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ScienceDirect

Energy Procedia 105 (2017) 1434 – 1439

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

Mapping of heat and electricity consumption in a medium size municipality in Sweden

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Abstract

The Nordic electricity system faces many challenges with an increased share of intermittent power from renewable sources. One such challenge is to have enough capacity installed to cover the peak demands. In Sweden these peaks appear during the winter since a lot of electricity is used for heating. In this paper a mapping of the heat and electricity consumption in a medium size municipality in Sweden is presented. The paper analyze the potential for a larger market share of district heating (DH) and how it can affect the electrical power balance in the case study. The current heat market (HM) and electricity consumption is presented and divided into different user categories. Heating in detached houses not connected to DH covers 25 % of the HM, and 30 % of the electricity consumption during the peak hours. Converting the detached houses not connected to DH in densely populated areas to DH could reduce the annual electricity consumption by 10 %, and the electricity consumption during the peak hours by 20 %.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
Keywords: District heating;heat market;electrical power balance;combined heat and power;detached houses;electricity consumption

1. Introduction

Important challenges in the Nordic, and also the European, energy systems are to mitigate greenhouse gas emissions, increase the amount of renewable energy and to increase energy efficiency [1]. The renewable energy techniques with the fastest growth rates are solar power and wind power [2]. All four future scenarios done by the research project North European Power Perspectives show an increase in wind power in the Nordic countries until 2030 and 2050 [1]. One of the challenges with more renewable power in the form of wind power is that it is intermittent power; it is dependent on the wind blowing [3].

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Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.534

The electricity consumption in Sweden is temperature dependent [4] since a lot of electricity is used for heating. This means that the consumption is much higher during the winter. At least 15 % of the electricity is used for heating and another 35 % is used for other purposes in the residential sector [5]. Some heating is however included in the statistics for other purposes in the residential sector [6–11], which means that more than 15 % of the total electricity use in Sweden is used for heating. The electrical heated detached houses have a substantial impact on the maximum power demand in Sweden. A much colder winter than normal could increase the peak load with 1.5 GWh/h (maximum peak load during a normal winter is around 25.6 GWh/h) [12].

Combined heat and power (CHP) can be a part of the solution for at least two of eight challenges identified for a system with a high share of intermittent power [13]: CHP is controllable production and can contribute with peak power capacity, and the use of district heating (DH) from CHP instead of electrical heating reduces the electricity peak demands. CHP based DH can therefore play an important role in the future energy system with more intermittent power.

This paper analyzes the potential for a larger market share of DH and how it can affect the electrical power balance in a case study: the medium sized Swedish municipality Falun with a population of around 60 000. This is done by analyzing the current heat and electricity market in the region.

2. Methodology

The current energy situation in Falun has been studied using hourly consumption and production data for electricity and DH during a period of one year (Feb 2015-Jan 2016) obtained from the local energy company. This period contain both the highest DH and electricity consumption in Falun which makes it a suitable period when analyzing how DH can affect the electrical power balance. The total heat market (HM) is constructed and divided into different user categories depending on building type and if the building is connected to DH or not. The electricity consumption is also divided into different user categories depending on the size of the fuse at the grid connection, and if the electricity is used (or probably used) for heating or not.

The HM for detached houses is based on hourly measured DH demand. The total number of detached houses in Falun is roughly 13 000, of which around 2 000 have DH and another 3 000 lies within what the local energy company has defined as *DH area*. A total of 9 000 detached houses lies within densely populated areas. The average DH consumption for detached houses, representing the average HM per detached house, is scaled up to the 11 000 detached houses that does not have DH and is called *non-DH HM*. The non-DH HM from detached houses is then, based on national statistics [14] regarding heating systems in detached houses, divided into energy carriers supplying the heat today: electricity, ambient heat via heat pump (HP) and biofuel. The national statistics contain information regarding the share of different heating systems (DH, HPs, electrical heating, biofuel and combinations of these) so different assumptions are made in order to translate these shares of heating systems into energy carriers. For example HPs in detached houses are recommended to cover around 50-75 % of the heat power demand [15–17]. Based on this, the ground source HPs and air source HPs are assumed to cover 65 % and 50 % of the heat power demand respectively. The coefficient of performance (COP) used to calculate the electricity needed for the ground source HPs is set to 3 for the whole year, according to a test of installed ground source HPs in Sweden [18]. COP for the air source HPs are calculated for each hour as a function of the outdoor temperature. The function used to calculate the COP is the Carnot efficiency-equation scaled so that the COP at -15°C is at 2.2 according to a test of installed air source HPs in Sweden [19].

The non-DH HM for large buildings (>63A) is based on hourly measured electricity use. All grid connections with fuse sizes of 63A or above are divided into two groups depending on if the electricity consumption profile has a seasonal variation or not. All consumption with seasonal variation is assumed to be used for heating and is included in the non-DH HM for large buildings. The non-DH HM for smaller buildings (<63A) other than detached houses is also based on hourly electricity use. The grid connections smaller than 63A is however not hourly measured individually and can therefore not be divided into two groups depending on if the individual connections have a consumption with seasonal variation or not. Instead all these points are treated as one group which in total has a consumption profile with seasonal variation and assumed to be used for heating. All electricity consumption with a seasonal variation for these small and large buildings is probably not used for heating purposes. But neither is it probable that all of the electricity is used for electrical heating without HP. Many users probably use a HP which makes the heat demand larger than the electricity consumption. The non-DH HM from these small and large buildings is therefore roughly estimated as equal to the electricity consumption. 80 % of the power demand during the summer is however assumed to be consumption without seasonal variation (domestic and business electricity) and is subtracted from the HM.

3. Current energy situation

The DH in Falun consists of four networks with annual delivery of heat around 300 GWh, where the main network accounts for 95 % of the total delivery. The base load in the main network is covered by biofuel based CHP and the peak load is covered by biofuel-, LPG- or oil based heat only boilers.

The annual electricity consumption in Falun is around 550 GWh. The daily average electricity consumption for the studied period can be seen to the left in Figure 1 together with the week with the highest hourly electricity consumption to the right. The seasonal variation is obvious with a lower consumption during the summer period. This is a consequence of a lot of electricity being used for heating in Falun. It is clear how unpredictable the wind power is by looking at the wind power production in Figure 1 compared to the hydropower and power from CHP in the same figure. It is shown to the right in Figure 1 that Falun can be self-sufficient regarding electricity for a few hours during a cold week with high consumption, see for example the first half of the second peak when there is no import. However, a few hours later the import covers roughly 80 % of the consumption when the wind power has decreased rapidly. On yearly basis, the import supplies about 25 % of the total consumption, with a net import of 15 % counting the export from the region.

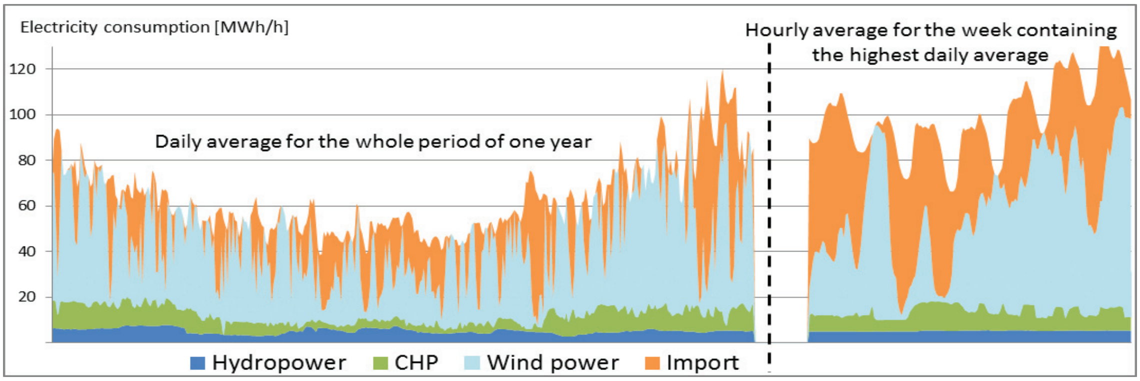

Figure 1. Electricity consumption divided into import and the three local production sources (hydro, CHP and wind). Daily average for one year to the left and hourly average for the week containing the highest daily average consumption to the right.

The total HM in Falun divided into *HM covered by DH*, *non-DH HM for detached houses* and *non-DH HM for other buildings than detached houses* is shown in Figure 2. DH covers around 50 % of the total

HM and of the non-DH HM detached houses stands for 50 %. The non-DH HM has a similar seasonal variation as the HM covered by DH.

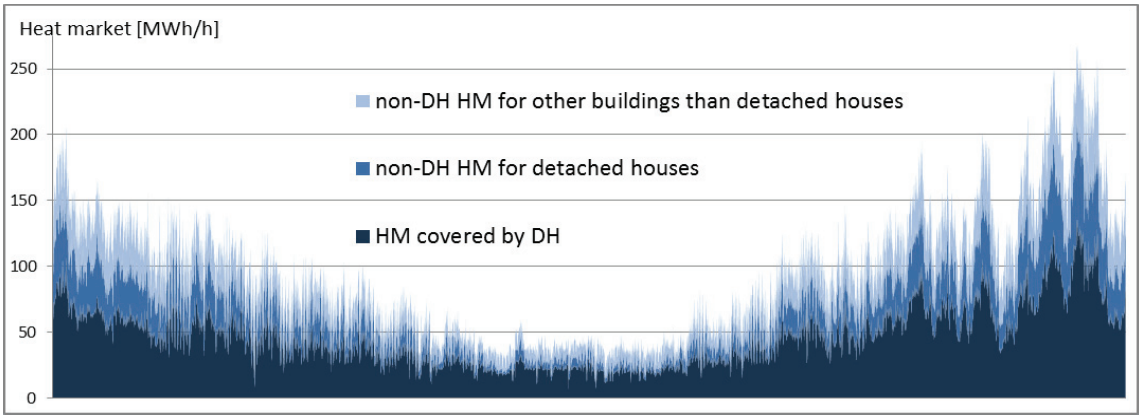

Figure 2. The total heat market (HM) in Falun for one year, divided into what is currently covered by district heating (DH) and what is seen as a potential extra heat market for DH. The non-DH HM is divided into detached houses and others buildings.

The non-DH HM for detached houses divided into different energy carriers is illustrated in Figure 3. The largest part of the energy used is electricity, followed by biofuel. During the summer period where no space heating is needed, electricity based heating supplies almost the whole HM. It is during the winter period that biofuel and ambient heat via HP is used as well. Since HPs are assumed to cover less than 100 % of the maximum heat demand, the electricity share increase during the peak demands and the share of ambient heat via HP decrease (see the peaks to the right where electricity covers almost 50 % of the non-DH HM, and the ambient heat via HP covers only around 15 %).

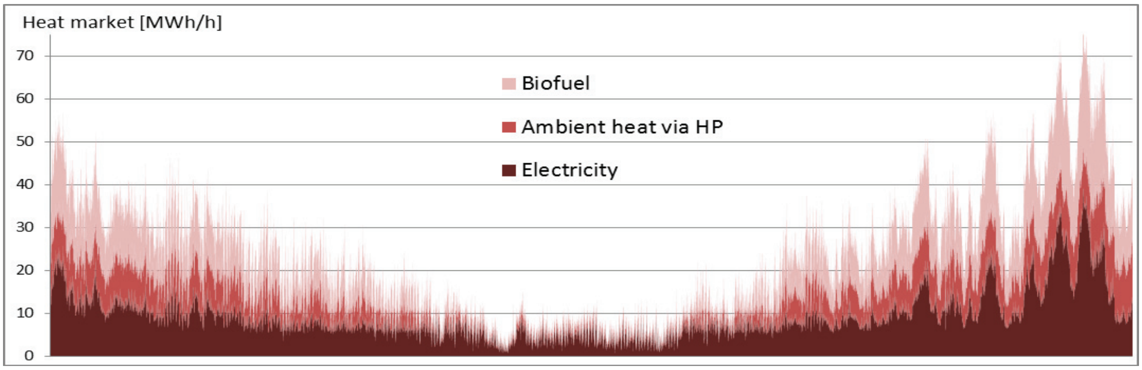

Figure 3. The non-DH HM for detached houses, divided into the energy carriers electricity, ambient heat via HP and biofuel.

Figure 4 again displays the total electricity consumption in Falun, this time divided into different user categories instead of production as in Figure 1. During the hours with the highest total consumption, only 25 % is used by large users (>63A) with a consumption profile without seasonal variation during the year. The remaining 75 % is consumption for users with a seasonal variation where 30 % is used for heating in detached houses, 10 % is for large users (>63A), and 35 % is used by all other small users (<63A).

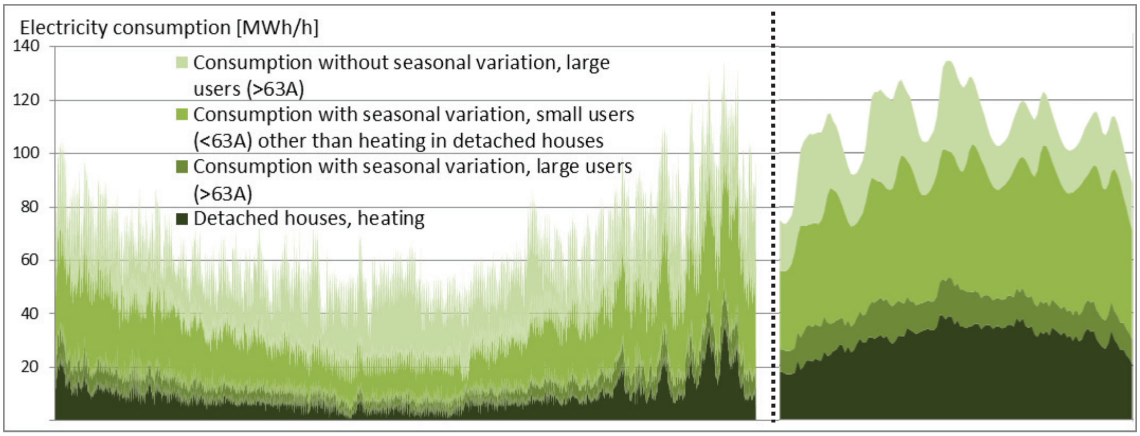

Figure 4. The total hourly electricity consumption in Falun divided into different user categories depending on connection size and consumption profile. To the left is the hourly consumption for the whole period of one year and to the right is the week containing the highest hourly average consumption.

4. Analysis and discussion

A large share of the HM is today supplied by some kind of electricity driven heating technology (with or without HPs). The electricity peak demand in Falun could theoretically be lowered by around 30 % if all electricity used for heating in detached houses were replaced with other energy carriers. A part of the remaining electricity demand with a seasonal variation, which covers around 45 % of the demand during the peaks, is probably also used for heating and could be replaced with other energy carriers. 25 % of the detached houses not connected to DH lies within the DH area and could easily be connected to the DH network. 25 % of the electricity used for heating in detached houses corresponds to 10 MWh/h during the peak hour and a total of 20 GWh during the whole period of one year, which could be saved by changing energy carrier to DH. Another 35 % of the detached houses not connected to DH lies in densely populated areas but outside the current DH area. Connecting these buildings to the DH as well could in total save 25 MWh/h electricity during the peak hour, corresponding to 20 % of the peak power demand, and a total of 50 GWh during the whole year which corresponds to 10 % of the total electricity consumption in Falun.

A higher share of the HM covered by DH could, in addition to reducing the electricity consumption, also increase the electricity production if the DH is produced using CHP. CHP plants are however not dimensioned with respect to the peak load. The economical profitability is instead based on the annual heat delivery. To cover the peak loads with CHP in a seasonally varying consumption profile with peaks several times higher than the base load is therefore not a profitable investment. A higher heat load during the summer period would reduce the seasonal variation and a higher share of CHP would then be economically feasible. The need for import of electricity to Falun would decrease as a consequence of reduced consumption, and possibly as a consequence of increased local CHP production. Falun could probably even become a net exporter of electricity, with biofuel based CHP, wind power and hydropower as only production technologies.

The future development of DH and the future development of buildings and their heating systems are important factors when discussing the electrical power balance in regions using a lot of electricity for heating. A follow up journal article is therefore in writing with different future scenarios regarding the future HM together with different market shares of DH and HPs.

5. Conclusions

A mapping of the heat and electricity consumption in a medium size municipality in Sweden has been presented. The study shows that 50 % of the heat market (HM) is supplied by district heating (DH). Detached houses not connected to DH stands for an additional 25 % of the HM and 30 % of the electricity consumption during the peak hours. Converting the electricity based heating systems in detached houses within densely populated areas to DH reduces the annual electricity consumption and especially the electricity peak loads during winter periods. The annual electricity consumption could in this case be reduced by 10 %, and the consumption during the peak hours could be reduced by 20 %.

6. Acknowledgements

The work has been carried out under the auspices of the industrial post-graduate school Reesbe, which is financed by the Knowledge Foundation (KK-stiftelsen) and Falu Energi & Vatten AB.

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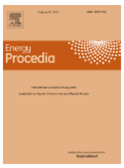

Biography

Moa Swing Gustafsson received a master of science degree in chemical engineering from Chalmers university of technology in 2013. She is currently a PhD student at Mälardalen University and Dalarna University in the research school Reesbe (Resource-Efficient Energy Systems in the Built Environment).