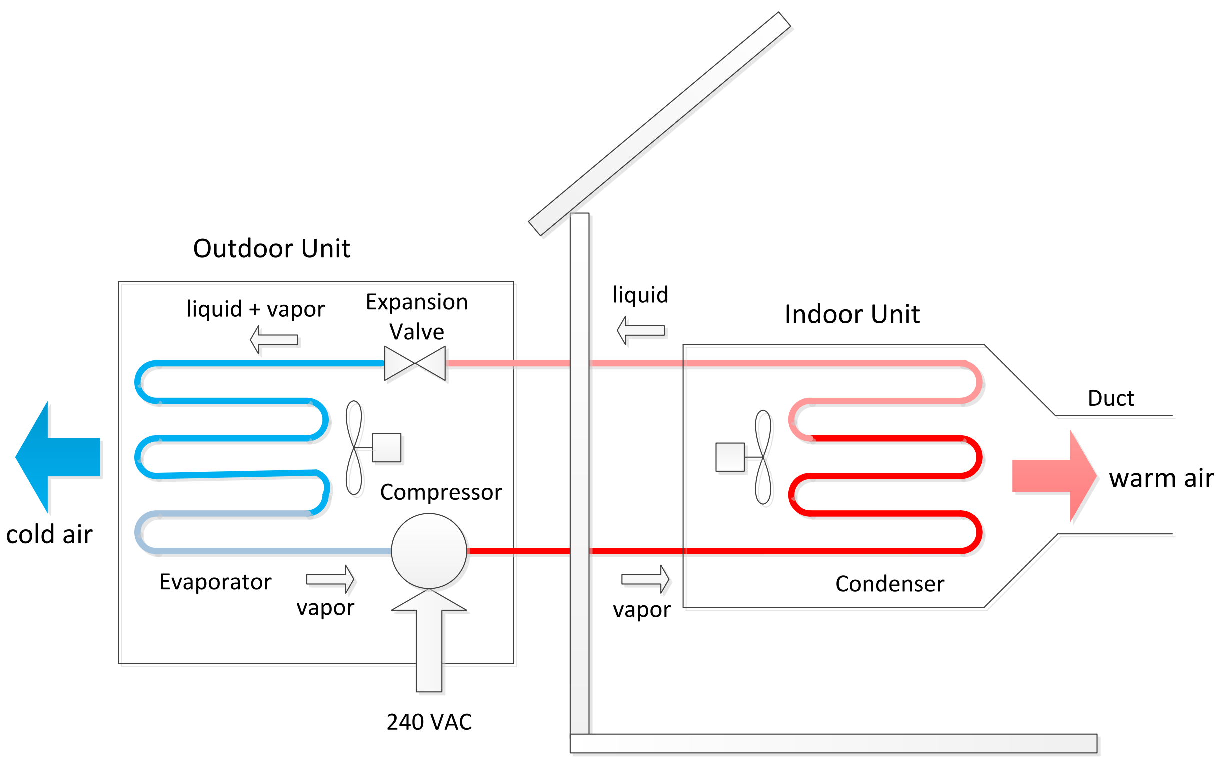

Figure 1. Heat Pump system simplified block diagram.

In describing heat pump performance, we are interested in the quantities of heat flow and electrical power input. Power input has units of kilowatts (kW). Heat flow has units of kW or BTU/h, where 1 kW equals 3412 BTU/h.

The amount of heat leaving a home due to air leakage, thermal conduction, and other causes is called the *thermal load* – the heat pump must provide this amount of heat output. The *capacity* of the heat pump is its maximum heat flow output in BTU/h or kW. Capacity is a function of the outdoor temperature. Unlike a furnace, capacity decreases with decreasing temperature, as shown in Figure 2 for my home's heat pump.

A figure of merit for a heat pump is the Coefficient of Performance (COP):

$$COP = \frac{P_{load}}{P_{in}} = \frac{Heat\ flow\ output\ (kW)}{Electric\ power\ input\ (kW)} \qquad (1)$$

My heat pump has COP of 3.5 at 47 F/8.3 C: it provides 3.5 kW of heating for every 1 kW electrical input. In other words, the efficiency at 47 F is 350%. For comparison, the COP of an electrical resistance heater is exactly one. COP is also a function of outdoor temperature, as shown in Figure 3. Of particular interest for my climate, the COP at 17 F/-8.3C is almost 2.5.

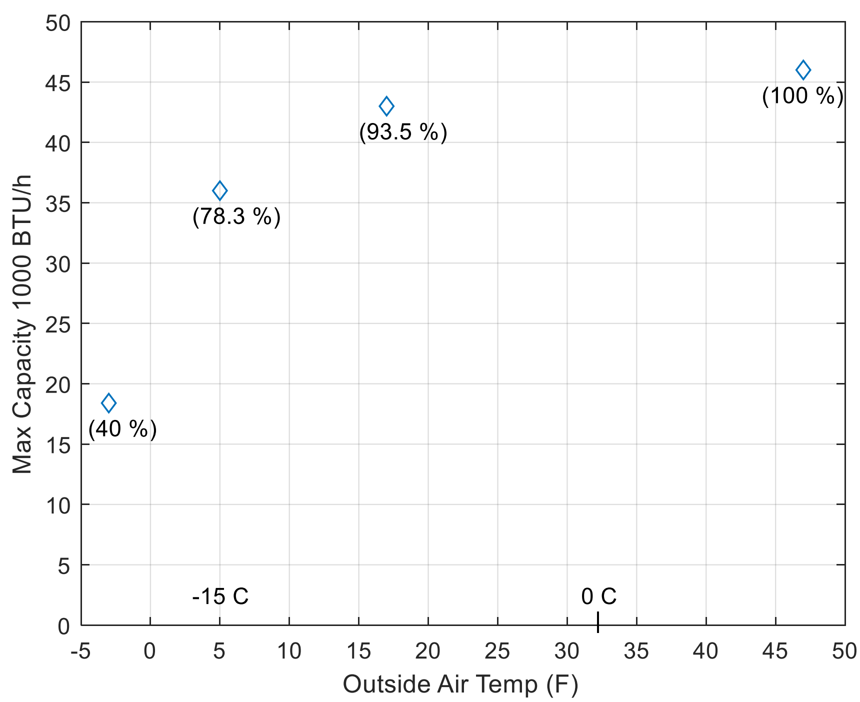

Figure 2. Heat Pump maximum capacity specification vs. outside air temperature for Bryant model 284ANV048 [5]. Inside temperature = 70 F/21 C.

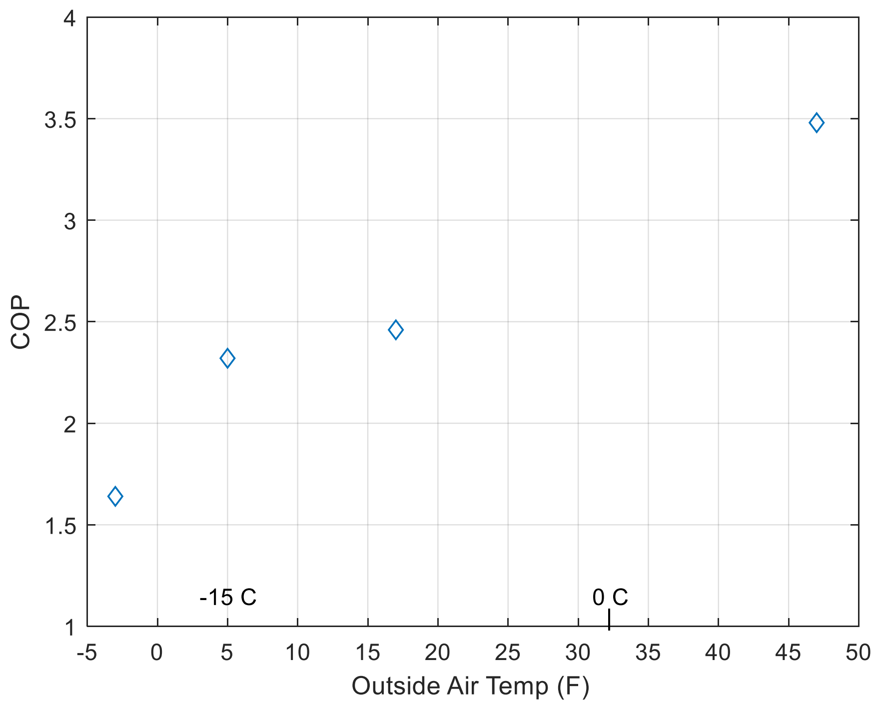

Figure 3. Heat Pump COP at maximum capacity vs. outside air temperature for Bryant model 284ANV048 [5]. Inside temperature = 70 F/21 C.

My House and Climate

My home was built in 2004. It's a 2000 square-foot (186 sq. meter) single story house with vaulted ceilings. There is some solar gain from four double-pane south-facing windows of clear glass (although sunny days are rare in winter). Before installing the heat pump, I had attic insulation increased from R25 to R47, and had additional air-sealing performed. I live near Columbus, Ohio (US). Average low temperature in January is 22 F/-5.5 C, and average high temperature is 37 F/2.8 C. The distribution of January daily low temperatures over a 10-year period is shown in Figure 4 (top). The distribution for January 2025 is shown in Figure 4 (bottom). January 2025 was unusually cold; as shown, four days had lows below 5 F/-15 C.

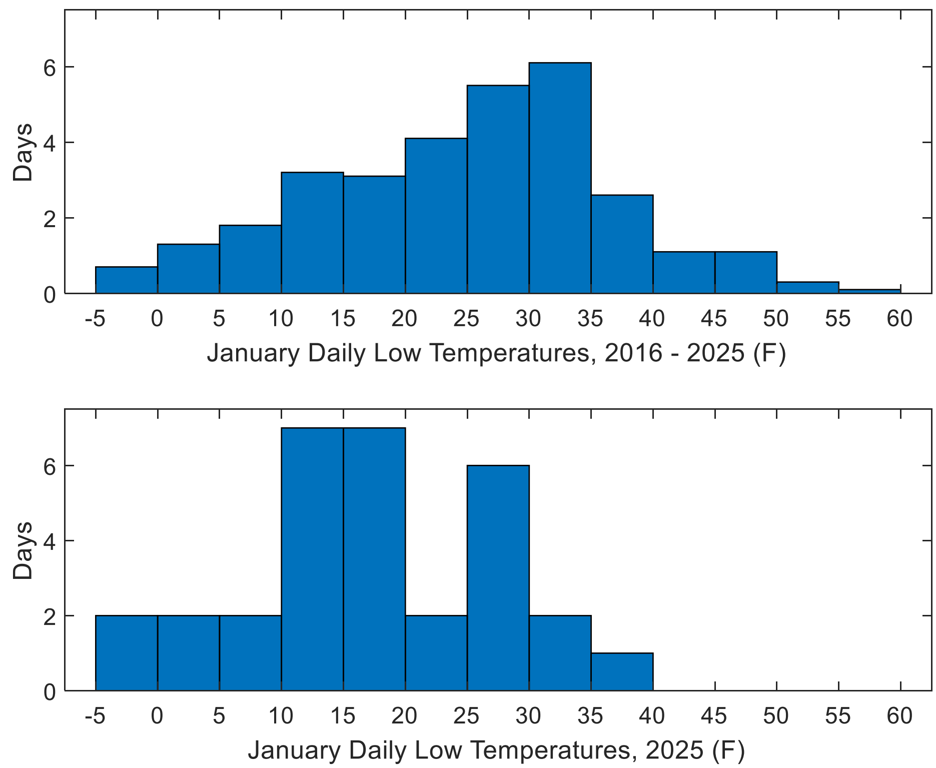

Figure 4. Top: Columbus Ohio January Daily Low Temperature Distribution, 2016 – 2025.
Bottom: January Daily Low Temperature Distribution, 2025.
Measured at station KCMH [6]. Note: sum of bins is 31 (days).

My Heat Pump

My heat pump is a centrally-ducted unit from Bryant, model 284ANV048 (Figure 5). This high-efficiency model qualified for a $2000 credit on my US federal taxes. The outdoor unit sits on feet about 6 inches above the pad; this keeps the coils above the snow line and allows for drainage of water during the defrost cycle. The indoor unit is in the basement.

Choice of heat pumps is limited to the brands offered by local HVAC companies. (You can compare heat pump specifications on the NEEP website [5]). As shown in the capacity plot (Figure 2), my heat pump, while not having the best available performance, nevertheless maintains 93% of full capacity at 17 F/-8.3 C. This temperature is below the January average low of 22 F/-5.5 C. On very cold days, the heat pump output is supplemented by a resistive electric heater located in the indoor unit. This auxiliary heat is employed in stages as needed, from 5 kW to 20 kW. Also, should the outdoor unit fail, this auxiliary heater can heat the house by itself. Since the efficiency of the resistive heater (i.e. 100%) is less than half that of the heat pump, energy use spikes when the auxiliary heat is enabled. The auxiliary heat is also used during the defrost cycle, as described later in this article.

A given heat pump model is available in various capacities, such as 24,000, 36,000, 48,000, or 60,000 BTU/h at 47 F/8.3 C. My unit has 48,000 BTU/h nominal capacity. The required capacity depends on climate, home size, ceiling height, insulation, air leakage, and windows. In central Ohio, a larger home than mine might well require two outdoor units. A heat pump's capacity is almost always less than that of the fuel-burning furnace it replaces. For example, the gas furnace I replaced had an output of 70,400 BTU/h, while my heat pump capacity at 17 F/-8.3 C is 43,000 BTU/h. As mentioned, the heat pump's capacity is supplemented by the auxiliary resistive heater on very cold days.

To minimize electricity use, it often makes sense to improve attic insulation and perform air-sealing before purchasing a heat pump. In my case, I also replaced decorative vent covers with ones having minimal blockage of air flow.

Finally, when installing a heat pump, the home electrical panel must have adequate amperage.   If the home already has a central air-conditioner, the heat pump outdoor unit can use its existing 240 V circuit. However, the auxiliary electric heater can use a lot of current, in my case, up to 80 A at 230 V. My 200 Amp panel proved to be adequate.

Figure 5. Bryant model 284ANV048 outdoor unit.

System Balance Point Temperature

For a given indoor temperature, the heat lost to the outside, or *thermal load* of a house is linear vs outside temperature T:

$$P_{load} = C(T_0 - T) \quad kBTU/h \quad (2)$$

where C is heat flow per degree F (kBTU/h/F), and T_0 is the outside air temperature for which $P_{load} = 0$. For my house, C is approximately 0.68 kBTU/h/F and T_0 is approximately 63.2 F when the thermostat is set to 70 F. Equation 2 is plotted for my house in Figure 6, which also shows the heat pump maximum capacity.

The heat pump's capacity decreases with decreasing temperature, while the thermal load or *load line* increases with decreasing temperature. At below roughly 10 F/-12.2 C, the heat pump capacity is less than the thermal load, and auxiliary electric heating is required. The temperature at which the capacity curve crosses the load line is called the *system balance point temperature*. A balance point of 10 F/-12.2 C is pretty good for Ohio, but would not be adequate in Minnesota.

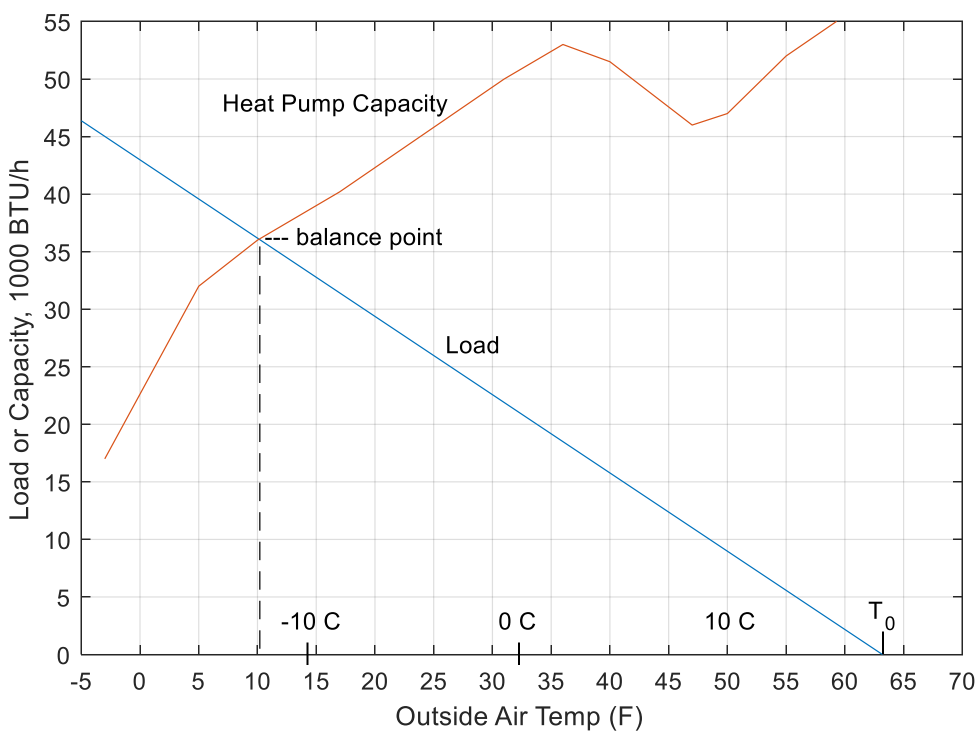

Figure 6. Approximate load line for my house, with heat pump maximum capacity. Bryant model 284ANV048 [5]. Inside temperature = 70 F/21 C.

Actual Cold Weather Performance

Figure 7 (top) shows the mean and low temperatures for each day of January 2025, which was colder than normal. The average low temperature for the month of January in Columbus is 22 F/-5.6 C, while the average low for January 2025 was 17 F/-8.3 C. There were 6 days with low temperature below the system balance point temperature of 10 F/-12.2 C.

Figure 7 (bottom) shows the energy in kWh used each day during January, with heat pump input power in blue and auxiliary electric heat in red. This data was obtained from the system's thermostat. The auxiliary heat includes electric heat used during defrost. During four days with low temperature below 5F/-15 C, the auxiliary heat was quite high: the energy used during these days was 25% of the total for the month. A typical January has just two days with temperature below 5 F/-15 C (Figure 4). Performance at very low temperatures can be a weak point of air-source heat pumps, although performance vs. cost should improve in the years ahead. (When I bought my heat pump, a better-performing system was bid at a six-thousand dollar premium above the system I chose).

Figure 8 (top) shows the mean and low temperatures for February, and Figure 8 (bottom) shows the energy in kWh. February had one day with low temperature less than 10 F/-12.2 C.

Table 1 lists degree days and my system's energy use for December, January, and February. A degree day is equal to 65 - daily mean temp (F). For example, if a given day's mean temperature is 40 F, then that day has 65 – 40 = 25 degree days. It is assumed that no heating is required when the mean temperature is greater than 65 F (0 degree days). Degree days for a given month is the total of the degree days of every day of that month. Table 1 also lists the ratio of auxiliary energy to total energy used. As already mentioned, auxiliary energy use was high in January due to several very cold days.

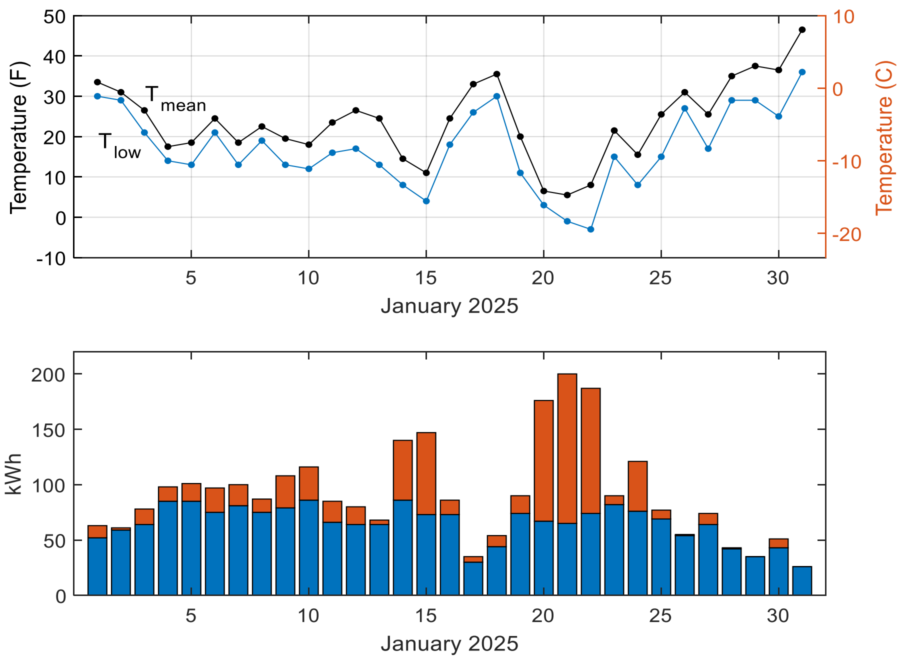

Figure 7. Top: Daily low and average temperatures during January 2025.

Bottom: Energy used by heat pump and defrost/auxiliary electric heat.

heat pump input energy auxiliary electric heat, including during defrost

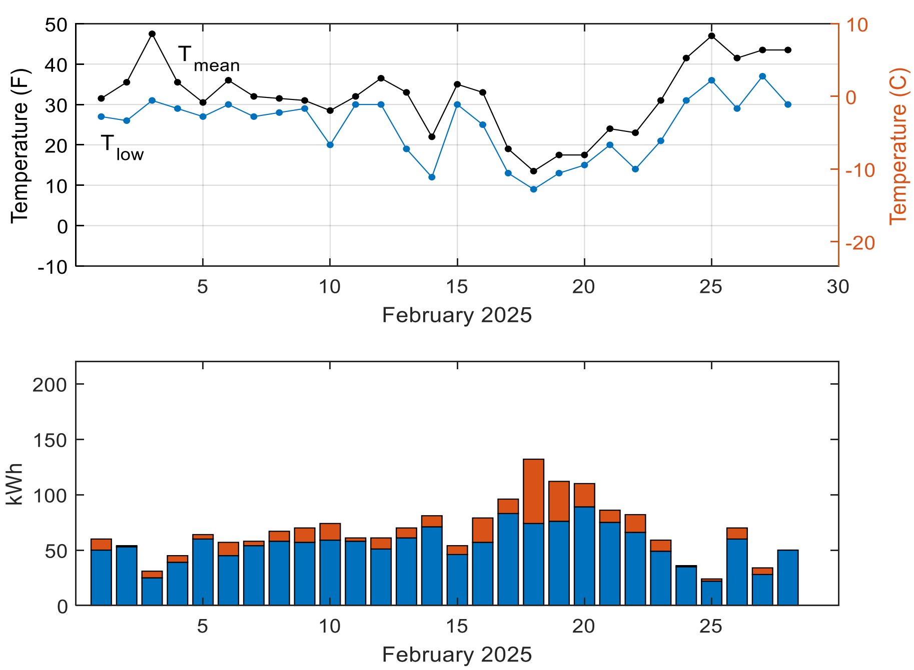

Figure 8. Top: Daily low and average temperatures during February 2025.

Bottom: Energy used by heat pump and defrost/auxiliary electric heat.

heat pump input energy auxiliary electric heat, including during defrost

Table 1. System energy use, winter 2024/2025.

Month	Degree days	Days below 10F/ -12.2 C	kWh	Average kWh/day	Aux energy/total energy
December	866	0	1476	47.6	6.8%
January	1256	6	2829	91.3	29%
February	930	1	1877	67.0	17%

Some Operating Details

Using a heat pump is not just like using a furnace. Here are a few peculiarities of heat pump operation.

Variable Speed. High-efficiency heat pumps have a variable speed compressor, like those used in high-efficiency air conditioners. The heat pump runs at the lowest output needed to maintain the temperature setting. In my case, at temperatures below freezing, the heat pump runs almost continuously, at varying speed. This feature results in lower noise from both the outdoor unit and indoor blower, except at colder outdoor temperatures.

Duct air temperature and maximum fan speed. The air temperature at the supply vents of a heat pump system is lower than the temperature for a furnace. This means that the heat pump system must supply more air to achieve the same heating. To do this, the system runs longer (higher duty cycle) and may have higher maximum fan speed. On cold days, particularly during the morning temperature recovery period, the indoor unit fan may operate for an extended time at maximum speed. Aside from this recovery period, my system runs at less than maximum fan speed when outdoor temperature is above roughly 20 F/-6.7 C.

Temperature setback at night. Many homeowners who have a furnace turn the thermostat down a few degrees at night. This can be done with a heat pump, but given the heat pump's lower capacity, it takes noticeably longer to reach the desired temperature setting in the morning, unless the auxiliary electric heat is used. But enabling the auxiliary heat will probably use more total energy than leaving the thermostat at the daytime setting! To avoid lengthy temperature recovery, the nighttime setting should not be set too low. For example, I set my thermostat to 68 F/20 C at night. To prevent use of the auxiliary heat, I set the heat source option to "heat pump only" (which still allows auxiliary heat for defrost mode) unless very cold temperatures are expected.

Defrost mode. Since the coil of the heat pump's outdoor unit is colder than the air, it can accumulate frost at outdoor temperatures below roughly 40 F/4.4 C. To remove the frost, the heat pump enters defrost mode occasionally. Defrosting starts with a brief, loud whooshing noise, and lasts for five to fifteen minutes. In this mode, the outdoor coil becomes the condenser, which causes it to become warm, melting the ice. The indoor coil, which is now the evaporator, cools. The indoor blower and auxiliary electric heater are enabled. The auxiliary heater is used to prevent blowing cold air from the registers. This causes some additional energy use.

Behavior on very cold days. At cold temperatures, heat pump capacity starts falling off (Figure 6). When the temperature is less than about 10 F/-12.2 C, my system uses both the heat pump and auxiliary electric heater. The auxiliary heat is enabled in increments of 5 kW, up to 20 kW (For my house, the 20 kW stage is adequate for outside temperature of -30 F/-34.4 C).

Compressor Noise. Compressor hum from good-quality heat pumps is not loud. But for those sensitive to noise, the outdoor unit can be located away from first-floor bedrooms.

Software Control. A variable-speed heat pump is a complex system with compressor, fans, auxiliary heater, and valves, all of which are controlled by a smart thermostat, using data from sensors. My system uses software that is occasionally updated over a WiFi (wireless) internet connection. There is always a possibility of software bugs, which in a very unfortunate case could result in no heat. I have not experienced such a failure -- but I admit to owning several plug-in electric heaters as a partial back-up, just in case!

Conclusion

A heat pump system performed very well in my Ohio home; I was able to reduce my carbon emissions with no sacrifice of comfort. There were some very cold days that required significant auxiliary electric heat, but these days (with lows below 5 F/-15 C) don't occur often in my area (Figure 4). Performance was helped by adding insulation and air sealing to my home before installing the heat pump. Performance on very cold days can be a weak point of air-source heat pumps, but performance vs. cost should improve in the years ahead. A possible future innovation is Thermal Energy Networks [7], which are basically community-wide ground-source heat pumps.

Obtaining the heat pump was not difficult; there are several HVAC contractors in my area who are well-versed in heat pump installation. Quotes from different contractors (each for a different brand heat pump) varied by several thousand dollars. For my moderate-sized house (2000 square-foot/186 sq. meter), only one outdoor unit was needed. Installation, including adding 240 V electric circuits for the indoor unit, required one day.

Units of Energy

BTU	British Thermal Units 3412 BTU = 1 kWh
Wh	watt-hours (watts x hours)
kWh	kilowatt-hours (1000 watt-hours)

Units of Power/Heat Flow

BTU/h	BTU/hour 3412 BTU/h = 1 kW.
kBTU/h	1000 BTU/hour
W	watt
kW	kilowatt (1000 watts)

Abbreviations

ASHP	air-source heat pump
C	degrees Celsius
COP	coefficient of performance (see Equation 1)
F	degrees Fahrenheit
h	hours
HVAC	heating, ventilation, air conditioning
NEEP	North-East Energy Partners

Websites

Energy Sage https://www.energysage.com/shop/heat-pumps/

Carbon Switch https://carbonswitch.com/heating-and-cooling/

Rewiring America https://homes.rewiringamerica.org/projects/heating-and-cooling-homeowner

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Neil Robertson March 2, 2025