Energy Economics Group

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Das Energiesystem nach Corona: Irreversible Strukturänderungen - Wie?

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The Transition to a Renewable Electricity System - the Role of Electricity Storage

Storage

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Motivation and research question

The goal of the European Union is to be climate neutral in 2050. To achieve this, with the "Clean energy for all Europeans package" concrete targets with a high share of renewables were set, implying that wind and solar generation will shape the European power system. Looking at the situation in Austria this development can already be seen, as electricity generation from intermittent sources such as wind and solar (excluding hydro) has already increased dramatically, from about 1.6 TWh in 2005 to over 9 TWh in 2020.
The resulting challenges have already been extensively discussed in the literature. One much-touted solution is the installation of additional storage options. However, the investment costs of electricity storage such as batteries or power-to-gas are extremely high. Questions arise about how storage can best be integrated into the electricity market design, at what times this additional storage capacity will be needed, and how its cost will evolve, see Fig.1.

Methodology

Our approach is based on: (i) a model of the Austrian power generation system for different points in time until 2050 to analyze the required storage capacity over a calendar year on an hourly base based on the residual load curve, see Fig. 2; (ii) an economic discussion regarding the profit of additional storage capacity given decreasing full-load hours, lower arbitrage opportunities and grid fees; (iii) a comparison of the cost development of different storage solutions based on the technological learning approach.

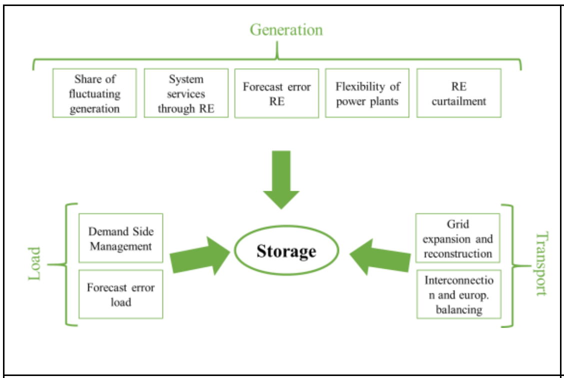

Fig. 1. Factors influencing the required storage capacities (based on Sterner et al. 2019)

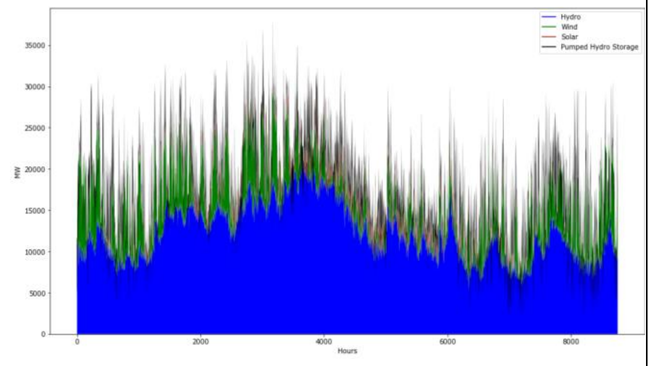

Fig. 2. Model of variable renewable power generation over the year 2019 on an hourly basis for the example of Austria

The costs of storing a kWh of electricity C_{STO} for different storage technologies are calculated with equation (1) and the results are displayed in Fig. 3.

$$C_{STO} = \frac{\frac{IC * C.R.F + C_{O\&M}}{T} + C_E}{\eta_{STO}} \quad \text{(EUR/kWh)} \qquad (1)$$

With:
IC … Investment costs of a storage (EUR/kW)
C.R.F. Capital recovery factor (1/year)

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C_{OM} … Operation and maintenance costs of the storage (EUR/year)
C_E … Costs of electricity (EUR/kWh)
T … FLH (hours per year)
η_{STO}… Storage efficiency

Results and conclusions

To date, pumped hydro storage (PHS), with a share of 97% of all electricity storage in the EU in 2019, an efficiency of more than 80%, and very fast response times is the main storage solution. Only in recent years other storage technologies, such as electrochemical or chemical storage systems, are starting to play a role in the electricity system.
In the hourly model of electricity generation and load profiles, we determine the storage requirement of each point in time and also consider other possible flexibility options such as demand-side management or curtailment of renewables.
Another important part of the analysis is electricity prices, which depend on both load and generation. This is because a major source of revenue for storage operators is the arbitrage profit they can generate by buying electricity at times when the price is low due to high production and low demand and selling it at high prices. However, each additional storage capacity installed reduces the required peak load and thus also the price differences, reducing the possible arbitrage profits. Following the same principle, each additional storage capacity installed reduces the total full-load hours and thus increases the overall costs, unless renewable fluctuating generation capacities are added to the same extent. Another issue is grid fees, which must be paid by every electricity producer and consumer that feeds into or consumes from the high-voltage grid. According to an EU survey, fees for storage power plants are levied at the transmission level in 8 countries. However, there has been a recent change in the grid tariff principles and these include an exemption or reduction from the network tariff for offtake and injection, under certain conditions (European Commission 2020).

Based on the initial storage costs, the future economic performance of the different storage technologies is modeled with the technological learning approach using experience curves. For the calculations, learning rates of 20% for batteries and 18% for electrolyzers were considered, in line with IEA (2020) except PHS, for the reasons that the components already have been optimized to a large extent and possible technological learning is largely compensated by higher construction costs of PHS plants and more complex permission processes. Alternative storage solutions will become more economically attractive in the future, while the investment costs of PHS might even increase, see Fig.4.

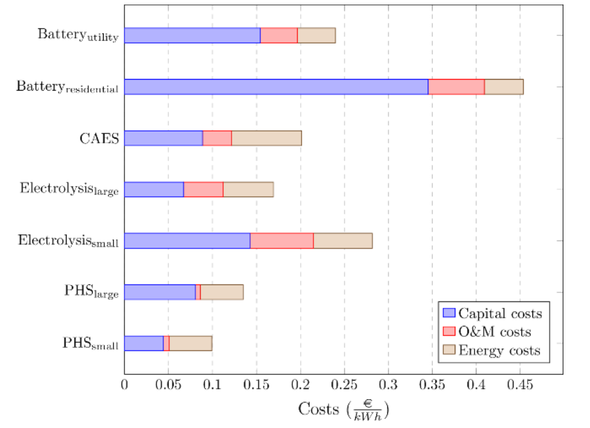

Fig. 3. Storage costs in total for electricity using various technologies in 2020

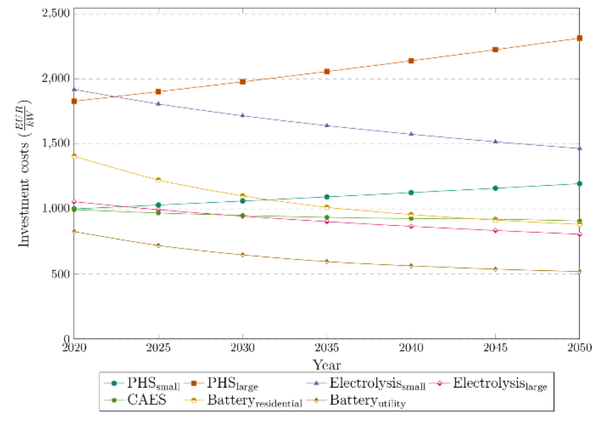

Fig. 4. Investment costs of different storage technologies up to 2050 based on the TL approach

Literature

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