HEAT SOURCES

Technical Report of the IEA DHC TS3 “Hybrid Energy Networks”, subtask A “Technologies and synergy potential”, WP2 “Experiences with hybrid energy networks based on large-scale heat pumps”: *Heat sources*.

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Content

1 Heat source overview

When considering heat pump options, an initial screening of the relevant heat source alternatives is necessary. To compare the advantages, disadvantages, and feasibility of available options, a first step can be to address the flow chart in Figure 1 and the overview in the following sections. In general, the highest temperature heat source can enable the highest COP levels and thereby the least electricity use per unit of supplied heat. Local conditions can influence the stepwise approach, but the figure can illustrate the idea of considering various options before choosing a specific solution. Though the efficiency using other sources is in general higher, air has in many cases proven to be the chosen/available heat source in the end as indicated in the document “Market status, incentives and policies in Denmark”.

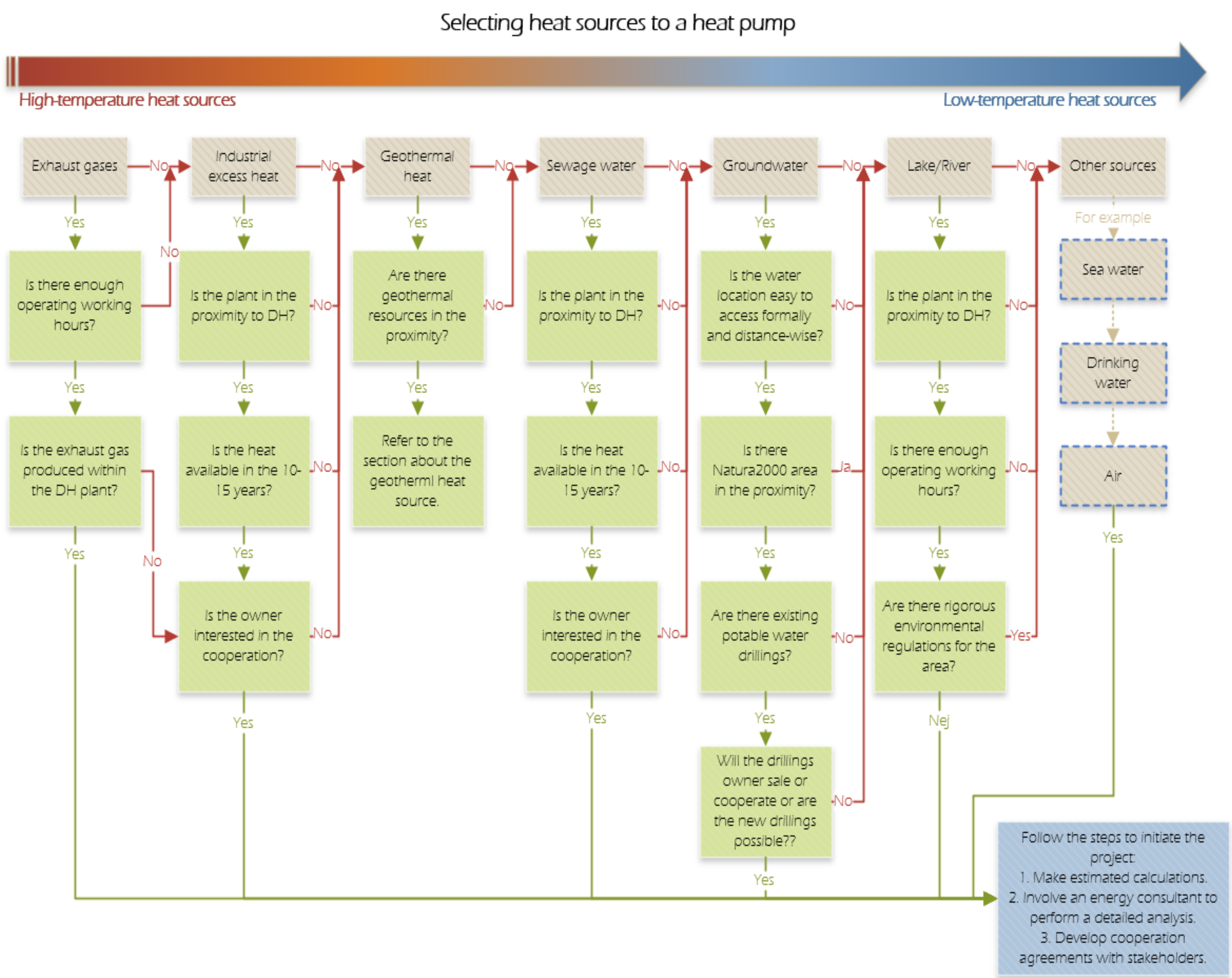

Figure 1. Heat source selection flow chart.

2 Strength and weaknesses of different options

In the following section, advantages and disadvantages of the heat sources indicated in Figure 1[1] are listed.

2.1 Exhaust gases

Every exhaust gas (or flue gas) produced by combustion of a fuel (fossil or non-fossil) can be cooled down before being led out to the surrounding environment. If the flue gas is warmer than the return temperature of the DH network, it can be used to warm up the water directly (using a heat exchanger). When the temperature of the flue gas is below the return temperature, a heat pumps is required to extract the heat.

Temperature:
Temperature levels can range from approximately 50 °C up to more than 100 °C.

Advantages:

- Relatively low-cost unit and installation compared to heat pumps with other heat sources.

Disadvantages:

- Flue gas condensation contains pollutants, that must be contained and disposed properly if it cannot be party/completely neutralized and diverted to the sewer. This entails a cost that must be considered in the feasibility of the solution.
- The heat pump operation is linked with the operation of a fuel-based device. The heat pump will only be able to recover 5-10% of the energy from the flue gas, which limits the savings potential.

2.2 Industrial excess heat

Excess heat can be retrieved from the industry, including chemical processes, food production and from data centres. An increasing number of data centres are built, and it can be useful to initiate an early dialogue with the owners to investigate the option of installing equipment preparing the excess heat utilization already during the data centre construction phase. In case water cooling of servers is implemented, the extraction of heat to be used for DH is more straightforward and efficient, but this is not a necessity for utilizing data centre heat as a source.

[1] A source of information involves the gathered experiences described in the Danish "Drejebog til store varmepumpeprojekter i fjernvarmesystemet" (guidebook for large-scale heat pump projects in the district heating system) from December 2017.

Regarding agreements between the DH company and industries a list of topics is found in the document "Tendering process".

Temperature:
The heat can be utilized in three different ways, depending on the temperature level and the requirement of the specific DH network:

- High temperature: Direct heat exchange without the use of heat pumps (e.g., excess heat cooled from 95 °C to 40 °C, while DH is heated from 35 °C to 75 °C).
- Medium temperature: A combination of direct heat exchange and utilization of a heat pump is possible (e.g., excess heat cooled off from 55 °C to 25 °C using direct heat exchange as the first step and a heat pump as a second step, while the DH is heated from 35 °C to 75 °C).
- Low temperature: A heat pumps is used for the entire energy volume (e.g., excess heat cooled from 25 °C to 15 °C, while the DH is heated from 35 °C to 75 °C).

Advantages:

- The temperature of the heat source is often warmer than a natural heat source thus enabling higher COP levels.
- Utilization of excess heat can simplify the operation for companies, including odour and noise from active cooling units as well as helping to reduce water consumption for wet coolers.
- Both the industry and the DH company can profit from the investment in the long run.
- For the industry, the utilisation of excess heat may represent a promotional value and/or a step towards CSR strategy goals.

Disadvantages:

- Companies usually require very short repayment periods (down to 1 year), while heat pumps for industrial excess heat often have a payback time of up to 5 years.
- It may be difficult to enter agreements with an industry which does not prioritise energy but rather focus on their production chain. Besides this, they will often not rely on the DH offtake of heat thus in any case install their own cooling units – at least as backup.
- If the industry closes, the DH company is left without this production capacity. In this case, the associated investment may be useless.

2.3 Geothermal heat

The temperature of the ground increases approximately 25-30 °C per km of depth. Geothermal heat is therefore attractive for district heating as its temperature may be higher than other natural heat sources.

Temperature:

Depending on the depth of the boreholes, different temperature levels can be achieved. In the Danish cases, temperatures of 43-48 °C are reached at 1.2-1.3 km of depth. In another case, the temperature is 73 °C at a depth of 2.6 km. Often the best properties for geothermal reservoirs are found at a depth between 800 and 3000 m. There are several reasons why drilling typically does not go deeper and aim for temperatures above 100 °C. A balance should be found between the achievable temperature levels and associated costs and risks. Both porosity and permeability decrease with the depth due to increased pressure, and the rising temperatures cause chemical precipitation processes that fill the pores in the sandstone. The properties of the underground are, however, varying heavily between the different global and even local regions. New geothermal systems are currently being planned for Danish DH based on heat purchase agreements in order to reduce the risks for the individual DH company.

Advantages:

- The heat source has a high temperature. How deep it is profitable to drill depends on the temperature gradient for the location in question.

Disadvantages:

- Risk of unsuccessful effort to reach the expected heat supply thus risking that the plans of a geothermal plant must be cancelled after significant spendings associated with the attempt.
- Risk of precipitation of iron and lime to be handled (increasing costs).

2.4 Sewage water

Sewage water (or “wastewater”) treatment plants are often located in places where it is possible to utilise the heat for district heating. However, in some cases the distance to the DH network is too long and the heat potential too small to ensure that the solution is feasible compared to alternative options.

Temperature:

The temperature in an outlet from a typical Danish sewage treatment plant is approximately 10 °C, and during the summer period up to about 20 °C.

Advantages:

- The heat can be extracted all – or almost all – year round, though it can provide more heat during the summer period than in winter due to the temperature of the water.
- A relatively easy installation process which does not require special environmental permits compared to groundwater heat pumps.

Disadvantages:

- The heat production is highly dependent on the continuous operation of the wastewater treatment plant. If it closes or changes handled volumes, the heat pump operation is directly affected.
- The sewage water will in general not be sufficient to cover the DH demand since there is simply less potential energy present in the wastewater produced per inhabitant than what the same person needs to cover the heating demand. Hence, sewage water is typically considered *part of* an energy (and heat source) mix rather than covering the majority of the DH demand.
- It must be ensured that no fouling or corrosion occurs, to avoid environmental contamination.

2.5 Groundwater/drinking water

Groundwater and drinking water are in general a sensitive topic and the concerns regarding risk of contamination often lead to a longer permitting process or even a halt in the initial phase. In many locations groundwater is suitable for the establishment of groundwater-based heat pumps. However, it is important to examine local conditions before investing in a heat pump. Groundwater is found in different depths and the groundwater reservoirs are of different sizes. For groundwater to be relevant as a heat source, it must be possible to pump up relatively large amounts of water from the groundwater. As a first step it can be investigated if nearby drillings can indicate the amount of groundwater. A test drilling can be a second step to ensure that there is sufficient flow for a desired heat pump capacity.

Another option is to cool drinking water, which is in any case pumped from the ground. However, the amounts may not be aligned with the heat demand and the supply will therefore only represent part of the heat supply similar to what is seen for sewage water.

Temperature:

The temperature of groundwater in Denmark is largely constant all year, with temperature approximately between 8-11°C.

Advantages:

- Numerous groundwater reservoirs suitable for the establishment of groundwater-based heat pumps.
- Data from existing boreholes may be available in national databases which can indicate whether or not there is a possibility to use groundwater as a heat source.
- The temperature of groundwater is approximately the same all year round thus representing a stable heat pump operation and heat supply.
- With regular maintenance, a groundwater-based heat pump solution can have a long service lifetime. In Denmark there are boreholes which are more than 100 years old.

Disadvantages:

- The feasibility studies to assess the technical possibility of groundwater heat pump operation can be expensive when it comes to pumping tests to check the actual conditions of the area.
- Due to the value of clean groundwater and the large amounts extracted, there is often a strong concern associated with the establishment of groundwater heat pump facilities and their potential impact on groundwater resources. Preliminary studies and environmental assessment from the municipality will often take at least one year before having the approval. In some cases, it might take even several years.
- It will most likely not be possible to obtain permission for groundwater heat pumps in areas with special drinking water interests due to the protection of future water supply.

2.6 Lake, river, or sea

For both seawater, lakes and rivers, there are temperature constraints. It must be ensured that the inlet water does not drop below approximately 4 °C for an extended period in winter since the risk of freezing in the heat pump must be avoided. In these systems, regular cleaning of heat exchangers must be taken into account. Some things may be filtered while others cannot. As an example, for sea water heat pumps, the formation of mussel larvae can be filtered whereas biofouling cannot. In some cases, it can be useful to install a back flush option. In any case it is important to ensure the ability to dismantle the heat exchanger and install valves to avoid the need of emptying of the pipes and remaining system when doing so.

Temperature:

Compared to the sea, lakes tend to develop a water stratification due to stagnation. As an example, the temperature of Danish lakes fluctuates significantly between summer and

winter, going from 4 °C up to 17-18 °C. In other countries the differences may be even higher.
Concerning rivers and streams, the temperature is usually relatively stable though it depends on the size, location, and source of the river (e.g., if glacier meltwater affects the temperature). When the stream is an effluent from a lake, then its temperature is highly dependent on the lake water.

Advantages:

- Many lakes and streams/rivers are big enough to allow extraction of heat through heat pumps.
- Extraction and discharge of lake or river water is relatively cheap and easy to establish compared to other solutions.

Disadvantages:

- Lakes, rivers/streams and the sea cool down during the autumn and winter and may freeze over, which correlates with the periods when most heat is required.
- The permitting process can be time consuming due to concerns regarding contamination.
- Heat exchangers and other components require regular cleaning due to fouling.
- The water intake is difficult to access (inspect, clean or repair) due to its position somewhat away from shore to ensure sufficient water flow.

2.7 Air

Air-source heat pumps represents the majority of heat pump systems currently installed in Danish DH as described in the document "Market status, incentives and policies in Denmark".

Temperature:
The temperature of outdoor air follows the seasons which during a year follows an almost inverse trend compared to the heating demand but is highly dependent on the geographical location. Even small distances between locations may represent a change in climate conditions. This can a result of a difference between coastal and inland climate or a difference in height above sea level. Local conditions should be taken into account when evaluating the feasibility of an air-source heat pump.

Advantages:

- The benefits of using air as heat source include the abundancy of ambient air, i.e., the availability everywhere.

- Typically, the permission process is shorter and less comprehensive compared to other sources.

Disadvantages:

- Typically, the seasonal COP (SCOP) is lower than for other heat sources. The varying air temperature reduces the COP and thermal capacity when heat is needed the most in winter.
- The air coolers require more space than evaporators used for other heat sources. In this respect it is relevant to consider both the area allocated for the air vents and the necessary open space around them to ensure a free flow of air.
- Since the energy density of air is relatively low, a large flow is needed for a given heat supply, compared to other sources.
- Defrosting of the evaporators to handle condensed, frozen moisture from the air, represents a loss of energy.

More information on air as heat source is found in the dedicated document in this series: *"Air-source heat pump operation"*.