LARGE-SCALE HEAT PUMPS IN DISTRICT HEATING NETWORKS

# ECONOMICS AND THE ELECTRICITY GRID CONNECTION

IEA DHC ANNEX TS3 – HYBRID ENERGY NETWORKS

# 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": *Economics and the electricity grid connection*.

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# Content

# 1 Economics of heat pumps

## 1.1 Electricity prices

The electricity prices have seen large variations during the last couple of years compared to previous periods, as illustrated in the Figure 1 example for eastern Denmark. The trend of increasing prices has shown not to continue in 2023 and as indicated by IEA the levels are expected to be lower compared to 2022 in the coming years[1]. Besides this, the average values also cover fluctuations including hours with low prices. Two similar average values can hide big differences in terms of the hourly values behind it. Hence, high-resolution (hourly) analyses are relevant when calculating the operation costs of a heat pump.

Heat pumps for district heating will typically prioritize operation according to not lowest electricity prices – or at least avoid the most expensive prices. Hence, the average spot price will not necessarily be representative since an average operation electricity price can be below the market average. However, the weighted average during operation will also be affected by the load curve representing a larger electricity demand in winter than in summer due to the space heat demand. This means that for a heat pump with surplus capacity in summer and insufficient capacity in winter, the weighted average will be affected by the affected more by winter electricity prices than the corresponding summer values.

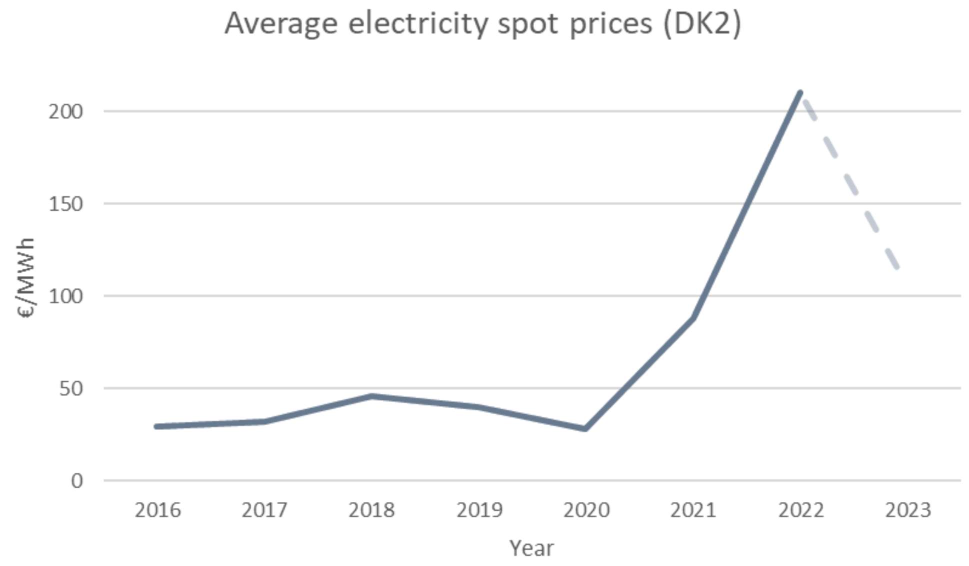


*Figure 1. Average electricity spot prices for eastern Denmark 2016-2022 incl. indication of the average level at the of beginning of 2023.*

[1] IEA, *Electricity Market Report 2023*, Indexed quarterly average wholesale prices for selected regions, 2019-2024, www.iea.org/reports/electricity-market-report-2023.

## 1.2 Investment costs categories

The capital costs cover a range of different sub-categories with the main hardware units representing half or even more of the total capital costs (compressor units being the larger of the two):

- Main hardware
    - Compressor units
    - Evaporators and cooling circuit
- Secondary hardware
    - DH connection (e.g., transmission line depending on location)
    - Pumps and electric motors
    - Valves
    - Technical building/room
    - Noise and vibration reduction (if required)
    - Heat exchangers
    - Refrigerant, oil and other liquids
- Labour
    - Design, documentation and quality assurance
    - Site conditions check (area measurements, condensate drainage ability)
    - Consultants and gathering permissions from authorities
    - Installation of heat pump unit and associated equipment
    - Piping
    - Insulation of the heat pump and piping
    - Electrical installation
- Other
    - Control system of heat pump
    - Integration in the DH control system (SCADA)
    - Electricity supply (connection fee and remote surveillance/control hardware)

## 1.3 Operation costs

Operation & maintenance (O&M) – not including the cost of electricity and associated taxes/tariffs – represent service agreement fee and spare parts/replacements not covered by such agreement as well as the labour costs associated with the operation.

The compressor unit(s) are the most critical component. There is a distinction between piston and screw compressors, where piston compressors require more maintenance due to a larger number and complexity of moving parts. As a general estimation, inspections seen in the table below are expected.

| | |
|---|---|
| All types of systems | |
| Every 5000 hours | Small inspection with control of oil , filters, safety automation etc. |
| Every year | Statutory inspection of pressure vessels, safety valves, piping systems, gas detection system, etc. |
| Every 4th and 8th year | Thorough inspection of pressure vessels and piping system |
| Screw compressors | |
| Every 30-40000 hours | Inspection and possibly replacements |
| Piston compressors | |
| Every 10000 hours | Surveying and checking, possible replacements |
| Every 30000 hours | Main inspection, replacements of bearing and maintenance rod bolts |

## 1.4 Average total heat price

An example of heat price distribution between the main cost categories (capital costs, operation & maintenance, and electricity) is seen below in Figure 2. Average electricity costs including taxes/tariffs are assumed to be either 80, 120 or 160 €/MWh to indicate examples of lower, medium or higher levels respectively though neither of these represents extreme values. O&M represents around 3 €/MWh. The capital costs are based on a summary of real cases applying an interest rate of 3.5% and a payment period of 15 years. This results in heat production costs between 39 and 63 €/MWh.

Since most of the examples gathered lies a few years in the past and prices have been seen to increase significantly in 2022 compared to previous years, the similar figure has been applied adding 30% to the capital costs as an approximation to indicate the cost difference between the average realised costs and what is expected in 2023. This results in Figure 3. In this case, the average heat production prices ranges between 43 and 67 €/MWh.

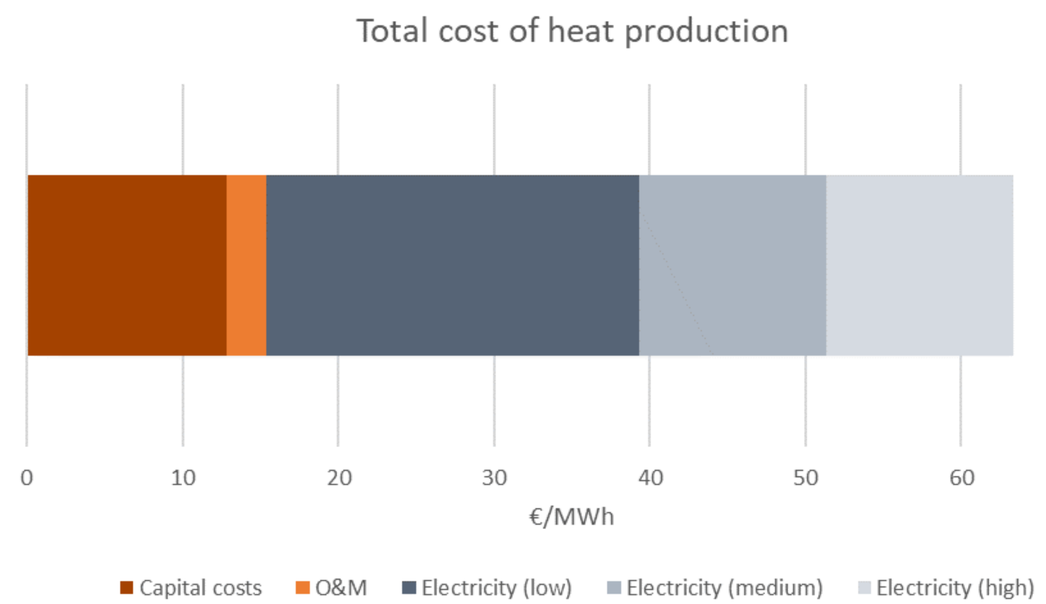


*Figure 2. Total cost of heat production based on real cases.*

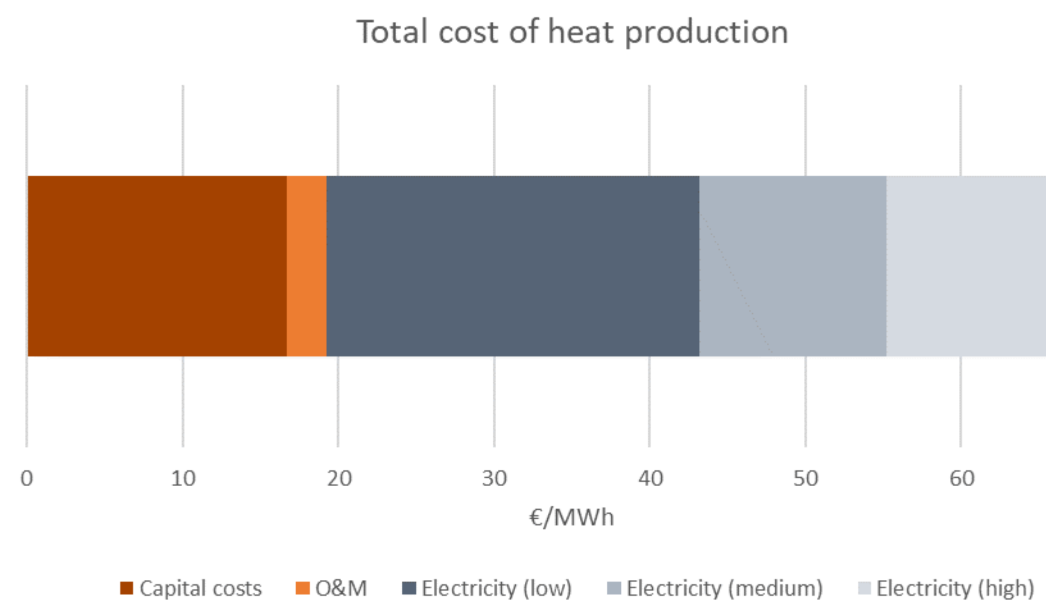


*Figure 3. Total cost of heat production based on updated heat pump investment cost levels.*

Another way to illustrate cost distribution is seen in Figure 4 where the the split between the main cost categories are seen for the case of a low, medium and high electricity price respectively.

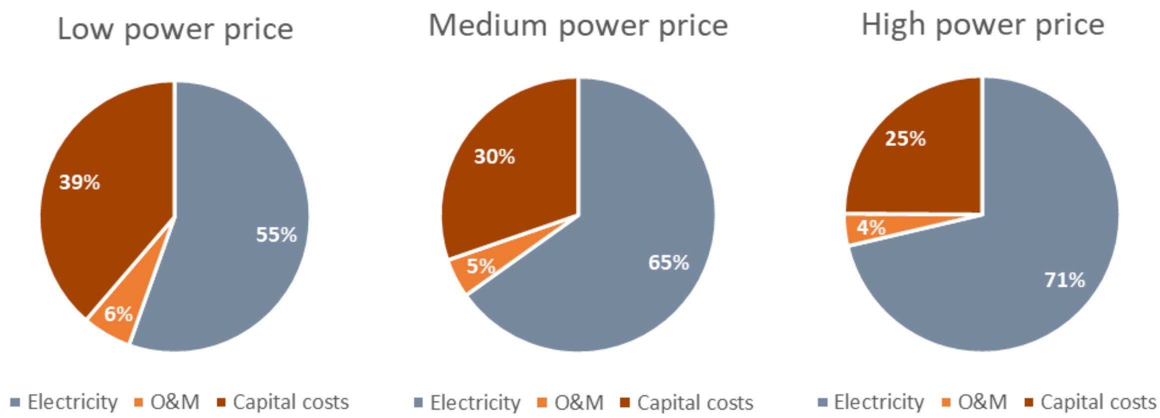


*Figure 4. Cost distribution examples based updated heat pump investment cost levels.*

Regarding the comparison between different configurations and the optimization of design considering both efficiency and costs, see also the document "Configurations and energy system integration".

# 2 Electricity grid connection

## 2.1 Connection points

It is recommended to initiate a dialogue with the DSO early in the process to evaluate what options are present for the point of connection (POC). The grid tariffs may be very dependent on the POC and voltage level where the principle is to pay a fee for the category of grid used. Hence, if the low-voltage grid is not used, due to a POC at a higher voltage level, the low-voltage grid fee does not apply.

Relevant voltage level options for heat pumps in a Danish context:

- A-High: The costumer is connected at 60 kV at a 60/10-20 kV transformer station
- A-Low: The costumer is connected at 10-20 kV at a 60/10-20 kV transformer station
- B-High: The costumer is connected at 10-20 kV at a 10-20/0.4 kV transformer station
- B-Low: The costumer is connected at 400 V at a 10-20/0.4 kV transformer station

## 2.2 Disconnection risk vs. full access

The cost of connecting a heat pump depends on the type of connection. For full access to the electricity grid, the cost in Denmark is around 140,000 € per $MW_{electric}$. Another option is to get a discount where the district heating company only covers actual costs for the electricity company representing mainly the hours for administration and RTU[2] box necessary for monitoring and remote (simplified) control. This could instead cost around 30-40,000 € in total. In turn, the district heating company risk at all times to be disconnected from the electricity supply in case there is a shortage of power in the grid. Many Danish district heating companies have until now taken advantage of this solution to save on the heat pump investment costs, since the disconnection typically never occur. However, there is an focus on the stress of the electricity grid in some periods, thus indicating that the risk of being disconnected will likely increase in the future.

In any case, the cost for the district heating company also includes the electric cable. This should be taken into account when evaluating the most suitable POC.

## 2.3 THD

Electrical noise represented by Total Harmonic Distortion or (THD) as a result of the installation of large-scale heat pumps is to an increasing extent becoming an issue in Denmark and attracts attention from the electricity company often requiring an electric filter which represent an additional non-neglectable cost. The dialogue with the electricity company should be initiated early in the process to clarify necessary measures to be taken into account.

## 2.4 Electricity grid services

Besides optimising the heat pump operation according to the lowest electricity spot prices, the potential financial gains from supplying electricity grid services can be substantial. Regulating power (up/down) is a suitable area where heat pumps can play a role. In this case the flexibility and backup option of a thermal storage can be of extra importance[3]. However, in case of accepting a disconnection risk as described in section 2.2, it is not possible to offer extra regulating power (by lowering electricity demand for the heat pump) since this regulation option is considered already activated by the electricity company which is able to disconnect the heat pump if necessary.

It will likely be feasible to prepare the system for remote operation if the district heating operator wishes to outsource the activity of supplying electricity grid services. Heat pumps may also individually be too small (e.g., under 5 $MW_{electricity}$) to enter all markets but can be virtually pooled in order to enable additional market options.

[2] Remote Terminal Unit

[3] See the document on "Configurations and energy system integration".

When it comes to response time based on external signals, heat pumps are not as flexible as electric boilers. Hence, in a district heating perspective, the FRR as indicated in the table below, is more suited for electric boilers.

| Abbreviation | Response time | Name |
|---|---|---|
| FRR | 0.7-1.3 seconds | Fast Frequency Reserve |
| FCR<br>(FCR-D, FCR-N) | 30 seconds<br>(5-30/150) | Frequency Containment Reserve<br>(-Disturbance/-Normal) |
| aFRR | 15 minutes | Automatic Frequency Restoration Reserve |
| mFRR | 15 minutes | Manual Frequency Restoration Reserve |

In many Danish cases, district heating plants invest in both heat pumps and an electric boiler simply to be more flexible – including in terms of such electricity service markets. Especially when a heat pump is already in operation and is able to adjust quickly (i.e., not having to perform a cold start), it may also enter frequency markets thus enabling additional revenues making the heat pump investment even more feasible for the district heating company and its consumers.

*Figure 5. Small section of the electric hardware for a large-scale heat pump. Though the installation can be complex, the revenue from enabling optimized (possibly remote) operation may be substantial.*