MODELLING ELECTRICITY STORAGE NEEDS IN EUROPE: A SEPARATION OF DRIVERS

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Overview

Wind and solar PV are the most relevant renewable energy sources in many European countries when it comes to decarbonizing the European economy. Recent policy proposals, such as the “European Green Deal”, underline their importance for the years to come. As the supply of renewable energy sources depends on weather and climatic conditions, it is variable and cannot be dispatched as needed. Increasing the share of such variable renewables in electricity demand, therefore, requires increasing flexibility in the power system to deal with this variability. In general, literature identifies spatial flexibility options, such as interconnectors between countries, and temporal flexibility options, such as electrical storage.

Several studies have estimated storage needs for Germany and Europe for high shares of renewables. A recent literature review by Cebulla et al. (2018) identifies a positive, linear relationship between renewable energy shares and optimal energy storage deployment. However, the exact future storage requirements for Germany vary considerably across studies (such as Agora Energiewende, 2014; Haller et al., 2012; Jägemann et al., 2013; Nagl et al., 2013; Pape et al., 2014; Scholz, 2012), even for the same renewable share in the system.

From a techno-economic perspective, interconnectors and storages are substitutes to a certain degree. Our paper intends to disentangle this trade-off. In an application for Germany, we aim to shed light on how and why the level of interconnectivity with neighbouring countries influences domestic storage requirements. Specifically, we separate the drivers for storage requirements in cross-border vs “Germany only” settings: (1) connection to each of Germany’s neighbours, (2) differences in countries’ load profiles, (3) differences in renewable generation profiles, and (4) differences in generation portfolios. In the literature, such systematic account of the trade-off between spatial and temporal flexibility and, especially, a systematic account how spatial flexibility influences the need for temporal flexibility is missing. We contribute to filling this gap.

Methods

To disentangle why and how spatial flexibility shapes the need for temporal flexibility we use the *Dispatch and Investment Evaluation Tool with Endogenous Renewables (DIETER)*. DIETER is a numerical optimization model of the European electricity system. It minimizes total system costs of providing electricity for one year in an hourly resolution. Central input data are time series of renewables availability and demand per country as well as assumptions on costs and availabilities of generation and flexibility technologies. The model endogenously determines the optimal dispatch and investment, taking into account hourly market clearing per country and a range of technical and policy constraints on the electricity system. The model has been applied previously to assess long-run storage needs for Germany (Schill & Zerrahn, 2018), and decentral solar PV and battery systems (Schill et al., 2017). For this application, the model covers Germany and its neighbouring countries, connected in a net transfer capacity model. Temporal flexibility options are short-term batteries, pumped-hydro storage, long-term power-to-gas storage as well as a representation of hydropower reservoirs.

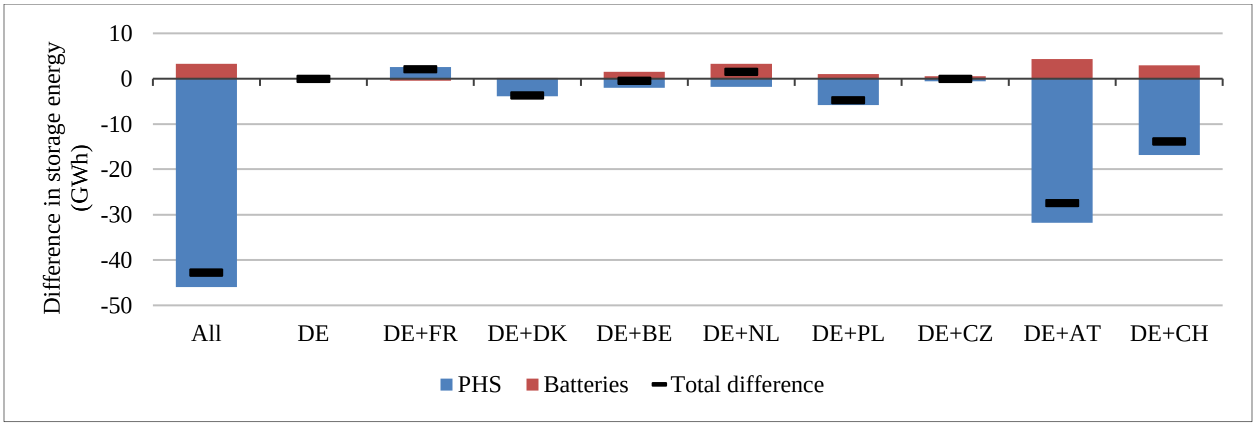
To disentangle the drivers of optimal storage requirements, we separate between effects related to geographical scope and country-specific factors effects. The latter comprise a country specific load profile, renewable availability profiles, and generator portfolio effects. To isolate geographical scope effects, we devise counterfactual simulations in which Germany is connected only to one specific neighbouring country. To isolate country-specific factor effects, we run counterfactual simulations with alternative load profiles, renewable generation profiles, and generation portfolios for the neighbouring countries. This adjustment preserves the total level of supply and demand in each country but equates the temporal patterns to the patterns of Germany. In a final step, we run simulations in which we let country and factor effects interact with each other.

Preliminary results

Preliminary results show, in line with the literature, that German storage requirements decrease with increased interconnection. In terms of the geographical scope separation, Figure 1 gives an overview of the results: especially

Austria and Switzerland drive down German storage need through their large hydro reservoir capacities. However, these results are strongly driven by the assumptions on their their operational flexibility. The impact of interconnections to other countries on German storage needs are only limited. Also in terms of the country-specific factor separation, hydro reservoirs dominate our first results. Differences in load and renewable generation profiles do not reduce Germany's storage needs substantially. Further robustness checks will include more weather years, an enhanced representation of reservoirs in the Alpine region as well as systematic variations in the interconnector capacities between countries.

Figure 1: Change in storage energy needs in Germany due to interconnections



Source: Own illustration; *Note:* PHS: Pumped hydroelectric storage

Conclusions

The identification of storage requirements is of high relevance for the design of future energy systems. To disentangle how and why interconnections with other countries affect storage requirements in one country, Germany, we apply an open-source numerical simulation model to a range of counter-factional scenarios. First results show that the interconnection between Germany and neighbouring countries drives down storage requirements. Specifically, this is due to access to flexibility options across the border and less so due to complementary patterns of demand and renewables feed-in.

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