FUTURE LOAD SHIFT POTENTIALS OF ELECTRIC VEHICLES IN DIFFERENT CHARGING INFRASTRUCTURE SCENARIOS

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Introduction

Electric vehicles can be a means to reduce greenhouse gas emissions if powered with renewable electricity. However, in a significant number, they risk to cause additional load peaks which need to be balanced out. While most studies focus on domestic charging facilities (Dallinger et al. 2013) or include additional charging at work of private passenger cars (Babrowski et al. 2014), this paper also considers commercial plug-in electric vehicles (PEV) and the use of public charging stations.

The aim of this paper is to assess the extent to which additional charging facilities contribute to PEV market penetration in Germany and shaving of peaks in the residual load.

Methods and data

The market diffusion of PEVs is simulated with the model ALADIN (Alternative Automobiles Diffusion and Infrastructure) which was described in detail in (Gnann 2015). One main advantage over other models is the use of conventional vehicle driving profiles which are simulated as PEVs to determine their technical substitutability by battery electric vehicles or the electric driving share of plug-in-hybrid electric vehicles. Thereafter, the utility maximizing drive train of each vehicle is determined in a utility function which was extended in (Gnann 2015) to also cover public charging infrastructure. The share of PEVs on all driving profiles is equal to the new vehicle registrations which diffuse into the vehicle stock. This permits the simulation of the charging point usage distinguished by accessibility paired with the market diffusion of plug-in electric vehicles.

The potential contribution of PEVs to net load smoothing is determined with the eLOAD (energy LOad curve ADjustment) model. Primarily, eLOAD aims to estimate the long-term evolution of national electricity system load curves through structural changes on the demand side and the introduction of new appliances (such as electric vehicles).

In a second step, eLOAD simulates national demand response programs that aim for an adjustment of the net load. With respect to PEVs, eLOAD considers technical (battery storage size) and organizational constraints (driving and parking cycles, charging capacity) when determining the least-cost scheduling of PEV-charging. The problem is solved by mixed-integer linear programming. The underlying hourly price signal reflects the wholesale price volatility at the spot market which is, in turn, an indicator for net load peaks or a surplus of renewable electricity generation. See (Boßmann 2015) for further information about eLOAD.

Framework assumptions for case study

In the present modeling exercise, we aim to assess the impact of different charging infrastructures on the contribution of electric vehicles to net load smoothing and the integration of renewable energy sources.

In the simulations, we consider three scenarios which were described in detail in (Gnann 2015). In scenario S1, only domestic charging is permitted (i.e. commercial charging for commercial vehicles). In scenario S2, charging at work for private users is allowed additionally and completed by public charging infrastructure in S3. For reasons of simplicity, all charging options are considered to permit charging with 3.7 kW. With respect to demand response, all scenarios make use of the same constraints, except for the availability of PEVs for charging which varies according to the results from the ALADIN model.

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Results and discussion

The simulation results for the PEV diffusion in 2030 are shown in Table 1. In scenario S1, 4.6 million PEVs diffuse into the German vehicle stock, while results in scenario S2 and S3 are about 15% higher (5.3 million). This can be explained by the additional charging options for private PEVs which permit higher shares of electric driving and thus a higher utility for PEVs. Public charging points do not increase the number of PEVs, although these charging points are largely subsidized. The number of private PEVs is 3.4 million PEVs in stock in 2030 in scenario S1 and increases to 4.1 million in S2 and S3. Since the number of commercial PEVs is not affected by these additional charging options, it remains at 1.2 million PEVs in all three scenarios.

Scenario	S1	S2	S3
Private PEV stock 2030	3.4 million	4.1 million	4.1 million
Commercial PEV stock 2030	1.2 million	1.2 million	1.2 million
Total PEV stock 2030	**4.6 million**	**5.3 million**	**5.3 million**

Table 1: PEV stock in different scenarios.

Uncontrolled charging of electric vehicles at work, at home and in public (S3) would raise electric load by more than 2 GW, in particular at current peak hours (at 10am and 7pm, see Figure 1). Considering demand response, charging in summer time is primarily shifted into midday hours due to substantial PV-based power generation and a correspondingly low level of the net load. In the winter season, vehicle charging is partially shifted into night time hours, especially at days with low solar generation.

With respect to the overall impact on the net load, electric vehicles can facilitate peak shaving by about 2 GW or 3.2%. The surplus of renewable electricity can be reduced by 1.1 TWh or 19%.

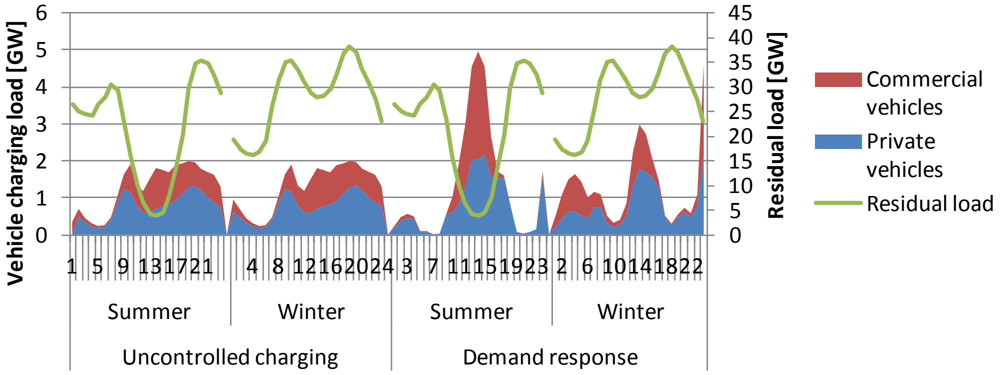

Figure 1: Average vehicle charging and net load in 2030 in the S3 scenario.

Simulations carried out for scenarios S1 and S2 (for the years 2020 and 2030) indicate that additional charging infrastructure at work (and, to a more limited extent, in public) does not only enhance the diffusion of private electric vehicles but also enables vehicle charging during midday hours when solar electricity generation is highest. It, thus, facilitates peak shaving and renewables integration.

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