# Guidelines for integrating industrial heat pump

## Short summary

This short guideline is intended to help planners and end-customers to prepare when starting a project involving the integration of steam-generating heat pumps in their industrial processes.

## Before implementing a steam-generating heat pump

Installing a steam-generating heat pump in a running industrial plant is not trivial. It requires a lot of preparation and information about the whole plant, not only where the heat pump will be installed.

There are two possible locations to install an industrial heat pump:

1. **Centralized heating** and cooling of the whole plant
2. Installation for one or a few **specific processes**

For the centralized heating and cooling, it is usually a bit easier to determine the requirement for the heat pump, since fuel data is available in most cases. However, since central supply temperatures are usually higher than the temperature range of the processes, this solution can lead to poor efficiency. In most cases simply replacing a fossil-fuel based steam generator with a heat pump is not successful.

For a heat pump installation on a specific process, a **Pinch Analysis** of the process and the knowledge of **any potential modification planned on the process** are necessary before going forward with the project.

To have a good overview of the heating and cooling demand and to be ready to ascertain if a heat pump is the best technology for a centralized heating and cooling solution, it is highly encouraged to perform a **Pinch Analysis** of the whole plant. This analysis generates a grand composite curve of the plant for different periods of the year. Using this graphical summary of all the flows, it is convenient to determine the temperatures and capacities where a simple heat recovery via a heat exchanger is possible and where heat could be upgraded via a heat pump. The temperature lift between the cold and hot demand and the capacity are visible, clearly showing if and where a heat pump is the right solution. Results of a Pinch Analysis also help planners choose the right type of heat pump for the application. However, for simple processes, a full Pinch analysis may not be necessary. The list of process streams (with mass flow and temperatures) may be enough to design the best heat pump system.

It is also very important to have a **plan of future modifications to the plant** that are foreseeable. Heat pumps are designed to work at particular temperatures and capacity. Modifying the temperatures or the capacity can greatly reduce a heat pump's efficiency or even make it impossible to deliver new heating and cooling demands. While they can be very efficient, they are not as flexible as current steam boilers.

If the process does not match its cooling and heating demand well, looking for nearby process demands with similar running profiles is recommended.

Furthermore, a heat pump can only run if adequate cooling and heating demands are available at the same time. It is important not to neglect the **temporality of the processes**. If discrepancies exist or processes are not steady in power and temperature, adding heat storage is necessary.

It is also important to know that an electric-driven heat pump needs a heat source, unlike a fuel-burning system. Therefore, if the heat pump is linked to the process that will produce this heat source,

**another provider of heat may be needed to start up**. It can be an electrical, fuel-fired, or heat storage system. For example, if a proposed heat pump supplying heat to a plant uses the waste heat from the plant, another heat source is needed to start the process.

Finally, before looking more into heat pump design, it is important to ensure the **heat flows delivered to the process are optimal in terms of temperatures**. To have a more efficient system, heat flows need to be at the lowest possible temperature, and cold flows need to be at the highest possible temperature to reduce the heat pump's temperature lift and increase its coefficient of performance (COP). If steam is used as a heating medium, an analysis should be made to confirm that it cannot be replaced by hot water (even pressurized hot water). Heat pump efficiency typically drops for 2-3% per Kelvin increase in temperature lift.

## Before going into detail

After having analyzed the desired processes or those of the whole plant, it is important to collect the following information concerning some aspects of steam-generating heat pumps:

1. What is the temperature lift between the hot (heat sink) and the cold temperature (heat source)?
2. Heat pumps use refrigerants to work. It is important to seek out internal regulations concerning the use of chemicals in the company, as some refrigerants are toxic or flammable (e.g., ammonia and propane, respectively). The newest heat pump refrigerants are hydrofluoroolefins (HFO), which are being regulated, especially in Europe, and may be phased out. The trend and the current most future-proof refrigerants are natural refrigerants (e.g., water, ammonia, and hydrocarbons), which might require additional safety measures.
3. High temperature heat pumps are a family of different cycles, each cycles have different advantages and disadvantages; therefore it is difficult to compare heat pumps.
4. If steam is required and the heat source has a high temperature (i.e. in excess of 80-90°C), vapor recompression using water as refrigerant should be investigated as it brings the best efficiency.
5. To know the size of the heat pump, rough capacities of the cold or hot side are needed. Furthermore, estimating the operating hours per year is useful in determining the duty cycle of the heat pump.
6. The potential installation location for the heat pump needs to be investigated, as a heat pump can require larger space than an electrical heater of the same capacity. It is hard to quantify the size of such system, heat pump of around 1MW are estimated to be around from 45 to 75m3 for a compact one or two stages heat pump. However, place around the heat pump and place for the electrical cabinet needs also to be taken into account.
7. Noise pollution should be considered when choosing their location.
8. Heat pumps need to be maintained at room temperature to start. High-temperature heat pumps (HTHP) with a bottom and a top cycle may need to be heated before starting. Furthermore, due to heat loss, a heat pump also heats its direct environment and may thus need to be in a ventilated area or even cooled down while running.
9. The most common heat pump technology is the vapor compression cycle. However, for some cases, absorption heat pumps (incl. absorption heat transformers) may be an appropriate solution.
10. Current and future energy prices are necessary to estimate the payback time: electricity and gas rate (eventually annual fee), $CO_2$ levy, etc. A financial tool is available online[1].
11. Information on the possibilities of financial help such as KLIK, EnergieSchweiz, SFOE, Canton, Commune or Government funding needs to be collected.
12. Any specificity of the process or plant, such as pipe material, chemical usage (for the refrigerant choice), and the importance of not having oil or other substances in the heating medium, should

[1] https://www.sweet-decarb.ch/decarbonization-tools

be collected before making a heat pump feasibility study to speed up the process. In Some cases it might be necessary to include intermediate circuit to avoid refrigerant or oil leaking into the process in case of heat exchanger failure.

Once the information is collected, consultation with a research institute or an engineering bureau is recommended. An Excel file to **estimate the payback time** of a heat pump is available online[1].

## Details of industrial heat pump pre-study

It is important to precisely evaluate the temperatures needed on the heating and cooling sides. As written earlier, ensuring that the hot temperature is the lowest and the cold temperature is the highest possible will increase the heat pump's efficiency.

Large industrial heat pumps need high voltage and electrical power to run. That means that an electrical power cable able to deliver the correct voltage and current will have to be pulled up to the potential location of the heat pump. That may constrain the potential location of the heat pump.

Large industrial heat pumps are also heavy. Thus, the heat pump's potential location should be stable and strong enough to support a heavy machine that vibrates. The ease of access to bring the heat pump to the potential location may also restrict the potential location.

Depending on the heat pump design, the heat pump may need to be kept at room temperature before starting or even being heated up thus the location of the heat pump should be hot enough before it starts. That means an additional heating system for the heat pump may be needed for startup.

When running, the heat pump suffers from heat loss through its electrical drive & control, hulls, pipes, and heat exchangers, which may lead to overheating of the location. Therefore, ventilation of the heat pump space may be needed.

Safety measures are well-defined and standardized. Some refrigerants, such as ammonia, can be toxic, while others, such as butane or pentane, can be flammable. Hence, it is important to include the personnel in charge of the project's security and safety at the plant site.

Once the heat pump is in operation, the process engineers must monitor its performance. Thus, it is important to include them from the beginning of the project to learn from their knowledge and explain and prepare them for the change the heat pump will have on their work.

As mentioned above, start-ups of heat pumps are more complex than fuel boilers; thus, a start-up concept should be clearly defined.

## Particularity of a steam-generating heat pump

Water vapor suffers from heat and pressure loss. Therefore, the pipes must be adapted to **minimize these losses**.

If the process using the steam delivered from the heat pump starts with a separate system, then the steam valves between the start-up steam (or network steam) and heat pump steam must be very well designed to **avoid any backflow** or similar problems.

As steam is a corrosive material, the pipe material should be adapted. Each plant has a different standard in terms of its piping material; please check the plant standard to ensure the plan does not have to be modified later.

Similarly, **the heat pump heat exchanger and piping material should be defined and discussed with the** manufacturer.

In terms of storage, steam storage is available on the market (for example like the "Dampfspeicher CoPES" from Jaske & Wolf Verfahrenstechnik GmbH) even though it is much less common than water storage or other thermal storage[2].

[2] Many information can be found on www.sweet-decarb.ch and https://heatpumpingtechnologies.org/annex58/