ANOTHER SOURCE OF INEQUALITY? HOW GRID REINFORCEMENT COSTS DIFFER BY SOCIO-ECONOMIC EV USER GROUPS

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Overview

In the last years, electric vehicle (EV) adoption has increased tremendously. This high proportion of EVs however also poses challenges to the grid. Driving profiles have shown that many users tend to charge their EVs during similar times in the day (late afternoon-evening), which according to previous literature could lead to significant load peaks (e.g. Clement-Nyns et al (2010), Lopes et al. (2011), Yu et al. (2020)). Although the majority of literature modelling these load peaks simulates charging behavior equally for all households, EV adoption, usage and charging actually differ significantly between social-economic groups (e.g. Fischer et al. (2019), Lee et al. (2021)). This poses the challenge of a fair allocation of costs for necessary grid enforcements. Most likely, electricity prices will increase for all consumers although the additional costs can be traced back to certain socio-economic groups.

Our paper simulates the EV charging requirements, grid overloads and required grid enhancements for neighborhoods of differing socio-economic status in order to quantify the extent to which wealthy neighborhoods contribute to grid enhancement costs. This analysis will allow us to evaluate policy measures on their potential to mitigate the resulting inequities.

Methods

A shortcoming of the majority of literature modelling of the impact of EV charging on grid overloads is that an equal EV adoption, usage and charging behavior is assumed for all households. This is however unrealistic, as literature shows that there are significant differences depending on socio-economic factors of a consumer group.

Regarding EV adoption, multiple authors have shown that several socio-economic factors such as income, education, age or place of residence influences EV adoption. Especially high income and high education was identified as a significant driver for EV adoption by multiple authors (e.g., Chen et al. (2020), Lee et al. (2021)). Analyzing panel data from 20 different leading EV countries, Xue et al (2020) find that even with tax reductions and subsidies in place, household income is a big contributor to EV adoption.

Also regarding EV usage and charging, significant differences between different socio-economic groups can be found. For example, Zhang et al. (2020) find that age, gender and level of education influence the travel schedule. Lee et al. (2021) deduct that charging location is influenced by age, gender, income and type of residence. Lee et al. (2021) further derive that the place of residence (urban, suburban) has significant impact on the daytime of charging.

Very few papers account for these differences in EV adoption, usage and charging behavior when quantifying the effects on household loads and grid overloads. Kelly et al. (2012) was one of the first papers incorporating socio-economic factors. Examining PHEV charging behavior simulated based on the U.S. National Household Travel Survey, they find that the charging demand of high-income groups is 41% higher than of low income groups. Also, electricity demand for PHEVS in rural areas was 19% higher than in urban areas. Fischer et al. (2019) simulate the impact of EVs on the household load peaks based on several socio-economic factors. They find that full-time working EV users have the highest energy consumption and cause the highest and latest load peaks. Lee et al. (2021) find that high-income, highly educated socio-economic groups have the fastest increasing electricity load, while the impact of the lower-income groups is years delayed. They raise that sharing grid enhancement costs evenly is not equitable.

Contributing to this research stream, we aim to quantify the related costs incurring for required grid enhancements by simulating the EV charging demand for neighborhoods of differing socio-economic groups. In our work, we therefore aspire to answer the following research questions:

1. How do EV charging loads change between simulated neighborhoods of differing socio-economic status?

2. To which extend do overloads occur and which grid enhancements are required per neighborhood type?

3. What are the costs associated with grid enhancements for differing neighborhoods and to which extend are groups of lower socio-economic status overcompensating these costs?

4. Which implications arise for appropriate government interventions and current and future grid policy actions?

We first analyze EV adoption and usage data on different socio-economic EV user groups in order to simulate charging loads for different neighborhood types. These neighborhood types are e.g. a high-income high-education suburban area compared to a lower-income working class suburban area. We then leverage representative electric grid data to identify potential overloads in the grids. In cases where overloads occur, we assess the costs of grid enhancements on the affected grid elements.

Results

Depending on the differences occurring between different neighborhood types, we assess to which extend the groups of lower socio-economic status are paying for the over-proportional costs caused by wealthier neighborhood groups. Finally, we determine which policy actions are appropriate to compensate for these effects. One could, for example, consider reducing government subsidies for premium EVs or EVs with very fast charging power and high capacity. One could also consider linking grid enhancement costs more closely to high electricity load peaks.

Conclusions

From our analysis, we are able to conclude recommendations on grid enhancements required based on differing neighborhood types and related costs. Our results are highly relevant for grid providers as they allow for more accurate and differentiated grid planning. Policy makers might use our results to ensure equity between different socio-economic groups through suitable interventions.

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