FAHRENHEIT
Cooling Innovation.

HyCool eLearning

Hybrid Heat Pump

Lesson 1. Basics

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eLEARNING COURSE

Lesson 1. Basics

Lesson 2. Construction and Features

Lesson 3. System Planning

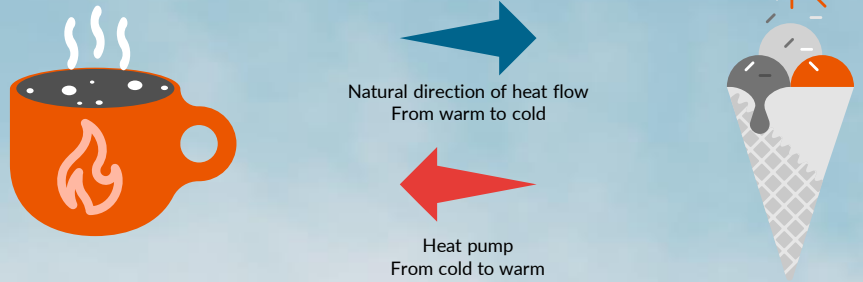
Lesson 4. Operation and Maintenance

LESSON CONTENTS

Hybrid Heat Pump - what is it?

Heat Pump is a thermal machine forcing the heat to flow from an area with a lower temperature to an area with a higher temperature. This process runs against the natural direction of heat flow and takes place due to external mechanical or thermal energy. Heat pump can be used as a chiller or as a heating appliance.

Hybrid Heat Pump is a term used to describe a device consisting of two or more interconnected and co-operating heat pumps based on different principles of operation. In the context of the HyCool project, the HHP comprises an adsorption and a vapour compression heat pump. These two types of heat pumps are interconnected to maximize the use of benefits of both, and to avoid or mitigate their drawbacks. There are multiple possible layouts of HHP depending on how the two heat pumps are interconnected – in parallel, in series or in cascade.

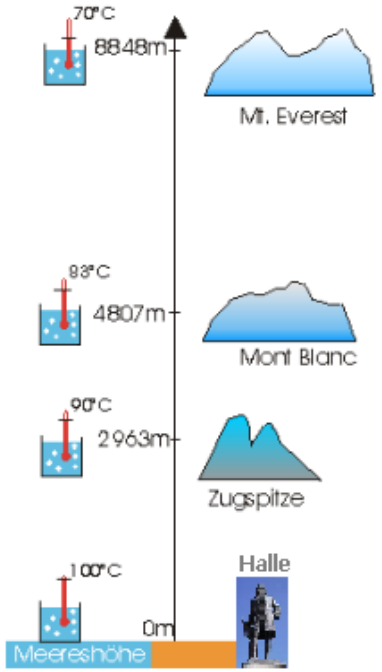


Evaporative cooling

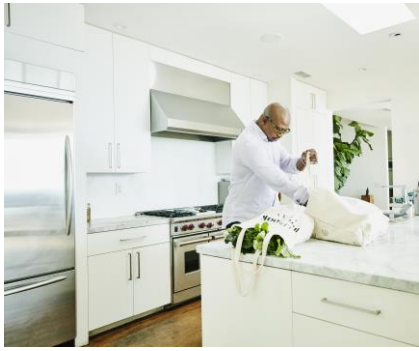
If you want to cool an object down, you must lower its internal energy by absorbing the heat from this object.

Evaporation is a very efficient way of absorbing the heat. The simplest example of cooling with evaporation is sweaty skin or when you feel cold after getting out of the sea. The water droplets evaporate from your skin taking up the heat from your body.

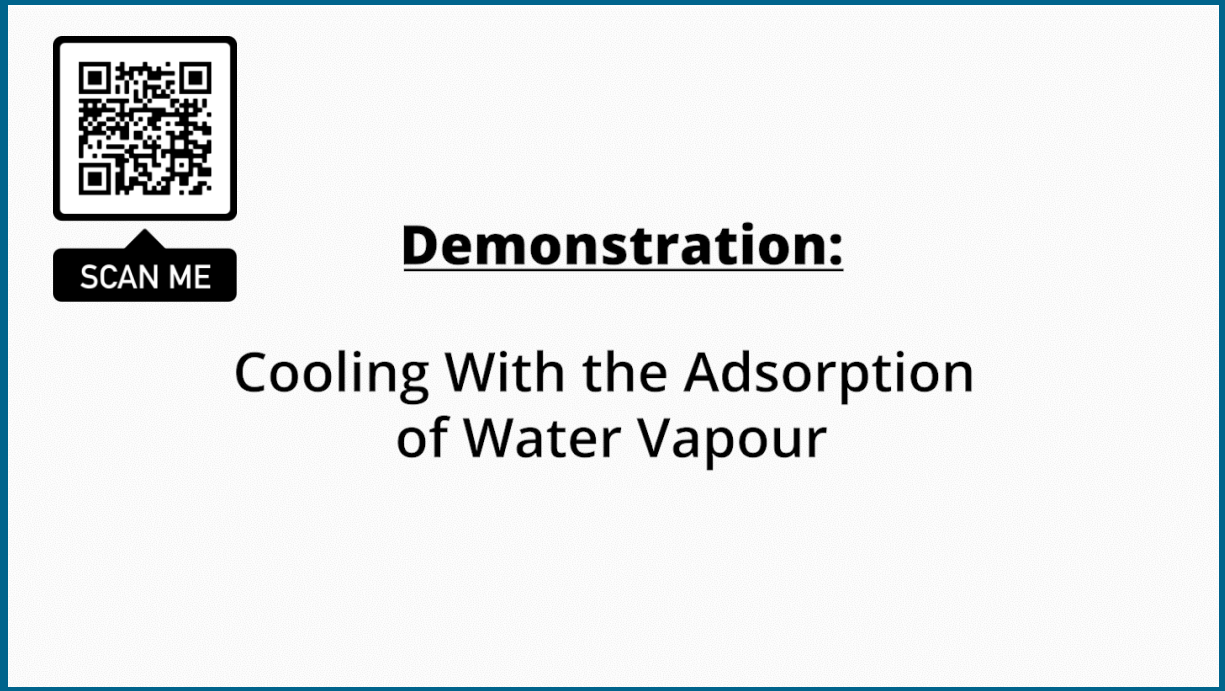
Moreover, since temperature of evaporation depends on the pressure of the medium, you can force the medium, for example water or synthetic refrigerant, to evaporate (and absorb the heat) at desired temperature by changing its pressure. Hence, it is possible to achieve the temperatures even below ambient. That's the operating principle of your refrigerator!



Evaporation temperature of water changes with pressure



EVAPORATIVE COOLING VIDEO

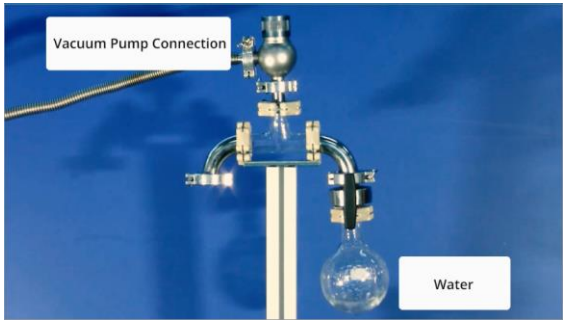


The video presents two types of compression:

1

Mechanical compression with pump

The vacuum pump is sucking the vapour out of the right bulb by mechanically forcing the movement of the particles. Therefore, the pressure in the right bulb decreases and water starts to evaporate.



2

Thermal compression with solid sorbent

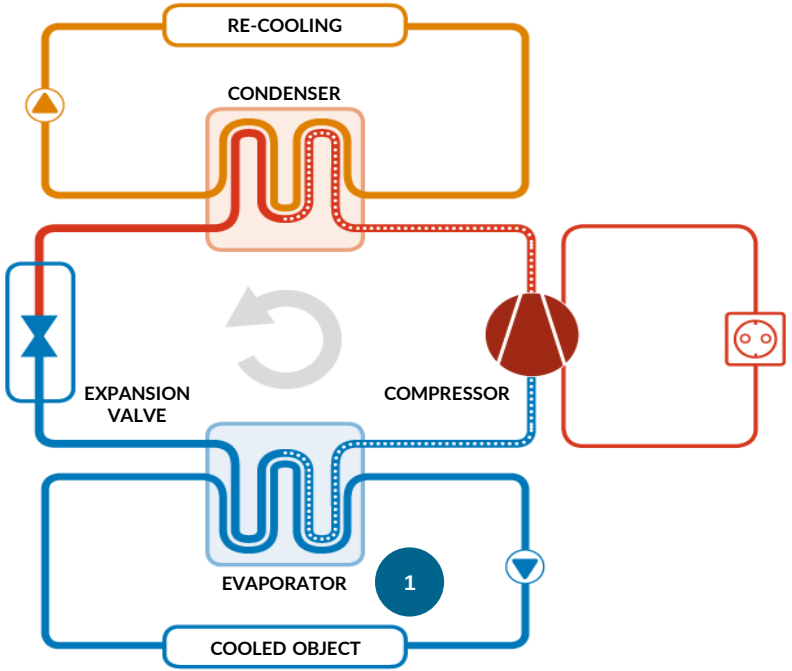
The sorbent is forcing the movement of vapour by sucking it in (adsorbing). The pressure drop causes the evaporation of water and decrease in its temperature hence water in the right bulb froze.

As you can see, the sorption process can induce evaporative cooling just as a compressor does in the commonly used compression chillers and heat pumps.

Vapour compression heat pump

Consists of four basic elements:

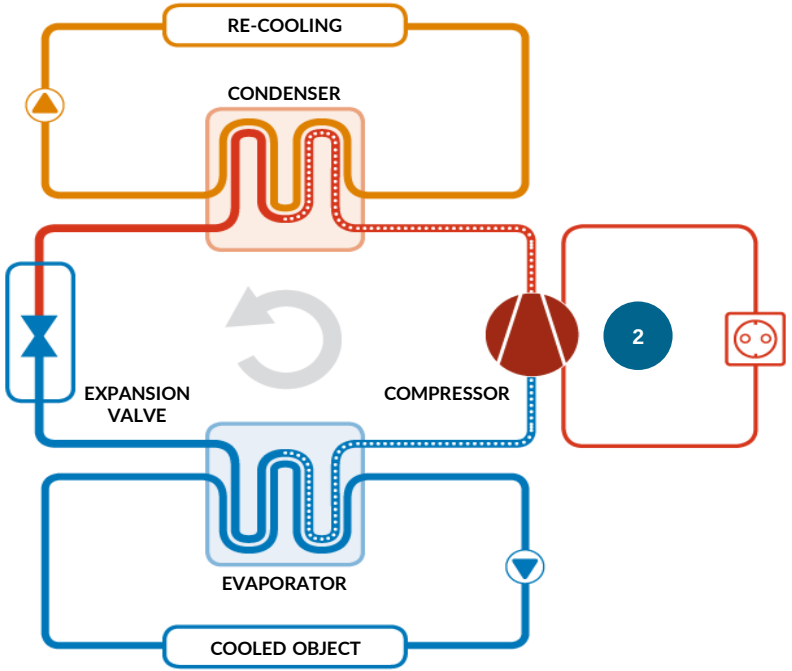
1 **Evaporator** – heat exchanger in which refrigerant evaporates and cools down the second working medium. The second working medium could be air (direct air cooling), water or brine (for temperatures around and below 0 °C). For cooling of water and brine usually a plate heat exchanger is selected. For air cooling, evaporators are usually designed as finned tube accompanied by a fan to force the airflow.



Vapour compression heat pump

Consists of four basic elements:

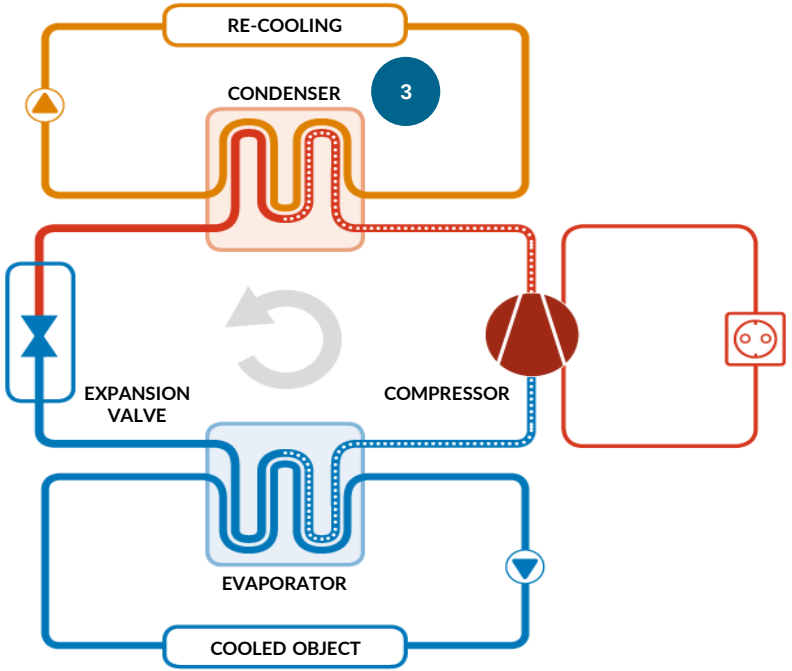
2 **Compressor** – a mechanical device that increases the pressure of a gas by reducing its volume. It increases the pressure of refrigerant to let it condense at a higher temperature than that at which the evaporation took place. There are three most popular types of compressors used in refrigeration: piston (reciprocating), screw and scroll. The compressor is the heart of the heat pump. Of all components, it has the greatest impact on the performance.



Vapour compression heat pump

Consists of four basic elements:

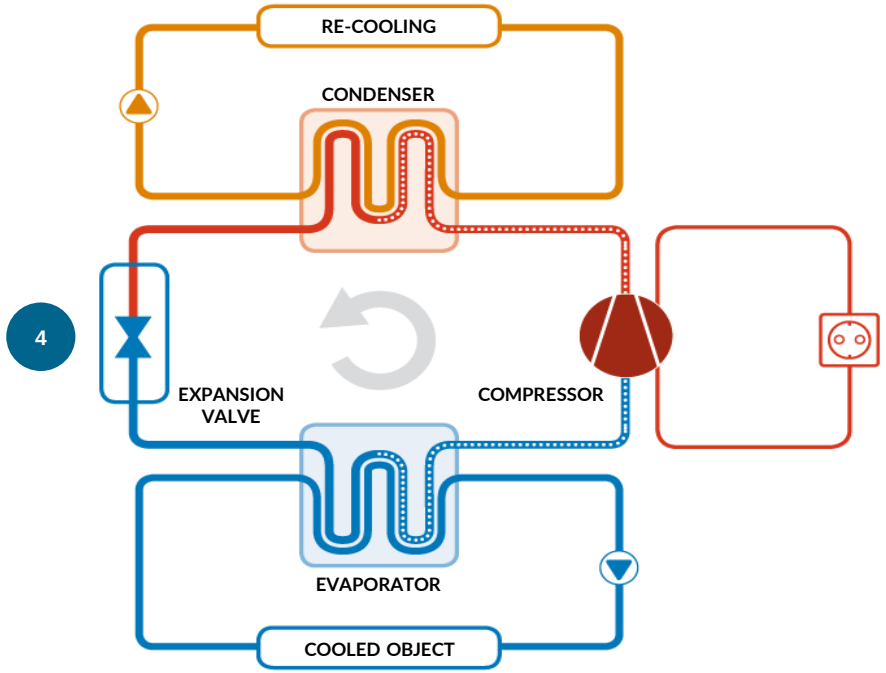
3 **Condenser** - heat exchanger in which compressed refrigerant vapour condenses and warms up the second working medium. The second working medium could be air, water or brine (if there is a risk that the temperatures fall below 0 °C). For operation with water and brine the first choice is usually a plate heat exchanger. The air-cooled condensers are built similarly to the evaporators - as finned tube accompanied by a fan to force the airflow.



Vapour compression heat pump

Consists of four basic elements:

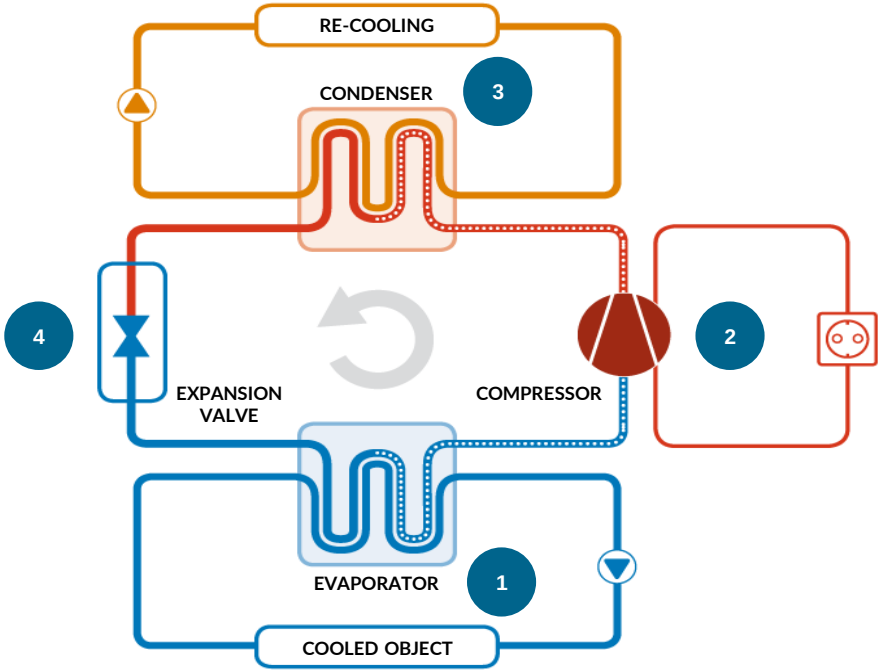
4 **Throttling device** – element of refrigeration automation. This valve in the refrigeration system is installed directly in front of the evaporator. This valve has two tasks: to decompress the refrigerant (decrease the pressure) and to maintain a constant charge of the evaporator with refrigerant (constant overheating). There are two main types of expansion valves – thermal and electronic.
Alternatively, a capillary tube can be used to throttle the refrigerant.



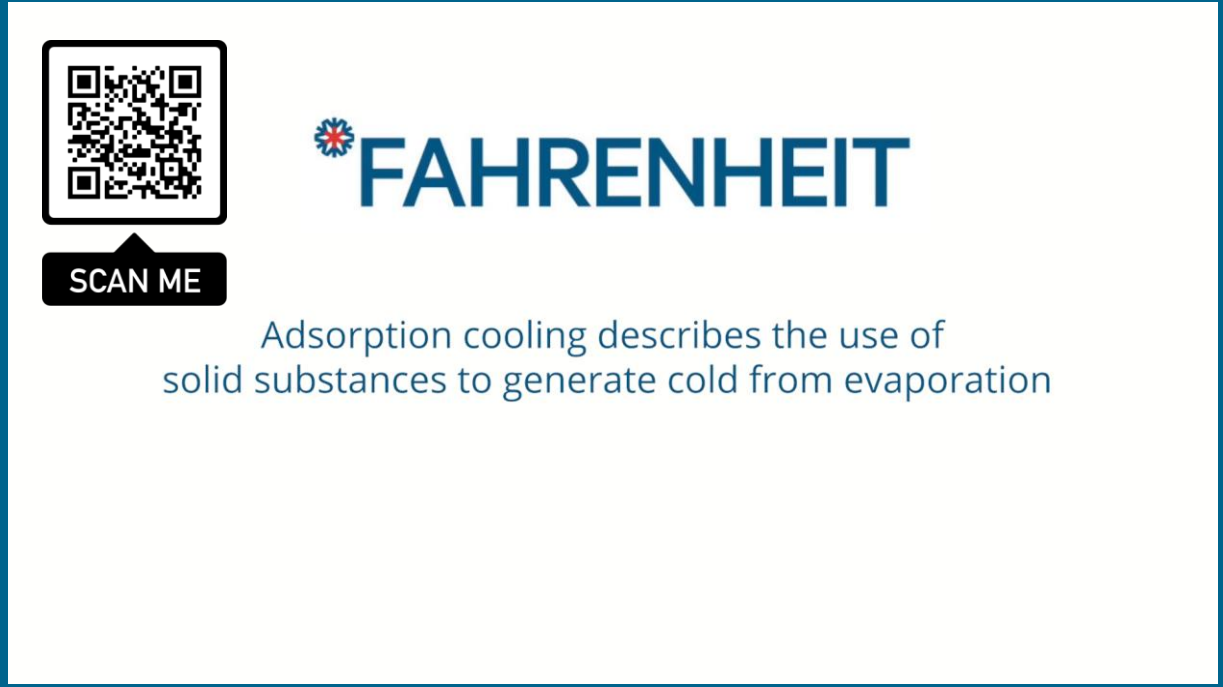
Vapour compression heat pump

The refrigeration cycle follows the four steps:

1. Evaporation of refrigerant at low temperature in the evaporator (e.g. at 10 °C).
2. Compression (pressure increase) of the refrigerant vapour in the compressor.
3. Condensation of the refrigerant vapour at high temperature in the condenser (e.g. at 30 °C).
4. Throttling (pressure decrease) of liquid refrigerant through the expansion valve.

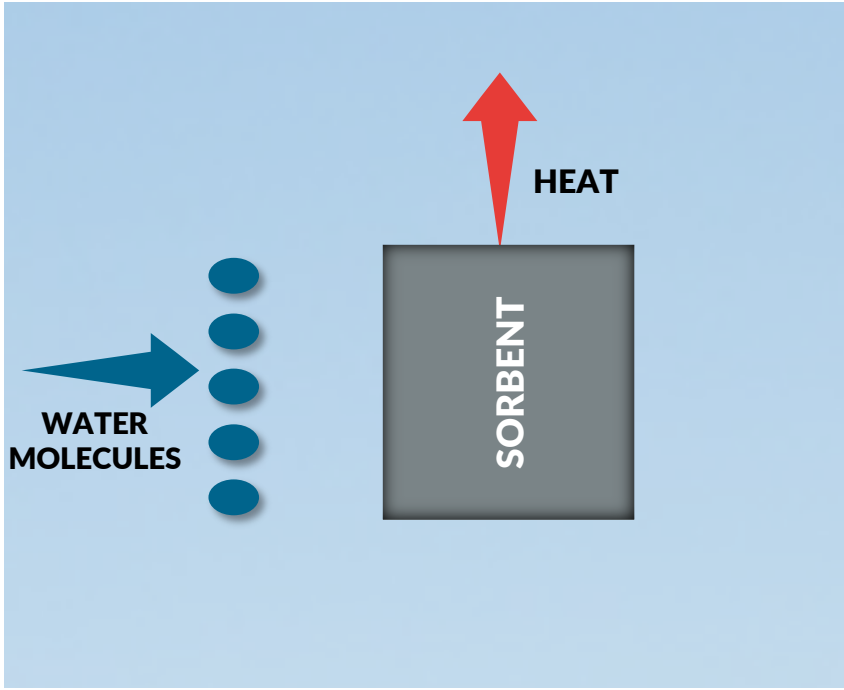


ADSORPTION COOLING VIDEO



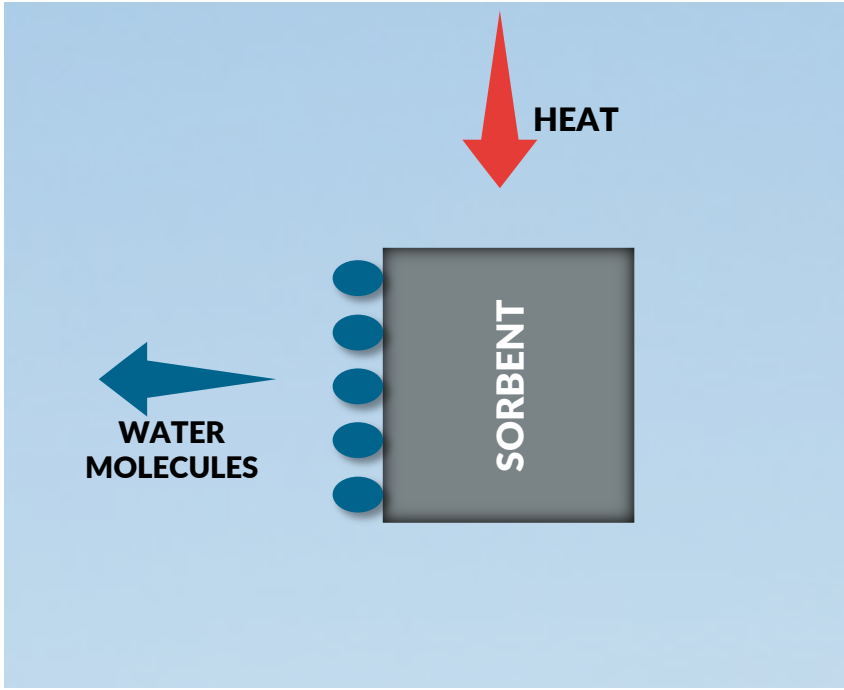
Adsorption process

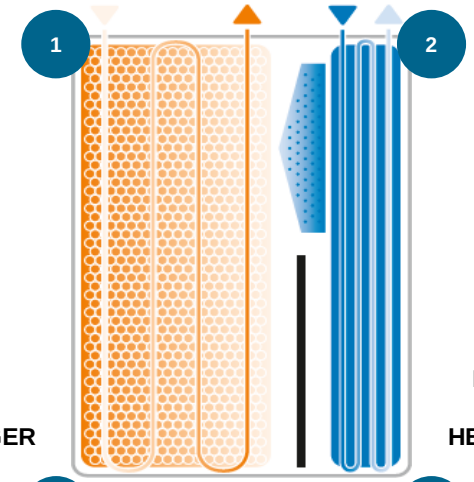
The sorbent (silica gel, zeolite) attracts the water molecules. In other words, it sucks in the water vapour.
At the same time, heat is released to the ambient, therefore we call this process exothermic.
If we want to dry the sorbent, we must somehow force the water molecules to leave. We can do it by heating up the sorbent. This process is called desorption...



Desorption process

The desorption is an endothermic process because we are adding the heat. You can see on the schematics that water molecules are expelled from the sorbent, the vapour is released, and the sorbent is regenerated. The regenerated sorbent must be cooled down and then the adsorption process may start again.





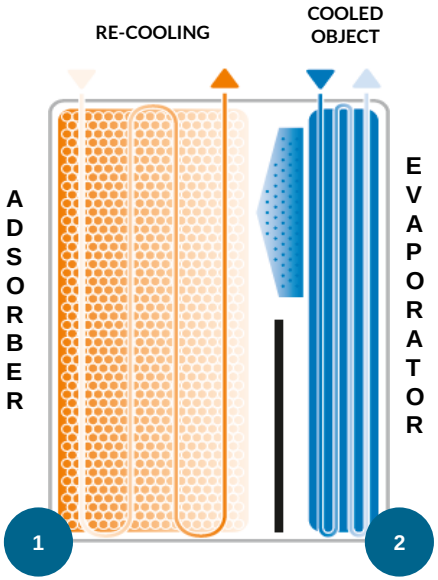
Adsorption heat pump

The adsorption module consists of two heat exchangers in one enclosure:

1. **Adsorber / Desorber heat exchanger** – its surface is covered with the sorbent (silica gel, zeolite). When the sorbent is adsorbing the water, the heat exchanger is called adsorber, during the sorbent's regeneration, the heat exchanger is called desorber.

2. **Evaporator / Condenser heat exchanger** - on its surface the refrigerant (water) evaporates and condenses depending on the operation phase.

I



Adsorption heat pump

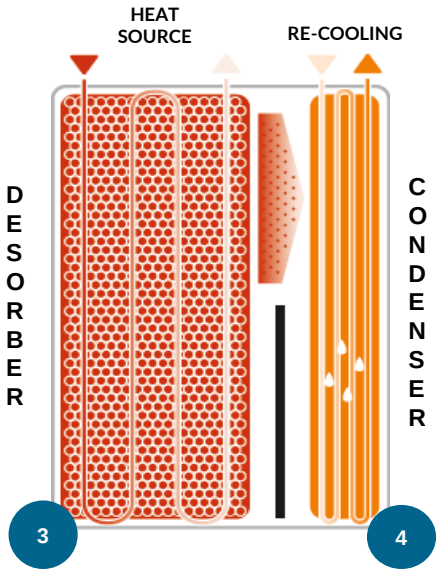
The cycle consists of 2 phases:

I **Adsorption / Evaporation phase**

1 Adsorption of the vapour in the adsorber/desorber heat exchanger. Heat is released (e.g. at 30 °C).

2 Evaporation of refrigerant at low temperature in the evaporator/condenser heat exchanger (e.g. at 10 °C).

II



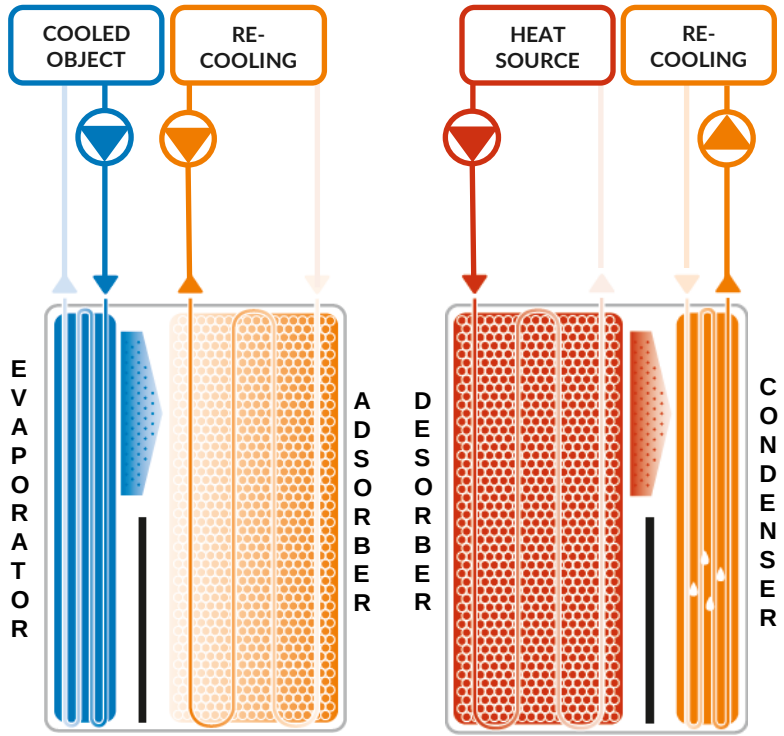
Adsorption heat pump

After reaching the saturation state, the following happens in the same heat exchangers:

II **Desorption / Condensation phase (regeneration)**

3 Discharge of vapour in the adsorber/desorber heat exchanger. Heat is absorbed (e.g. at 85 °C).

4 Condensation of vapour at higher temperature in the evaporator/condenser heat exchanger (e.g. at 30 °C).



SORPTION MODULE IN ADSORPTION/EVAPORATION PHASE

SORPTION MODULE IN DESORPTION/CONDENSATION PHASE

Adsorption heat pump

The cooling effect is provided only in the Adsorption / Evaporation phase. Therefore, in order to ensure continuous cooling, the adsorption heat pump consists of (at least) two sorption modules working in alternating phases.

When one sorption module is in the Adsorption /Evaporation phase, the second one is being regenerated (desorbed).

Adsorption and compression heat pumps, are very similar. In both, the refrigerant is evaporated, compressed, and condensed.

The difference between the adsorption and vapour compression heat pump is the type of compressor.

Both types of heat pumps have their own strengths and weaknesses.

ADSORPTION VS. COMPRESSION

STRENGTHS

- Refrigerant is pure water
- Powered mainly by heat (from renewable sources or waste heat)
- Low maintenance requirements
- No moving parts in the modules
- Silent operation
- No over-pressure in the modules
- Increases energy efficiency of an industrial plant
- Incentives available in many countries

- Reliable, independent from heat source
- Supply chilled water at exact required temperature
- Supply cooling in wide range of temperatures including sub-zero applications
- Available in wide range of sizes from many manufacturers
- Affordable and well-known technology
- Easy to find installation company proficient in this type of heat pumps
- Usually in relatively small size and volume

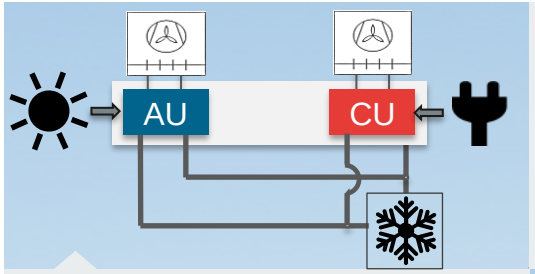
WEAKNESSES

- The allowable chilled water temperature range is 8-21°C*
- Fluctuations in chilled water temperature outlet (can be smoothened by buffer tank)
- Sensitive to high re-cooling temperatures*
- Operation dependent on heat availability (or heat storage capacity)
- Require bigger capacity of re-cooler**
- Bigger volume, weight and size**
- Higher price**

- High consumption of electrical energy
- Require frequent maintenance and leak checks
- Often utilize synthetic refrigerants (natural alternatives are flammable, toxic or require high operating pressure)
- Underly the Pressure Equipment Directive
- Mechanical compressors are noisy
- The most expensive component (compressor) is subject to wear, short life expectance

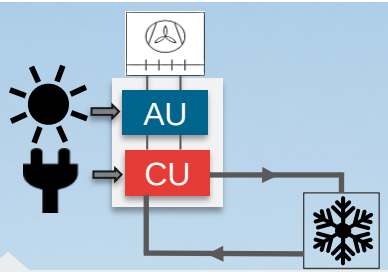
**based on silica gel machines*
*** in comparison to state-of-art vapour compression heat pumps*

Hybrid Heat Pump Layouts



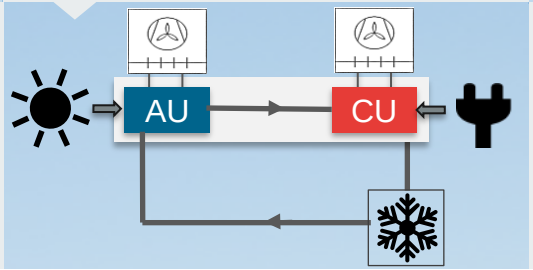
Serial connection

Water (or brine) is firstly cooled down by the adsorption heat pump, and then the compression heat pump cools the medium further down to the required temperature.



Parallel connection

The adsorption and compression heat pumps operate in parallel to each other supplying cold water to one common cold consumer.



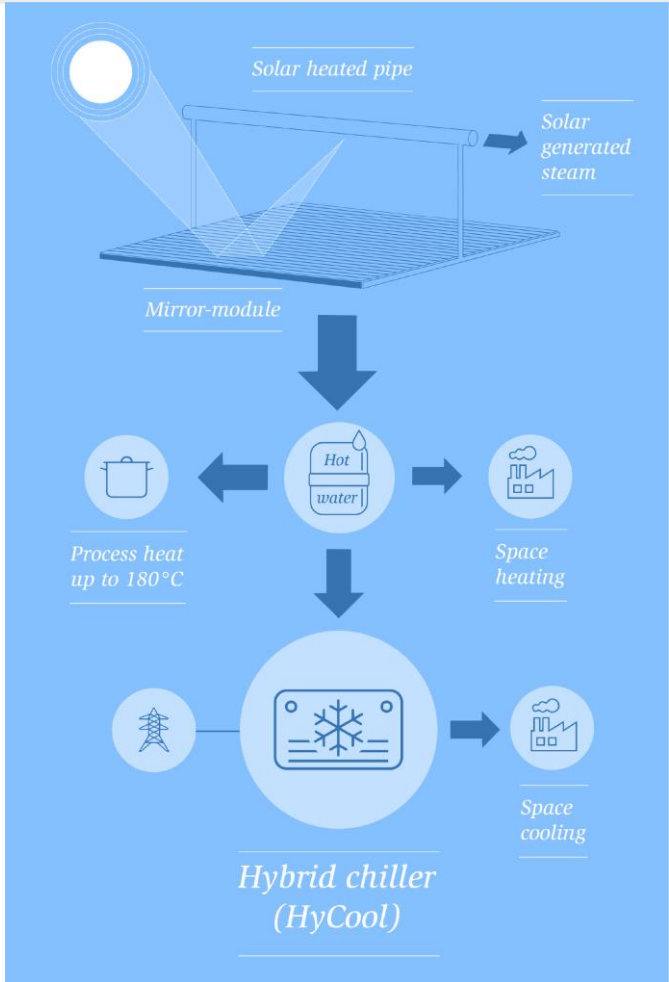
Cascade connection

The adsorption heat pump cools down the condenser of the vapour compression‘s one. The condensation temperature is lower than the one resulting from the outdoor conditions and the efficiency of the HP is greater.

Application in HyCool

In HyCool the Hybrid Heat Pump is used to provide cooling of space and processes in two industrial demo sites.The drive heat comes from Fresnel concentrating solar collectors – a perfect source of high-grade, renewable heat! These CSP generate the heat for industrial processes, for space heating, and for cooling. At both demo sites, based on the estimated economical and environmental benefits, special energy management algorithm decides by which consumer the heat will be used.

The Hybrid Heat Pump consumes less electrical energy than standard vapour compression chiller alone, while providing the same amount of cooling capacity. At one demo site the HHP is built in cascade layout (adsorption unit‘s evaporator cools down the compression unit‘s condenser), at the second one the two HHPs are connected in series (adsorption unit pre-cools the medium and compression unit cools it further down to the required parameter).



That‘s all in Lesson 1.

You can now proceed to Lesson 2.