THE IMPACT OF SECTOR COUPLING OPTIONS ON ELECTRICITY SYSTEMS – AN EVALUATION OF DIFFERENT FLEXIBILITY OPTIONS

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Overview

The challenge of decarbonizing the energy system involves not only the electricity sector, but also transportation and heating. Yet, there is no clear vision about how these sectors are going to merge into an integrated system with almost zero emissions. Given that the power sector is arguably easier to decarbonize, as well as the versatility of electricity as an energy carrier, a transition towards a fully renewable power sector is mandatory. Various studies show that this transition is driven by wind, solar PV and hydro-based generation (Jacobson et al. 2016; Ram et al. 2017; Gerbaulet and Lorenz 2017). However, future cost and technology developments are highly uncertain (e.g. power-to-gas or storages developments) which leads to no clear answer about the shape of future energy systems. In addition, model results are subject to underlaying assumptions about future demand patterns and development. More specifically, the level of integration of electric vehicles, smart-grids, demand-side management, economic growth and efficiency gains determines the resulting demand. Policies fostering a specific technology or influential stakeholders might also affect the development of technologies, which might be outside of the scope of the models despite their importance.

The presented work aims to analyze different power sector scenarios in a decarbonized energy system and determine the impact of different uncertain parameters. A focus is set on different configurations for sector coupling and resulting implications on flexibility options as well as system costs. Following variations will be subject to a sensitivity analysis:

1. The deployment of electric vehicles and their interaction with the power grid,

2. Costs for hydrogen-based technologies and the demand for hydrogen products (e.g. in the chemical industry or the transportation sector),

3. Conventional power demand,

4. And insulation of buildings, installed heat pumps and hybrid heating, resulting in different heat demand profiles and additional flexibility.

We use a model-based approach to identify determining factors on the generation expansion. The sensitivity to different realizations and implementation of sector coupling system costs, installed generation capacity and their generation, renewable curtailment, and electricity prices.

Methods

We use the open source electricity system model DIETER, developed by Zerrahn and Schill (2015). The model's objective is to minimize overall system costs, consisting of investment and operational costs. It was originally designed to analyze the role of flexibility options, such as power storages, demand-side management, prosumer influence, and electric vehicles. To accomplish that, the model is configured in a one-year greenfield setting where investment costs are annualized. Generation technologies are described by investment and operational costs as well as their operational flexibility. The dispatch is calculated for a whole year at an hourly resolution. Contrary to conventional technologies, solar PV and wind are considered as non-dispatchable energy sources and are characterized by a weather-dependent generation pattern. In addition, different storage options, such as pumped-storage or batteries, are considered to allow for an inter-temporal shift of load or generation, respectively.

The model has been extended with modules that introduce electrical vehicles and power to heat representations. For this analysis we additionally implemented a power to gas formulation to be able to compare different sector coupling possibilities and their impact on an optimal electricity system.

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Preliminary Results

Preliminary results show that certain varying parameters can increase the total system cost significantly. Electric vehicles that do not cooperate with the system operator force higher investments into capacities and storages. Also, higher hydrogen demand coming from transport and industry lead to higher system cost, but can reduce the required amount of other storage technologies significantly. Results are highly sensitive to the conventional electricity demand, efficiency and insulation of buildings. This is due to the high power demand of the building sector when considering high shares of heat pumps or electric heaters. On the other hand, hydrogen cost have little to no impact on the overall results apart from replacing storages. Further analyses have to be conducted to analyze interactions between the different factors.

Conclusion

Integrating the heat and transport sector into the power sector, coupled with uncertainty when it comes to technology and demand developments, can result in different future implications for the power sector. Each scenario yields different challenges for a decarbonized electricity system. Thus, understanding the implications of different sector coupling options on a electricity system is necessary. The presented sensitivity analysis yields some insights into effects of sector coupling.

References

Gerbaulet, Clemens, and Casimir Lorenz. 2017. "dynELMOD: A Dynamic Investment and Dispatch Model for the Future European Electricity Market." DIW Berlin, Data Documentation No. 88. Berlin, Germany.

Jacobson, Mark Z., Mark A. Delucchi, Guillaume Bazouin, Michael J. Dvorak, Reza Arghandeh, Zack A.F. Bauer, Ariane Cotte, et al. 2016. "A 100% Wind, Water, Sunlight (WWS) All-Sector Energy Plan for Washington State." *Renewable Energy* 86 (February): 75–88. https://doi.org/10.1016/j.renene.2015.08.003.

Ram, M, D Bogdanov, A Aghahosseini, A.S. Oyewo, A Gulagi, M Child, H Fell, and C Breyer. 2017. "Global Energy System Based on 100% Renewable Energy - Power Sector." Lappeenranta, Berlin: Lappeenranta University of Technology and Energy Watch Group. http://energywatchgroup.org/wp-content/uploads/2017/11/Full-Study-100-Renewable-Energy-Worldwide-Power-Sector.pdf.

Zerrahn, Alexander, and Wolf-Peter Schill. 2015. "A Greenfield Model to Evaluate Long-Run Power Storage Requirements for High Shares of Renewables." DIW Berlin, Discussion Paper 1457. Berlin, Germany: Discussion Papers, Deutsches Institut für Wirtschaftsforschung. https://www.diw.de/documents/publikationen/73/diw_01.c.498475.de/dp1457.pdf.