TOWARDS CARBON NEUTRALITY AND ENERGY INDEPENDENCE IN EUROPE: CAN NEW STORAGE AND RENEWABLES PUSH FOSSIL FUELS OUT?

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Overview

Variable and renewable energy (VRE) sources lie at the core of the European energy decarbonating and independence strategy. A larger share of renewable generation requires flexibility options to cope with production fluctuations. In this context, energy storage is acknowledged as a promising solution to cope with intermittency but its contribution to the power system is still uncertain. We investigate in this paper the development of energy storage solutions as dispatchable assets to compete with existing and future fossil fuel power plants. We present a theoretical model showing that storage can increase or decrease CO_2 emissions but may support the development of solar and wind. We confirm these results with a stochastic competitive equilibrium framework, calibrated on the current Western European power system, to derive the market value of new storage technologies and their impact on the power system. We estimate the long-term equilibrium of flexibility and renewable capacities under a coal phase-out policy. We subsequently analyze the CO_2 emissions and the fossil fuel consumption. We find evidence that the development of storage, stationary or vehicle-to-grid, is delayed by the competitive advantage of new gas power plants. We underline that storage provides moderate beneficial effect on CO_2 emissions or energy independence. However, our results suggest VRE development could in the long term be accelerated by storage, making a case for a smart design of transition policies.

Methods

As recent literature showed the role of storage was ambiguous, we first introduce a two-period stylized theoretical model. We account for two fossil generation technologies, baseload and peaking units, and two renewable sources, solar and wind. We demonstrate that because of efficiency, dispatch and investments effects, storage does not necessarily reduce CO_2 emissions in the short and long term. Interestingly, storage support the development of the most intermittent VRE technology, solar, but has unequivocal impacts on wind energy. We therefore raise awareness on the necessary conditions for storage to sustain the energy transition and highlight the importance of empirically assess the situation in Europe.

To quantify the energy-only market-based development potential of promising storage technologies and their impact on the price structure, we propose an empirical model representing the current and future Western European electricity power system. We simulate an interconnected version of the European grid until 2040, with 10 of the most important countries for comparison. Our framework relies on stochastic optimization methods to better suit and handle the intermittent nature of renewable-based power systems. On top of providing a probabilistic and frequency analysis, such method renders robust results for the consideration of VRE and storage economic viability, to depict an accurate situation of the near future.

We construct scenarios by sampling weekly historical data, similarly to a Monte-Carlo approach, which aim at faithfully representing the fundamental discrepancies between seasons and the various states of the power system. Secondly, we derive long-term market equilibria, under efficient hypothesis, by minimizing the total cost of the European power system by allowing investments in new storage and gas capacities. Solving the two-stage problem – capacity expansion and operation - involves a multi-cut algorithm based on Benders decomposition. Our model is calibrated on the Western European power system, with fine modelling of the existing flexibility park, including pumped-hydro storage and nuclear availability. Our work relies on an exhaustive, heterogeneous, and unit-level representation of existing power plants.

Results

We first derive from our methodology estimates of the long-term equilibria of flexibility capacities under different environmental policies. In particular, we investigate the possibility of a complete coal phase-out in Western Europe and its consequences on flexibility needs. We find evidence that the development of storage is moderate and located in a few countries of interest. Overall, intermittency stemming from ambitious renewables targets is largely mitigated by the predominant contribution of new gas facilities and, to a lesser extent, of V2G, as it accounts for the main share of the new storage capacity. New gas facilities remain strong competitors to stationary storage indeed and completely preclude it from the market. Moreover, the V2G market size only amounts to 8% of the electric fleet. In case of new gas moratorium, V2G ensures most of the flexibility needs before 2030 but stationary storage (Li-ion batteries and power-to-hydrogen) becomes cost-optimal in Northern countries (Germany, the Netherlands and the United-Kingdom) and amounts to 30 GW by 2040.

Secondly, we analyze incremental investments due to the presence of storage on the wholesale market and their distributions among renewable firms. We highlight a positive effect of storage on solar and offshore wind, but no effect on onshore wind. Remarkably, V2G tend to better suit solar production while stationary storage copes with offshore fluctuations. These findings confirm the theoretical results.

Finally, we characterize to what extent new storage reduces fossil fuel consumption and CO_2 emissions. A pathway relying on new gas facilities prevents approximately one year of emissions by 2040, due to an early and steady reduction of coal consumption. It however increases the energy dependence towards fossil gas. Freezing new gas investments increases CO_2 in the short term, but by supporting investments in VRE, ends up being more promising for the 2040-2050 period. These metrics are of utmost importance to apprehend the possible path towards energy independence and carbon neutrality, as well as the way to reinforce renewable investments. Our results indicate that additional value is to be found in supporting storage development at the expenses of new gas.

Conclusions

In the recent years, storage has regularly been presented as the last piece to solve the energy transition and independence dilemma by complementing renewable sources. We bring evidence that market-based storage development remains uncertain without additional policies. Reaching the critical market size for storage will require stronger energy commitments and a concerted reflection of the role of fossil gas in the transition. As the main takeaway, renewable expansion will sooner or later face dropping market revenues, that storage could alleviate but not gas power plants. By supporting low prices and reducing volatility, storage sets up a more sustainable environment for renewable development. Additional value is also to be found in the reduction of fossil fuel consumption and CO_2 emissions. Our study consequently makes the case for an adequate and smart design of support policies that integrates the transfers storage operates between market firms, and the non-market welfare improving services it provides.

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