

Cold Climate Heat Pumps in Vermont

As the popularity of cold climate ductless mini-split heat pumps (ccHPs) continues to increase, there is a need to ensure that utility and energy efficiency program planners have the necessary information about the technology. To help with this, the Department of Public Service commissioned an in-depth study of how cold climate heat pumps are being used in Vermont. The study had three high-level objectives:

- To investigate energy consumption, performance, and operational characteristics of ccHPs installed in Vermont;
- To estimate any increase or decrease in the average electric and fossil fuel energy use that result from installation of a ccHP; and
- To better understand the extent to which the state should promote cold climate heat pump efficiency measures to various markets.

The study lasted from November 2015 through the spring of 2017 and examined a total of 77 ccHPs installed at 65 residential locations in Vermont. The study involved the following activities at each of the participating homes;

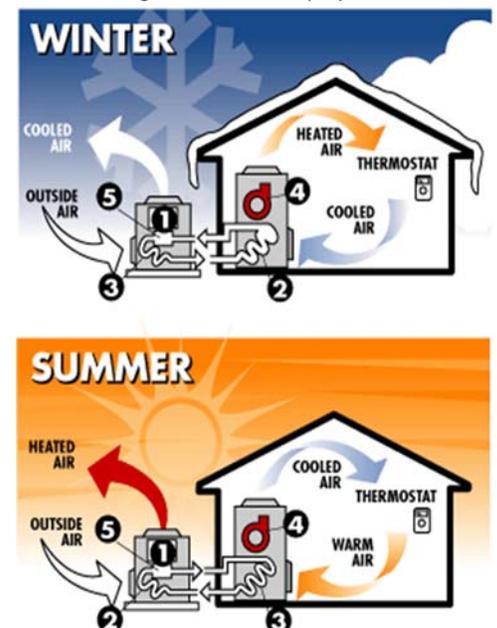
- Electric meters were installed on all ccHPs
- Fuel and electric meters were installed on all existing heating systems
- Historic annual heating fuel consumption data was collected
- Interviews were conducted with the homeowners to understand how they operated the ccHPs in their homes
- Electric meter data were analyzed

On average, a ccHP in Vermont consumed 2,085 kWh and supplied 21.4 million Btu of heating capacity during one heating season. This translates to an average seasonal efficiency of 314%. (See sidebar on next page).

How Heat Pumps Work

Heat pumps use a similar technology as a refrigerator in that they move heat energy from one place to another. A heat pump can move a large amount of heat energy using a relatively small amount of electrical energy. That is why we see heat pump “efficiencies” well above 100%. Heat pumps have a compressor (Figure 1, #1) that moves refrigerant fluid around a closed loop between two heat exchange coils; one outside (Figure 1, #3) and one inside of a building (Figure 1, #2). The liquid refrigerant absorbs heat when it evaporates under low pressure. In the winter, even though the outdoor air is cold, the outdoor coil is able to absorb heat from the outdoor air by reducing the pressure on the refrigerant, causing it to evaporate into a gas. The compressor then compresses the evaporated refrigerant and sends the gas under pressure into the indoor coil, where it condenses back to liquid, and releases the heat absorbed from the outdoor air. In the summer, the heat pump reverses the cycle, moving heat from indoors to outdoors. Fans in the outdoor unit and indoor unit (Figure 1, #4) force air across the coils to speed up the heat transfer.

Figure 1. Heat Pump Cycle¹



This high efficiency does not directly translate into energy cost savings, however. Even though heating systems that use non-electric heating fuels are less than 100% efficient, some might cost less per Btu of delivered heat than a ccHP. The study found that, due to the wide variety of ways that ccHPs were operated, the energy savings varied just as widely. The average annual energy cost savings was approximately \$200 per heat pump, significantly less than had been assumed before the study. (Energy savings is the cost of fuel saved by using a heat pump minus the cost of electricity used to run the heat pump). The study indicates that greater savings are possible by providing education for the homeowner regarding the most cost-effective way to operate their heat pump. With the proper location of the indoor fan unit and its thermostat, along with proper thermostat program settings for both the ccHP and the back-up system, the heat pump can both improve comfort and maximize energy cost savings.

These findings do, however, come with a number of caveats:

1. Overall dollar savings are impacted by the efficiency of the back-up fossil fuel system. The higher the efficiency of the existing system, the smaller the amount of fuel use being displaced by the ccHP.
2. Homes with poor insulation levels and air leaks will not get as much benefit out of a ccHP as will tight, well insulated homes.
3. It is unlikely that a heat pump by itself would be sufficient to heat a typical home without use of a traditional heating system.

Given the average cost of approximately \$2,500 to install a heat pump, fuel savings of \$200 per year would pay for the equipment in 12.5 years, based on current fuel prices. However, of the 135 homeowners surveyed, none expressed dissatisfaction with their choice to install a heat pump.

With the adoption of cold climate heat pump technology accelerating in Vermont, it is important that consumers are making an informed decision when purchasing an expensive piece of equipment that will affect their energy bills for years to come. Simply because a ccHP is “high efficiency” doesn’t necessarily mean that it will lower energy costs. There is a need for sufficient information for customers regarding: (1) the benefits of weatherization in increasing fuel savings, (2) the limitations of ccHPs, especially during cold weather periods (including the continued reliance on existing heating systems); and (3) how different ways of operating ccHPs will impact fuel savings.

HOW CAN HEAT PUMPS HAVE EFFICIENCIES HIGHER THAN 100%?

Heating efficiency is generally defined as the ratio of heat output to energy input. Electric resistance heat has efficiency of 100% - all the input electric energy is converted to heat. A heat pump operates at an efficiency much higher than 100% because it only uses energy to move heat from one place to another – a compressor to keep the refrigerant cycle going and fans to speed up the heat transfer to and from the coils. Heat pumps can achieve seasonal average efficiency well above 200%. Other heating fuels (wood, oil, propane) have heating efficiencies less than 100% because some of the heat released by combustion is lost up the chimney or out the wall vent, and because it takes additional energy to move the heat in a building (i.e. furnace fan or boiler pump).