THE PROSPECT OF A LARGE-SCALE WIND FARM IN THE NORTH SEA ON GAS AND ELECTRICTITY INFRASTRUCTURE INVESTMENTS TOWARDS 2050

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Overview

The transition to a low carbon energy system is creating challenges in multiple fronts. In the electricity sector, this largely means accommodating a large share of Renewable Energy Resources (RES), while for the gas sector, it mainly involves re-routing gas in a short period of time to provide fast ramping response from gas power plants to RES fluctuations. This is especially evident in EU countries facing a major energy transition on its power system such as Germany and the UK, which are dependent on gas coming from the Norwegian continental shelf and are expected to have a large RES share. Even more so, if the European electricity grid faces difficulties in expanding cross border capacities, gas power plants could be the main flexible supply option between 2030 and 2045.

An alternative or a complement to the European gas infrastructure could be the development of the large Wind Power Hub in the North Sea, which according to our model results would allow a 75% higher offshore wind production. The Wind Power Hub implies a spatial spread of offshore wind power and a reinforcement of the cross-country interconnections through the North Sea (see Fig 1.).

Methods

To analyse the effects and evolution of the energy infrastructure towards 2050, we use multi-horizon stochastic programming models to represent long-term infrastructure investment decisions. On one hand, for the electricity sector, we implement the EMPIRE model (Skar 2016, Marañon-Ledesma et. al. 2018) which performs country-level investments in generation capacity and inter-country exchange capacity investments. EMPIRE represents hourly generation dispatch decisions by technology type per country along with cross-border flows interactions. On the other hand, for the gas sector, the RAMONA model (Fodstad 2016) is a capacity expansion model of the European gas grid. Given the gas demand evolution and indigenous gas production in each European country, the model outputs the optimal expansion and operation of the gas grid.

We analyse a case with no transmission expansion possibilities. We assume that current ENTSO-E expansion planning holds up to 2025, but no further endogenous expansions are allowed in the model. This case is compared to our reference case, in which we assume flexible demand from industry, services and residential sectors and an optimist battery storage cost evolution. Carbon Capture and Storage is not considered as a technology in either of the cases and nuclear has limited prospects. It is expected that much more installed capacity will be needed in each country to cover the individual demands with respect to the case where transmission expansion is allowed. The third case focuses on the future North Sea super grid generation and transmission possibilities. The North Sea Wind Power Hub (WPH) is a large-scale offshore wind project located in the northeast end of the Dogger Bank. Five project stakeholders (TenneT Netherlands, TenneT Germany, Energinet.dk. Gasunie and the Port of Rotterdam) signed a memorandum of understatement to investigate the capabilities of the WPH. The island, which will work as a hub for several clusters of wind parks, will be developed from 2030 and completed in 2050. The countries that would be potentially connected are Germany, UK, Denmark, Netherlands and Norway (Solli 2017).

Since there is no possibility to cover the demand from other neighbours' RES generation, each country requires capacity from affordable and low carbon emission technologies like gas. The objective is to see how important gas could be in the generation mix up to 2050. Will there be much more generation from gas in a low transmission capacity situation? Will that happen constantly between 2030 to 2050 or just between 2030 and 2040? However, gas is not the only alternative to satisfy the energy needs in North-western Europe. The WPH capacity could dampen the needs of backup capacity from gas plants.

Results

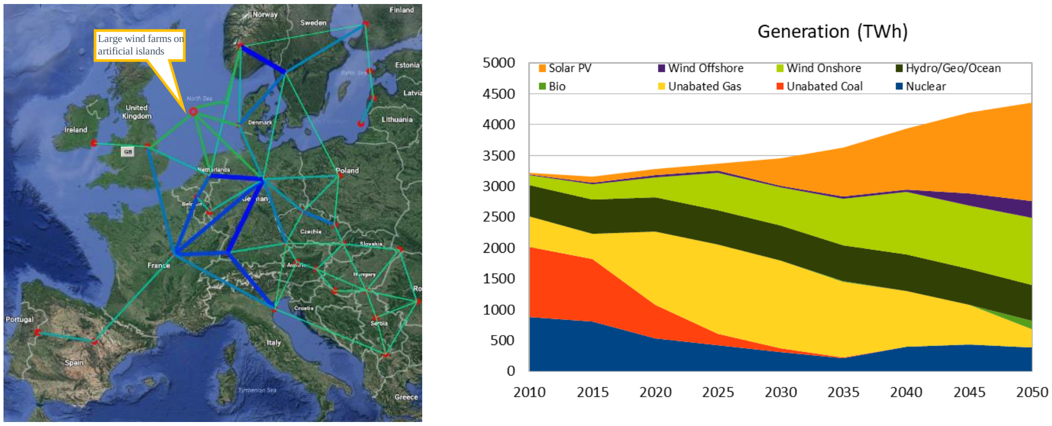

Figure 1: EMPIRE and RAMONA models' spatial resolution. Results of the generation mix for the NTE case.

The results show that in the no transmission expansion case (NTE) there is more installed gas capacity and more electricity gas generation (both from Open Cycle Gas Turbines and Closed Cycle Gas Turbines). Starting from 2030, when high CO2 emission costs are expected, there is high electricity generation from gas. The difference with the reference case between 2030 and 2045 varies between 160TWh and 255TWh. That means as much as a 6% gas energy difference with respect to the total energy mix. For offshore wind generation, the results illustrate an increase of up to 100% in NTE, while the relative differences in onshore wind and solar are low. The reason is the need of extra capacity when there is a lack of transmission capabilities – even though offshore wind is one of the most expensive technologies. That aligns with the possibility of supplying offshore wind energy from the North Sea wind hub. It is expected that the availability of the wind hub will decrease the dependency of the system on gas.

The effect on the North Sea countries (Belgium, Germany, Denmark, France, United Kingdoms, Netherlands, and Norway) is significant. In 2030 the gas electricity generation is 3% higher in NTE and in 2050, 13% higher.

The WPH case shows significant differences with the NET. The 70GW capacity of the WPH from 2035 reduces the gas electricity generation in the corresponding countries, especially in Germany and the UK, which have the highest gas electricity generation. The WPH affects the energy mix by reducing the generation from gas and nuclear power. The capacity mix is less affected because those capacities are needed during moments of low wind production. The share of offshore wind in the 2050 generation mix increases by 75% with respect to the NET case (additional generation from the WPH). The pillars of 2050 generation mix are wind and solar power, which are not affected by the generation from the WPH. The decreasing generation effects are distributed on nuclear and gas generation.

Conclusions

Wind offshore will double under the installation of the WPH. The production from the WPH is beneficial for the North Sea countries, in a context of low transmission capacity expansion. Specially imports dependent countries (UK, Netherlands and Denmark) improve their energy mix since they can import the WPH production and import electricity from the connected countries. From a system perspective, the WPH increases the spatial wind distribution, which alleviates the fluctuating wind and solar production in some countries. In addition, the wind hub acts not only as a source of energy production, but also might be an alternative transmission capacity route to exchange power among North Sea countries.

References

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