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European Electricity Grid Infrastructure Expansion in a 2050 Context

Abstract submission

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1 Overview

The European climate policy targets until 2050 require an adaptation of the generation portfolio in terms of renewable and fossil based generation. In energy system models assumptions on the timeline of the targets and the availability and costs of generation technologies are used to optimize the cost-minimal system transformation. The results of these calculations include investments in generation technologies and their national allocation. Yet, the models currently used are limited to national aggregation and lack the spatial resolution required to represent individual network investments and related costs. In this paper, we analyse the impact the results of an energy system model have on the network demand in the European power grid in a line-sharp grid representation. A cost minimizing mixed-integer problem (MIP) model calculates where in the European electricity grid extension needs to take place for different time steps (2020/30/40/50) in order to obtain a cost minimizing power plant dispatch and grid expansion. Scenarios based on the generation infrastructure options from the PRIMES EU-wide energy model scenarios invoke different expansion needs and are compared. The model allows investments in the AC network and an overlay DC grid. Resulting investment costs are compared to the numbers of the European Energy Roadmap 2050.

2 Methods

We formulate an investment model as a Mixed Integer Linear Problem (MILP). It contains two decision levels, the transmission investment and the market dispatch. These two stages are reduced to one level assuming perfect competition and a European central planner that expands the transmission network with the objective to minimize total system costs. The total system costs include the variable system cost of operation and the infrastructure cost of network investments. The applied methodology does not include combined investments in generation and transmission as the generation capacities are exogenous parameters provided by the EMF28 framework for the different scenarios.

Each time step accounts for 10 years and for 2020, 2030, 2040, and 2050 the model optimizes the network topology in regard to the EMF28 scenarios thus applying a rolled planning approach, as the results of one calculations is the starting grid configuration for the consecutive time step.

3 Scenarios & Results

The results of the calculations for three scenarios provide interesting insights in the grid expansion that is needed to provide a dispatch while achieving minimal total cost. The EU6 and EU10 scenarios target an 80% GHG reduction until 2050 which imposes a significantly different generation mix that leads to more transmission investments. Furthermore the EU10 being a “green” scenario with the highest increase in RES is expected to have the highest expansion cost of all scenarios.

The scenario EU1 shows the lowest overall total investment both in terms of cost and kilometers with € 31 bn compared to the EU6 and EU10 scenarios with about € 57 bn. The total investment cost for EU6 and EU10 do not vary significantly. Therefore the difference between the “default” and the “green” scenario is not directly evident. While most of the investments in the EU6 scenario occur in the first three time periods, in the EU10 scenario 43% of the total investment sum is spent in 2050.

Looking at the investments in the DC grid infrastructure a trend can be observed as well. Only few HVDC lines are built, with the main characteristic of almost all lines being offshore-lines.

4 Conclusions

In this paper we explore model-based development scenarios for the future European electricity grid. Our point of inception are three scenarios for European electricity generation capacity, that differ i) by the degree of CO_2-reduction (40% and 80% compared to 1990, respectively); and ii) by the share of renewables in the generation portfolio (medium and high, respectively). We use a node- and line-sharp model of the European electricity market with a high granularity of technical-economic detail. We are particularly interested in the future architecture of the network, and the interplay between AC- and DC-development.

In a European-wide analysis, we find that a strongly-meshed HVDC-network is unlikely to emerge. Note that this is in contrast with most of the literature, which assumes a future HVDC-meshed European grid. Instead, our model results suggest that the lowest cost feasible solution seems to be the upgrading and extension of the national AC networks, and the extension of AC interconnectors between countries. Thus a sensible expansion of the 380kV AC grid can to a certain degree substitute the development of a DC overlay grid. This is particularly visible in the EU10 scenario where only a single onshore DC connector between neighboring countries is built despite high transmission demand.

The different assumptions for each scenario have a significant influence on future transmission needs. Especially climate-oriented goals like GHG emission targets determine the grid capacities needed as renewable generation and demand are often geographically spread far apart. Comparing the scenario EU1 against EU6 and EU10 the resulting grid expansion in the low emission scenarios is almost twice as strong both in terms of kilometers as well as investment cost.

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