Assessing and improving resiliency of the electricity system in sector-coupled energy system models

Themenbereich 7 – Energiesystem- und Klimamodellierung
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Motivation and central research question

The global energy transition requires a massive re-thinking of the ways we generate, consume, and transform energy. To achieve the set climate targets of 100% emission reductions in 2045-2050 [1,2], heavy electrification, combined with a significant expansion of variable renewable energy sources (vRES) is required. This drastically increases the complexity of the electricity system, which needs both short- and long-term storages, to bridge gaps in renewable generation. Considering the uncertain nature of fluctuating renewables (and the possibility of extreme events such as floods or droughts), the question remains how robust cost-optimizing energy system modeling results are in terms of supply security.

Methodology

There are multiple ways of dealing with such uncertainty in numeric modeling. One solution to include this into optimization models is by using stochastic modeling approaches, which, however, drastically increases the complexity of the process, usually requiring simplifications in other areas. Instead, this paper proposes using ex-post analyses on energy system modeling results from the Global Energy System Model (GENeSYS-MOD), an open-source, cost-optimizing energy system model, focused on long-term analyses of energy system developments for the sectors electricity, buildings, industry, and transport. [3] One general problem with cost-optimizing models is that the resulting energy system will usually be "on the edge", just barely fulfilling the set demands, in order to save costs. This can of course be counteracted by using appropriate constraints, implementing buffers for unforeseen events outside the model scope. Still, the result is heavily dependent on any input assumptions, especially also of renewable timeseries, which are usually taken from one or a few "representative" weather years. Here, the results for the 100% renewable energy system in 2050 generated by GENeSYS-MOD will be tested using a full-hourly electricity dispatch model (see Figure 1), for a multitude of different weather years. This process will then show the adequacy and robustness of the overall system.

Results and Conclusions

By performing an ex-post analysis of the generated energy system for Europe, the overall robustness and resilience to outside shocks, such as renewable droughts, can be assessed. Expected results should show that the results are generally fine for average weather years, and especially those that have been used in the original model set-up, but will most likely fail when more extreme weather years are considered. By using the insights into the amount of unmet demand and shortages of peak capacities, a feedback loop into the energy system optimization can be established, creating new boundary conditions and constraints that force a more robust system setup. This would then trade an increase in system costs for improved security of supply, and showcase where these measures are the most cost-efficient (e.g., the choice of flexibility options, such as grids, storages, hydrogen, etc.). By performing the analysis using a Pan-European model set-up, an analysis of most affected countries can be performed, enabling a targeted improvement of the nodal model set-up.

In general, the paper can therefore show the current shortcomings of many cost-optimizing energy system models, and give out recommendations for best practices into how to improve the results with respect to the high degree of uncertainty in a 100% renewable energy system.

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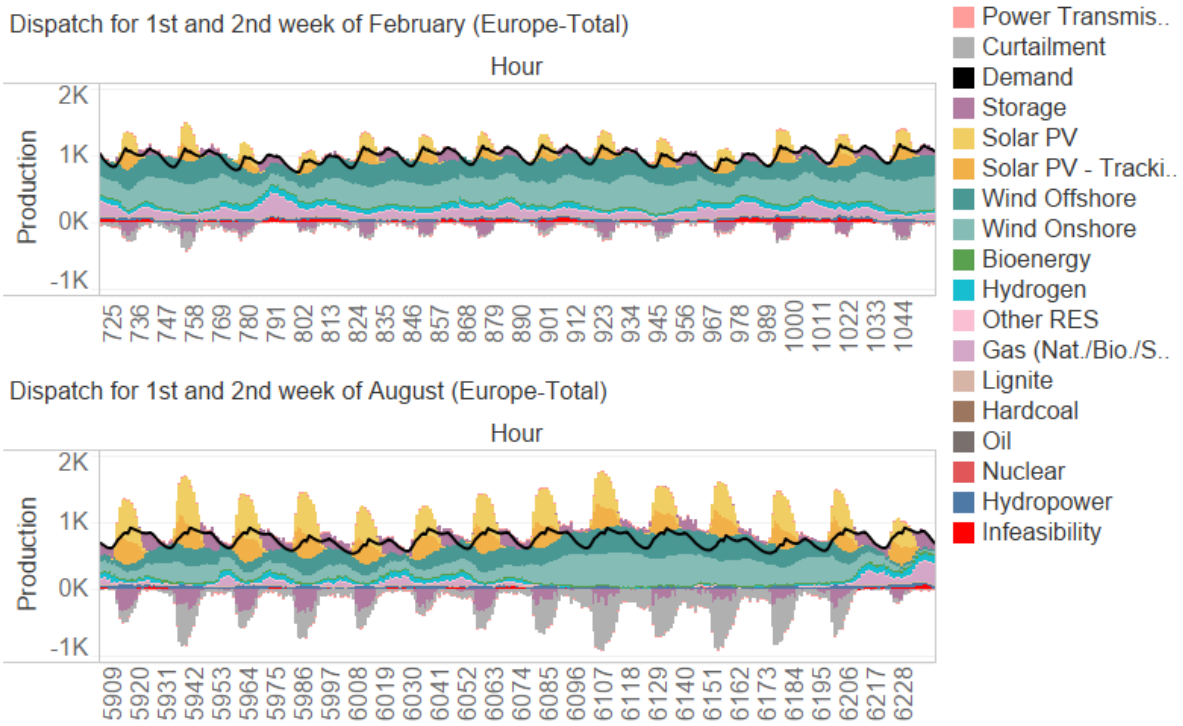

Figure 1: Hourly electricity dispatch results for an European energy system generated by GENeSYS-MOD

Literature

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