

# The Profitability of Energy Storage in European Electricity Markets

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Variable renewable energy sources (vRES) have been rapidly penetrating the markets and increasing the volatility of the residual load, which intuitively suggests that energy storage requirements in the system increase. We therefore study the profitability of energy storage exploiting the temporal price variations in three European electricity day-ahead markets in the period 2006–2016, a period during which significant investments in vRES took place across Europe. More precisely, we disentangle the main drivers of profitability (contribution margins) and operation (operating hours) of differently sized energy storages (1–13 MWh/MW) and focus on the effects of wind and solar generation, electricity demand, carbon emission prices and the price differential between coal and gas commodities. We analyse both operational storage profits and storage operating hours since operating hours are a good indicator for the system’s storage capacity requirements, whereas the operational profits are a good indicator revealing whether the markets as they exist today reward storage capacity. Studying both together allows for identifying potential misalignments between system needs and market design.

Our methodological approach combines optimisation and econometrics. We are therefore able to abstract from restrictive technological and cost assumptions associated with specific storage technologies. In our analysis, we focus on (i) the evolution of the contribution margins of energy storages with different storage volumes (the different storage volumes mimic the real-world technologies, such as batteries or pumped hydro, serving different purposes in the energy systems). Subsequently, we carry out an econometric analysis to understand the main fundamental drivers behind the evolution of (ii) the contribution margins and (iii) the operating hours of the considered storages.

Our main findings can be summarised as follows:

1. We empirically show that the operational profits expressed as contribution margins declined over the studied period 2006–2016 in Germany and the UK and exhibit high intra- and inter-annual variability in the Nordics;
2. Under today’s market conditions, only the smallest considered storages would be needed, which mainly balance hourly variations and also that these would only become profitable in the studied wholesale markets if storage costs can be decreased strongly;
3. Electricity demand is a significant positive driver of profits across the studied markets and storage sizes, which is also the case for the gas-coal spread in Germany and the UK;
4. Wind generation is associated with increasing profits and number of operating hours in Germany, which we argue is due to its innate nature of variability and lower predictability;
5. Solar power generation in Germany is associated with a positive effect on the number of storage operating hours but, particularly for the larger storage sizes, with a negative

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effect on profits, i.e. despite the greater number of storage operating hours, storage operators gain lower profits in Germany as solar PV generation increases. This finding underpins the necessity to explicitly consider both profits and operating hours in our analysis.

Our findings may be of use for policy makers, investors or storage technology developers in a number of ways. In general, the declining operational profits of energy storages should point out to the fact that the markets do not send any investment signals, suggesting that there is no additional requirement for energy storages so far and that the current power markets are sufficiently flexible. At the same time, however, the finding that solar PV generation has a positive effect on storage operating hours in Germany implies that the storage requirements in the system increase. Together, these two findings indicate a potential misalignment between system requirements and market rewards. Policy makers need to monitor the development of the existing electricity markets to be able to identify needs for modification in due time. For storage technology developers our sensitivity analysis on storage costs is a useful basis to derive a target invest. Overall, our analysis shows the uncertainty potential investors are confronted with and what drivers are most relevant.