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CHARGING ELECTRIC CARS UNDER REAL-TIME ELECTRICITY PRICES AS AN ACTION OF DEMAND SIDE MANAGEMENT

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OVERVIEW

In contrast to conventional vehicles electric cars offer the technological opportunity to decarbonize individual motor car traffic. Moreover, a switch to electric mobility reduces crude oil dependency. Thus, electric cars may support sustainability and security of supply in the energy sector and may be viewed as an important technological option. According to the *The Federal Government's National Development Plan for Electric Mobility* ([1]) there will be one million electric cars in Germany until 2020. If all these cars were charged simultaneously with a charging rate of 3.7 kW the system load would increase significantly: The additional demand would equal the generation of three nuclear power plants. This might reinforce peaks and increase prices. If consumers charged the batteries on the basis of real-time prices their demand for electricity would become elastic. Furthermore, the possibility for car owners to feed power to the grid might cause them to take advantage of spot price differences. This might smooth the additional demand and even the system load in such way that prices would increase only slightly (short-term view) or would even decrease (long-term view). Hence, charging of electric cars under real-time electricity prices may be viewed as an action of demand side management ([2]). This paper analyzes the accumulated charging decisions of car owners in 2020 and 2030 in Germany with a model-based approach. Moreover, the possibility of feeding power to the grid is evaluated. To the author's knowledge such an analysis has been conducted only in a qualitative way so far ([3]).

METHODOLOGY

The modelling approach is conducted in two-stages: First, the development of the EU-wide electricity markets is simulated using the linear model DIME provided by the Institute of Energy Economics at the University of Cologne (EWI). Results of the model are investment decisions such as the commissioning and decommissioning of conventional power plants. Renewable Energies are treated exogenously. The model minimizes total costs of power supply in Europe until 2020. Second, the resulting power plant mix is implemented in the linear short-term dispatch model DIANA provided by EWI, which leads to an hourly power generation mix in 2020. This model minimizes the total costs of power generation in Europe in 2020. In both models, the presence of electric cars and their actions on the electricity spot market are taken into account. To achieve that, the electric vehicles are aggregated and modelled as virtual power storages. These are characterized by constraints regarding storage capacity (in kWh), charging and discharging rates (in kW) as well as charging and discharging costs (in €). These restrictions are all time-dependent since the fraction of vehicles that are connected to the grid is assumed to change periodically over time. Moreover, the connected vehicles interchange with the non-connected, which leads to complex storage equations in order to describe the evolution of the inventory level. According to car owner's need for mobility additional constraints are imposed. These include that a vehicle has to be fully recharged in the morning if it is connected to the grid during the night. Furthermore, average hourly vehicle miles have to be achieved. Using the long-term investment model DIME under consideration of electric cars guarantees a consistent development of generation capacities. The dispatch model DIANA simulates a short-term dispatch and implicitly calculates the charging decisions of electric car owners who can act on real-time electricity spot prices.

PRELIMINARY RESULTS AND CONCLUSIONS

It turns out that, on the one hand, the mean accumulated charging power is quite regular and flattens residual load. Vehicles are charged basically at night. Moreover, feeding power to the grid is not cost-efficient. Figure 1 shows the mean residual load for every hour in 2020 without consideration of electric vehicles (grey line). The black line equals the sum of residual load and the mean accumulated demand of electric vehicles.

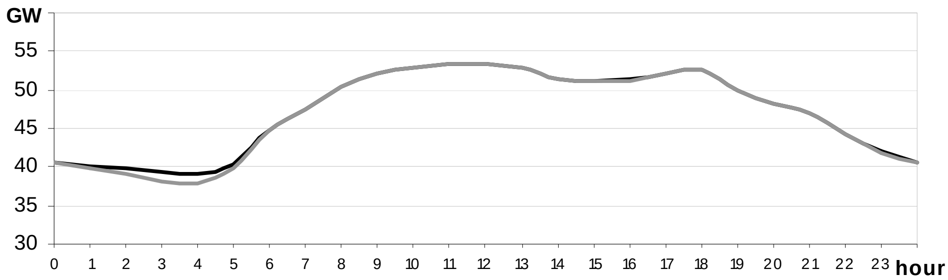

Fig. 1: Mean charging power in 2020 and its impact on residual load (source: author)

On the other hand, accumulated charging power deviates from this structure when this is cost-efficient. Figure 2 illustrates an exemplary weekday: the valley in the afternoon, which is due to a high level of wind power generation, is partly filled by the additional demand of electric vehicles. The grey-colored area describes the allowed area for shifting residual load.

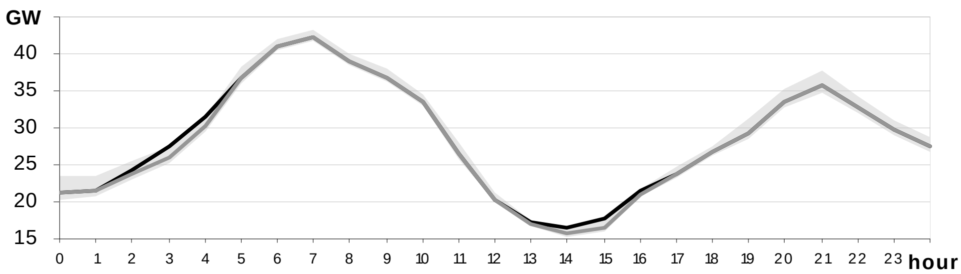

Fig. 2: Accumulated charging power fits residual load when this is cost efficient (source: author)

The full paper will address further questions and will conduct the analysis for the year 2030 which is characterized by a higher share of renewable energies and electric vehicles.

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