Uncertainty in energy system modeling – lessons from case-studies with GENeSYS-MOD

Themenbereich 7 – Energiesystem- und Klimamodellierung

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Motivation and central research question

Considering the tremendous effort necessary to transform the energy system, policy and decision makers rely on clear and adequate communication of findings and conclusions by researchers and practitioners. However, the current energy crisis showcases that reality is likely to look very different from model results and outcomes which highlights the requirement for model(er)s to provide insights about the system itself instead of single numbers and values. This raises the question of what best-practice examples for energy system modeling exercises are and which common findings and no-regret options can be communicated to policy and decision makers.

Methodology

Within the context of energy system modeling, various types of uncertainty must be accounted for. Following the classification of Peltz et al. [1], we define three types of uncertainty: (i) data uncertainty regarding parameter values of the past, present, and future, (ii) interaction uncertainty which describes possible inaccuracies in mathematical model formulation, and lastly (iii) system uncertainty since not all possible components of the future energy system are known to date. Different approaches exist in the field of energy system modeling, ranging from scenario over sensitivity analysis to stochastic optimization – each suited to deal with a different type of uncertainty (Figure 1, left). Therefore, this paper synthesizes findings from numerous case studies using the open-source energy system model GENeSYS-MOD to define and highlight common findings across multiple studies. Scenario analysis, sensitivity analysis, model comparison, and myopic foresight exercises are performed to address the transformation of the German and European energy system. In doing so, robust findings and no-regret options can be identified which can be used by policy and decision makers to base their decisions on. Additionally, all case-studies, data, and model code are published fully open source, allowing other researchers and practitioners to validate and verify the findings.

Results and Conclusion

First, best-practices with respect to modeling 100% renewable energy scenarios are identified. Open source is a major cornerstone; however, it is not applied sufficiently which leaves many open questions for policy makers or other non-modelers. Additionally, sectoral, regional and temporal disaggregation levels show high influence on model results but are typically not described adequately.

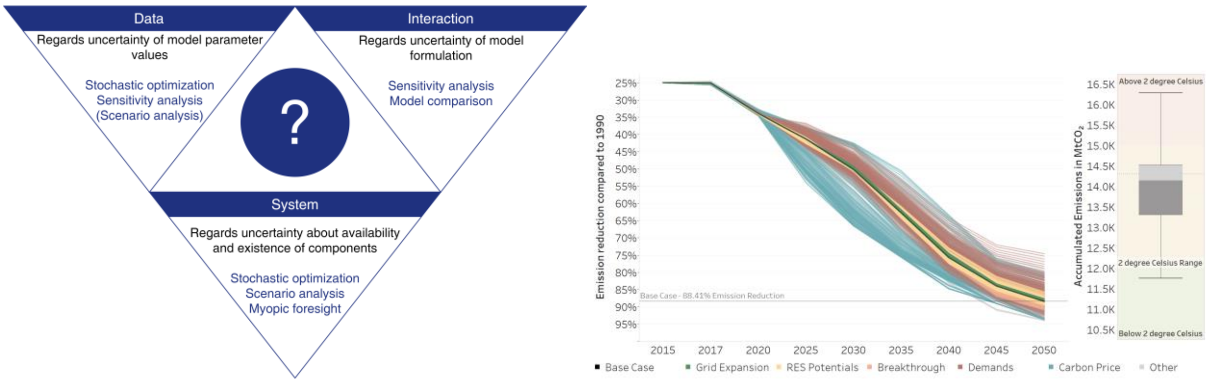

Figure 1: Types of uncertainty and how to hedge against it (left) and sensitivity analysis on the German emissions until 2050 (right). Sources: Own illustrations.

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Second, challenges for specific countries and unions of countries (e.g., European Union) are highlighted. To help with emission reduction, energy demand and carbon prices prove to be two levers which can significantly assist with that goal. As illustrated in Figure 1 (right), a sensitivity analysis on the German energy system shows that emissions are significantly affected by a carbon price in the intermediate term, while energy demand reduction show high effect long-term. Policy makers should focus on policies targeting these areas to achieve decarbonization targets.

Third, general no-regret options are identified, regardless of input assumptions or methodology, including: no need for fossil fuel capacity expansion, the need for immediate action, and electrification of all sectors. Overall, robust energy system analysis approaches are required to inform and assist policy makers and to transfer scientific findings into the political debate and decision process.

Literature

[1] Pelz, P. F., M. E. Pfetsch, S. Kersting, M. Kohler, A. Matei, T. Melz, R. Platz, M. Schaeffner, and S. Ulbrich. 2021. „Types of Uncertainty.“ In Mastering Uncertainty in Mechanical Engineering, edited by P. F. Pelz, P. Groche, M. E. Pfetsch, and M. Schaeffner, 25–42. Cham: Springer International Publishing.