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Flexibility potential of heat pumps in Swedish thermal grids: for district heating companies and end users

Meng Song[a], Anna-Lena Lane[b], Markus Lindahl[b*], Tommy Walfridson[c], Metkel Yebiyo[c]

[a]Electric Power Systems, RISE Research Institutes of Sweden, Stockholm, Sweden
[b]Energy and Resources, RISE Research Institutes of Sweden, Borås , Sweden
[c]Energy and Resources, RISE Research Institutes of Sweden, Stockholm, Sweden

Abstract

In a power system with a large share of intermittent sources, the need for flexibility to balance variations in electricity production will increase. Flexibility can also help to reduce problems with bottle necks 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. This article discusses the potential of using the flexibility of heat pumps in Swedish thermal grids from the perspective of energy company and end users. In an interview study with district heating companies that have heat pumps in their thermal grids, possibilities and barriers to use heat pumps for flexibility was investigated. It was found that those who have heat pumps already use them for flexibility. Barriers for even more use was investment cost for new heat pumps. More frequent shifts are connected to organizational, behavioral, and technical barriers. The study also investigates the economic benefits for end users by utilizing the flexibility of heat pumps combined with district heating. Simulations are carried out for buildings located in different electricity price areas and climate zones in Sweden. It also considers different price scenarios for electricity, grid tariff, district heating and system services The result shows that the energy cost for end users could be effectively reduced by using the flexibility of the hybrid heating system. The cost saving potential varies among locations, price scenarios and the type of system services provided by the heat pump.

Keywords: Heat Pump; Thermal grid; District heating; Flexibility; Demand response; Load control

1. Introduction

In a power system with a large share of intermittent sources, the need for flexibility to balance variations in electricity production will increase. Flexibility can also help to reduce problems with bottle necks and shortage of capacity in the electricity grids. An advantage of using a combination of heat pumping technology and thermal networks is the greater flexibility in heat production and storage options that it entails. Today, there is an ongoing work to find affordable solutions to increase the robustness and flexibility of the power system. Several international reports [1]-[3] have in recent years pointed out the combination of heat pumps and district heating as a technical solution that can help to manage an increasing share of electricity from intermittent sources. Here Sweden is an interesting county to evaluate since the country has well-developed district heating systems in almost all cities as well as a large number of heat pumps installed, giving good conditions to combine district heating and heat pumps for a more flexible energy system.

Within EU there is an ongoing trend with an increasing share of electricity from renewable sources. EUs Renewable Energy Directive towards 2030 [4] sets a binding target for the EU for 2030 that 32% of the final energy consumption should come from renewable sources, and there are ongoing discussions to increase the target to 40% as part of the European green deal [5]. Sweden has similar targets, with a political goal that 100% of the electricity should be fossil-free by 2040 [6][7]. There is also an ongoing electrification of the whole

* Corresponding author. Tel.: +46 10 516 5529
E-mail address: markus.lindahl@ri.se

Swedish society. "Fossilfritt Sverige", an initiative to reduce the climate impact from different industrial sectors in Sweden, has developed several roadmaps for different industrial sectors and many of them points out an increased electrification as the way forward to reduce the climate impact of their respective industries [9]. In order to support the transition, the Swedish government has published an electrification strategy [8]. The strategy highlights a flexible use of electricity as one important part and mention especially a higher degree of flexibility related to electrical heating. All this indicates that an increased load on the electricity grid is to be expected in the future and a large part will be covered by intermittent sources.

1.1. Background

Most Swedish buildings are today heated by district heating, followed by electricity, either by a heat pump or electrical heaters, on third place comes biofuel-boilers. While heat pumps and electric heaters are most common in single-family homes, district heating dominates in apartment buildings. Today there are almost 1,5 million installed heat pumps in Sweden, mainly in the approximately 2 million single family-houses in the country [11]. When it comes to heat pumps installed for production of district heating a survey from 2016 identified 149 units of large-scale heat pumps (>1 MW_{th}) from 11 different countries. According to the survey Sweden is by far the country with the largest installed capacity in Europe (approximately 1200 MW). Many of these Swedish heat pumps was installed during the 80´s and have now been in operation for many years [12].

Using heat pumps located at the end users for demand response, without altering the heat source between heat pump and district heating, makes use of the thermal inertia of the building to shift the heat production in time. The thermal inertia makes it possible to start or stop the heat production for a while without any large impact on the indoor comfort, for how long depends highly on the thermal inertia of the building. A study simulating single family buildings in Denmark [14] concluded that it is possible to shift the heat production by 2-5 h in poorly insulated buildings and still maintain a good comfort. For well isolated buildings (passive house standard) the allowed shifted period could be even longer, a complete shutdown of the heating system is possible for more than 24h while still fulfilling the defined comfort criteria. Weiβ et al. [13] showed by simulations in IDA ICE that for residential buildings in Austria, built according to Austrian standards after 1980, at least 50% of domestic heating peak loads can be shifted to off-peak periods during the day, using a comfort band between 19-22°. For heat pumps located in the district heating grids the thermal inertia is many times larger due to the possibilities to store heat in pipes and accumulator tanks. [28]

1.2. Scope

The scope of the study is to evaluate potentials and constrains to use heat pumps for increasing the flexibility of energy systems. It investigates two types of heat pump systems: 1) centrally placed heat pumps in thermal grids which are operated by district heating companies; and 2) decentralized heat pumps which are installed on customer side and combined with district heating as a hybrid heating solution.

1.2.1. Delimitations

The article focusses on Swedish conditions in terms of climate, demand for space heating and hot water consumption, prices for heating and electricity, market conditions for frequency regulation services, projection of future scenarios, etc.

1.3. Definition flexibility

Flexibility and demand response are broad terms without a clear definition. EU:s Electricity Directive [10] states that: "*demand response' means the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market … whether alone or through aggregation*."

In this study, we focus on demand response of heat pumps that are owned either by district heating companies or by property owners with a hybrid heating solution. The demand response refers to the adjustment of heat pump operation for two purposes:

1. Respond to dynamic prices such as the variations in price for electricity, district heating or fuels.
2. Respond to dedicated markets for flexible resources such as local flexibility markets or TSO's market for ancillary services.

The flexibility is achieved by varying the running order between different heat sources, or utilizing the heat storage in the thermal grid, accumulator tanks or thermal inertia of buildings.

2. Interview study with district heating companies using heat pumps

2.1. Method in interview study

An interview study has been done with district heating companies in Sweden that have heat pumps in their production mix. Statistics about heat production in district heating system for 2020 and 2017 [15][16] have been used to find companies for interviews. About 17 companies with heat pumps in the production in 2020 was found. To find informants on these companies the contact network within the project has been used along with contact details from the energy companies. Some contacts have been found on the energy companies web pages. Contacts has been taken by email with 16 persons representing 14 different companies. The contact details did not match for 4 and 3 did not answer and 1 turned out to not have a heat pump in the grid. Finally, 8 interviews, (named I1-I8 in the study), with 13 persons were booked and finalized, representing 10 district heating grids distributed across Sweden. The interviews were done with the digital meeting tool zoom and recorded. Notes were also taken during the interviews that lasted between 30-60 min. The informants had both strategical roles and works closely with the production.

Before the interviews was conducted a semi structured interview guide was developed including the following themes: background about the informants and the company, facts about their thermal grids and production, their heat pumps, their attitudes and actions for flexibility, and finally their attitudes on decentralized heat pump at end consumers. Recordings and notes from the interview have been analyzed to find how heat pumps in district heating grids are used and what possibilities and barriers there are for contribution to flexibility.

2.2. Results from the interview study

2.2.1. Heat pumps in the district heating grids

In the 1980’s many heat pumps were installed in district heating grids in Sweden. Since these decisions were taken about 40-50 years ago, knowledge about the accurate basis for decisions may only be found in old documentation.

” They wanted to replace heavy oil... I found some old document from when decisions were made, and then it was expected that there were quite high electricity prices for that time, but they were stable and then you dared to make this investment.” I5

The informant I5 talks about ambitions to reduce fossil fuels in combination with a lot of available electricity from nuclear plants and with stable electricity prices as motivation of the investment back in the 1980’s. Some of those heat pumps are still in use in district heating grids, but in need of reparation and maintenance. Three different ways to handle this have been found in the study. The first way is to replace the heat pump by other heat production. One example is described by I7:

” It was old, since 1984, and expensive to renovate. More power was needed as the city grow, then they installed a new heating plant with bark and wood chips. . . and scrapped pellets and heat pump. They had calculated that it was much cheaper to run on bark and wood chips than the electricity price for the heat pump. I don't think the heat factor was very good. ... I know that when I ran it, it took water from about 8 m depth. It was about 2 degrees Celsius. It wasn't even 4 degrees.” I7

The heat pump was scrapped because of age, high costs for renovation and a low coefficient of performance, COP, which contributed to calculated higher energy production cost than with bark and wood chips. One reason for low COP was that the inlet of seawater was not deep enough to deliver 4 degrees C which normally is the bottom temperature due to high density, during winter when the sea water is cold. For some of the old heat pumps in the study there are plans for replacing them with other kind of production further on. This is the most common way and probably the answer to why there is less heat pumps in 2020 than 2017. The second way is to maintain the heat pumps to pro long their lifetime. There is a variation from smaller reparations to replacement of vital parts. Lack of spare parts is a barrier for reparations that some companies overcome it with special manufacturing based on old drawings. The most deep-going renovation is described by I3 where the control system and vital parts are renovated to prolong the lifetime with 30 years. This was motivated by a good heat source on the cold side and that there was no other heat production that was suitable in the system near a city with limitations for combustion. The third way is to replace the old heat pump with a new. I8, describes how the old heat pumps were demolished as they were found unprofitable since they had built new production with biogas as fuel. A few years later the gas price was high, and it was considered profitable to install new heat pumps, which was done in 2017.

There are also some other heat pumps that are installed in recent years in district heating grids where there is an available heat source for the cold side of the heat pump. District cooling is an upcoming product for energy companies. Some of these plants are also used for production of heat during winter. Other more recent heat pump installations are “island installations” where the normal grid is not connected.

2.2.2. District heating production and heat pumps

The informants describe how their district heating production is planned based on a forecasted heat need in the coming day and week according to weather forecasts, historical data and fuel prices. Available production units and personal resources are also considered as input for the planning. The planning results in a dispatch order for the different production units connected to the grid.

2.2.3. Flexibility in district heating grids

One way to create more flexibility than the thermal inertia of the supply pipes is to add an accumulator tank in the grid. This has been adopted by almost every grid in the study. The companies who have heat pumps in their grid describe the accumulator tank as an asset for accessing flexibility when the electricity price varies. On the other hand, it is hard to motivate an investment in heat pump only for getting more flexibility because of the low profitability. The startup time for heat pumps is shorter than that for other heat production units e.g. boiler with wood chips. Technically it is possible to start or stop heat pumps almost immediately, but in practice the minimum running time for heat pumps lasts from at least 3-4 hours to 12 hours in most grids. Frequent start and stop increases the risk of higher maintenance costs, especially for older heat pumps. Many of the informants also talk about the easy capacity regulation as an advantage of heat pumps. But there is a limitation in delivered temperature that must be supplemented by other fuels, at least in wintertime.

Barriers for the use of existing heat pumps, even when electricity prices are low, have been found in the study. The first barrier is that other production must be up and running and then fulfills the heat demand. A Typical example is the waste combustion i.e. where there is a commitment to combust a specific volume of waste and it is not possible to save it for later needs. The second barrier is the monthly electrical power fee that occurs when a heat pump is used. The size of the fee is so high that it is unprofitable to start a heat pump if it is not going to be used at least for about 7 days in the actual calendar month. The third barrier found is the lack of capacity on the cold side of the heat pump, caused by for example low water temperatures in sea water, low volumes of wastewater or lack of waste heat caused by revision or lower production. The fourth barrier is a need of both available and motivated personnel to start or stop a heat pump when the electricity price change. The larger energy production units are seldom fully automated, so active control by personnel is needed to change between production units.

2.2.4. District heating companies’ view of smaller heat pumps located at end-users in their grid

Informants from the district heating companies in the study describe existing or possible customers using heat pumps as a competitor situation and how they use pricing to overcome this.

“We price against customers who have heat pumps so that we outcompete it.” I8

The reason why combination of heat pumps and district heating is rarely seen as a referable combination from the district heating companies is because it causes more costs and is hard to plan.

"Nope... But really, we think they're free riding on us. They remove the base load when we have the best production and then they want to buy peak load production from us that is expensive, difficult to provide and has poor environmental performance.” I2

They also say that using district heating as peak load often results in the need to have and use fossil production, which causes bad environmental performance. In the company in I7 they have handled the situation with a special agreement for customers who only use district heating as peak load. The aim is to make it more profitable for the district heating company and provide fairer pricing for their other customers who use district heating for all their consumption. One argument against the smaller heat pumps is that the district heating company cannot control them. In the study there are few examples of the collaboration between energy companies and customers for and controlling the smaller heat pumps in the grid. The company in interview I8 gives one example: where the district company has bought a 0,8 MW-size heat pump installation, (which are seen as a small heat pump), from a customer and now use and control it. The informant I8 describe it as a win-win situation for both customer and district heating company. Heat pumps out in the grid compensate for heat losses and contribute with higher temperature and capacity out in the grid. Economic benefits for energy customers to use the flexibility of heat pumps.

3. Economic benefits for energy customers to use the flexibility of heat pumps

This section analyses the economic benefits of Swedish property owners for utilizing the flexibility of heat pumps. It focuses on the customers who use a hybrid heating system i.e. heat pump combined with district heating. It firstly identifies the cost and revenue streams for the common Swedish energy customers with hybrid heating solutions. Then it introduces a simulation model for analyzing the energy usage and operation cost of the heating system. The model is applied in a case study to simulate the operation of a hybrid heating system under different conditions. The simulation results are shown and discussed in the end.

3.1. Cost and revenue of property owners with both heat pump and district heating

A Swedish property owner with a hybrid heating system needs to pay both electricity cost and district heating cost. The electricity cost is related to the electricity consumed by the heat pump. It consists of two parts: one part is paid to the DSO (distribution system operator) for connection and usage of the power grid; another part is paid to the electricity retailer for buying the electricity. The district heating cost is paid to the heat supplier for extracting heat from the thermal grid. The property owner signs separate contracts with DSO, electricity retailer and district heating supplier. [18] Table 1 lists the cost components that are usually included in the three contracts. The electricity price paid to retailer is mainly affected by the price on the wholesale electricity market. The grid tariff and district heating tariff are defined by DSO and heat supplier and supervised by Swedish Energy Markets Inspectorate.

Table 1. Cost components in customer contracts with DSO, electricity retailer and heat supplier [17][18]

DSO contract (Grid tariff)	**Electricity retailer contract**	**Heat supplier contract (District heating tariff)**
Annual fee	Electricity price	Energy price
Subscription fee	Green certificate	Flow price
Distribution fee	Fixed fee	Effect price
(Power fee)		(Fixed annual cost)
Energy tax		

Note: the cots components in the parentheses are not always included in the contract.

With the thermal inertia of the building envelope, the property owner can also provide flexibility to the power system by adjusting the default set points of the heat pump. The flexibility can be used as different types of services. This study focuses on four frequency regulation services purchased by TSO (transmission system operator) on the corresponding reserve markets. Table 2 is an overview of the four reserve markets [19]. As a service provider, the property owner could get compensation for the reserved capacity and/or the actual delivered regulation volume.

Table 2. Overview of the four frequency regulation services analyzed in the study [19]

	FCR-N	FCR-D up	aFRR	mFRR
Full name	Frequency containment reserves for normal operation	Frequency containment reserves for disturbances	Automatic frequency restoration reserves	Manual frequency restoration reserves (“regulating market”)
Regulation direction of the product on markets	Symmetric	Up-regulation	Separate products for up- and down-regulation	Separate products for up- and down-regulation
Minimum bid size	0.1 MW	0.1 MW	5 MW	10 MW (5 MW in price area SE4)
Activation	Automatically activated when the frequency deviates within 49.90 – 50.10 Hz	Automatically activated when the frequency deviates within 49.9 – 49.50 Hz	Automatically activated through a central control signal if the frequency deviates from 50.00 Hz.	Manually activated at the request of Svenska Kraftnät
Activation time	63% within 60 sec. and 100 % within 3 min.	50% within 5 sec. and 100% within 30 sec.	100 % within 120 sec.	100% within 15 min.
Endurance	1 hour	at least 20 minutes	1 hour	1 hour
Capacity compensation	Pay-as-bid. Will change to marginal pricing in 2024.	Pay-as-bid. Will change to marginal pricing in 2024.	Pay-as-bid. Has changed to marginal pricing since 2022.	None
Energy compensation	According to up/down regulation prices.	None	According to up/down regulation prices.	According to up/down regulation prices.

3.2. Simulation model

A python-based model is developed to simulate the operation of the hybrid heating system in buildings. The model structure is illustrated in Figure 1. The input of the model includes parameters about the building, heating devices, climate, and the information from market and system. The model simulates both normal and flexible operation modes of the heating system. Both operation modes are formulated as optimization problem.

For the normal operation mode, the objective function is to minimize the indoor temperature deviation from the desired set point during the planning horizon. It subjects to the constraints for estimating the heat balance and indoor temperature at each time step, and the capacity limits of the heating devices. The solution of the optimization problem is the total heat demand at each time step. It is assumed that the heat pump is always prioritized in the normal operation mode. District heating is only used when the demand exceeds the heat pump capacity. Accordingly, the heat power provided by heat pump and district heating are estimated for each time step, respectively. Then the corresponding cost is calculated. For the flexible operation mode, the objective function is to minimize the energy cost during the planning horizon considering the potential revenue from providing frequency regulation services. It subjects to similar constraints as in the normal operation mode. Additional constraints are considered to fulfill the requirements of the specific reserve markets. The heat power provided by heat pump and district heating are estimated by solving the optimization problem. The corresponding cost and revenue are calculated accordingly.

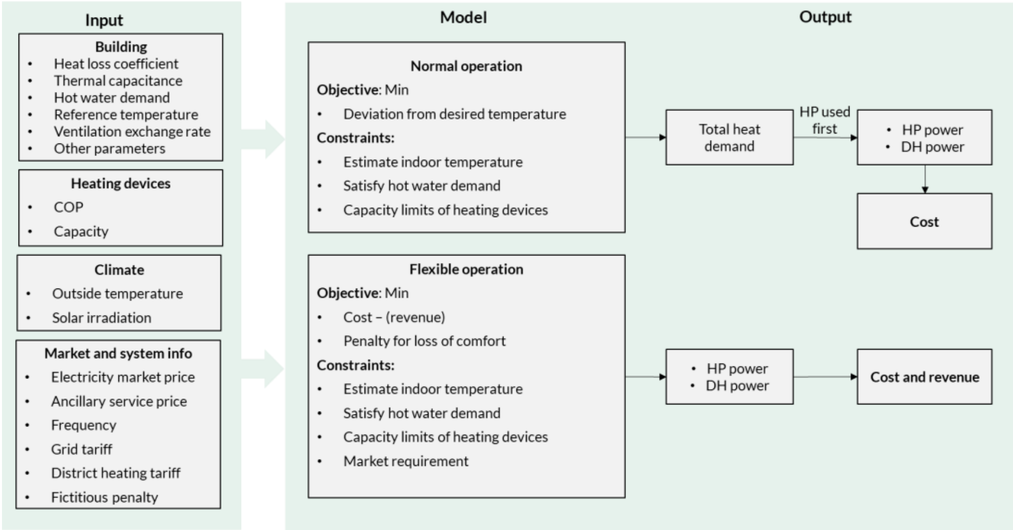

Figure 1. Simulation model for the hybrid heating system in a building

3.3. Case study

The case study analyzes the economic benefits of a property owner in different situations. It is based on a residential building with 93 apartments and 7161m^2 heating areas. The thermal inertia of the building is estimated based on parameters specified in **Error! Reference source not found.**. The building is installed with a ground source heat pump system and district heating. The COP of the heat pumps are affected by the outdoor temperature as shown in Table 3 and has a maximum heating capacity of approximately 350 kW (at +2°C), giving the building in the case study a bivalent temperature of -12°C. A validation of the model has been carried out by comparing the modelling results in the normal operation mode with a previous study [29]. The yearly energy consumption and cost estimated from the model are on the similar level as in the previous study.

Table 3. COP of the heat pump

Outdoor temperature (°C)	**COP Space heating**	**COP Hot water**
-21	3.50	3.00
-15	3.75	3.00
- 7	4.00	3.00
2	4.50	3.00
7	5.00	3.00
12	5.50	3.00

Four locations are investigated for the building: Kiruna, Östersund, Stockholm and Malmö. The four cities represent different climate zones in Sweden from north to south. In addition, they belong to the four electricity price areas which are divided because of the transmission bottlenecks. For the building at each location, six operation modes are simulated for the heating system:

- ref: normal operation, prioritize HP, no frequency regulation service is provided.
- DR_None: flexible operation, cost minimization, no frequency regulation service is provided.
- DR_FCRN: flexible operation, cost minimization, provide FCR-N service.
- DR_FCRD: flexible operation, cost minimization, provide FCR-D service.
- DR_aFRR: flexible operation, cost minimization, provide aFRR service.
- DR_mFRR: flexible operation, cost minimization, provide mFRR service.

For each operation mode, 16 scenarios are analyzed to represent the possible price for energy and frequency regulation services in the future. The spot price scenarios are based on the long-term market analysis by Svenska Kraftnät [20]. The scenarios are defined for the Nordic power system in 2035 and 2045, considering the growing electricity demand, higher penetration of renewable energy, coupling with hydrogen production and grid expansion. The grid tariff and district heating tariff in 2035 and 2045 are estimated according to the base tariffs in 2021 [22][23] and the historical price development trend [24][25]. The price on different reserve markets and system frequency are based on the historical data in 2018-2021, which are extracted from ENTSO Transparency Platform [26] and FinGrid Open Data [27].

Figure 2 shows the simulation results of the yearly heating cost of the building. Each box indicates the cost distribution among the 16 scenarios. In general, the cost increases from Malmö in the south of Sweden to Kiruna in the north. It is mainly due to the climate conditions i.e. more heating energy is needed in colder regions. For each location, the costs in the five DR cases are apparently lower than the cost in the reference case. It implies that the flexible operations with cost minimization can effectively reduce the overall cost for heating. The cost reduction is achieved by utilizing the thermal inertial of the building and actively selecting the heating source with a favorable price. Figure 3 shows the annual bought energy for the heating system in an example case, in which the building is assumed to be in Stockholm and the spot price scenario for 2035 is adopted. It indicates that the heating system consumes more district heating energy and less electricity in DR modes compared with the reference operation mode. Further analysis shows that the increased heat extraction from the thermal grid mainly happens in summer when the heating price is low.

The cost could be further reduced when the heat pumps provide frequency regulation services. However, the economic potential may vary among locations and scenarios. In most scenarios, the lowest cost can be found when the heat pumps provide FCR-N or aFRR service. Taking the building in Östersund as an example, the lowest cost is found when the heat pumps provide FCR-N service. The reason is that the property owner gets both capacity and energy compensation from TSO when participating in FCR-N and aFRR markets.

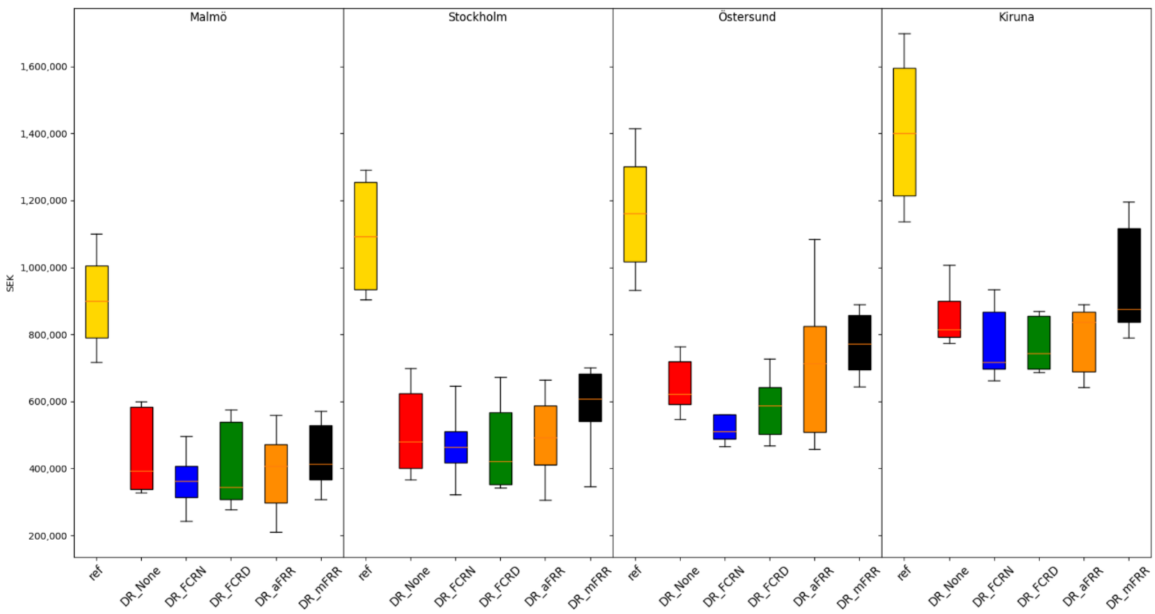

Figure 2. Annual heating cost for the building in different conditions

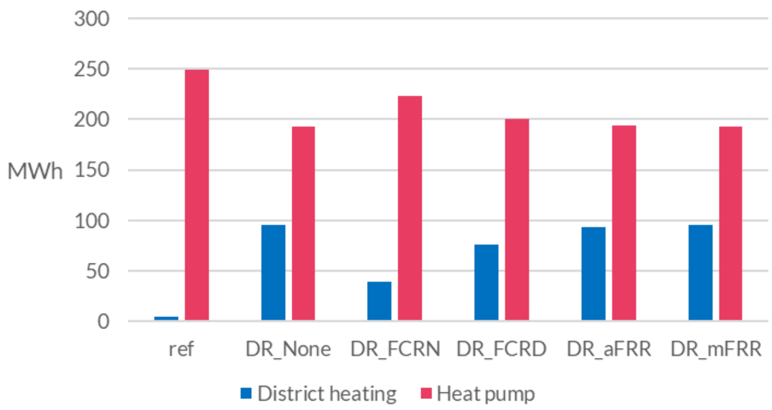

Figure 3. Annual bought energy (district heating and electricity to the heat pump system) for the example heating system: Stockholm, spot price scenario 2035

4. Discussion

In the interview study with district heating companies, it was found that it is an asset to have heat pumps in the district heating grid for flexibility. They also are perceived as easy to regulate and have shorter start and stop time than many other production units. The largest barrier to an increased use of heat pumps in the thermal grids is the investment. The investment cost is high, and it is mostly hard to motivate new installations and it compete with investments in combustion units that could cover all temperatures and heat need and may also produce electricity. Only in one of the interviews they had found it more profitable with a heat pump, but then their other production was based on gas, which have rising prices. To plan and produce heat to the lowest cost and to use inertia in grid and accumulator tank to cut peak loads is an everyday activity in district heating companies and how things have been done for long time. Heat pumps could be used more in the thermal grid if some barriers could be removed as for example monthly calendar basis for power fee. There is also a potential for more flexibility with motivated and available resources in personnel, so the fast variation in electricity price could be met. Traditional planning goes out from the nearest 24 hours and the coming week.

The case study of decentralized heat pumps shows that large economic potentials could be expected for the property owners when utilizing the flexibility of heat pumps. However, the potentials vary among scenarios, and it is based on the assumption of perfect market forecasts. Further studies are needed to investigate how the uncertainties in the market price and required regulation directions would affect the benefits for the property owners. Economic potential of delivering ancillary services to the TSO is a focus of the analysis. But in practice, before this is up and running there are still technical issues to solve on how to communicate with the heat pumps and how the heat pumps should react on signals to deliver the demand response to the grid. One barrier to solve is to make sure that the heat pumps can react and adjust the power consumption fast enough on signals for demand response, although the ramping rate of heat pump is not considered in the model. Among the frequency regulation services analyzed in this study, FCR-D up is the fastest reserve with an activation time of 50% within 5s and 100% within 30s. Discussions with the Swedish heat pump manufacturers indicate that it should be possible from a technical point of view to fulfill the demands for FCR-D, but updates of today's heat pumps might be needed. Another issue to solve is how to fulfill the requirements on the verification of delivered flexibility since todays' heat pumps have no electric meters installed.

The interview study shows that energy companies consider customers with the hybrid heating solution, i.e. heat pumps combined with district heating, as lost customers or free riders. The customers are blamed for only using district heating during peak load period and causing more combustion with expensive fossil fuels. Some district heating companies choose to use a special pricing scheme to overcome it. On the other hand, the case study of decentralized heat pump shows that the property owners may consume more district heating energy annually in DR modes compared with the reference level. If more customers in the thermal grid adopt the hybrid heating solution and apply similar flexible operation modes, the heat demand could be significantly changed from today and consequently affect the planning and operation of district heating production. However, this does not necessarily lead to an increase of peak load in the thermal grid. The analysis shows that in DR modes district heating would be mainly used during summer when the heat demand is conventionally low.

Therefore, more studies are needed to further clarify the effects of decentralized heat pumps on the thermal grid, especially when demand response is taken into account. Better data exchange between energy companies and end customers would be needed to enable energy companies to have a better overview of the grid. More active actions should be taken by the energy companies by e.g. improving the forecast of heat demand and flexibility potential of customers, and enhancing the efficient planning and operation of the heat plants with different energy mix. A holistic strategy is needed to coordinate the flexibility from both centralized and decentralized heat pumps and utilize them in a more efficient manner.

5. Conclusions

This article discusses the potential and constraints of using the flexibility of heat pumps in Swedish thermal grids from the perspective of energy company and end users, respectively. An interview study with district heating companies has been carried out to identify the possibilities and barriers to use heat pumps for flexibility services. The study shows that the companies with heat pumps in their grids today think it is an advantage to use them for flexibility when electricity prices variates. But to invest in a new heat pump to get additional flexibility is described as hard to motivate and to get profitable. Technically it is possible to start or stop heat pumps almost immediately, but in practice the minimum running time for the heat pump is from at least 3-4 hours or 12 hours in most grids. Other identified barriers for additional use of existing heat pumps are: 1) other heat production must be up and running, e.g. waste combustion; 2) a high monthly electrical power fee makes it unprofitable to start a heat pump if it is not going to be used at least for about 7 days in the calendar month; 3) lack of capacity on the cold side of the heat pump, caused by for example low temperatures in sea water, low volumes of wastewater or lack of waste heat; 4) need of both available and motivated personnel to start or stop a heat pump.

In addition, a quantitative analysis has been performed to investigate the economic benefits for end users by utilizing the flexibility of heat pumps combined with district heating. It is based on the simulations for buildings located in different electricity price areas and climate zones in Sweden, and considers the future price scenarios for electricity, grid tariff, district heating and system services. The analysis shows that the energy cost for end users could be effectively reduced by using flexibility of the hybrid heating system, whereas the cost saving potential may vary among locations, price scenarios and the type of system services provided by the heat pump. More studies are needed in the future to further clarify how demand response of customers may affect the operation of the district heating production, and how the flexibility from centralized and decentralized heat pumps can be coordinated and utilized in a more efficient manner.

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