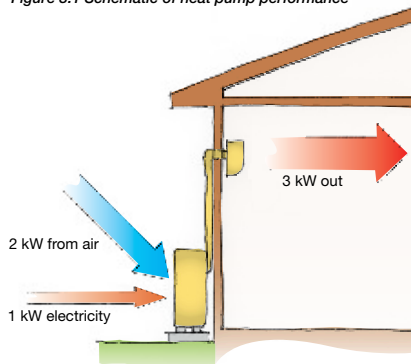


3.0 Heat pump performance

This section covers the performance of heat pumps and the different factors that impact on their efficiency. It includes how heat pump efficiencies are determined, where you can find that information, how temperature affects performance and the impacts of the defrost cycle on efficiency.

Understanding heat pump performance is essential when it comes to selecting a heat pump (which is covered in Section 4.0 of this guide).

Figure 3.1 Schematic of heat pump performance



In theory, the total heat that could be available for heating is the sum of the heat extracted from the source plus the energy required to drive the heat pump. Thus, if 1 kWh of electricity is required to drive a heat pump and 2 kWh of energy can be extracted from the heat source, the total energy delivered could theoretically be 3 kWh, giving an efficiency of 300% (Figure 3.1).

In practice, other factors that must be considered to determine the actual efficiency of a heat pump are:

- climate
- heating and cooling demands
- source and supply temperatures
- auxiliary energy consumption (pumps, fans)
- heat pump size to meet heating/cooling demand
- operating characteristics.

3.1 Heat pump efficiency

Heat pump efficiency is the ratio of the heating or cooling delivered to the electrical energy required to operate the system.

The ratios are given in two ways:

- coefficient of performance (COP) – the ratio of heating delivered to the electrical energy input
- energy efficiency ratio (EER) – the ratio of cooling delivered to the electrical energy input.

The higher the COP or EER, the greater is the efficiency of the heating or cooling system.

COP can be calculated by taking the heating output (in kW) and dividing it by the electrical input (in kW). These values can be found in the energy rating label (see Section 3.2) or manufacturer's information.

An acceptable level of COP should be at least 3, and better products may well have a COP of 3.5 to 4.

3.2 Energy rating label

Figure 3.2 Current energy rating label for heat pumps/air conditioners



The energy rating label (Figures 3.2 and 3.3) gives information on how much energy (at an ambient temperature of 7°C) a product uses so you can compare models. Every heat pump sold in New Zealand must display this label. The number of stars tells you how well the product performs – the more stars the better.

Figure 3.3 New energy rating label from October 2009 for heat pumps/air conditioners



Figure 3.4 ENERGY STAR® mark



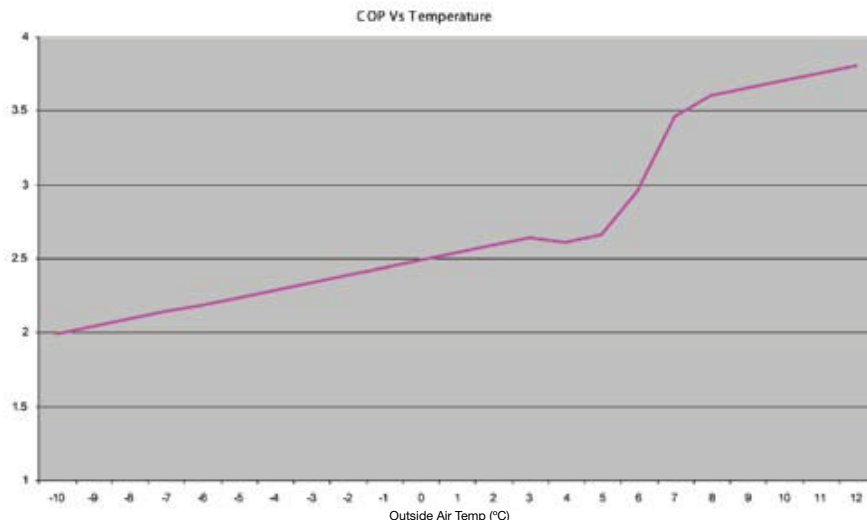
The blue ENERGY STAR® mark makes it easy to choose the most energy efficient appliances. It tells you at a glance which models are the very best. ENERGY STAR qualified heat pumps are, on average, 15% more efficient than non-qualified models. ENERGY STAR criteria cover cooling as well as heating performance. That is important if a heat pump is to be used for cooling in summer as well.

3.3 Effects of temperature on efficiency

Efficiency of a heat pump system is not constant – it varies along with the temperature differential between indoor and outdoor air. A heat pump’s rated efficiency is for an outdoor temperature of 7°C, so when designing a system it is important to understand how it will perform at lower temperatures.

Whether a heat pump is in heating or cooling mode, as the difference between outdoor temperature and desired indoor temperature increases, the efficiency of a heat pump system decreases. This is illustrated in Figure 3.5, which shows the efficiency of a heat pump in heating mode reducing as the outdoor temperature decreases.

Figure 3.5 Graphic representation of heat pump efficiency



Different heat pumps will perform very differently at sub-zero temperatures – some may keep performing down to -20°C while others will struggle at temperatures below freezing.

Another temperature-related factor that can impact on efficiency is the extra energy that may be required for defrosting at low temperatures. At just a few degrees Celsius, any water vapour in the air will start to condense and freeze onto the evaporator (outdoor heat exchanger) coils. This will disrupt the heat flow, and the coils must be de-iced for heating to be able to continue (see **3.4 Impacts of defrost cycle on efficiency**).

While heat pumps have to be rated for efficiency under laboratory conditions at a 7°C ambient outdoor temperature (called H1), actual mid-winter temperatures in some parts of New Zealand, particularly in the central North Island and in the South Island, will give significantly different performance.

For this reason, standardised testing of heat pumps can also be rated at two additional levels of specific temperature and humidity. These are called H2 and H3 and are shown in Table 3.1.

Table 3.1 Outdoor ambient temperature rating conditions

Rating	Outdoor ambient temperature (°C) rating conditions
	Dry bulb (DB)
H1	7°C
H2	2°C
H3	-7°C

These ratings allow a wider range of design temperatures to be used to select heat pumps for areas where the temperature may often be below 0°C and ensure that, at low ambient temperatures, the heat pump will still provide the expected performance (see **4.5 Step 3: Calculate heat load requirement**).

Manufacturers will often test their product at other temperatures (e.g. -5, 0, 5, 10 etc).

3.4 Impacts of defrost cycle on efficiency

For optimal heat pump efficiency, a system must be correctly sized to minimise energy losses that occur during the defrost cycle.

The defrost cycle is necessary to remove ice build-up on evaporator coils. Ice build-up occurs at around at 0-4°C (7°C in high humidity), when any water vapour in the air will start to condense and freeze onto the evaporator (outdoor heat exchanger) coils. This will disrupt the heat flow, and the coils must be de-iced for heating to be able to continue. To remove ice build-up on the coils, most heat pumps have a defrost cycle where the system switches into cooling mode (taking some heat from inside), which could effectively cool the room.

Some systems have a closed loop cycle to use waste heat from the motor/compressor to defrost the coils. While this is occurring, no heat is supplied to indoors.

The defrost frequency and performance are critical to heat pump efficiency. Undersized heat pumps will need to defrost frequently in low ambient temperatures, reducing the system's ability to reach and maintain set point. If the defrost cycle operates too frequently or if it does not operate often enough, it will not provide sufficient heating, and heat pump operation will be compromised.

The defrost cycle control is either:

- a time-temperature defrost starting and stopping at preset times (30-, 60- or 90-minute intervals); or
- on-demand defrost, which is generally more efficient because it operates only when it detects frost build-up on the outdoor coil by monitoring air and coil temperature, outdoor airflow, pressure differential across the coil and refrigerant pressure.

Systems that include a dry-coil defrost cycle briefly run the outdoor fan at maximum speed before the system starts to heat again, to remove any water that may still be on the coil fins and would immediately refreeze. This operation can be seen by water vapour blowing from the outdoor unit before the heating cycle resumes.