Norway as a flexibility provider for a low-carbon European energy system

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Overview

In the transition to a low-carbon future European energy system the shares of intermittent renewables will continue to increase. This imposes challenges in terms of balancing supply and demand of power as significant parts of the generation capacity will be non-controllable. Previous studies have shown that the Norwegian hydropower resources, with an installed capacity of about 30 GW, 85 TWh reservoir capacity and approximately 130 TWh annual production, can be a valuable low-carbon balancing resource (Graabak & Korpås, 2016). However, the ability to use Norwegian hydropower to balance intermittent power production warrants an increased transmission capacity as discussed in Farahmand et al. (2013) and in the recent Nordic Energy Technology Perspective 2016 by IEA (IEA, 2016).

Another source of flexible power production which can help balance fluctuating renewables is natural gas. As a significant natural gas exporter, it is important for Norway to be flexible in its deliveries in order to allow for natural gas power plants to operate dynamically.

In this study we will look at how Norwegian hydropower function in a European power sector decarbonization by providing flexible low-carbon power production. We will also focus on the role of natural gas in countries to which Norway exports to see how the operation of the supply infrastructure can be impacted by a more fluctuating production pattern.

Methods

Using the power system investment model EMPIRE, see Skar et al. (2016), we analyse, given a carbon reduction policy, the cost-optimal transition of the European power sector from today in five-year time steps until 2050. EMPIRE is formulated as a multi-horizon stochastic program where investments and operation are co-optimized, and the investment decisions are subject to uncertainty about annual operational conditions (e.g. load and intermittent production profiles). This allows the model to compute investments which are more robust to variations in yearly weather patterns. Generation, cross-border interconnectors and storages are considered.

We use EMPIRE to optimize the system development for two pathway scenarios, a baseline scenario and a scenario where carbon capture and storage (CCS) is not available. In both scenarios we impose a carbon emission constraint which linearly decrease emissions in the European power sector by 90% from 2010 to 2050.

As we include the Norwegian hydropower resources and interconnector capacities from Norway to connected European countries this study provides a perspective of how Norway can contribute to the European decarbonization as an integrated part of the system. Also, results from EMPIRE can be used to study the role of natural gas in the emission reduction pathways, both its total share in the fuel mix and the operational production pattern of the power plants. The latter information is used to evaluate the necessary flexibility in the Norwegian natural gas supply to Europe.

Results

Sample results from EMPIRE for the two scenarios are shown in Figure 1 (European power sector energy mix) and Figure 2 (hourly utilization of Norwegian hydropower).

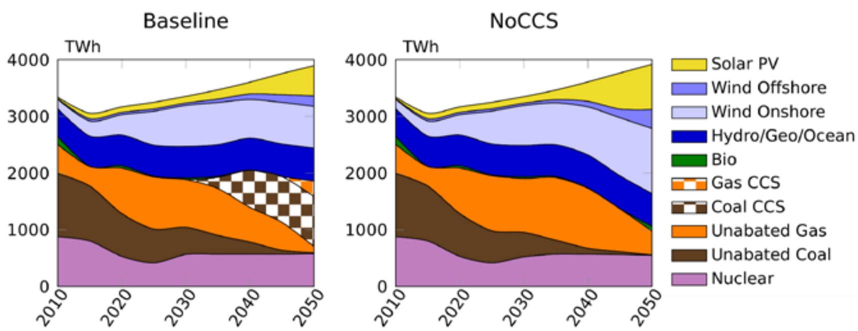

Figure 1: Comparison of the optimal energy mix computed by EMPIRE for two decarbonization scenarios for the European power sector.

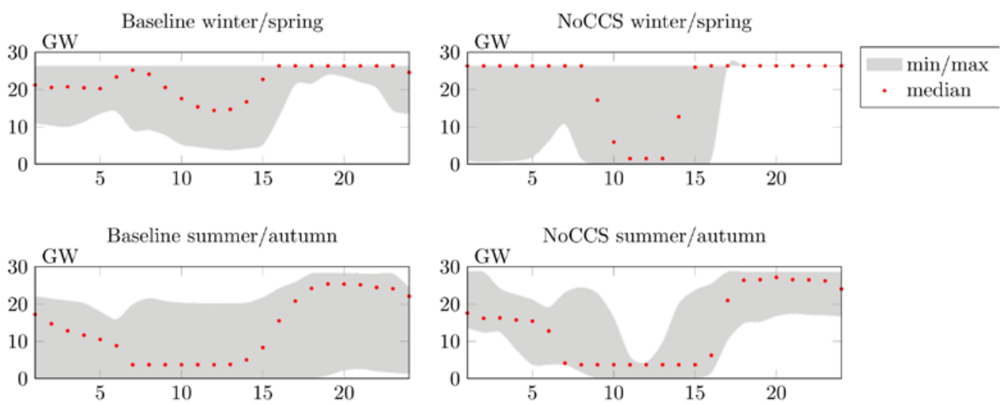

Figure 2: Statistics of daily variations in Norwegian hydropower production in 2050 for selected seasons in the Baseline and NoCCS scenario

Conclusions

The optimal expansion in transmission capacity between Norway and connected countries is highly dependent on the scenario. In the NoCCS scenario, the total exchange capacity between Norway and its neighbors is double that of the baseline scenario. There are large differences between daily production profiles of Norwegian hydropower, although there is a clear trend that the production is decreased during mid-day when the European solar power production peaks. This indicates that Norwegian hydropower is being utilized as a balancing measure for renewables.

Our decarbonization analysis shows that naturals gas plays a significant role as a bridging fuel in the period 2020-2030. Beyond 2030 the role of gas is highly dependent on CCS deployment. The operation of natural gas fired power plants tends to be stable baseload for plants equipped with CCS and highly dynamic, with low utilization, strong cycling, steep ramping for unabated plants. This will require significant flexibility in natural gas supply system and the infrastructure has to be designed and operated to accommodate large fluctuations in the offtake.

Policy implications of the above findings will be further discussed in the presentation.

References

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