Towards a simulation-based policy analysis framework for electric vehicle adaptation on a regional scale

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Abstract

To meet the climate protection goals in the transportation and energy sector, we implement a simulation-based policy analysis framework to investigate future electric vehicle (EV) adaptation scenarios on a regional scale. The uncertainty of possible development paths, regarding the availability of charging infrastructure and the distribution of EV ownership is seen as a challenge, but also provides opportunities for the energy transition, which we quantify with our framework. In this work we describe a first version and application of our framework in the European metropolitan region of Nuremberg (EMN), Germany and show a significant reduction of more than 12 % of the mean aggregated charging peak load in the city of Nuremberg through extended accessibility of home chargers in rural municipalities.

Introduction and Motivation

In order to reduce global warming and mitigate the effects of climate change, greenhouse gas emissions need to be reduced to a minimum. In the transportation sector, EVs are seen as one main driver to reach the desired reduction. However, there are fears that the electricity grid will be overloaded due to increased simultaneous charging. Known literature often focuses on utilizing time flexibilities of charging events and performing temporal load shifting to reduce peak loads [1]. Yet, the load of the electrical grid is not limited to the temporal dimension. It also depends on the charging location, which again is flexible and can be optimized to further reduce peak loads or to better integrate electricity generated by renewable energy sources. To investigate the flexibility potentials of spatial load shifting, a regional model is required that goes beyond the scope of known charging behavior models which are often limited to city boundaries or single charging hubs, and at the same time is open to unknown development paths. Existing literature [2] suggests to model EV user behavior based on real charging event data of charging hubs or EV fleets. The contained usage patterns, however, strongly depend on environmental conditions, only represent a given development state and adequate access to real EV operation data is limited, which complicates the application of this approach in a regional model. In this work we introduce an agent-based policy analysis framework which address the resulting research gap.

Applied Method

Based on OMOD [3], we simulate individual charging behavior on a regional scale in space and time using discrete event simulation and adaptable agent and rule-based behavior modeling. Availability of charging infrastructure and the electrification rate of light duty vehicles can be adjusted in spatial resolution. One application of our model is to visualize the effects of a stronger adaption of EVs in rural areas in contrast to public-transport-oriented cities. We performed a first parameter study, varying the home charger availability for different EV ownership distributions in the surrounding areas of Nuremberg and aggregated simultaneous charging loads at chargers in the city. We explicitly did not apply any temporal load shifting to keep the focus on the potentials of spatial flexibility and assumed immediate charging for all charging events, provided that the need and availability of charging is given.

Results

Starting from a moderate value, we increased the availability of home chargers for EV owners in rural municipalities. The results of the study show reductions in the average maximum cumulated charging load at chargers in the city of Nuremberg of up to 12 % with rising access to home chargers in the remote areas of the city. This can be explained by a shift of the charging locations of commuting EV owners towards private charging options. The induced charging behavior change through regional changes of the charging infrastructure underlines the relevance of a deeper understanding of charging behavior patterns, their causes and impacts on spatial energy demand. Further insights on the results can be presented at the conference.

Conclusions

A first application of our policy analysis framework shows that uncertainties in the adaption of electromobility results in significant fluctuations of local charging energy loads. These, on the downside, must be considered in the systematic expansion of the electricity grid, but at the same time also indicate spatial flexibilities in the charging location choice, which can be utilized to better integrate renewable energies. In future applications, we aim to investigate possible benefits of spatial load shifting concerning a wide range of future developments such as demand side management, smart charging and vehicle-to-grid solutions.

References

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