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Challenges in the Future Swedish Energy System

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Abstract – The ongoing switch towards more sustainable energy system is one of the most important challenges that society today is facing. The energy system in Sweden is currently confronted with questions as for example unprecedented electricity prices driven both by geopolitical constrains and supply constrains in the European energy system. Consumers have also experienced significant difference in price within the country, and existing bottlenecks have resulted in substantial income transfer from the consumers to the transmission system operator. This situation is mainly based on the fact that most of the production of electricity occurs in the north of Sweden, whilst the demand is relatively higher in the south of the country. Sweden faces a delicate balance between increasing electricity demand and the need for sustainable, efficient, and resilient energy systems. The energy system in Sweden needs to be resilient and at the same time meet the upcoming significant increased demand of electricity. It is vital that all available energy sources are included in planning of the future energy system. Sweden has a higher use of electricity compared to other European countries, mainly due to historical low electricity prices. This means that there is a potential to reduce the use of electricity in Sweden, which needs to be considered to avoid risk to miss the potential of more efficient use of electricity. There are several studies that are analysing the most optimal mix of electricity production. The aim of this study is to give a review of current research studies dealing with the opportunities and challenges linked to the need for a future resilient Swedish energy system that meets both the today´s and futures need of electricity.

Keywords**:** electricity demand, electricity production, prognosis, energy system, system perspective

1. Introduction

The redirection of our energy system towards sustainability is urgent and must address challenges as for example energy security and accessibility. Energy accessibility include the possibility to obtain electricity from affordable, reliable sources, while energy security refers to uninterrupted availability of energy sources at affordable prices [1-2]. Due to conversion to less dependence of fossil fuels, and thus also increased possibilities to meet climate goals, the use of electricity in Sweden is predicted to increase significantly in the coming years [3-6]. The use of electricity is predicted to increase above all in industrial processes and more specifical within production of hydrogen through electrolysis. The demand for electricity is also predicted to increase in the transport sector [3-5]. Today those two sectors stand for two thirds of the greenhouse gas emissions in Sweden [4].

In Sweden the use of electricity per capita is about 13 kWh compared to 6,7 kWh in Germany and 5,6 kWh in Denmark [7], which means that the electricity use in Sweden is higher than in other European countries. The explanation of the higher use in Sweden is most likely the historical lower electricity price for Swedish consumers, which has led to that electricity has been the natural choice from an economical perspective, when comparing different energy sources for example industrial processes [8].

There are several studies that show the possibility to increased energy efficiency in Sweden [8-9], which would reduce the demand for electricity. It would also free electricity that can be used elsewhere. More efficient use of electricity is vital both since it is a measure that has a short-term effect compared to expansion of more electricity production, and also since it will lower the cost for electricity use for different consumers. The combination of more efficient use of electricity, and a rapid expansion of more electricity production is therefore vital to meet the upcoming increase in electricity use that the society stands in front of. In planning of new electricity production, it is important to include all available energy sources and energy technology. The challenge is to analyse how all the different sources can be combined, and how they in a system perspective can contribute to the upcoming higher need for electricity. A power system that is recognized with a high security of supply, competitive prices and with low environmental impact, will continue to be crucial for Sweden´s prosperity [4].

2. Prognosis of Future Demand of Electricity

There are several studies that analyse what the future demand of electricity will be in Sweden. According to [10] the most extreme scenarios of future electricity use predict a consumption of 300 TWh in 2050, compared to 134 TWh in 2023 [11]. A challenge that often is discussed is the redirection to an energy system with a large part of power production that is intermittent since this will affect the security of supply [10], and that an upcoming energy system in Sweden where a great share of power production consists of solar and wind energy will lead to a substantial risk of capacity shortages, especially during winter with challenging weather conditions. Cost-measures including cost-efficient energy storages and initiatives from Distribution System Operator could though reduce such risk [12]. It is important to build up a strategic reserve as an insurance, which includes production facilities that can be used at short notice if needed [12]. Ongoing electrification that occurs in other countries might also have a large influence on the future necessary expansion in Sweden of electricity production and the electricity grids [4]. Swedish Energy Agency conclude that that the need for electricity will be about 280 TWh in 2035, which requires an expansion rate for new electricity production higher than is has been in a historical perspective [6].

The demand of future fossil-fuel free electricity production has been analysed by using different scenarios [3]. The analyses are based on high-level scenarios, where the need for electricity is studied if all announced investments in electrification are being implemented. Results from the scenarios show that the demand for electricity can increase to 240 – 310 TWh for 2045. This will lead to an increase in power demand from todays´s 26 GW to 59 GW. [3]

Government Offices of Sweden have presented a national electrification strategy [4]. The strategy consists of the following twelve steps (see table 1). The authors of the strategy conclude that the electricity system is moving from a managing phase to a phase that is highly expansive, which among other things requires that everyone is pulling in the same direction. [4]

Table 1: Electrification strategy [4]

No	Step
1	Enhanced planning
2	Collaboration, roles and responsibilities
3	Efficiency – energy, power and resources
4	A well-integrated energy system
5	Greater flexibility and energy storage
6	Proactive work for effective expansion
7	Shorter lead times
8	Secure electricity supply
9	Remove barriers to power generation
10	Improved electricity market
11	Skills provision and knowledge
12	The social contract

Svenska kraftnät [13] have made long-term analyses over the northern European energy system. The aim of the scenarios is to identify future challenges for the electricity grid. Flexible use of electricity, increased transmission capacity, both within Sweden and between Sweden and other countries will be important to meet the upcoming future demand of electricity. The authors also conclude that in the short term it needs to investigate whether installations of synchronous compensators are needed to in a reliable manner enable continued expansion of wind power and other power electronics connected production. If the system for transmission capacity does not meet the future changes in both production and consumption patterns that are predicted to occur, the climate and energy political goals will be hard to achieve. This will also lead to that society´s welfare and development will be deteriorated. [13]

In October 2022, the Tidö Agreement for Sweden was presented. The agreement can be described as a political platform for the Government´s future work. Some of the reforms that are highlighted in the agreement are prerequisites for investments in nuclear power, governmental changes for investing in new nuclear power, new rules for the electricity market, better conditions for cogeneration and hydropower, expanded investment in charging infrastructure, and eliminated subsidies for offshore wind power. The agreement also announced a reduction in the reduction obligation that entered in force first of January 2024. For Sweden to reach the climate goals, this can lead to a need for an even faster pace of the electrification within the transport sector. [5]

The Swedish Energy Agency has analysed different scenarios for the development of the Swedish energy system. The aim of the scenarios is to give an overall picture and to increase knowledge about the challenges and possible future developments that are linked to the redirection of the energy system. In the scenario that analyses the most expansive progression of electrification, the demand for electricity is expected to increase from 134 TWh in 2020 to 349 TWh in 2050. Swedish Energy Agency concluded that det actual demand for electricity in Sweden is highly depended on decisions linked to electrolysis-based hydrogen production. This means that if there are barriers for this production that are not handled with, it will have a great impact on the future electricity use within Sweden. Even in the years 2030-2035 there is significant increase in the electricity use [5]. To be able to meet this higher need in the near future, a very large amount of new electricity production and electricity grid, as well as reinvestment in the existing energy system are needed [5]. When analysing a scenario that includes high electrification, new electricity production is needed already 2030. If not barriers and challenges regarding expansion of the electricity grid, and investment in new electricity production, Swedish Energy Agency argue that there is a risk that some planned initiatives will not be realised. [5]

Considering that any expansion of new electricity production will take time, energy efficiency will be increasingly important to meet the significant expansion in the short perspective. In combination that Sweden has a higher per capita use of electricity than other European countries, the potential for increased energy efficiency is particularly interesting for Sweden.

4. Scenarios of Possible Future Electricity Production

As argued above the significant increased demand of electricity in Sweden in both a short-term and long-term perspective, leads to a need for more electricity production. Göransson and Filipsson [14] have analysed three different energy systems that meet the upcoming need of electricity and in the same way fulfil climate goals according to the Paris agreement [15]. The analysed energy systems are shown in table 2 and presents different changes in electricity supply.

Table 2 Analysed energy system [14]

Scenario	Analysed energy system
1	No nuclear power
2	Nuclear power 9 GW
3	Offshore wind power 26 GW

The authors of the report conclude that all three energy systems have the possibility to meet both the climate goals according to the Paris agreement, and the upcoming industrial electrification. There are also only small differences related to electricity price between the three scenarios. These conclusions mean that according to the authors it is possible to meet the significant higher demand of electricity with an energy system that is designed with a large share of weather-dependent electricity production. By combining different flexibility measures, variations in the electricity system can be balanced in a cost-effective way. Example of measures are batteries, hydropower, production of hydrogen, large-scale heat storage and district heating. [15]

Swedish Energy Agency state that given the upcoming increase in electricity demand, the challenge is to expand electricity production in Sweden so that the demand for electricity can be met. Land-based wind power has the greatest potential given the short time horizon but means that barriers including state trials and social acceptance must be overcome.

Offshore-based hydropower together with solar power are recognized with some potential in the short term. New nuclear power is possible if a period of 10 years is considered. In a longer-term perspective 2035-2045, the electricity production needs to expand with about 110 TWh. This expansion can be met with offshore wind power production according to Energy Agency. [6]

5. Conclusion

There is a great challenge to redirect Swedish energy systems towards sustainability and less dependence on fossil fuels. The redirection means that the demand for electricity will increase significantly due to conversion to electricity from other fuels within above all industrial processes, but also within the transport sector. This change of the energy system is urgent and must include areas as accessibility and energy security.

There are many studies that analyse the prognose regarding future demand of electricity in Sweden. The studies often have different time perspectives, which must be taken into consideration. The common conclusion is that though that the demand will be historically high, both in a short-term perspective, and in a long-term perspective. The electrification brings possibilities to society as for example new business opportunities for Swedish industry but is also linked to challenges regarding how to expand electricity production to meet the higher demand of electricity use. Swedish Energy Agency conclude that in a short-term horizon land-based hydropower will have both technical and economical possibilities to provide for the coming higher demand for electricity production. In long-term perspective offshore wind power production can contribute with a large share of the needed expansion.

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