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Potential for district heating to lower peak electricity demand in a medium-size municipality in Sweden

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ABSTRACT

Sweden faces several challenges with more intermittent power in the energy system. One challenge is to have enough power available in periods with low intermittent production. A solution could be to reduce peak demand and at the same time produce more electricity during these hours. One way of doing this is to convert electricity-based heating in buildings to district heating based on combined heat and power. The study analyzes how much a Swedish municipality can contribute to lowering peak electricity demand. This is done by quantifying the potential to reduce the peak demand for six different scenarios of the future heat demand and heat market shares regarding two different energy carriers: electricity-based heating and district heating. The main finding is that there is a huge potential to decrease peak power demand by the choice of energy carrier for the buildings' heating system. In order to lower electricity peak demand in the future, the choice of heating system is more important than reducing the heat demand itself. For the scenario with a large share of district heating, it is possible to cover the electricity peak demand in the municipality by using combined heat and power.

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1. Introduction

Several future scenarios on how to decarbonize the electrical power sector include large shares of intermittent renewable power such as solar and wind power, for example for the Nordic countries (NEPP, 2015), the Baltic countries (Blumberga et al., 2016), the UK (Sithole et al., 2016), south-east Europe (Dominković et al., 2016), Germany (Lunz et al., 2016) and Portugal (Krajačić et al., 2011). In the report for the Nordic countries, (NEPP, 2015), it is stated that the scenarios resulting in a larger share of wind power take into account the decommissioning of nuclear power. Recently, the owners of two of the three nuclear power plants in Sweden announced that they plan to shut down 4 (out of a total of 10) reactors in the years 2017–2020. This corresponds to around 30% of Swedish nuclear power capacity (OKG, 2015; Vattenfall, 2015), and 10% of the total estimated available power capacity in Sweden (Energy Panel of the Royal Swedish Academy of Sciences (2015)). The installed wind power capacity in Sweden corresponds to 15% of the total installed power capacity, and 10% of the annual electricity production (Swedish Energy Agency, 2017). The future power demand in Sweden in 2050 increased for a reference scenario modelled by Rydén B et al. (Rydén et al., 2015). If decreased power capacity from the decommissioning of nuclear power and increased future demand are to be covered by intermittent renewable power, Sweden faces several challenges. One of them is to have enough capacity for periods with high power consumption and low intermittent power production (NEPP, 2014). According to the Royal Swedish Academy of Science's scenario for the year 2050, with an installed wind power share of 22%, only 3.8% should be counted as available power (Energy Panel of the Royal Swedish Academy of Sciences, 2015). In periods with high consumption and low production from wind power, back-up power is necessary. Variations in wind power output can be lowered through the geographical allocation of wind power sites (Olauson et al., 2015; Reichenberg et al., 2014), where it is as important to increase the capacity for cross-country transmission as that for inter-country transmission. For political reasons, however, it is preferable for the countries to have their own electricity production in order to have control of the situation themselves.

Electricity consumption in Sweden, and for the Nordic countries

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as a whole, is temperature dependent. This is a consequence of electricity being used for heating, which means that the required back-up power is determined by the maximum power demand during winter. Lowering the peak power demand would decrease the back-up power needed and could make it easier to integrate more intermittent renewable power. One way to do this is to reduce the amount of electricity used for heating by installing efficient heat pumps (HPs), and another way is to replace it by district heating (DH), which would reduce the amount of electricity used even further. With a larger DH share, electricity production could increase if DH is based on combined heat and power (CHP) (Sköldberg et al., 2013). CHP has other advantages as well as increased electricity production. It contributes, for example, with inertia and balance regulation (Sköldberg et al., 2015). It has also been shown that flexible systems where CHP plants take part in active power balancing make it possible to integrate more wind power (Lund and Münster, 2006; Østergaard, 2006). Due to the balancing power of CHP, a higher wind power share is then possible without causing imbalance in the electricity system. The CHP has a heat-tied element but according to Levihn (Levihn, 2016), it is still able to be flexible with its electricity production by for example switching from turbine bypass to back pressure operation and thereby help balancing intermittent renewable power. For a Danish case, it has also been shown that letting CHP units participate in the electrical balancing task makes CHP more economically feasible (Sorknæs et al., 2015). For a lot of cases, DH based on CHP has been showed to have a positive impact on greenhouse gas (GHG) emissions inside DH areas, when comparing to electricity based heat solutions assuming fossil marginal electricity production (Gustafsson et al., 2016; Lundström and Wallin, 2016). Connolly et al. have also concluded that expansion of DH could reach the European GHG emission goal to a lower cost than the measures proposed in the current energy efficiency scenario by the European commission (Connolly et al., 2014). When it comes to the GHG intensity of electricity based heating in the future, it all depends on how the transition to low carbon power production develops. In any case HPs will be considered as an efficient heating technology in the future, together with DH.

Expansion of DH is part of the best solution for a Danish 100% renewable energy sources scenario for 2060 (Lund et al., 2010). It is also shown that it can be cost effective to increase the share of DH (Münster et al., 2012) and that it can contribute to the security of supply of future energy systems (Hagos et al., 2014; Münster et al., 2012). The challenge for DH is to adapt to being an integrated part of future smart energy systems (Lund et al., 2014). For the Danish system, one proposed solution in order to get DH more integrated with the power system is to introduce large scale heat pumps. The heat pumps could help balancing the fluctuations from intermittent power sources. It has been shown by Lund et al. (Lund et al., 2016) that there is a socioeconomic potential for introducing such heat pumps in the Danish system. The best solution for a 100% renewable energy system does, however, depend on local conditions. The energy system in Sweden differs from the Danish one, since Sweden, for example, has a lot of hydropower. This means that one can draw experience from other work, but one cannot copy the conclusions straight off because of different conditions. The Swedish and Danish systems are similar in the way that both have a lot of DH, and even though Denmark today has a lot more wind power, that could be the case in Sweden as well if the nuclear power in Sweden are to be replaced by renewables such as wind power.

DH covers around 50% of total heating demand in Sweden; the other half is mostly covered by electricity-based heating systems, with or without the use of HPs (Sköldberg and Rydén, 2014). Sweden consists of 290 municipalities, of which 285 have DH available. Therefore, there is a potential to increase the share of DH and, as a consequence, decrease the share of electricity-based heating and electricity demand. On a national level, the peak power demand for heating has been estimated (Rydén et al., 2015). The potential to decrease this demand by using a larger market share of DH has not been made. This is done in this study, using a bottom-up approach analyzing one of the municipalities in detail.

This paper evaluates and quantifies the market potential, i.e. the potential for different market shares of heating technologies, to lower electricity peak demand with the use of both more efficient HPs and DH on a local level using existing technologies, with a focus on DH. This study is therefore made as a case study for one municipality. This kind of detailed analysis has not been carried out before on this level for a single municipality. The case study is set up as future scenarios representing the year 2050. Falun, which is chosen for the case study, is a medium-size municipality with a population just a bit higher than the average in Sweden. DH is available in Falun and supplies 50% of the total heat demand, which is the same as the total in Sweden. In this way, Falun is considered an average Swedish municipality. In the case study, it is quantified how electrical peak power demand is affected by different future market shares of heating technologies covering the heat demand. Six future scenarios for 2050 are analyzed: two different development scenarios of the heat demand volume (based on the current energy situation in Falun described in a conference paper (Swing Gustafsson et al., 2017)), and for each of these, additionally, three different market share scenarios regarding DH, HPs and other types of heat production. Three possibilities for producing electricity using CHP-based DH is analyzed using two of the six future scenarios.

2. Method

The analysis is carried out as a case study of the medium-size municipality of Falun, which is located in the middle of Sweden with a population of around 60 000. The future scenarios are based on the current energy situation which is described in the conference paper *Mapping of heat and electricity consumption in a medium size municipality in* Sweden, (Swing Gustafsson et al., 2017). The mapping is based on hourly DH and electricity consumption data obtained from the local energy company. One of the assumptions is that buildings with DH are assumed to have similar energy performance as buildings that are not connected to the DH system, which is considered to be accurate enough for this kind of systems analysis over long time horizons. Basically, the total heat demand is estimated using hourly DH consumption that is scaled up to include buildings not connected to DH, together with an analysis of electricity consumption with a seasonal variation. The data used is for a period of one year, from February 2015 to January 2016. This period represents a cold year, and contains the hours with the highest DH and electricity consumption during the last 8 years (which is the data that was available) and is therefore best suited since peak consumption is analyzed. Mapping of the current heat consumption divided into energy carriers and divided into different user categories, based on the data and results from (Swing Gustafsson et al., 2017), is presented in Section 3. A more detailed description of the method used to map the current energy situation may be found in the conference paper (Swing Gustafsson et al., 2017).

Based on the current heat demand and the results from the project “The heating market in Sweden”, (Sköldberg and Rydén, 2014), two scenarios for future heat demand in 2050 are constructed, one scenario with a high future heat demand and one scenario with a low future heat demand. Data collection and

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