ECONOMIC ANALYSIS OF PUMPED HYDRO STORAGE

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Overview

The shift to a fully renewable power system is inevitable, and with it comes certain challenges. Among them is the variable nature of wind and PV electricity generation, which put storage technologies further in the spotlight for balancing supply and demand, see Figure 1. The main storage technology to date is still pumped hydro storage (PHS), which amounts to 96% of installed power capacity and 99% of stored energy worldwide (Blakers et al. 2021). The current worldwide installed capacity of 161 GW is expected to increase to 300 GW by 2030, according to IRENA (2020). In this regard, an economic assessment of newly installed PHS is essential, as conducted in Figure 2. Besides the cost aspect, it is also important to investigate the possible revenues. Storage operators can generate profits depending on the market system through energy arbitrage, ancillary services or capacity payments. When the energy arbitrage possibility is regarded, a large price spread on the wholesale market is important. Several factors like renewables or storage capacity expansion (Steffen und Weber 2016) and CO_2 price (Zöphel und Most 2017) have an influence on the arbitrage possibility.

The core objective of this paper is to analyze PHS storage costs as well as the possible revenues in consideration of the rapidly changing electricity system. We do consider the influence of electricity price changes due to variable renewables, increasing CO_2 cost, as well as possible operation times of existing PHS due to overall storage capacity increases.

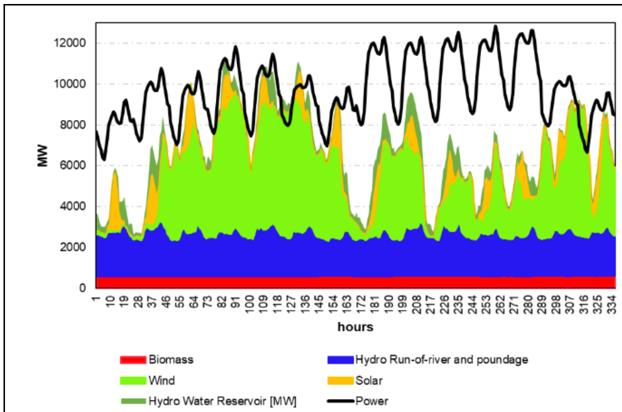

Fig. 1. Model of the Austrian Electricity Generation in 2030 for two winter weeks in January

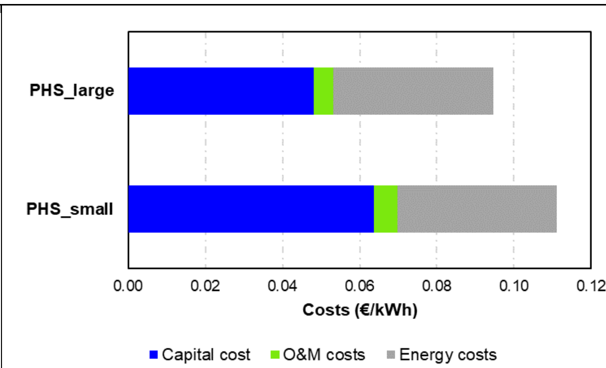

Fig. 2. Cost calculations of newly installed PHS plants

Methods

Our analysis is conducted threefold. First, we model the Austrian power generation for different renewable expansion targets and analyze the resulting required storage quantities depending on the duration of storage (daily, weekly or monthly). Second, we undergo an economic analysis for newly installed PHS plants taking investment-, operation and maintenance-, and energy costs as well as efficiencies and full-load hours into account and third, we analyze the possible arbitrage profits of the storage operator and influencing factors. The factors such as renewable and storage capacity as well as CO_2 prices and grid fees are taken into account.

Results and Conclusions

The mentioned influencing factors on the electricity price and consequently on the arbitrage opportunities have different effects. An increase in the expansion of renewable generation, as well as an increase in the CO_2 price, leads to an increase in the price spread and possible arbitrage profit, see Figure 3. The introduction of a CO_2 price will increase the economic viability as the wholesale price will increase at times of scarcity, as fossil generation is becoming more expensive. On the other hand, we can see that additional installed storage capacities decrease the possible arbitrage profit (self-cannibalism of storage) together with the possible full-load hours of the existing storage capacities. An additional grid fee for electricity storage when it is considered an electricity producer as well as a consumer as applied in several European countries (Andrey et al. 2020) also further increases the price spread hence the arbitrage profit as modeled in Figure 4.

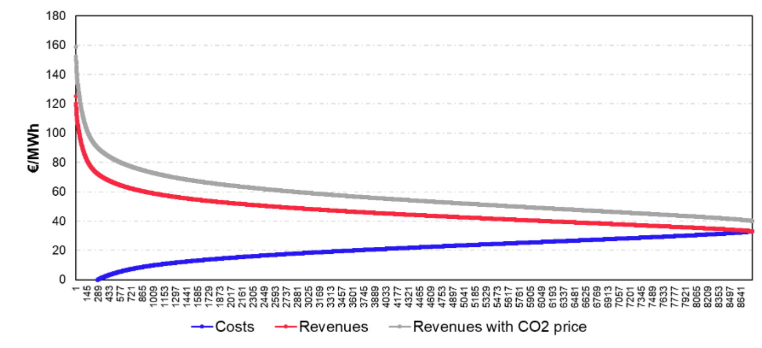

Fig. 3. Costs and revenues for arbitrage of a storage operator, including a CO_2 price (data based on wholesale prices in Austria in 2020, EXAA)

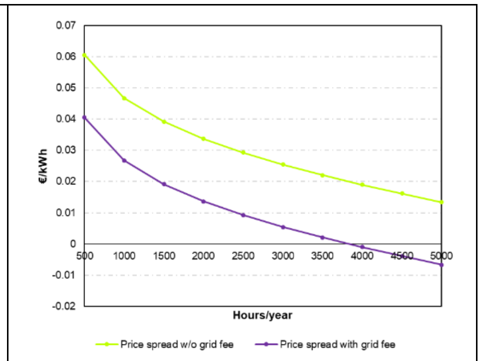

Fig. 4. Calculated price spreads (arbitrage profit) with and without a grid fee of 0.01 €/kWh (wholesale prices in Austria in 2020, EXAA)

The amount of pumped storage capacities that will be built in upcoming years will depend largely on the economic performance hence on the development of the influencing factors. No further cost reductions are expected on the capital costs as PHS is already a well mature technology and the best topographical sites are already allocated. One discussed opportunity for cost reductions is closed-loop pumped hydro storage sites with an estimated worldwide potential of 23 million GWh (Stocks et al. 2021). Through the independence from rivers and the consequences on its ecosystems, construction costs might decrease.

References

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