Assessing Potential of Electrified Transport for Enhancing Flexibility in Integrated Renewable Energy Systems

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Overview

According to the European Green Deal, greatly increasing the share of renewable energy and eliminating fossil fuel in all sectors of the economy are crucial steps toward climate neutrality by 2050. Wind and solar energy are key renewable sources in this transition. However, their intermittent nature poses a challenge for their integration into the energy system. To overcome this challenge, flexibility on the supply and demand side of the energy system is needed. On the supply side, solutions like energy storage, transmission infrastructure, and zero-carbon thermal plants can add flexibility and ensure reliable energy supply. On the demand side, flexibility can be provided through flexible loads, like electric vehicles, demand response programs, and small-scale distributed generation that all add flexibility on the demand side.

Electric vehicles are inter-sectoral devices that can serve as a flexible load by utilizing corresponding charging strategies. Given that they are often parked, they can be leveraged to mitigate the curtailment of renewable energies such as solar. Furthermore, electric vehicles can be used as energy storage systems through vehicle-to-grid (V2G) technologies, thereby reducing the need for additional investments in energy storage infrastructure. This demonstrates the potential for electric vehicles to contribute to the transition to a sustainable and climate-neutral energy system.

Studies aimed at decarbonizing the transport sector (e.g., Gschwendtner et al. 2023; Mangipinto et al. 2022) often examine EV charging loads and their potential to enhance power system flexibility. However, all these studies are solely focused on the transport sector and do not consider the interaction of vehicle charging with other elements of the energy system.

In this study, we use a comprehensive planning model of the European energy system based on the AnyMOD framework to analyse how different charging strategies of electric vehicles impact supply and demand in renewable energy systems (Göke 2021; Göke 2022). This integrated approach captures interaction between sectors and can analyse how charging strategies impact the provision of flexibility from other technologies, like energy storage or transmission infrastructure.

Methods

For our analysis, we apply a linear optimization planning model that analyzes the expansion and operation of technologies needed to meet final energy demand. The model covers the entire European continent, divided into 96 regions, which is crucial for achieving a large spatial scope and resolution to account for the impact of transmission infrastructure in mitigating local fluctuations in wind and solar generation and enhancing system flexibility.

The objective of the model is to minimize the total system costs, which include annualized expansion and operational costs for technologies and energy imports from outside the system. The expansion and operation in the model include technologies for the generation, conversion, or storage of energy carriers and grid infrastructure to exchange energy between different regions.

To examine how various electric vehicle charging strategies impact the overall energy system, we implement three different scenarios that successively increase the level of flexibility from vehicle charging. The first scenario assumes charging is completely inflexible and does not adapt to the supply of renewable generation. The second scenario assumes charging is flexible but captures how battery capacities and their connection to the grid restrict consumption. The final scenario additionally assumes electric vehicle cannot only consume electricity but also feedback into the grid, also referred to as vehicle-to-grid (V2G).

Preliminary results

First results suggest that the charging strategies of electric vehicles have great impact on the overall provision of flexibility in renewable energy systems. Flexible charging can serve as a substitute for other sources of short-term flexibility, like battery storage directly connected to the grid or transmission infrastructure. In addition, the added flexibility increases investment in complementary photovoltaic generation that requires short-term flexibility to match generation during the day with demand peaks in the evening.

Conclusions

The added benefits of flexible charging suggest that public policy should provide corresponding price incentives or implement other measures to leverage the identified potential. In addition, results show that a narrow focus on decarbonizing one sector, like transport or power, ignores important interdependencies and leads to less effective strategies.

References

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