Executive summary

Europe accelerates towards zero emissions

This year's analysis reinforces our main view over the recent years. The European power system is moving towards zero carbon emissions, and a system mainly based on solar and wind power. The main difference compared to our last Long-term Market Analysis (LMA2018) is that we also assume a *zero-carbon energy system in Europe by 2050*. This implies a much higher growth in the power demand and production than predicted in our last analysis. Our new base case includes the following:

- The power demand increases twofold, driven by a massive electrification - direct and indirect
- Most of the power production is from wind and solar power – the volume increases tenfold
- Fossil power plants are phased out completely by 2050 – a lot is out already in 2040

Reaching zero emissions also requires massive contributions from recycling and energy savings. A lesser contribution implies higher electrification. Our assumptions on demand and production is of similar magnitude as other zero-carbon analysis, including updated analysis from the EU Commission.

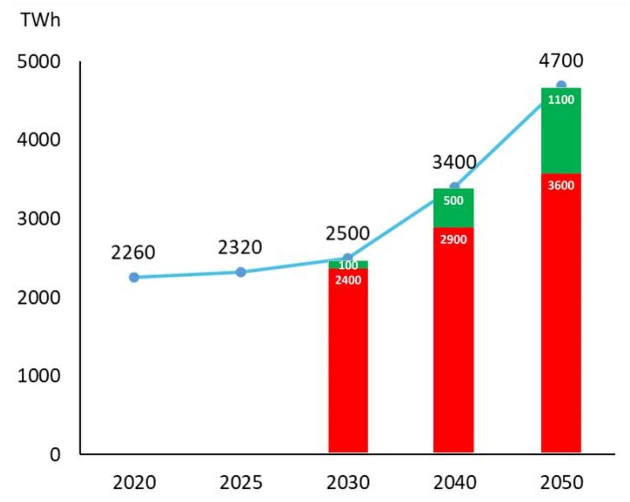

Figure 1-1: Total power consumption in EU11[1]. The consumption is 6700TWh for whole of Europe in 2050, assuming EU11 represents the same share of EUs total power consumption in 2050. The green shaded area represents consumption to electrolysis.

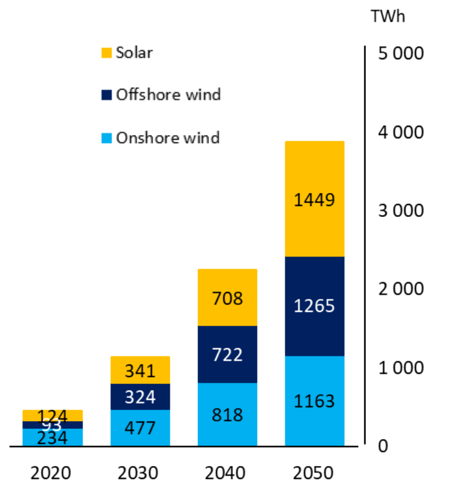

Figure 1-2: Production from wind and solar power in EU11

A review of existing national energy and climate plans, and several long-term analyses show that the pace of the transition needs to increase further towards 2030 and 2040. In our opinion this is both possible and probable:

- The EU Climate Law will legislate climate neutrality in 2050 and the 2030-target is tightened
- The reformed emission trading system is well-functioning and gives a higher CO2-price
- Technology improvements reduce costs and make the transition cheaper
- The transition brings more jobs and less import of energy from other continents
- The financial system emphasizes climate risk and awards green projects
- Consumers put pressure on the business sector to reduce its emissions
- The effects of climate change are increasingly visible and the sense of emergency increases

[1] EU 11 represents the countries we model outside the Nordics: UK, France, Germany, Switzerland, Austria, Italy, Poland, Belgium, Netherlands, Czech Republic and the Baltic countries. The area represents round 70 % of the total power consumption in the EU today.

These and other factors reinforce one another, resulting in an increased pace in the transition. The development is further reinforced by analysis and prognosis showing that a zero-carbon energy system is both feasible and affordable. Thus, it is more likely that national energy and climate plans will be revised to be coherent with the target of net zero carbon emissions in 2050.

Although the transition is moving in the right direction, there is obviously uncertainty related to whether the energy and power sector will have zero emissions within 2050, or whether this will happen somewhat later. New solar and wind power will among other things replace todays fossil power production, contribute to the electrification of the transport sector, and cover production of hydrogen and ammonia, which requires massive volumes. Additional production of energy on this level poses several challenges, for instance lack of suitable land areas. Other uncertainties are whether it is possible to procure enough flexibility within demand and storage, and whether the technology development is at a sufficient high pace.

Production of so-called blue hydrogen through reforming of natural gas and import of hydrogen produced through electrolysis, from for instance North-Africa, can reduce the need for wind and solar power in Europe. The prerequisites to investigate this topic further is here lacking, but we assume that this will not affect the growth of solar and wind power.

Even if Europe obtains a zero-carbon energy system in 30 years, research and other prognoses show that this will most likely not be the case globally[2]. There are however substantial plans for a green transition elsewhere in the world, which contribute to the technological development that enables the European transition.

Flexible demand, hydrogen and batteries facilitate the system both economically and financially

The road to zero emission affects the power prices and the profitability of reinforcements of the grid internally and out of Norway. Moreover, the energy transition and power prices will manifest the challenges to the market and the system. In this analysis we have focused on the economical interaction and interconnection between electrification, hydrogen, storage and solar and wind power, and the effect on power prices.

It is widely acknowledged that a system mainly based on power production from solar and wind needs greater adjustments in demand, to a much larger extent than is the case today. Put simply, Europe will transition from a power system where the production adjusts to the demand, to a system where the demand adjusts to the production. Flexible production of hydrogen in periods of high renewable production will become central, as well as interaction with the heating sector, batteries and other forms of energy storage. Further on, it is realistic that the power demand from electrification will decrease in periods with low production from solar and wind. Given this, it seems feasible that batteries, hydrogen and biogas peakers can cover the rest of the demand, when there is no sun nor wind.

Although hydrogen causes a lot of energy loss during production, storage and use, it becomes central in the energy transition. Mainly because zero carbon hydrogen cuts emissions in sectors where direct use of electricity does not work. Also, electrolysis can exploit the periodic overproduction of wind and solar power. Our simplified calculations confirm that it is profitable to concentrate hydrogen production during periods of overproduction of solar and wind power and low power prices, even though it implies less full load hours, investments in oversized electrolysis capacity and hydrogen storage. The fact that hydrogen production concentrated in the hours with low prices is more profitable than a stable level of hydrogen production is a key to making the energy transition

[2] DNV GL, IEA, among others.

economically cohesive. We assume a lot of hydrogen production from electrolysis in hours with high wind and solar power production and find that this helps to prevent price collapse during these hours. This makes it economically justifiable to develop much more wind and solar power. Falling technology costs for electrolysis and the development of infrastructure and a hydrogen market will be crucial to make this work.

We assume that the use of hydrogen as a fuel in power plants and fuel cells can contribute to solving the challenge of periodically low wind and solar power in Europe as a whole. Low efficiency makes hydrogen power plants and fuel cells relatively expensive to operate, but due to few other options and few full load hours, it still appears rational.

Our model simulations indicate that a reasonable economic market equilibrium can arise between the various players in a future zero-carbon energy and power system. Meaning that the market players earn enough to cover running costs and investment costs with a relatively low level of subsidies and guarantee schemes. At the same time, we get moderate energy and power prices overall. However, there are several uncertainties in this regard. The main one is the degree of flexibility in consumption and storage. Our simplified modeling of the system in 2050 provides enormous variations in the use of batteries, charging of electric cars and production of hydrogen, at relatively small price differences and with little spill of energy. It is likely that our model exaggerates what is possible to achieve. A less flexible response will result in more energy loss, higher costs and an increased need for support schemes. Another point is that in some areas, extensive support and guarantee schemes will be necessary to reach a sufficient pace in the transition.

The reformed emission trading system has resulted in a much higher CO2 price over the last couple of years, and we assume that the price will increase slightly from the current level in our base case. This contributes to the transition. How high the price can and should go is still a key uncertainty, handled in our alternative scenarios. At the same time, the CO2 price clearly has the most effect on the power prices and the pace of the energy transition the first 10-15 years, and there is less of a need for high CO2 prices in a fully developed zero-carbon energy system.

Moderate European average prices and increasing price volatility

Despite the high growth in production and consumption, the simulated average prices over the year are quite similar to those of the previous LMA. Higher CO2 prices and increased production of hydrogen, in combination with a lot of wind and solar power production give somewhat increased average prices until 2040. After this, average prices are reduced, driven by increased renewable production and a technological development that provides cheaper solar and wind power, batteries and electrolysers. At the same time, our simulations show a trend towards more volatile power prices, although electrolysis, batteries and flexible charging of electric vehicles to some extent counteracts this.

Most of the offshore wind production will be linked to multiple countries. This provides increased grid capacity between the countries around the North Sea and the Baltic Sea, and thus more similar power prices in this region than in the previous analysis. Furthermore, the introduction of hydrogen power plants provides several hours with prices around 60-100 EUR / MWh. In our updated data sets, we have a relatively low number of hours per year with higher price peaks where consumption balances the market. However, these hours of high prices are important for the profit of, among others, the hydrogen power plants.

Towards 2030-40, the continental power prices range from 35 to 60 EUR / MWh as an average over the year. The most important uncertainties are the prices of CO2 and gas, the adequacy, the proportion of hours with prices down to zero and the degree of subsidies for wind and solar power.

After 2030, however, hydrogen, consumption and batteries affect the prices in an increasing share of the time. Gradually, the power prices will become a function of the long-term cost level of renewable power production, energy storage, electrolysis and consumption flexibility.

One important note is that higher prices over the next 10-20 years can contribute to lower prices further on in time. A higher CO2 price could lead to a faster transition and technology development which subsequently will reduce the power prices. This is one of the reasons why it is difficult to map out scenarios that result in consistently high and low average price throughout the analysis period. We have chosen to illustrate this point with the high price scenario until 2040 having the lowest prices in 2050, while the low-price scenario until 2040 has the highest prices in 2050. After 2040, some of the most important uncertainties for power prices are related the threshold for the power price where electrolysis stops, and the interaction with the hydrogen market.

The Nordic region - high growth in consumption and production
Developments in the Nordic countries follow the same trend as elsewhere in Europe. Electrification of transport and various industrial processes, industrial growth and new data centers provide significant consumption growth. In our updated base case for the Nordic region, consumption will increase by 40% by 2040. A larger expansion of data centers and industry can lead to even greater growth. In Norway and Denmark, much of the electrification of current energy consumption has been completed by 2040, but in Sweden and Finland it is likely that we will see further growth by 2050 in order to achieve the goal of an emission-free energy sector. Growth in Sweden and Finland may also come earlier and will then lead to even greater Nordic consumption growth by 2040.

Wind power will mainly cover the increase in consumption and reduced nuclear power production in the Nordic region. Some of the wind capacity will probably come as offshore wind. The proportion of offshore wind will be important for future bottlenecks, especially north-south in Sweden, where offshore wind in the south can replace some of the land-based wind power in the north. A development of offshore wind without subsidies in the Nordic region requires higher prices or greater cost reductions than we have in our updated base case. In case of stronger restrictions on onshore wind power, this could dampen growth in industrial sectors that are more price-sensitive.

As a result of high consumption growth, we expect the surplus on the Nordic energy balance to remain at a moderate level of 10-30 TWh. Also, the Nordic region is increasingly dominated by unregulated production that varies according to the weather conditions. This results in increased price volatility and larger fluctuations in the power balance, among other things.

Norway - increasing consumption and production growth in line with consumption
In Norway, we expect significant growth in consumption. In our updated base case, this implies an increase from the current level of just over 140 TWh to 180-190 TWh in 2040-50. The growth is significantly greater than in the previous analysis, due to both plans for electrification and new industry. The pace and volume of the consumption growth is uncertain. Because of this, we operate with alternative scenarios with both higher and lower growth. The extent of electrification of the petroleum sector and how fast the consumption declines as a result of declining activity in the sector is uncertain. As well as the extent to which growth in power-intensive industries is dampened by restrictions on further development of onshore wind power.

Given the consumption in our base case, Norway will have a power deficit, and higher power prices relative to our neighboring countries, in absence of new production beyond what is currently under construction. Without taking into consideration the encroachment on nature, further development of land-based wind power and hydropower to cover the growing power demand is the cheapest option. In our updated analysis, onshore wind power is still economically profitable without subsidies. Given the political processes of the last two years, however, there are likely to be stronger restrictions on the development of onshore wind power. In our updated base case, we have therefore assumed low continued growth in onshore wind power, from the point in which current projects under construction has been put into operation. We assume both new hydropower, more solar power, and offshore wind from 2030, even though this does not seem to be initially profitable without subsidies. In sum, the energy balance is slightly positive through the year in Norway throughout the analysis period.

Norwegian prices in our base case – in line with historical prices but more volatile
In the base case, the average price in southern Norway is in the range of 35-40 € / MWh after 2030. This is the same level as in previous editions of the LMA and somewhat lower than on the continent. In Northern and Central Norway, prices are much lower in 2030, but are approaching the level in Southern Norway towards 2040. Nevertheless, if the profit locally in Northern Norway is greater than what we have assumed in our base case, the local power prices will fall relatively quickly. The price variation between years due to weather conditions remains at the current level. The difference between winter and summer is reinforced, with lower prices in summer than in winter.

In previous analysis, we have shown that the Nordic countries will have more variable prices within shorter time intervals such as days and months than seen historically. This will also affect Norway, even though the effects are somewhat more subdued here. In the new analysis, this is reinforced, in addition to the changes happening somewhat faster. This is due to more wind and solar power in the Nordics and increased price variations in Europe.

After 2040, developments on the continent indicate that we are moving towards somewhat lower average prices in Norway. Increasingly cheaper energy storage and other flexibility means that price volatility does not increase further. In the long run, this can also lead to lower volatility.

The Norwegian power prices is in the range of round 30 € / MWh to just over 50 € / MWh
There is considerable uncertainty associated with numerous factors that affect power prices in Europe, the Nordic countries and Norway. Thus, we have a large sample space for prices. Previously, we have assumed that increased wind power production in Norway will be able to curb the increase in power prices due to higher CO2 price. Similarly, we have assumed that increased demand from industry will trigger more power production. Increasing resistance to wind power may, however, lead to fewer wind power licenses being granted. Then power prices can be raised more if European prices become high or if industrial consumption increases. Towards 2050, we believe that declining technology costs will dampen the upside in prices. Several other factors can also lead to lower prices than in our base case, for instance the large-scale development of solar and wind power in Europe can provide several hours with very low prices, which will reduce the Nordic prices.

We expect greater price differences both internally in Norway and abroad
From 2030 to 2040, the differences in average prices between Northern, Southern and Central Norway will be smaller in our Base case. Nevertheless, our simulations indicate that the hour by hour price differences between the various areas in Norway can increase. For instance, prices in northern and central Norway will to a greater extent follow wind power production in the two northernmost price areas in Sweden. In southern Norway, prices will vary to a greater extent with the contribution from wind power in and around the North Sea. In addition, prices are more affected by solar power. Meaning that the areas with the highest and lowest price will vary more than today. There will also be several hours of bottlenecks internally in southern Norway. This will primarily result in a price difference between NO2, and NO1 and NO5. This will also lead to an increased price difference between Norway and the surrounding countries.