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Topical Article

Flexibility Potential With Heat Pumps In Swedish Thermal Grids

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Markus Lindahl and Anna-Lena Lane, RISE Research Institutes of Sweden

The ongoing electrification of the society, in combination with an increasing share of electricity from intermittent sources, puts pressure on the power grid and increases the need for flexibility to balance variations in electricity production and consumption. Flexibility can also help to reduce issues related to bottlenecks or capacity shortages in the power grid. One alternative is to use heat pumps in thermal grids to deliver flexibility. This has been investigated in project within IEA HPT Annex 57 by focusing on the Swedish energy system, and both possibilities and barriers have been identified. The thermal grids have many times alternative heat production units available, and the thermal system gives high inertia and larger storages, which increases the possibilities for a flexible operation of the heat pumps, but on the other hand, the high investment cost for the heat pump is pointed out as a barrier.

The electrification increases the need for flexibility

The transition to a low-carbon energy system requires a high penetration of renewable electricity sources, which are often intermittent and variable. This poses challenges for the power system, which needs to always balance the supply and demand of electricity. Moreover, the ongoing electrification of the society increases the demand for electricity and puts pressure on the existing grid infrastructure. Here, the need for flexibility to balance variations in electricity production and consumption will increase to achieve a resilient and efficient power system. Flexibility can also help to reduce problems with bottlenecks and shortages of capacity in the electricity grids. An advantage of using a combination of heat pumping technology and thermal networks is the larger flexibility in heat production and storage options that it entails.

According to scenarios presented in the IEA World Energy Outlook [1], the need for short-term flexibility on a global level will significantly increase in the following years. The main reason is the fast-increasing use of solar PV, while batteries and demand response are cited as crucial suppliers of short-term flexibility. Here, heat pumps can have a role to play and, together with other sources like EV´s, support the power system with demand response. Today, dispatchable thermal power plants and hydropower provide most of the flexibility to the power system, independent of the time scale, but in the future, they are foreseen to mainly provide seasonal flexibility.

There are several potential markets for flexibility, either for implicit (voluntary adjustment of electric load due to, for example, variations in electricity price) or explicit services (to get revenues to adjust the electricity load as a service). The markets for explicit flexibility put technical demands on the heat pumps regarding activation time, duration, and possibilities to measure the flexibility delivered. While implicit flexibility is more of a voluntary adjustment of the electric load to decrease the electricity costs. These implicit services are generally easier to plan for as they are known in advance, and the need for challenging fast changes in the heat pump can be avoided.

The potential endurance of the flexibility service from heat pumps increases with larger storage volumes and higher thermal inertia. Here, it is a benefit for heat pumps connected to thermal grids due to the many times higher inertia and larger storage in the system. Therefore, the heat pumps can, for example, be switched off for longer periods without any large impact on the system and, in the end, provide comfort for the end consumers. But flexibility is all about moving electric loads in time. Sooner or later, the heat pump needs to run harder to catch up with lost heat production if no other units for heat production can cover up for the lost production. Here, heat pumps in thermal grids often have an advantage compared to stand-alone heat pumps in buildings as there might be alternative heat production available. Another advantage of large heat pumps, compared to heat pumps in single-family buildings, is that they do not require aggregation to reach the minimum bid size for delivering flexibility. Additionally, they have better possibilities for monitoring their electricity consumption. However, other barriers like high power fees or a limited heat source can force the heat pumps to operate in a certain way that limits their possibility of flexible operation.

To use heat pumps for explicit flexible operation is still unusual. However, there are international examples of heat pumps in thermal grids participating in TSO's ancillary markets. One example is the heat pump in Søndre Felding, which is the first in Denmark to obtain the official qualification to deliver an FRR regulation. In Denmark, this requires a start-up time of a maximum of 5 minutes and a minimum bid size of 1MW. In Sweden, Stockholm Exergi has participated with some of its heat pumps in the newly established local flexibility market, SthlmFlex.

Heat pumps in Swedish district heating grids

In Sweden, as in many other countries, there is an ongoing electrification of the society, and political goals are being made to increase the share of electricity derived from renewable sources. Therefore, an increasing strain on the Swedish power grid can be anticipated in the future.

A heat pump connected to a thermal network can either be centrally located within the thermal network or decentralized. A typical example of central heat pumps is the larger heat pumps present in district heating networks today, used for producing district heating. Decentralized heat pumps are typically situated at the end-users' premises and are often owned by the property owner. In such cases, a combination of heat pump and district heating is normally used to heat the building. Additionally, there are examples when district heating companies have their own heat pumps located further out in the network.

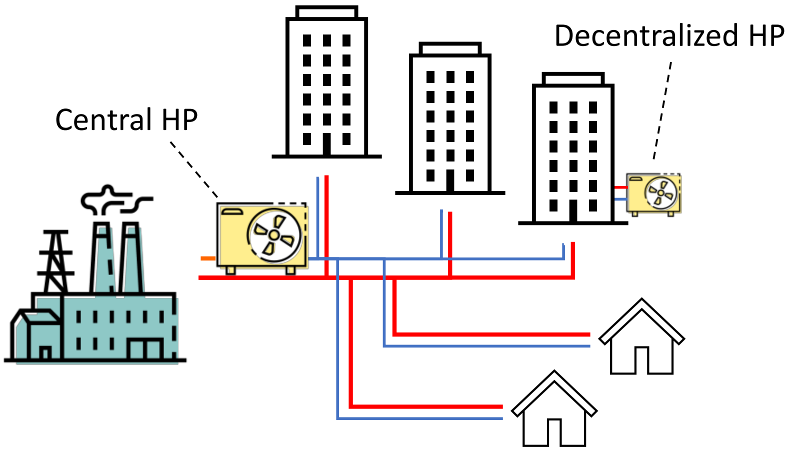

Figure 1. Schematic image of a centrally placed heat pump compared to a decentralized heat pump.

Sweden has a long tradition of centralized heat pumps in their district heating grids, with a significant installed capacity compared to other European countries. However, many of the Swedish heat pumps were installed during the 1980s and have been in operation for several years. Some of these heat pumps have been replaced by alternative heat production over the years, which is one reason for the gradual decline in the amount of heat generated from heat pumps in the Swedish district heating grids, as depicted in Figure 2.

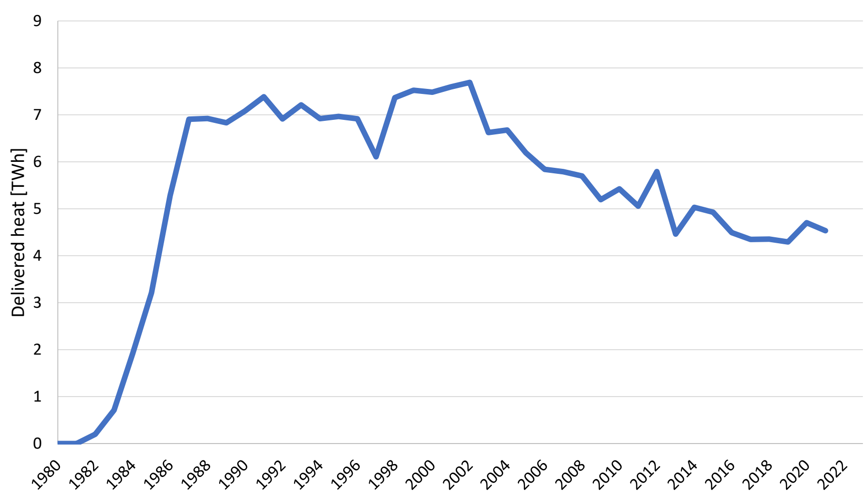

Figure 2. Delivered heat from heat pumps in Swedish district heating grids [2]

Interviews with district heating companies about heat pumps

Within the project, we conducted an interview study with district heating companies that have centrally located heat pumps in their production mix. The purpose was to identify possibilities and barriers for using heat pumps in a flexible manner, either to respond to variating electricity prices or to provide flexibility services to, e.g. TSO´s such as Svenska Kraftnät or local flexibility markets. Companies with heat pumps in their grids perceive it as

advantageous to use them flexibly when electricity prices vary. These heat pumps are also relatively easy to regulate and have shorter start-up and shutdown times compared to many other district heating production units. From a technical standpoint, it is feasible to start or stop the heat pumps almost immediately. However, in practice, the current minimum operating time is several hours, primarily to minimize wear and tear.
The study reveals that the primary barrier to increased utilization of heat pumps in the Swedish district heating grids is the high investment cost for the heat pumps. The cost makes it challenging to justify new installations compared to investments in new combustion units, which have the advantage of covering a wide range of temperatures and heat requirements. Additionally, combustion facilities often have the possibility to also produce electricity.

District heating companies routinely engage in the everyday practice of planning and producing heat at the lowest cost. They also leverage the inertia of the network and accumulator tanks to reduce peak power demand. However, there is untapped potential for more active utilization of heat pumps within thermal networks if certain barriers can be overcome. One such obstacle is the monthly power fee, which renders it uneconomical to start a heat pump if it is not planned to be used for more than a few days in a calendar month.

There is also a potential for larger flexibility, but since the operation of the older heat pumps in the Swedish grids is not automized, motivated and available personnel are required, so quick variations in electricity prices can be managed by starting or stopping the heat pump.
Other identified barriers to further utilization of existing heat pumps include the need for, or regulatory requirements, to keep heat production from other sources running, such as waste incineration. Additionally, interviews revealed that limitations on the cold side of the heat pump may arise due to factors like low seawater temperatures, insufficient volumes of wastewater, or a lack of waste heat.

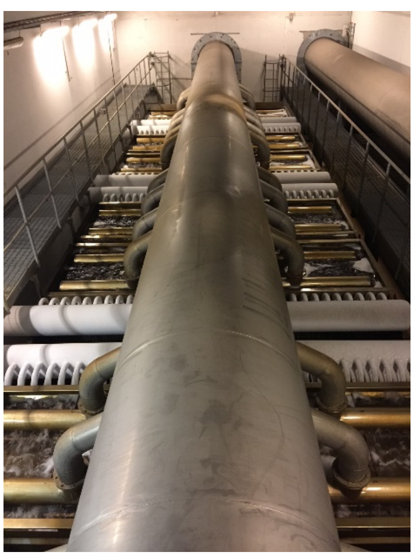

Figure 3. Detail from the heat pump system at Hammarbyverket, Stockholm

Results From Simulations
Within the project, we have also conducted simulations for both centrally located heat pumps and decentralized heat pumps. The purpose was to assess the economic potential

of controlling heat pumps to contribute with the flexibility to the power system. The results from the simulations clearly demonstrate that there is an economic potential for delivering various types of flexibility services in both scenarios. However, this potential hinges on overcoming the remaining technical challenges. These challenges may involve issues with communication with the heat pumps or ensuring that they can adjust their power consumption rapidly enough to meet the requirements from the TSO.

About the project
This article is based on findings from IEA HPT Annex 57 Flexibility by implementation of heat pumps in multi-vector energy systems and thermal networks, focusing on flexibility from heat pumps as well as the Swedish research project “Flexibility by implementation of heat pumps in thermal networks” which has been funded by the Swedish Energy Agency. The Swedish project is a collaborative effort involving RISE Research Institutes of Sweden, Halmstad University, and Lund University. For detailed results, I recommend the conference article titled “Flexibility Potential of Heat Pumps in Swedish Thermal Grids: A Perspective for District Heating Companies and End Users” [3].

References

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[3] Song et al. (2023), *Flexibility potential of heat pumps in Swedish thermal grids: for district heating companies and end users*, 14th IEA Heat Pump Conference, Chicago, USA. Avilabel from: https://heatpumpingtechnologies.org/publications/paper-no-394-flexibility-potential-of-heat-pumps-in-swedish-thermal-grids-for-district-heating-companies-and-end-users-14th-iea-heat-pump-conference-chicago-usa/

Author contact information

	Name	Markus Lindahl Anna-Lena Lane
	Title	Researchers
	Affiliation	RISE Research Institutes of Sweden
	E-mail address	markus.lindahl@ri.se anna-lena.lane@ri.se