"Future Electricity Supply in Sweden"

The Swedish economy is highly dependent upon industrial export. During the last century the Swedish industry has relied on the availability of clean and cheap electricity which has been provided mainly by hydro power and nuclear power. Today, Sweden's electricity production is 98 per cent carbon free.

The Confederation of Swedish Enterprise supports the Paris agreement and is determined that Sweden shall reach the climate goals by 2050, but the focus cannot solely be on emissions in Sweden. Due to the large extent of export and carbon free electricity production, Swedish industry also has a significant positive effect on global emissions.

As the Swedish society – as all other countries throughout Europe - now converts into a fossil free economy, we will face significant challenges. Therefore the Confederation of Swedish Enterprise has initiated the project **Future Electricity Supply in Sweden** where a wide range of areas concerning the electricity supply are being analyzed in order to provide policy recommendations that will ensure the transition into a fossil free economy with maintained prosperity.

A large part of today's electricity production in Sweden will reach the end of its life span in 2045. During the same time Sweden needs to increase the electricity consumption by more than 60 percent to be able to end the use of fossil fuels.

One of the main parts of the project is a scenario analysis performed by dr Staffan Qvist in cooperation with scientists from Princeton and MIT. According to the enclosed executive brief of the analysis, a Swedish energy system built solely on renewable electricity production will be at least 40 percent more expensive than a system allowing nuclear energy. A completely renewable system will therefore be a constrain to Swedish enterprises of which many depends heavily on Sweden's low cost, carbon free electricity production.

Due to the high share of export in Sweden (70 percent of the industrial production) and the relatively low degree of carbon emissions from the Swedish industry, such a constrain will also affect the chances of EU reaching the climate goals.

To be able to reach the climate goals with maintained competitiveness we need a policy shift. We will see a rapid growth of wind power during the next 20-25 years, but plannable energy production such as hydropower, cogeneration and nuclear production is essential to foster this growth. Otherwise, the Swedish energy system will be costly and vulnerable due to long periods with little wind and low temperatures. This is also the case in other countries with similar conditions. The EU taxonomy will hence have a huge impact on Sweden's ability to keep on providing products with a small carbon footprint to the European and the global market.

This is not only a Swedish concern. It is imperative that politicians all over Europe, see the need for – and the opportunity to – combine high climate ambitions with increased competitiveness. One of the key factors for achieving this on an European level is a strong focus on security of supply in a fossil free electricity system.

FUTURE *of* SWEDISH POWER SUPPLY

Long-term
Scenario Analysis

ENGLISH SUMMARY

Qvist Consulting Ltd

Executive Summary

The “Future Electricity Supply” (“Kraftsamling Elförsörjning”) Project

This report by Qvist Consulting Ltd provides an English-language summary of the work package ‘Long-term Scenario Analysis’ for the Swedish power system within the framework of the project “Future Electricity Supply” (“Kraftsamling Elförsörjning”), commissioned by the Confederation of Swedish Enterprise. The study analyses pathways for the development of the Swedish power system to enable a competitive and fossil-free economy in the long term. The basis of the study is detailed and comprehensive power systems modelling and optimization to find power system compositions that minimizes total system costs for a given set of input values. All modelling performed targets a completely decarbonized Swedish power system in the year 2045. The results of this study will be used to develop the necessary concrete recommendations for Sweden to be able to transition to a fully decarbonized zero-emissions society.

The ambition of the project “Kraftsamling Elförsörjning”, across nine different work packages, is to develop policy proposals that are backed up by careful analysis to help ensure that Sweden, even in the longer term, maintains a highly reliable decarbonized electricity system at competitive cost to consumers. The project has a clear consumer perspective - cost effectiveness and security of supply are crucial. Previous analysis within other work packages of the project have shown that Swedish electricity consumption will need to increase to at least 200 TWh/year by 2045, up from about 130 TWh/year today, in order to effectively drive decarbonization across other sectors. If a more complete decarbonization of the Swedish mining sector is included, this will result in even higher demand – on the order of 240-250 TWh/y by 2045 (85 % higher than today).

Introduction to the Long-term Scenario Analysis

The Long-term Scenario Analysis consists of twelve main “technology-neutral” modelling scenarios with varying basic assumptions and input. Technology neutral in this context means that all relevant power generating technologies are allowed to participate in the modelling and to compete for a role in the optimized power system on their own merits. In the modelling scenarios, input assumptions are varied relating to the assumed future capital and operating cost of different types of power generation and storage technologies, as well as assumptions regarding international electricity trade, the cost of capital and the level of flexibility of demand. The modelling is on an hourly basis for a full year with each of the four Swedish power regions (SE1-SE4) represented individually. The analysis is done with an assumed lower-than-average inflow to the hydropower system, a so-called dry year, to ensure that the systems are robust.

In addition to technology neutral analysis, a series of modelling scenarios were also studied where the technology stack is assumed to be limited on ideological/political grounds. These include modelling scenarios where only “renewable” power sources are allowed, and a set of scenarios where specifically investments in the long-term operation of existing nuclear power plants are excluded.

System boundaries and trade

In any power systems optimization study, system boundaries must be selected and justified. In this analysis, investment optimization is performed specifically and only for Sweden. A simplified model for electricity trade with Sweden's neighbouring countries has been used as part of the basis for system dimensioning. Since the analysis targets a fully decarbonized economy, the modelling only allows for the import of fossil-free electricity when international trade is included. In a subset of the modelling cases, Sweden is treated as an “island” system, meaning that international electricity trade has not been taken into account when dimensioning the power supply system.

Results

The very brief summary of the analysis results is that the cost-optimal future technology-neutral electricity system which, on an annual production basis in 2045, mainly consists of: 1/3 maintained hydropower, 1/3 wind power and 1/3 maintained and new nuclear power.

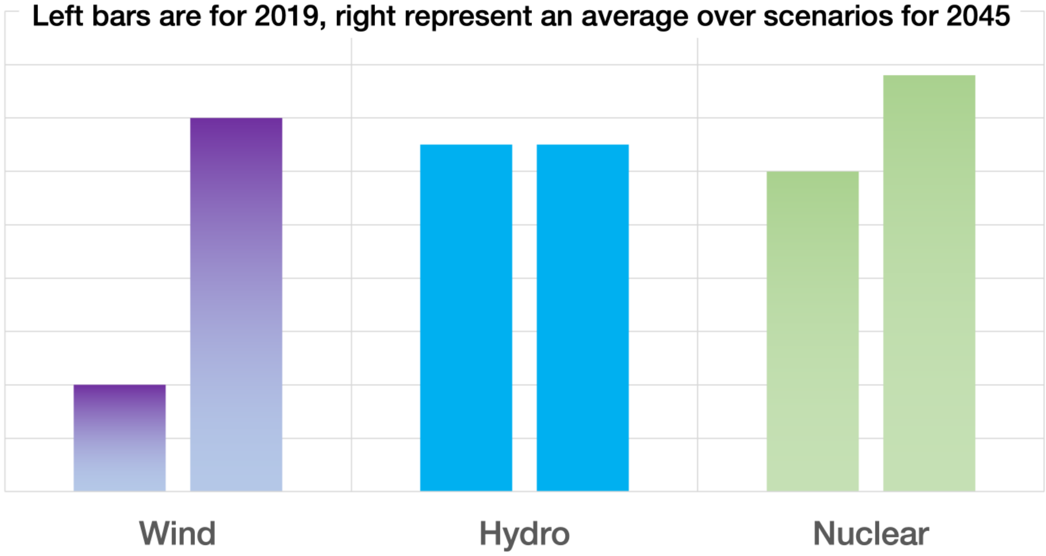

Figure 1, A schematic illustration of how the largest types of power in the Swedish electricity system produce on an annual basis today (left bar) and averaged over the most cost-effective systems modelled for 2045 (right bar). The illustration gives an average value for the modelled production in the technology-neutral scenarios, the results vary in the different scenarios.

The biggest difference compared to the current power system is a growing share of wind power and a more limited increase in the amount of nuclear power. The technology-neutral scenarios invest in the long-term operation of all existing Swedish nuclear power capacity. Biopower, mainly in the form of combined heat and power plants (CHP), currently accounts for about 9% of Swedish electricity production. When current biomass and waste-CHP capacity is held outside of the power system investment optimization, which may be relevant as other aspects of cogeneration (heat supply) should also be taken into account, CHP continues to contribute 5–9% of future electricity production, while full inclusion in the optimization leads to a smaller share. No technology-neutral scenario leads to investments in solar power or natural gas with carbon capture. In the scenarios that allow trade for system dimensioning, an average of 6% of the annual load is supplied through imports. In the cost-optimized modelling, which for reasons of robustness is done for a year with low inflow in the hydropower system, all systems are net importers on an annual basis. A year with average inflow to the hydropower system, most systems are in balance and production and consumption approximately match on an annual basis.

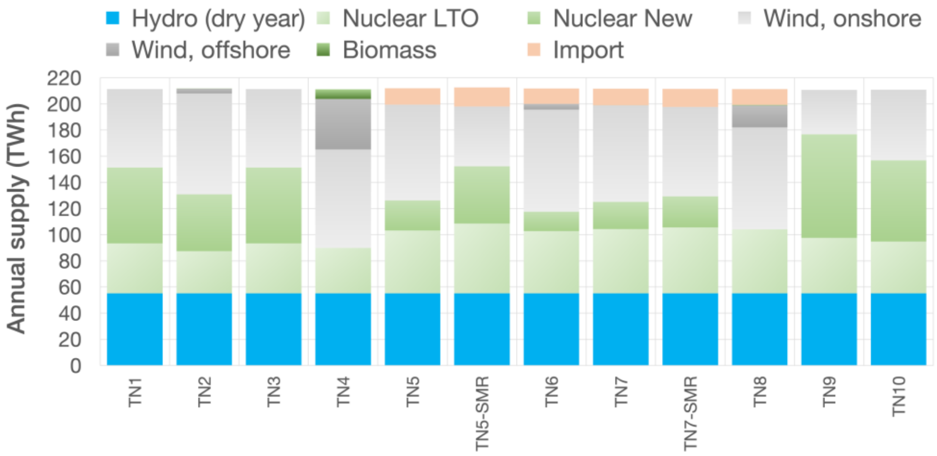

Figure 2, Annual supply of electricity by source for the 12 main technology-neutral scenarios

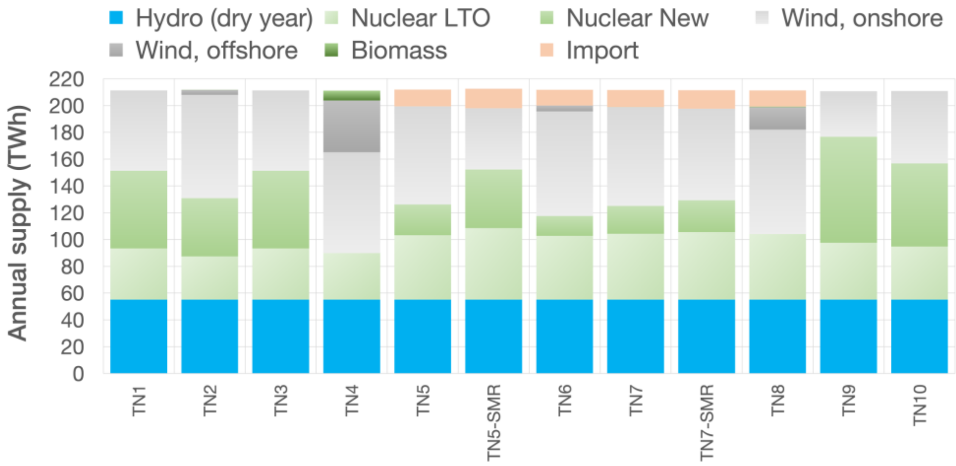

Figure 3, Installed capacity by source for the 12 main technology-neutral scenarios

In all modelled scenarios, it is assumed that identical basic investments corresponding to approximately SEK 500 billion will be needed in the distribution and transmission grids between today and the modelling year 2045. These investments are placed outside of the optimization calculations as they are considered necessary in all cases. The total system cost across all technology-neutral scenarios with differing input assumptions varies from 320 SEK/MWh up to just over 500 SEK/MWh. The most cost-effective systems are those that allow international trade as part of the system dimensioning, as they require lower investment in domestic capacity. However, this cost-effectiveness comes with a reduced level of robustness, as there is significant uncertainty regarding what export capacity neighbouring countries will actually have available hour-by-hour to help handle supply deficit situations in Sweden 25 years from now. When the analysis deviates from the principle of technology neutrality and is limited to only renewable electricity production, the total system costs increase by an average of 40 %. This figure does not include any of the additional costs for ancillary system services related to providing sufficient system inertia and reactive power balancing for voltage control. The all-renewable scenarios are also associated with a reduced level of security-of-supply, very significantly larger land use, higher materials use and higher lifecycle emissions of greenhouse gases. One potentially alarming finding is that the volatility of dispatch in the regulated hydropower system in Sweden will need to increase dramatically to handle the much larger unplanned variations of output when a larger fraction of the system consists of wind power, especially in scenarios aiming for a fully renewable supply system.

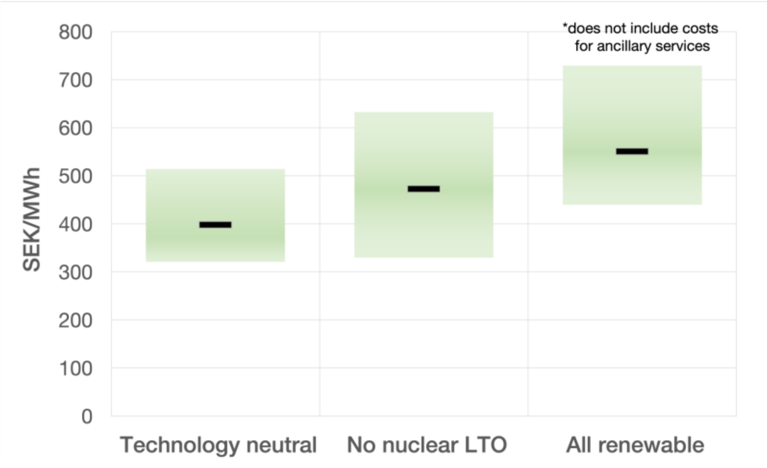

Figure 4, Average[1] and range of system costs for different scenario categories

The study concludes that by embracing a technology-neutral approach, the Swedish power system will continue to be able to deliver in a very competitive way for the Swedish economy. The base of the existing Swedish electricity system, its dispatchable fossil-free hydropower and its nuclear power capacity, constitute an ideal starting position for future power system in a transition to a completely decarbonized zero-emissions society.

[1] The average figure depends on the specific set of modelling performed in each category and is therefore indicative but not directly comparable.