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North Sea region energy system towards 2050: Offshore grid and sector coupling drive offshore wind installations

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Abstract

The North Sea offers high offshore wind power potential. In addition, several existing and planned transmission lines are located in the region. This paper models a meshed offshore grid in the North Sea to investigate the viability of connecting transmission and offshore wind generation investments. Generation and transmission investments, both onshore and offshore, and storage, are optimized to reach an integrated offshore grid scenario towards 2050 for the region. For comparison, a project-based scenario, where each offshore wind power plant is connected individually, is also analysed. The two scenarios are compared with focus on costs and variable renewable energy (VRE) shares.

This paper studies also the expected effects of sector coupling in the North Sea region. Electricity and heating sectors are optimized jointly towards 2050, with electrification of industry, district heating expansion and electric vehicle penetration considered. Electrification increases electricity consumption; however, the heating sector has also potential to provide flexibility to the system. The results show that sector coupling drives renewable energy investments higher, with offshore wind capacities significantly increased, helping Europe towards decarbonizing the whole energy system. Sector coupling can also provide flexibility to the power system, e.g., in utilizing heating sector flexibility. However, markets need to be highly integrated to reach these benefits.

Objectives

This paper studies the expected impacts of sector coupling and meshed offshore grid on the North Sea region. VRE shares, especially offshore wind installations, are compared in different scenarios to assess the impacts of these developments on the energy system towards 2050.

The presented work is part of the NSON-DK project, which studies how the future massive offshore wind power and the associated offshore grid development will affect the Danish power system on short term, medium term and long term towards a future sustainable energy system (www.nson-dk-project.dk).

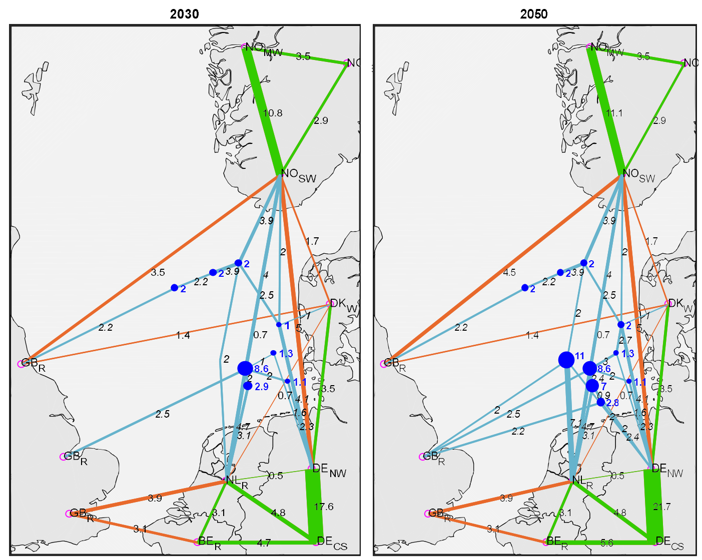
Methods

For energy system optimization, the Balmorel model (www.balmorel.com) [1] is used. It supports joint optimization of the electricity and heating sectors and analyses both transmission and generation investments. Balmorel is also used to model economic dispatch and unit commitment to simulate hourly dispatch from the generators in North Sea region countries. Joint modelling of the electricity and heating sectors allows assessment of benefits from integrating the markets of the different sectors.

The CorRES tool [2] is used to provide the wind and solar generation time series for Balmorel. CorRES models both the varying capacity factors depending on installation locations and the spatiotemporal dependencies in wind and solar generations. More information about the scenarios is given in [3].

Results

Transmission line and hub development [GW] towards 2050 in the integrated offshore grid scenario is shown below. A mixture of country-to-country offshore interconnectors (orange), meshed grid development (light blue) and onshore transmission reinforcement (green) is found optimal. Hub-connected offshore wind installations (dark blue) lead to approximately 10 GW more offshore wind by 2050 compared to the project-based scenario, as seen in the table. The integrated scenario shows lower system costs than the project-based scenario.



Year	Scenario	Electricity generation [TWh]	VRE generation share	Renewable share	Offshore wind installations [GW]
Starting point	Assumed by 2020	1199	28%	46%	22
2030	Project-based	1188	55%	75%	64
	Integrated	1193	56%	76%	69
2050	Project-based	1192	70%	88%	92
	Integrated	1207	72%	89%	102

The result above show stagnant overall electricity generation towards 2050, as sector coupling was not considered. However, with sector coupling modelled, electricity generation increases significantly, as can be seen below. Already by 2045, this drives offshore wind installations to approximately 27 GW higher than in the comparable project-based scenario above by 2050 (the studied scenario years are different due to some changes in the modelling).

Scenario year	Electricity generation [TWh]	VRE generation share	Renewable share	Offshore wind installations [GW]
2025	1318	28%	50%	27
2035	1329	67%	89%	107
2045	1447	75%	93%	119

Conclusions

1. Integrating offshore transmission and generation investments can be beneficial and lead to overall cost minimization in the North Sea region
2. Sector coupling is expected to boost renewable energy investments significantly, and power systems can benefit also from the increased flexibility
3. Going to an integrated North Sea offshore grid and unleashing sector coupling can increase offshore wind installations in the region by tens of GW

However, to reach these results, strong market integration, both geographically and between the different sectors, is required

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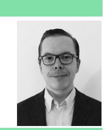

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