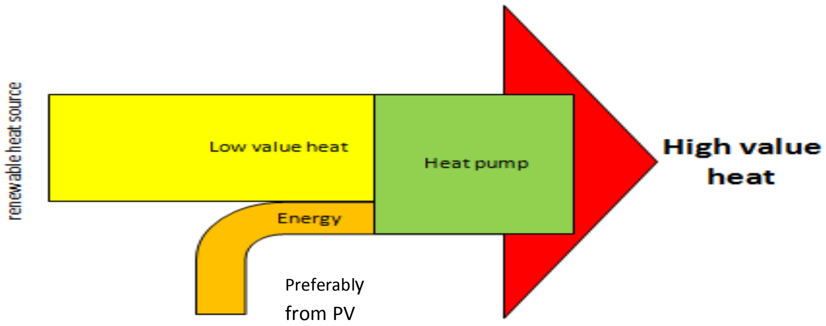
3 High temperature heat pump technology and overview of applications

3.1 Technology overview

3.1.1 Basics

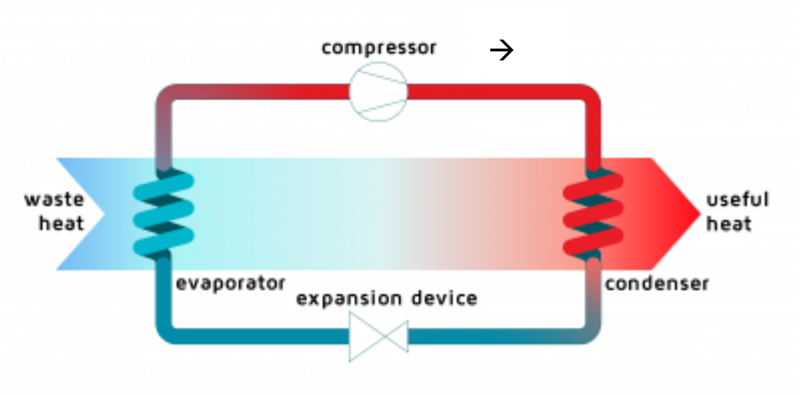
Industrial heat pumps use a refrigeration cycle to very efficiently transfer heat from the environment to waste heat streams. Heat pump technology (driven by electricity) can displace gas and upgrade heat (both sensible and latent) from waste streams such as waste water, hot humid air (e.g. from dryers) and condenser heat from refrigeration systems, for utilisation in a range of applications like blanchers, dryers and pasteurisers, as depicted in Figure 1 and 2 below.

Figure 1 – Heat pump leverage: Most input from lower grade heat streams or renewable sources



Source: Pachai, A C 2013, *Applying a heat pump to an industrial cascade system*

Figure 2 – Heat pump components



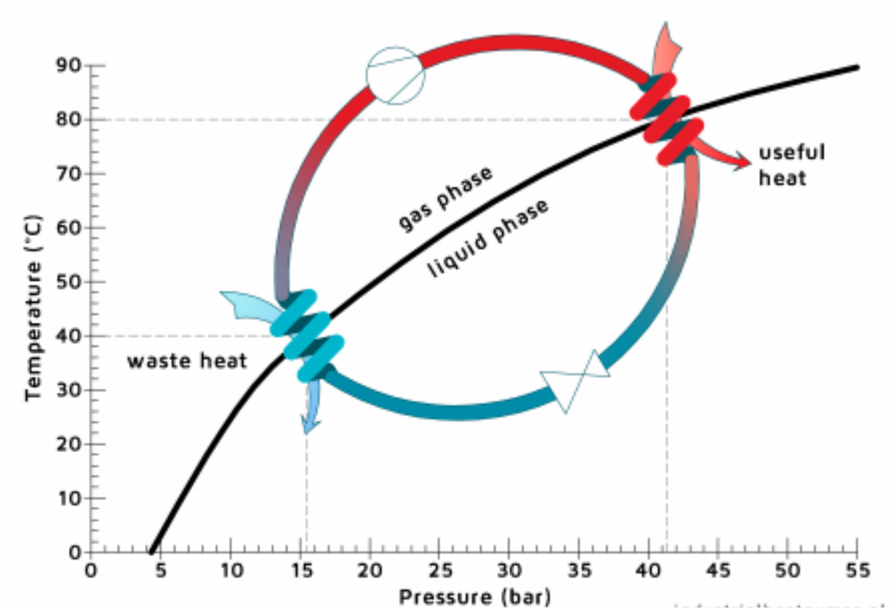
Source: De Kleijn 2017, www.industrialheatpumps.nl

Heat pumps can play a number of roles:

- Raise the temperature of a fluid.
- Simultaneously cool a fluid, which can also be used for dehumidifying.
- Recover waste heat from a stream, including latent heat from water vapour.

A low temperature waste heat flow can be upgraded to useful high temperature heat using a heat pump. The mechanical heat pump driven by an electric motor is the most widely used. Its operating principle is based on compression and expansion of a refrigerant. A heat pump has four main components: evaporator, compressor, condenser and expansion device. In the evaporator, heat is extracted from a waste heat source by evaporating the refrigerant at low pressure. The gas is compressed and its temperature increases (just like in a bicycle pump). In the condenser, this heat is delivered to the process at a higher temperature as the refrigerant condenses and releases its latent heat. Electric energy drives the compressor and this energy is added to the heat that is available in the condenser. The efficiency of the heat pump is denoted by its 'coefficient of performance' (COP), where a COP of 3 means three times as much heat energy is delivered as the amount of mechanical work input from the compressor.

Figure 3 – The thermodynamic cycle (using ammonia)



Source: De Kleijn 2017, www.industrialheatpumps.nl

In the figure above, the black line shows the relationship between pressure and boiling point of Ammonia. At low pressure and temperature Ammonia is evaporated in the evaporator, absorbing heat as the liquid is converted into gas – storing the latent heat of vaporisation. The energy needed for this is provided by a waste-heat stream. The compressor increases the pressure of the Ammonia vapour, increasing its temperature (like in a bike pump). The vapour is then condensed at high pressure and temperature inside the condenser, releasing its latent heat of vaporisation. During the condensation of Ammonia, heat is released at a higher temperature: a useful source of energy. The liquid Ammonia is transported to the expansion device that lowers pressure. The low temperature, low pressure Ammonia flows to the evaporator where it again absorbs heat energy as it evaporates.