Norway at the Capacity Limit of its Power System

The spot prices in an efficient electricity market are sensitive indicators of challenges in the power grid concerned. The southern Sweden and the southern Norway are currently experiencing very high prices in the day-ahead market. This note outlines the market conditions for the southern Norway. A similar analysis for the southern Sweden will follow.

From energy surplus in 2020 to energy shortage in 2022

The southern Norway (NO2) had very low prices in 2020 and very high prices in 2022 (fig. 1).

In 2020 a surplus of energy was trapped behind bottlenecks on international and local transmission links.

The situation was quite different in 2022. The high prices are good news for local producers of electricity and probably also for Norway as a whole, but they are bad news for Norwegian consumers.

Fig. 1 – The unusual price level in 2022 causes concern and divided interests.

The stable Nordic market model

Some people are wondering if it is possible to redesign the electricity market with the same price for all domestic consumers, but with high prices for exported electricity.

The Nordpool market system has been based on the same principles since the early 1990's. All market systems are compromises between conflicting interests. The general purpose is to let the market optimize the allocation of resources, even internationally. Protectionist measures would probably blur this target and reduce total efficiency.

The Nordic spot market has a number of price zones (fig. 2). This is a compromise between national price zones and "nodal pricing" with individual prices for each node in the transmission system. Nodal pricing is theoretically the most accurate model, but the market liquidity in each node would be insufficient in the Nordic area. The intention is that frequent bottlenecks should be coinciding with borders between price zones.

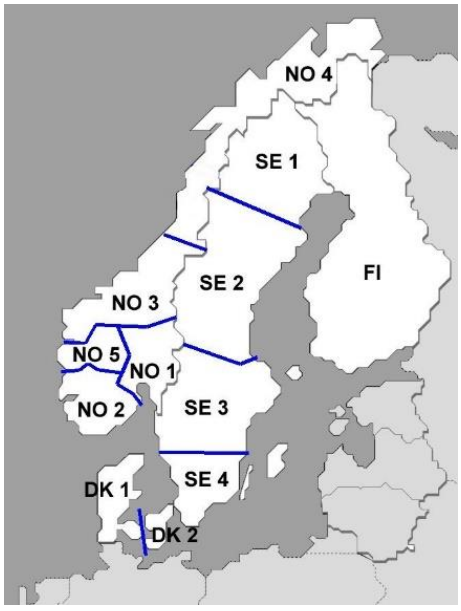

Fig. 2 - The Nordpool price zones

In any case, a fundamental change of the Nordic day-ahead market should be carefully considered, because the current model has served very well since the market introduction.

New links to Germany and England in 2021

Norway has a hydro power system with a storage capacity exceeding 80 TWh. The flexibility of this system makes exchanges with thermal power systems very attractive. The thermal power systems can provide energy reserves for dry years, and the hydro system offers surplus energy during wet years and short-term balancing services. The growth of wind and solar power has increased the demand for such services considerably.

NO2 is one of Norway's important areas for hydro generation, storage and international links. There are local transmission lines to NO1 and NO5, and the following international HVDC links:

- The Skagerak links to Denmark: 0.5 + 0.35 + 0.7 GW - 1977, 1993 and 2015
- The NordNed link to the Netherlands: 0.7 GW - 2008
- The NordLink to Germany: 1.4 GW – May 2021
- The North Sea Link to England: 1.4 GW – October 2021

This list explains the change from 2020 to 2022 (fig. 1). The export capacity from NO2 was reduced in 2020 due to cable problems. The new link to Germany was delayed. The water reservoirs ran full, and the spot prices approached zero.

Two years later, the total export capacity was 5 GW. Shortage of natural gas caused high spot prices for both gas and electricity all over Europe. The new links moved the bottleneck from export capacity to local Norwegian borders. *NO2 adopted continental price levels.*

As a consequence, the planned 1.4 GW NorthConnect link to Scotland was placed on hold by the Norwegian government.

Local bottlenecks divide Norway into high and low price areas

The Norwegian spot prices for 2022 clearly divide Norway into a high price area (NO1, NO2 and NO5) and a low price area (NO3 and NO4) (fig. 3). This result clearly locates the main bottleneck between the price zones NO1 and NO5 on one side and NO3 on the other. Congestion between NO3 and NO4 occurred in April 2022 (fig. 4).

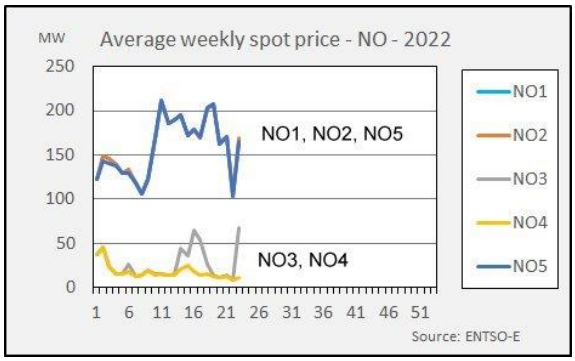

Fig. 3 - Norway divided into high and low price zones in 2022

Fig. 4 – A few days with congestion between NO3 and NO4

This division of Norway into two parts with very different conditions for electricity consumers has naturally caused some frustration, but the market model should not be blamed. The

main reason is an imbalance between demand from the new HVDC links and the transmission capacity between Norwegian price zones.

Southern Norway (NO2), week 24, 2022:

Hydropower reservoirs 8 TWh below normal in 2022

The water reservoirs in a hydropower system have the purpose to eliminate seasonal differences and, if possible, to eliminate variations in water inflow from year to year. Besides, hydro power provides perfect support for systems with fluctuating generation from wind and solar power.

Norway has by far the largest water reservoirs in Europe. Their total capacity is more than the rest of European countries together (fig. 5). But even this large capacity was challenged during the years 2019 to 2022.

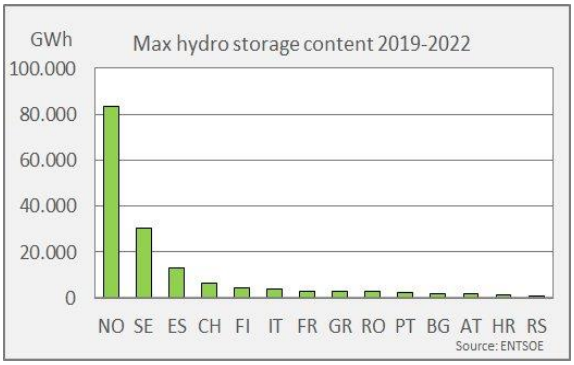

Fig. 5 - Norway has the largest hydro reservoirs in Europe

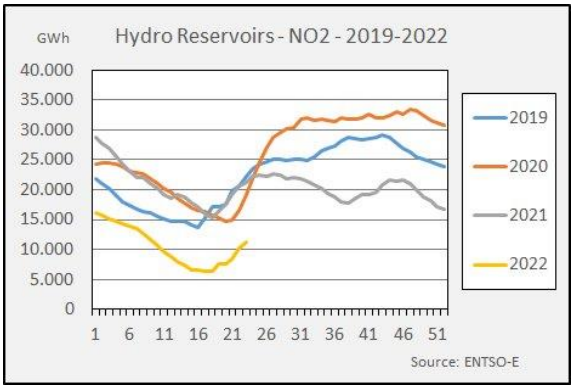

Fig. 6 – The four years are very different

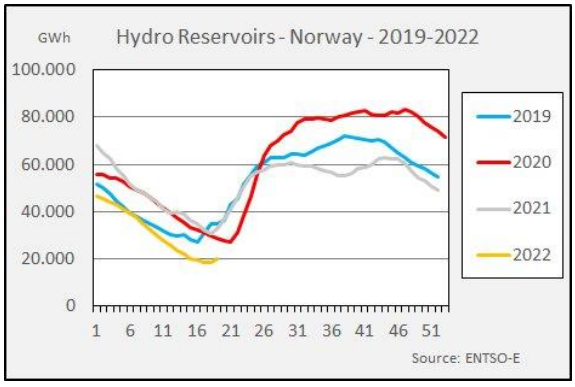

Fig. 7 - 2019 was a quite normal year in Norway

2019 was a rather normal year. For NO2 (fig. 6), the maximum filling was 86.1% (median value 83.6%) and the minimum 40.7% (median value 38.5%)[1].

The reservoirs approached overflow in 2020 with 98.5% for NO2 and 95.7% as Norwegian average. The risk of spilled water made spot prices in NO2 falling to nearly nothing (fig. 1).

The year 2021 began with high water levels. The international export from NO2 went up by 2.0 TWh and the generation by 2.8 TWh from 2020 to 2021. The result of increased generation and low inflow of water was that the reservoirs could not recover to normal levels after the spring season (fig. 6).

The minimum level for 2022 was 18.7% (median value 38.5%). At this moment (week 24) the storage content in NO2 is 8 TWh below the median value. This is bad news at a time of gas shortage.

The storage content for the whole country is 10 TWh below the median value (week 24).

[1] Source: nve.no

A complex operating pattern

The need for exchanges is unpredictable, particularly when fluctuating power sources play a significant role. As an example exchanges for each of the four links from NO2 are shown on fig. 8 for the first week of 2022.

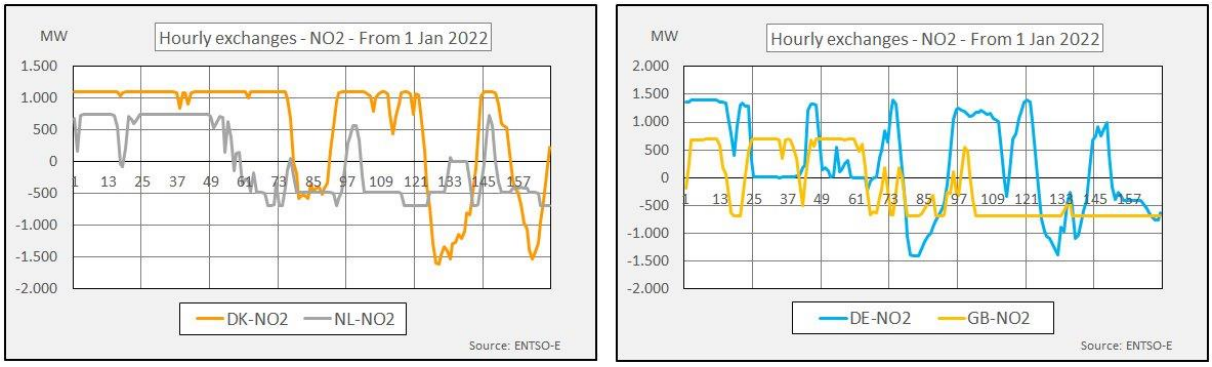

Fig. 8 – Data per link are shown on two charts to prevent a confusing image.

There are variations from hour to hour, in some cases with change of sign and ramps with large regulations per hour. There is no regularity for any of the four curves.

Fig. 9 shows the international and local net exchanges for NO2.

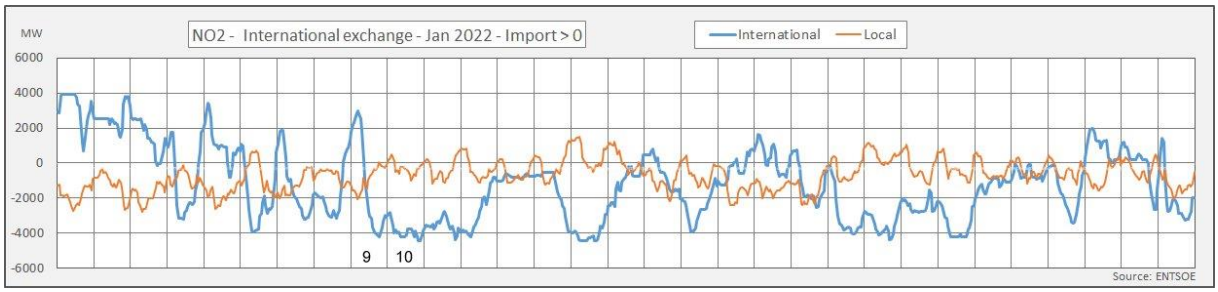

Fig. 9 - Case: Exchanges in January 2022.

The blue curve illustrates the character of the balancing service delivered by Norway. On 9 January, the variation was 7 GW in 14 hours or 0.5 GW per hour. Norwegian generation was increased by 5 GW in NO2 and 2 GW elsewhere in Norway.

Fig. 10 - German spot prices are more volatile, but NO2 has adopted the continental price level

The spot prices were steadily increasing on 9 January, at NO2 by 136 €/MWh and in Germany by 191 €/MWh. The spot prices were even higher on 10 January, but the export from Norway could not be further increased.

The recorded exchanges are results of day-ahead markets, intraday markets, regulating markets and some special measures. Therefore, it is not always possible to find a logical connection from the spot market to the exchanges.

Norwegian capacities for balancing services fully utilized

A well planned power system must be robust to unexpected events, such as fuel crises, weather variations, outages and delayed commission of new facilities. The large penetration of fluctuating power (wind and solar) has increased the need for balancing services. The irregular exchange patterns (fig. 9) show how Norway is able to meet this demand.

The four years from 2019 to 2022 have been challenging for power systems due to variations in inflow to the hydro and wind power systems and international political instability. The question is if the power systems should have been prepared for these events.

The Norwegian water storages have been utilized close to both maximum and minimum limits. Lack of export capacity contributed to full storages in 2020, and doubled export capacity reduced the Norwegian energy reserves in 2022 and divided Norway into high price and low price electricity markets.

It must be a Norwegian consideration, if this is a problem, but it is unlikely that Norway will be able to increase the sale of balancing services significantly.

Norwegian authorities have probably assessed each new link to be profitable, but putting the planned link to Scotland on hold indicates that the impact of new interconnectors on the Norwegian electricity markets has taken them by surprise.

Most countries have ambitious plans for new wind and solar plants. Additional transmission and balancing capacities must be established simultaneously with the commission of new generation. In some countries, large transmission projects are already several years delayed. This situation seems not to be fully recognized in Denmark and some other countries.