Centre for Sustainable Energy Studies

Norway´s role as a flexibility provider in a renewable Europe

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Asgeir Tomasgard, NTNU Department of industrial economics and technology management
Christian Skar, NTNU Department of industrial economics and technology management
Kjetil Midthun, SINTEF Technology and society
Stefan Jaehnert, SINTEF Energy
Marte Fodstad, SINTEF Energy

Executive Summary

In FME CenSES one of the main activities is scenario studies where we analyse transition of the European energy system. This report focuses on the European power system and its transition towards 2050 where 90% of the emissions are removed compared to 2010. Norwegian energy resources can potentially play a role in this transition, both in terms of flexible hydro power, natural gas and new wind developments. For the studies, we use the EMPIRE model developed in CenSES to handle both the long-term investment decisions and the operational uncertainty of the power system with large amounts of renewable generation from hydropower, wind and solar PV. The model is tailored to see how short-term uncertainty in inflows, load and generation affects the energy mix of the future in a setting where the European countries cooperate to build a cost-efficient power system. The model has also been used to study the role of CCS in the European power system in cooperation with the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP). When discussing the potential for Norwegian value creation we also include a short discussion on previous results from NTNU and SINTEF analysing the value of European cooperation for short-term balancing services and point to relevant results from the HydroBalance project in FME CEDREN.

The increase of the renewable share in the European power system provides Norway with the possibility to provide Europe flexible energy at different time horizons. Even though the renewable sources in Europe will be able to replace large amounts of fossil energy, scenario studies indicate that we will see periods from hours to several weeks with large amounts of deficit energy, and similar periods with large amounts of surplus energy. Due to the variability of wind and solar power, Europe will see larger variations in power generation leading to needs for flexible alternative capacity over multiple time scales including minutes, hours, days, weeks and seasons. Flexible generation capacity over these horizons will be needed to ensure a stable and reliable power supply.

In this report we present two different scenarios. In one of these, we assume that Carbon Capture and Storage (CCS) technologies are implemented commercially. In the other, we assume CCS it is not available. In both scenarios we focus on the role of Norwegian renewable resources and natural gas in the European power mix. The power generation technology mixes in Europe in 2050 in the two CenSES scenarios are shown in Figure 1. At a European level the analysis show that a balanced deployment of wind and solar, along with some natural gas power production is the cost-efficient pathway for a deep decarbonization of European power production. When CCS is allowed, use of natural gas is substantial, effectively doubling the share of natural gas in the mix compared to the situation without CCS, however, the system is still dominated by intermittent renewable and hydropower production.

The role of Norwegian hydropower and wind

Our studies confirm that in both scenarios, Norwegian renewable resources are attractive. As an assumption we have limited the amount of new potential installed capacity in Norway of onshore wind to 28 GW and of total regulated hydropower to 25 GW. The analysis suggests that a full development of this onshore wind potential along with some investments in new regulated hydropower will provide the optimal strategy for utilization of Norwegian resources when decarbonizing European power. Also, a substantial amount of off-shore wind is suggested, in particular in the case where CCS is not an available technology. The Norwegian resources are attractive because of the good conditions for energy production the covariation

pattern with European resources. Installed capacities (GW) in Norway in the two scenarios are shown in Table 1.

	2015	Baseline 2050	NoCCS 2050
Hydro regulated	22	25	25
Hydro RoR	8	8	8
Pumped hydro	1	1	4
Wind onshore	1	28	28
Wind offshore	0	20	81

Table 1: Installed capacities in (GW) the Norwegian system in 2050 in the two CenSES scenarios. For reference we include the 2015 numbers.

A substantial part of the value of Norwegian resources comes from the flexible hydropower. The CenSES studies show that hydropower reservoirs are used actively to maximise the value of flexibility by:

- Utilizing price variations over the day coming from both variations in European wind generation and the uneven generation from solar PV with its daily peak in the middle of the day. The studies show that the cables are used actively to import and export energy during the day utilizing price differences to generate a net profit for Norway coming from the flexibility of our system (see Figure 3).
- Utilizing that a major part of the needs for supplementing generation in Europe occur due to variability of wind on a weekly scale, with periods of high and low wind, typically from a few days up to a couple of weeks. There are long periods where there are significant imbalances between renewable generation and the load in the Northern-European power system, making the flexibility of hydropower reservoirs and natural gas systems valuable.
- Utilizing that there are differences between the seasons in European load and generation, making it attractive to change the import/export patterns based on time of the year and using the hydropower reservoirs to store water between the seasons. A main difference is that during summer, there is more pronounced effects of high solar PV generation in Europe with more import and less exports in these hours.

In addition, other studies by SINTEF and NTNU show that there is a high potential for creating value by European cooperation around short-term balancing services related to reserves and regulation power. This will require that European countries increase cooperation on these services. Markets should be developed that values these services high enough to incentivise investment in and reservation of the cable and generation capacity needed to collect this value.

The existing Norwegian hydropower system is flexible mainly due to the large storage capacity of 85 TWh in the Norwegian reservoirs. This storage volume has most of the time at least 10-20 TWh free capacity (see Figure 2). Studies from FME CEDREN shows that it will be necessary to build new PSH and to increase capacity in existing plants, but there is no need to build new reservoirs. All storage will use existing reservoirs within existing operational limits, which lead to no or less environmental impacts and social conflicts, compared to the construction of new reservoirs.

The conclusion is that Norwegian resources are attractive to develop and of potentially high value for Europe, both because of its flexibility and because of the attractive characteristics of the wind resources.

We do not study any changes in Norwegian energy demand, for example by increased national use. This would be an alternative to the net export suggested by the model studies and could potentially increase the value of Norwegian resources further.

The role of Norwegian natural gas in the power system

The balancing capabilities of hydropower are well known, but the potential to provide the same kind of services in the natural gas systems (fields and pipelines) is potentially equally high but less explored. A predicted variation in the consumption patterns for natural gas in the power system in typical weeks in 2050 is illustrated in Figure 4. It shows how natural gas can play a role as an important flexibility provider for the European power market. The large variations in electricity production from natural gas indicate that it could be valuable to offer flexible deliveries to Europe from the Norwegian natural gas pipeline system. This is flexibility that is needed in addition to the balancing from the hydropower system. For seasonal balancing, the production levels in the field can be varied. For the short- and medium term from hours to weeks, conventional natural gas storages as well as the storage capacity in the natural gas pipelines can be used to smooth variations in demand. We see in particular in summer the effects of high solar PV penetration. In some weeks natural gas use is strongly reduced in the middle of the day, in other weeks it is only present as peak generation.

The Norwegian natural gas pipelines are highly utilised and will be so the coming decade, providing a cost-efficient energy supply network to Europe. Utilisation of the storage capacity in the pipelines may offer additional value in the future under such situations. To achieve this, commercial flexibility services needs to be developed. We recommend that the trade-offs between increased costs and the potential value provided by these by such storage services is further investigated, and that relevant business models should be explored.

Recommendations

Our analysis shows that Norway can contribute to the European flexibility and storage needs with both hydropower and natural gas at many different time horizons. Hydropower can be used for providing flexibility in most time horizons from seconds, via hours, days, weeks and up to seasons.

Renewable energy:

If Norway wants to take a larger role as a provider of flexibility, more investments in HVDC cables to Europe are needed. To fully utilize the Norwegian resources, European cooperation on investments in the energy system needs to increase. Through the Energy Union, cooperation on market integration in intraday and spot-markets and to some degree short-term balancing markets increase in a positive way. The countries still tend to invest based on national interests related to welfare, jobs or security of supply. For countries like Norway that would invest in order to provide energy or services for other countries, that creates policy uncertainty related to the demand for the products. That policy uncertainty could prevent full utilization of the Norwegian resources, as potential investors face uncertainty on the demand side coming from political choices rather than from the markets.

- We recommend entering into EU-wide collaboration agreements or multilateral agreements between countries in order to reduce uncertainty by addressing the division of costs, revenues and risk between the participants in the relevant time-horizons.
- Capacity markets for generation is one mechanism that can be uses to promote coordinated investments. Norway should take an active role to ensure that these markets are not introduced nationally and uncoordinated. This is a major governance challenge that must be addressed.

In order to provide balancing services in the very short run, capacity in both cables and generation must be reserved. The trade-off related to using the capacity for energy exchange instead must be considered in pricing of such services, reflecting that the energy volumes are small but the value high.

- If capacity is going to be built to provide more of this short-term flexibility, cross-border markets for such services needs to be further developed and secured in the long run.
- It will be necessary to decide what tariffs should be used both for direct transmission of energy between countries and for cross-border transit as well as for system services mainly established to provide flexibility in the very short run.

The full utilization of Norwegian renewable resources requires more cables for import/export and a strengthening of the Norwegian grid. Traditionally, Norwegian consumers have taken the cost of grid investment. It can be argued that this is fair for parts of the infrastructure investments needed for domestic offering of balancing services in Norway and reducing security of supply issues. Parts of this new capacity will most likely benefit the consumers through increased security of supply and more stable prices.

- When it comes to net export of energy, capacity services and balancing services provided to other countries on the other hand, it is more difficult to argue that Norwegian consumers should cover the cost. A new regime for cost distribution related to the building of new cables with this purpose needs to be developed if the Norwegian renewable potential is to be fully utilized.

Natural gas in the power system:

- Our studies show that without CCS natural gas may still play a major role in the power sector in 2030 and 2040, but in 2050 the volume of natural gas used by the power sector in the NO CCS scenario is only half of the volume suggested if CCS is successful as a commercial technology. It is important to further support the commercialization of CCS value chains in order to secure the use of Norwegian natural gas.
- Although natural gas with CCS somewhat reduce the share of renewables in the generation mix, there are system benefits which can provide an argument for the positive side of this. Firstly, the availability of CCS reduces the need for over-investments in renewables which tend to cause substantial amounts of curtailed generation, even when inexpensive energy storage and demand response measures are available as investment options. Secondly, the need for transmission investments are reduced, saving system costs and thus reducing consumer prices. And lastly, having controllable generation capacity in the system will increase security of supply.
- Natural gas complements hydropower with the capability of pipelines to provide substantial flexibility in the horizon from hours to a few weeks and between seasons, using the storage capacity of pipelines as well as the seasonal storage capabilities in

reservoirs. Natural gas power production in a system dominated by fluctuating renewable generation will be highly varying, with steep ramps and significant differences between production peaks and valleys, see Figure 1. This will require a flexible and secure fuel supply.

- For natural gas, new services, business models, commercial terms and legislation is needed to promote flexibility services in the pipeline system. Today the gas storage capacity in the pipelines is reserved for security of supply purposes. It may require a change in legislation to offer part of this capacity as a commercial service, and Norway should take an active stance in identifying viable pathways for further development in Europe.

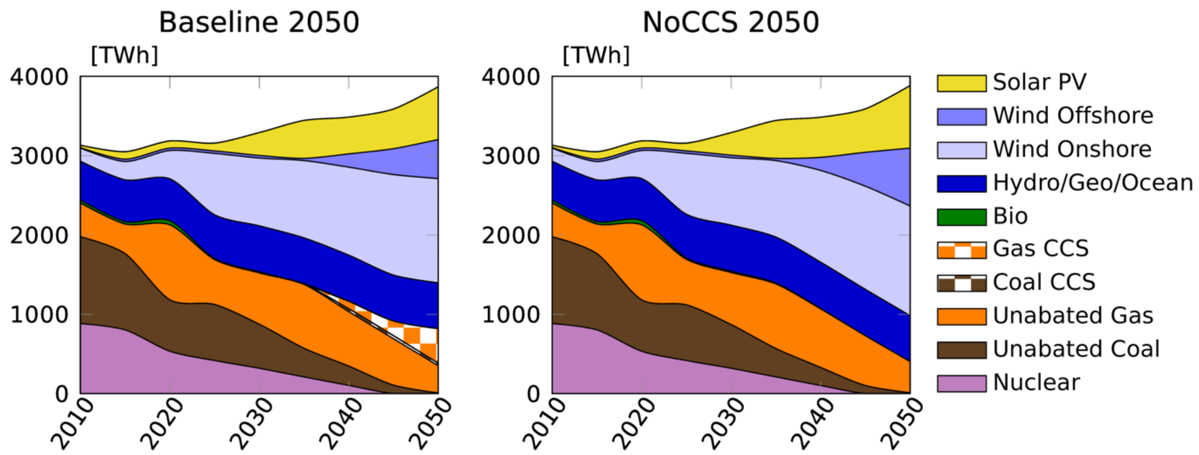

Figure 1: Generation mix in Europe in 2050 in the two scenarios based on EMPIRE analysis.

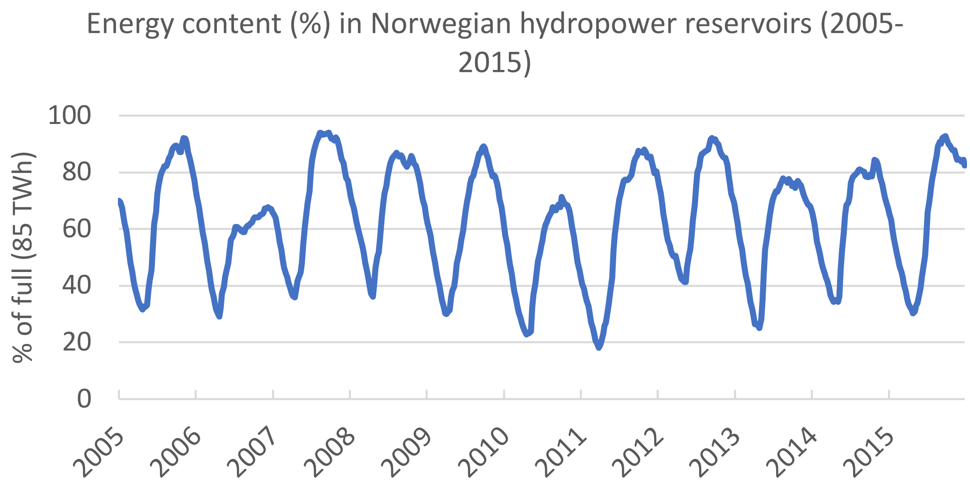

Figure 2: Energy stored in Norwegian hydropower reservoirs. (Data from NVE).

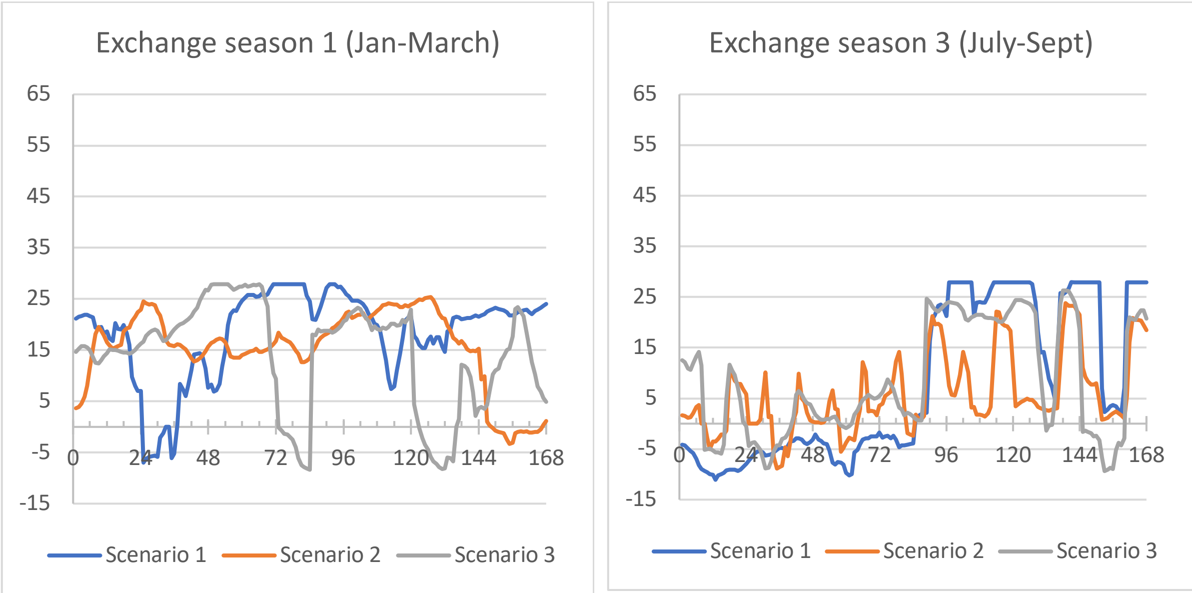

Figure 3: The exchange of electricity to and from Norway in 2050 in the baseline scenario with CCS. The figure shows the net exchange (GWh/h) for 168 hours in season 1 (Jan-March) and season 3 (July-Sept) . Positive values are export of electricity, while negative values are import of electricity.

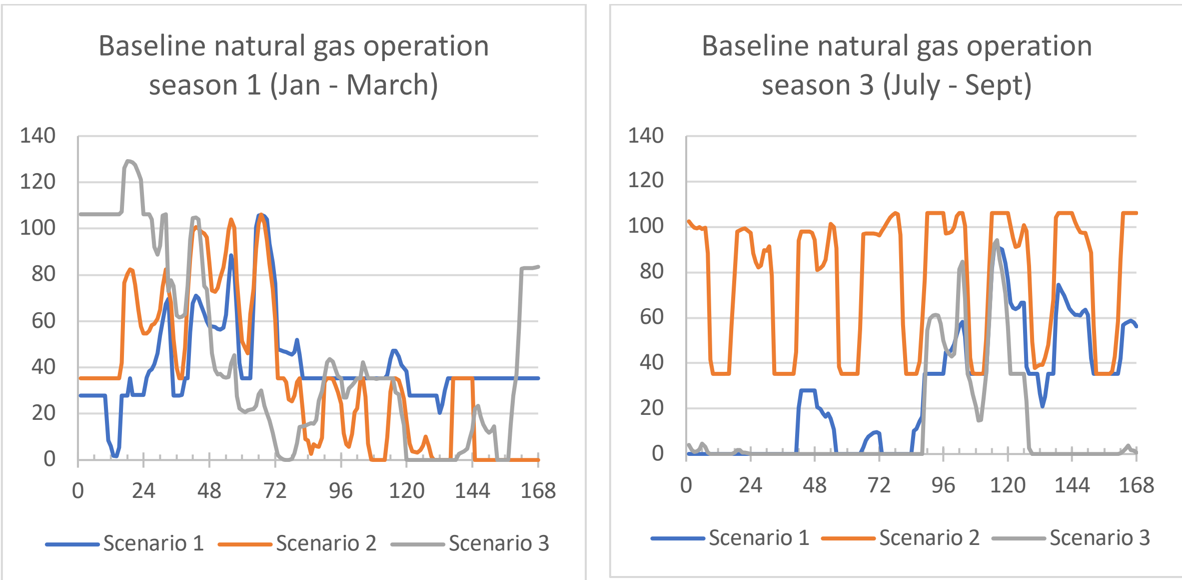

Figure 4: Illustration of the electricity production from natural gas in the four countries where Norway has an export pipeline (UK, Germany, France and Belgium) The graphs show the variation in production (GWh/h) over 168 hours for 3 different days within the season from January to March and July to September in typical weeks in 2050.