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Electric vehicle uptake in Germany - showcases from a decade of data

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Summary

NOW GmbH (NOW) is a subsidiary of the German Government, responsible for collecting, warehousing and analyzing data from other public authorities and private market platforms on sustainable transport. In this publication we showcase some novel results from NOW's data stock monitoring the uptake of battery electric vehicles in Germany over the last decade and discuss approaches for extending and improving on the state-of-the-art of market monitoring.

Keywords: BEV (battery electric vehicles), data acquisition, market development, modeling, passenger car

1. Introduction

Germany, which is among the world's largest emitters of greenhouse gas emissions (GHG) has committed itself to reducing its GHG emissions by over 40% by 2030 as compared to 2020 [1, 2]. NOW GmbH (NOW) is a federally owned company, which - on behalf of the German government - has been collecting, blending and analyzing data from other public authorities as well as private market platforms to strengthen data-driven decisions for sustainable transport policy in Germany. Here, we showcase some novel results from NOW's data stock collected over the last decade.

In this paper we focus on the branch concerned with monitoring the uptake of battery electric passenger cars in Germany. The uptake will be showcased from three perspectives: 1. historic developments of battery electric registrations, 2. implications on the mobile battery fleet in Germany, and 3. experimentation and discussion of forecasting approaches for the future battery electric uptake.

2. Battery electric vehicle uptake in Germany

2.1. Methodology

With regards to German electric vehicle data the most prominent data source is that of the Kraftfahrt-Bundesamt (KBA) [3], which is Germany's central authority for vehicle affairs, including vehicle registrations. KBA's detailed data corpus on German car registrations allows for the detailed analysis of Germany's vehicle stock and its ongoing electrification since the 2010s. NOW has received, transformed and re-modeled this data in order to warehouse and analyze registration data for both new car and used car markets in Germany. In this paper we showcase two prominent analyses illuminating two different perspectives on the market developments.

2.2. Results and discussion

Figure 1 visualizes the battery electric vehicle uptake in Germany since 2011, measured by the number of registrations by car segment. It shows how the market has both grown and matured. While the number of BEVs on German streets has steadily risen to a total sum of 618,460 cars in January 2022 some shifts have also taken place with regards to the segments in which those registrations have happened. More precisely, up until only a few years ago, battery electric vehicles in Germany were mostly only mini and small cars and some compact cars. However, since about 2017 other segments have started to increase their electrification, such that sport utility vehicles are now the second most dominant car segment among battery electric vehicles in Germany. Likewise, middle class cars have caught up with compact car registration levels. We believe this marks a completely new phase in the uptake of the battery electric vehicle market in Germany as the technology has finally left its small car niche and has started electrifying the rest of the passenger car market.

Figure 1 - Battery electric vehicle uptake in Germany, grouped by car segment

Our second dissection Germany's battery electric vehicle stock sheds some light on the vehicle owner groups and market actors responsible for the uptake. Figure 2 compares the absolute number of registered battery electric vehicles per owner group as well as their respective electrification rate in Germany in July 2021. The graph highlights in many ways the importance of the private sector for the electric vehicle uptake in Germany. More specifically, the analysis shows that even though the private sector has registered by far the most battery electric vehicles in absolute numbers (354,502 vehicles), it is absolute last of all sectors in terms of its relative electrification – a result of the overall very large size of the private car fleet. In contrast, the two sectors of energy and water utilities lead by some margin in overall fleet electrification with electrification rates of some 14% (9,093 vehicles) and 9% (2178 vehicles), respectively.

Figure 2 – BEV number (bubble size) and electrification rate of vehicle owner groups in Germany in January 2022

3. Mobile battery fleet

With the battery electric vehicle uptake becoming both steadier and more heterogeneous at the same time, the monitoring of technological parameters within the vehicle stock is increasingly important and feasible. For example, the capacity of the vehicle fleet's traction battery is a relevant technological metric within the market which is worth monitoring as it grows and becomes more interesting for energy utility purposes, for instance by bidirectional integration into the electric distribution grid.

3.1 Methodology

To determine the battery capacity of the German electric vehicle fleet the before-mentioned data corpus of vehicle registrations needs to be enriched as it does not contain any relevant technical parameters on the vehicle model level. Private market platforms on the other hand have made a business out of collecting and modeling such technical vehicle catalogues. Most prominently the German Allgemeiner Deutscher Automobil-Club (ADAC e.V.) is maintaining an exhaustive database of all past and present passenger vehicle models and their techno-economic characteristics [4]. We acquired this dataset with the goal of merging it with the above-mentioned vehicle registrations dataset.

The joining of the two datasets was done by a unique identifier which consists of a manufacturer's key (MKN) and the vehicle's model key. The KBA dataset provided the stock of registered vehicles from 2010 on an annual basis. In 2021 the KBA changed to a stock evaluation for every quarter. To calculate the stock of BEVs in between the quarterly inventory, the stock at the beginning of the year plus the accumulated vehicle registration of each month was calculated. This calculation method neglects some deregistration during the year and thus yields a slight overestimation. This overestimation is then corrected at the beginning of the next year.

Some of the model codes needed to be joined manually because the codes were not included in the KBA dataset. As not every model code had an affiliated unique value of battery capacity, it was aggregated for every model code and the according maximum, minimum and mean values were calculated.

3.2 Results and discussion

A matching quota between both datasets of over 98% could be achieved. Figure 3 illustrates one visual result: the growth of the battery capacity of Germany's passenger electric vehicle fleet of the last five years. Starting at around 1 GWh in 2017, Germany's mobile battery fleet has grown rapidly, reaching some 30 GWh in January of 2022. Just in the last three years, this capacity grew tenfold; a massive growth which was not only driven by a growing number of vehicles but also a strong growth of the average battery size within each new battery electric vehicle.

Figure 3 – Battery electric vehicle uptake, measured by the fleet's cumulated battery capacity

Visualizing the same data based on the vehicle fleet's location in Germany visualizes the mobile battery's regional distribution within Germany, see Figure 4. As shown in the left map, urban areas like Berlin, Munich and Hamburg have comparatively very high cumulative battery capacities on the street. In contrast however, the largest average electric vehicle batteries are not necessarily found in urban areas, see right map.

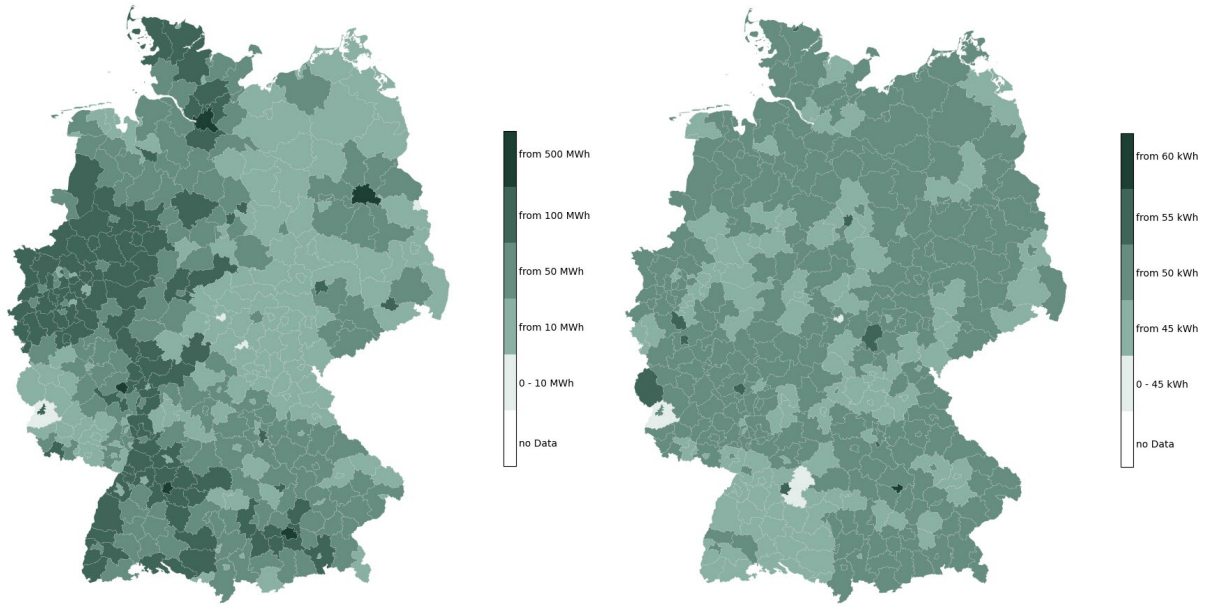

Figure 4 - Battery capacity of the German electric vehicle fleet per municipal registration district, absolute (left) and per-vehicle-average (right)

4. Forecasting approaches

It has been of great interest to forecast the future uptake of battery electric vehicles in Germany. In the last years we have observed a stable increase of the market share of battery electric vehicles among the newly registered cars in Germany, which allows for more robust predictions now more than ever before. For our predictions we focus on the ratio of battery-electric vehicles among all newly registered vehicles in Germany (market share). This allows us to be comparatively independent of dynamics of the absolute market volume of vehicles as well as to partially ignore periodic behavior in car purchases.

4.1. Methodology

While we are still in the progress of identifying the best forecasting strategy, first promising local forecasts could be provided using an approach of ARIMA time series forecasting [5] with varying parameters (see Figure 4). This is an established technique for the forecasting of time series and does not use any further assumption. However, not including any knowledge about the expected global structure of the curve can lead to an overestimation of the slope of the forecasted curve. For example, we know that the predicted market share cannot exceed the number one and we also expect certain saturation effects leading to a gradually decreasing slope from a certain point in time onwards. One possibility to include this knowledge is to model the uptake of the EV market share using a Bass model approach in which we set more explicit assumptions regarding the overall structure of the curve [6]. In this approach we assume that the general curve structure is that of an S-curve converging to 1. The model depends on two parameters, and we use a standard least squares minimization technique to find the parameters that fit best to the measured data

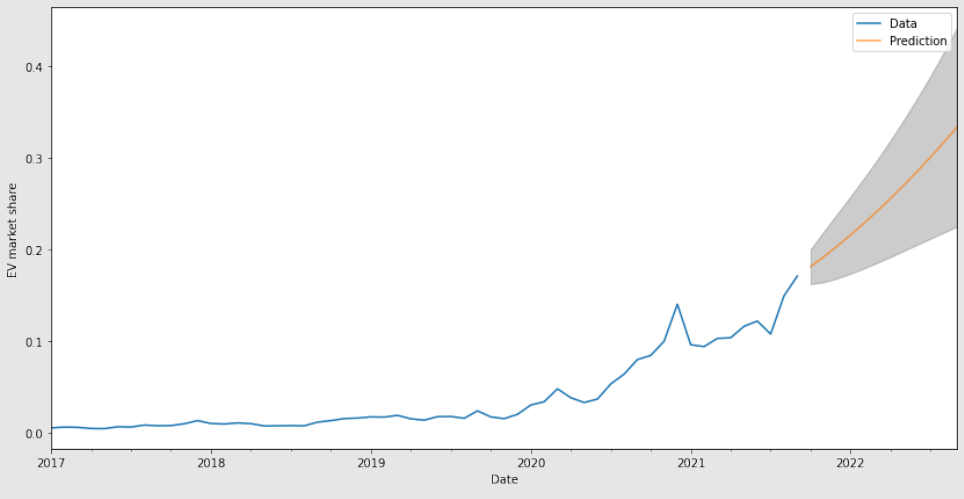

Figure 4 – Arima local forecasting of electric vehicle market share in Germany

4.2. Results and discussion

In our investigations so far we focused on the Bass model approach. One observation that we can make right away is that, although we consider the market share of BEVs, we still see quite a lot of oscillation of the observed data. One advantage of the Bass model approach is that we avoid overfitting in that case (see Figure 5).

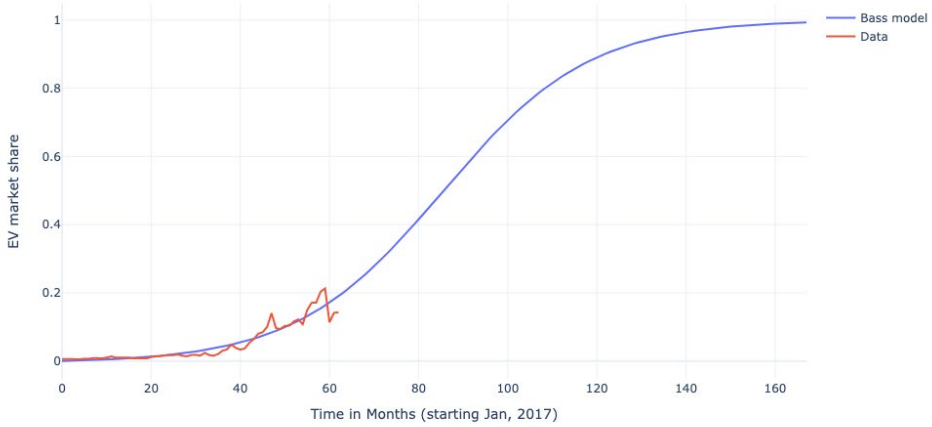

Figure 5 - Bass model global forecasting of electric vehicle market share in Germany

As a first step towards a detailed analysis of the quality of Bass model forecasts, we look at the development of its predictions over time for March 2022. We see that the model underpredicts the market share for March 2022 heavily during the first 40 months, but then suddenly increases steeply when market shares peak in December 2020. Afterwards it declines towards the actual value (see Figure 6). A promising observation is, however, that another peak of BEV market shares in December 2021 has led to a much smaller increase in the estimated value for March 2022. This gives evidence that the model might stabilize over time.

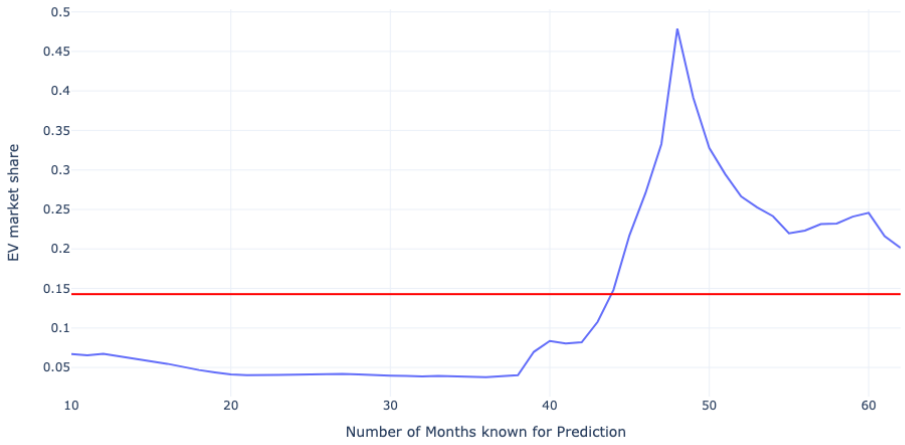

Figure 6 – Development of Bass model prediction for March 22

5. Summary and outlook

NOW GmbH (NOW) has been collecting, blending and analyzing data from other public authorities as well as private market platforms to strengthen data-driven decisions for sustainable transport policy in Germany. In this paper we presented some novel results from NOW's data stock on the uptake of battery electric passenger cars in Germany within the last decade. We showcased three perspectives: 1. historic developments of battery electric registrations, 2. implications on the mobile battery fleet in Germany, and 3. experimentation and discussion of forecasting approaches for the future battery electric vehicle uptake.

We were able to show that the battery electric vehicle uptake has just recently entered a new market phase. We believe it is now safe to assume that Germany has moved beyond the first market phase of early adoption and entered the second phase of early majority electrification. We showed that in this second phase, it is necessary for some vehicle owner groups to electrify even faster than in the past, which is true especially for the private sector.
The past uptake has rapidly fed the growth of the mobile battery fleet, which has already reached a comparatively large cumulative capacity of some 30 GWh.
As the momentum of uptake becomes steadier, a more robust data foundation has started to emerge for forecasting purposes. We experimented with and discussed some different forecasting approaches and were able to demonstrate their potential merit.

As the market electrification marches on and provides us with new data every month, we look forward to improving on our forecasting endeavors in order to narrow down on the best approach with robust and informative prescriptions for the future uptake of battery electric vehicles in Germany.

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