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Using real data to develop targeted government support of the electric vehicle market in Germany

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Summary

The funding programme 'Electromobility on Site' has evolved over the last decade within the climate action framework of the German Federal Government. Decisions of new measures and approaches to funding of municipal government and company fleet are taken by careful examination of market and vehicle trip data. These have revealed the need to identify high-mileage fleets and to increase the mileage of individual vehicles, which are being tacked through R&D as well as targeted procurement funding.

Keywords: BEV (battery electric vehicle), data acquisition, fleet, market development, municipal government

1 Introduction

This paper aims to present the context and history of German Federal Government support for electrification of individual passenger transportation, with particular focus on the funding programme 'Electromobility on Site'. It then presents the data gathered and analysed and the conclusions drawn for continued programme design.

2 Climate action in the German transport sector

German annual passenger and goods transport volumes have steadily grown since German reunification in 1991 [1]. This development, as well as the trend to larger, heavier and more powerful cars [2], [3] has compensated relative fuel efficiency gains and other emissions reductions achieved at individual vehicle level. As a consequence, absolute greenhouse gas (GHG) emissions in the road transport sector have increased since 1990 [4]. Road traffic volumes are expected to grow further until at least 2030 and then plateau towards 2050 [5], [6]. The pressure on the transport sector to reduce emissions is therefore significant, with decisive policy action required to initiate and further support the needed changes.

2.1 Historic development of the electromobility policy framework of the Bundesregierung[1]

At the beginning of 2009, €500 million of applied R&D funding for electromobility was included in the 'KoPa II' (Second Economic Stimulus Package)[2] in response to the global financial crash of 2008/09. This was flanked by a German national development plan for electromobility [7]. 2010 saw the founding of the German National

[1] Federal Government
[2] Konjunkturpaket II

Platform for Electric Mobility (NPE), an interdisciplinary advisory board, tasked with developing a plan on how to deliver the Federal Government's and industry's joint goal of 1 million electric vehicles on German roads by 2020. The original roadmap outlined first steps to move from initial 'market preparation' to 'market ramp-up' and finally a 'mass market' for electric passenger[3] vehicles. Measures included support for research and development (R&D), norming and standardisation, education and qualification as well as initial deployment and demonstration. Crucially, the underlying strategic vision since has been to establish Germany both as lead market (Leitmarkt) and lead supplier (Leitanbieter) for technologies within the ecosystem of electromobility [8].

Public funding continues to reflect the roadmap's market development phases: in the 'market preparation phase' the NPE placed emphasis on developing roadmaps for norming and standardisation as well as education [9]. Simultaneously several Federal Ministries funded vehicles as part of R&D projects at municipal level via a range of major regional clusters ('Modellregionen Elektromobilität' 2010-16 of the Federal Ministry for Transport and Digital Infrastructure, BMVI[4], see section 2.2) and living labs ('Schaufenster Elektromobilität' 2014-17 of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, BMU[5]) and to support this phase with practical examples and experiences.

In support of 'market ramp-up', the 2015 'Electromobility Law'[6] defines electric vehicles (battery electric, BEV; fuel cell electric, FCEV; plug-in hybrid electric, PHEV) and presents local authorities with options for their preferential treatment [10].

In 2016, the Ministry of Economy and Energy (BMWi[7]) launched the separate "Umweltbonus/Kaufprämie"[8], which buyers of BEVs and PHEVs matching the criteria[9] can apply for and which has to be matched by industry. This measure reflects the gradual shift from applied R&D funding in the 'market preparation' phase towards supporting purchase of electric vehicles by a variety of actors to fulfil the needs of the 'market ramp-up' phase according to the original NPE roadmap. This programme was extended at the end of 2019 and the bonus per vehicle increased [11].

In 2018, lower tax rates for the pecuniary advantage of electric company cars along with a package of other measures [12] were introduced, and at the end of 2019 extended and further adjusted to deliver greater benefits to consumers. Also in 2018, the NPE was integrated into the National Platform Future of Mobility as one of its 6 working groups dealing with topics from transport and climate change to alternative drive train technologies & fuels and digitalisation in the mobility sector [13].

Throughout the decade 2010 - 2020 and therefore spanning the NPE's 'market preparation' and 'market ramp-up' phases, the BMVI gradually developed, evolved and diversified funding mechanisms and frameworks. These target market ramp-up of BEVs, FCEVs, ICEVs in combination with advanced alternative fuels (including LNG for heavy duty road transport and shipping) as well as the development of charging and refuelling infrastructure. The corresponding federal public funding programmes of the BMVI include respectively:

- Electromobility on Site (focus of this paper, for details see section 2.2)
- National Innovation Programme Hydrogen and Fuel Cell Technology (NIP[10])

[3] Initial focus, this was broadened to all types of vehicles in the years following
[4] German acronym for Bundesministerium für Verkehr und Digitale Infrastruktur
[5] German acronym for Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit
[6] Elektromobilitätsgesetz („EmoG")
[7] German acronym for Bundesministerium für Wirtschaft und Energie
[8] Environment bonus/Purchase support
[9] Criteria include that buyers can be private individuals, companies, corporations, NGOs, clubs/associations. The Umweltbonus is not available for local authorities/municipalities, making the funding programme 'Electromobility on Site' the key programme to support these actors in the implementation of electric vehicles
[10] Nationales Innovationsprogramm Wasserstoff und Brennstoffzellentechnologie

- Mobility and fuel strategy (MKS[11])
- Charging Infrastructure

Despite the efforts and advances in vehicle deployment, the original target of one million vehicles on Germany's roads was not reached and is now expected to be achieved in 2022. The Klimaschutzprogramm 2030[12] published by the federal government in November 2019 states a goal of 7 to 10 million BEVs and PHEVs by 2030 as modelled by the NPM as necessary to reach the emissions reduction targets [14].

2.2 BMVI Funding Programme 'Electromobility on Site'

The funding programme 'Electromobility on Site' has its roots in the 2009 'KoPa II' economic stimulus package, when it mostly supported applied R&D projects and the formation of a well-networked electromobility community in Germany within the 2010-12 clusters 'Modellregionen Elektromobilität'[13]. The positive assessment of these activities led to the design of the 2012 version of the funding programme 'Electromobility on Site' with a focus on developing supply of the necessary products and technologies via further R&D funding as well as testing (Figure 1). The currently active 2015 evolution of the programme maintains support of the supply side via applied R&D funding. Incorporating experience from the living labs 'Schaufenster Elektromobilität', it also targets market ramp-up through increased demand by adding the pillars of vehicle procurement funding and financial support for the development of electromobility concepts both available to municipalities. Throughout this time (and reflected in the programme name) the focus on supporting the development of electrification of fleets owned by local authorities and businesses at municipal level has been the key defining feature.

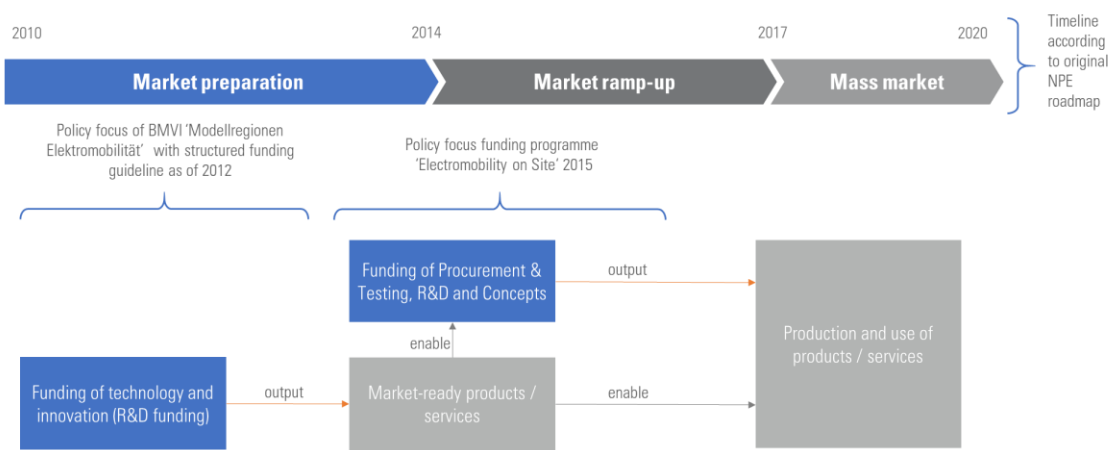

Figure 1 – Progressive funding approach of the programme 'Electromobility on Site' in line with original NPE roadmap (adapted from [15])

The remainder of this paper focuses on the assessment of insights gained through the active monitoring of the vehicles funded via the programme 'Electromobility on Site'

2.3 Role of NOW GmbH

NOW GmbH is a company fully owned by the federal government and tasked with the day-to-day implementation and strategic development of the above-listed BMVI funding guidelines and commissions by other federal ministries. Responsibilities include identification of focus areas for funding calls, technical evaluation of funding applications, coordination of electromobility research, accompaniment of funded R&D projects and pulling together insights, data collection and critical evaluation of federal funding strategy, strategic

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[11] Mobilitäts- und Kraftstoffstrategie
[12] Climate protection programme
[13] Model regions electromobility

development of policy frameworks as well as acting as consultant to BMVI and active networking with all relevant actors nationally & internationally. At the end of 2019, NOW was designated as 'Nationale Leitstelle Ladeinfrastruktur'[14] (NLL) with the mandate to implement the Masterplan Charging Infrastructure as part of the Klimaschutzprogramm 2030 [16].

3 Active monitoring of key aspects of e-mobility using real data

Several teams at NOW gather data relating to national vehicle registration numbers and public charging infrastructure installation as well as their use. This is a mixture of general national figures and specific information gathered from vehicles and infrastructure co-financed by the funding programmes. These data are a combination of basic physical characteristics, geo-location and operational contexts, as well as trip data from installed data loggers and individual charging sessions. Their analysis allows for investigation of the development of electromobility and assessment of, *inter alia*:

- suitability of electric vehicles in a variety of contexts,
- quantification of GHG reduction potential.

This section explains the data collection practice in more detail and in section 4 vehicle trip data is assessed to explore suitability and GHG reduction potential of the co-funded vehicles in their operational contexts.

3.1 Data collection practice

Several data bases are used and maintained by NOW to monitor various aspects of funding and development of the electric mobility market in Germany.

3.1.1 New registrations of electric vehicles in Germany

The Kraftfahrt-Bundesamt (KBA)[15] publishes new vehicle registrations monthly [17]. The NOW team monitors the development of electric vehicles (Figure 2) to keep track of the general development of the electromobility market in Germany.

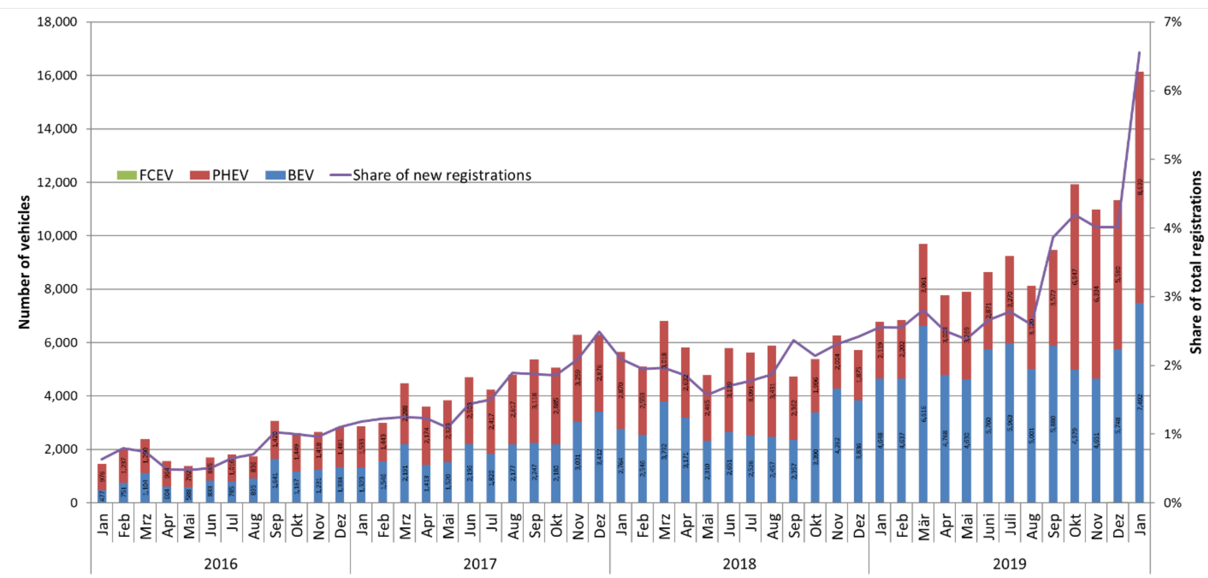

Figure 2 – Monthly new registrations electric vehicles (passenger cars) (data source [17])

[14] National Centre for Charging Infrastructure
[15] Federal Motor Transport Authority

The increasing dynamism in monthly registrations of electric vehicles catapulted Germany to third largest market for electric mobility globally in terms of absolute numbers in the second semester of 2019 [18, 19]. Before the Corona virus pandemic this dynamism was expected to continue. Drivers for passenger cars are mainly an increase of the 'Umweltbonus' (see section 2.1), lower tax rates for electric company cars and regulation at European level (notably the Clean Vehicles Directive[16] and Tailpipe Emissions Regulation[17]). Important stimulus is also expected from specific formulation of funding mechanisms for buses with alternative drive trains in public transport and heavy-duty transport due to be published over the summer months.

3.1.2 Public charging points in Germany

On 16 March 2016 Germany's Charging Station Regulation came into effect. While before only fast chargers (defined as >22 kW power) had to be registered with the Bundesnetzagentur (BNetzA)[18], from that date all publicly accessible charging points with more than 3.7 kW power had to fulfil European regulation regarding standardised charging plugs and be registered with the BNetzA [20]. As it is voluntary to retroactively register charging points installed before March 2016 and operators have to give permission to be included in the publicly available list, the BNetzA register does not necessarily include all public charging points in Germany. As of 2 March 2020, the BNetzA register contained 25,434 charging points, out of which 12% were fast chargers (above 22 kW) [21].

Another authoritative charging point register is the Ladesäulenregister[19] of the Bundesverband der Energie- und Wasserwirtschaft (BDEW)[20]. Figures in this register are generally higher than in the BNetzA register also includes semi-public[21] charging points and those that do not conform with regulatory requirements (e.g. CHAdeMO plugs only). As of 11 December 2019 the BDEW register listed 23,840 charging points with a share of around 15% fast chargers [22].

The Masterplan Charging Infrastructure published as part of the the Federal Government's 2019 Klimaschutzprogramm [14] has the target of 1 million publicly accessible charging points in Germany by 2030, with 50,000 new points installed by 2025 [23]. To enable these targets, the Federal Government has committed €3.3 billion until the end of 2023 [24].

3.1.3 Electric charging infrastructure data monitoring NOW 'OBELIS'

Operators of charging stations that received BMVI funding through the charging infrastructure programme are obliged to report a set of key data such as location, grid connection, charging power, access restrictions and installation costs as well as all charging sessions (duration, energy) every six months via the online portal OBELIS [25]. As of February 2020, 3,877 charging stations with 8,006 charging points and 1,001,364 charging sessions had been reported. The collected data are analysed by NOW's charging infrastructure research team and the insights gained about utilisation are then used within the StandortTOOL for the strategic planning of the roll-out of charging infrastructure [25]. The StandortTOOL connects geographical distribution, technology choices, utilisation rates and power grid loading to model future development of charging and refuelling infrastructure in Germany [26]. This also includes determination of funding levels and the development of new approaches to public funding of charging infrastructure to fulfil the responsibilities of the NLL and implement the Master Plan Charging Infrastructure [23].

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[16] Directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles

[17] Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new vans in the EU

[18] Translated as: Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway

[19] Charging point register

[20] Federal Association of companies in the energy- and water sector

[21] charging points that cannot be accessed 24 hours/7 days a week by any member of the public, for example on supermarket parking lots closed outside of opening hours

3.1.4 Electric vehicle central data monitoring NOW 'ZDM'[22])

The ZDM is a central database collecting data of vehicles and charging infrastructure that received federal public financial support in the various iterations of the BMVI 'Modellregionen Elektromobilität' through to the funding programme 'Electromobility on Site' as well as data from the 'Schaufenster Elektromobilität' described in section 2.2. It was established in 2014 with the explicit aim to support cross-cutting accompanying research and contains basic vehicle data (e. g. model, battery capacity), and trip data (via data loggers) are collected every six months and on an ongoing basis respectively on the basis of a standardised 'minimum dataset' [27]. Vehicle categories included in the ZDM are, *inter alia*, passenger vehicles, light & heavy-duty vehicles, buses and motor cycles. As of January 2020, the ZDM contained 39 million data points, 90% of which relate to trips and charging sessions generated by 1,164 passenger and light-duty vehicles, 50 heavy-duty and special vehicles[23] and 201 buses. The remaining data points comprise basic data of over 12,000 electric vehicles including 880 hybrid- and pure battery electric buses and 600 heavy-duty vehicles, which corresponds to around 4% of all registered EVs in Germany [28]. Figure 3 shows the distribution of vehicles entered in the ZDM throughout the last decade and according to the various phases of the funding programme.

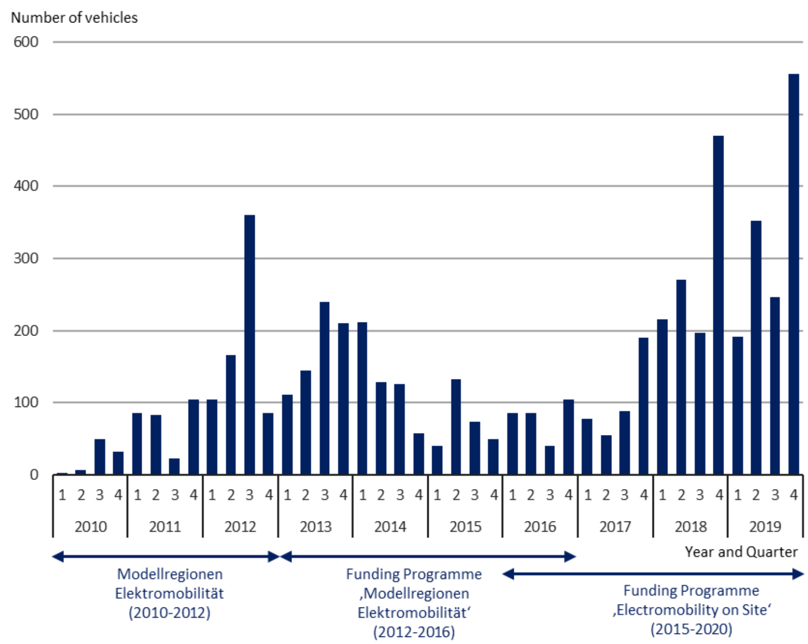

Figure 3 –Start of record of commissioned vehicles recorded in the ZDM database (adapted from [28])

The graph shows expected peaks in vehicle registrations towards the end of funding phases and a significant increase in volume of vehicles with the start of funding of vehicle procurement in addition to R&D projects. Further significant increase in registrations of vehicles supported by the current iteration of 'Electromobility on Site' is expected for 2020 due to approved funding support for high numbers of vehicles that are due to be delivered to customers.

4 Insights from vehicle trip data recorded in the ZDM database

It is instructive to compare trip data from the two latter phases of the funding programme to assess any differences between the initial use of vehicles as part of R&D projects and the current phase with most vehicles procured to replace ICE vehicles in existing municipal fleets. Most of the trip data of the early phase occurred in the years

[22] German acronym: Zentrales Datenmonitoring

[23] These include vehicles such as street sweepers, municipal solid waste collection vehicles, etc.

2015-16, recording 900,000 trips and 180,000 charging sessions of a total of 843 BEVs. For the current phase 219 vehicles delivered data in the years 2018-19, comprising 280,000 trips and 43,000 charging sessions [28].

Vehicles are used in three different types of contexts:

- Municipal fleets (vehicles owned and used by local authorities and other public entities)
- Commercial fleets (vehicles owned and used by local businesses operating in municipalities)
- Company cars (vehicles owned by businesses but assigned to the sole use by one employee)

This section explores a few key insights gained from the vehicles deployed in these contexts used by NOW to help develop a future iteration of 'Electromobility on Site'.

4.1 Mobility requirements in different contexts at municipal level can be amply serviced by electric vehicles available on the market today

Figure 4 presents a break-down of the annual mileage (in km) of vehicles funded within 'Electromobility on Site' in the three main operational contexts of 'company car', 'car part of a company fleet' and 'car part of a municipal fleet'. Several key observations can be made. Firstly, vehicles across all operational contexts assessed here are not driven as much as the average passenger car in Germany, where the average annual mileage is 14.700 km [29]. However, the operational contexts supported by the funding programme are uniquely tied to municipal fleets or businesses operating within these local communities and a general comparison to the national average mileage is not appropriate. Instead, several of the programme's funded municipal electromobility concept papers (section 2.2) [30] provide baseline data of the annual mileage of ICE fleet vehicles before the introduction of BEVs. Interestingly, these reveal that ICE passenger cars in these strictly municipal contexts have very similar daily and annual mileage (examples see [31], [32]) compared to the vehicles monitored in the ZDM (Figure 4).

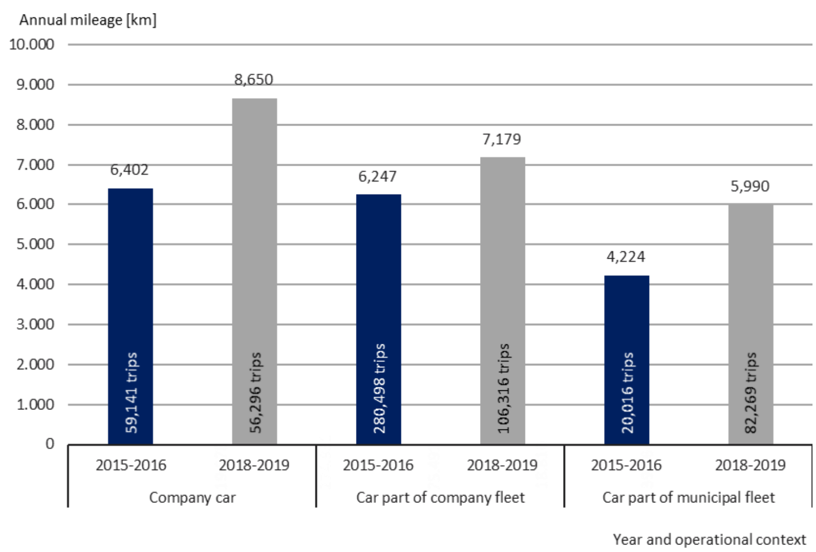

Figure 4 – Annual mileage of vehicles supported by public funds (adapted and translated from [28])

A second observation from Figure 4 is the increased mileage of vehicles when the focus of 'Electromobility on Site' from exclusively R&D contexts (2015-16) shifted towards funding the procurement of vehicles operated within regular use. Particularly significant are the 35% increase in the use of company cars and the 42% increase in the use of communal fleet vehicles between the periods 2015-16 and 2018-19.

The recorded daily mileage of the BEVs in the ZDM increased from an average 32.8 km to 34.0 km between the two periods. Average trip distances remained largely the same at just over 6 km. This points to similar types of trips across both periods, albeit with higher frequency in 2018-19 [28].

Data monitoring the state of charge (SOC) of the vehicles reveals that over 80% of these charging sessions start at an SOC of over 50%, with 85% ending at an SOC of over 91% (Figure 5). This result fits well in the context of the very short individual trip distances, low daily mileage as well as vehicles mostly used as part of fleets with dedicated charging points in the depots.

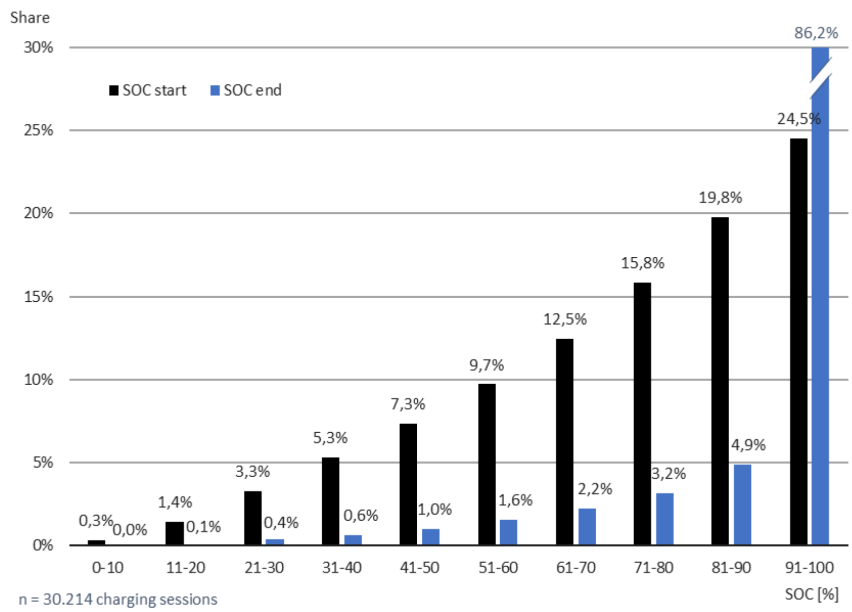

Figure 5 – SOC at start and end of charging session (BEVs in local authority fleets) (translated from [28])

Given the mileage results and battery SOC observations it can be concluded that the funded BEVs are fully able to replace ICE vehicles in these contexts. Moreover, the data evidence that the currently available battery capacities suffice to serve these mobility needs.

4.2 GHG benefits are currently low in these operational contexts but have the potential to improve in the future

Section 2 describes the reduction in GHG emissions as one of the key objectives of the electrification of transport. Many different authors continue to work on assessing aspects of GHG emissions of passenger cars (for a comprehensive overview see [33]). Earlier publications [34], [35] based on ZDM data, identified the following key areas responsible for GHG emissions:

1. The use of a BEV emits less GHG per kilometre compared to an ICE car, including the emissions of the electricity used to charge the BEV.
2. Consequently, the use of electricity from renewable sources to charge BEVs significantly lowers life-cycle emissions. Continued reduction of GHG emissions associated with the electricity mix will progressively improve these.
3. The higher the lifetime mileage of a BEV, the higher the GHG savings compared to ICE cars, even if the exact numbers vary according to a range of assumptions made regarding underlying data of the life cycle.
4. Production of BEVs has higher GHG emissions than ICE passenger cars mostly driven by the power required for battery (cells, modules, packs) production.

In light of the insights from section 4.1 the last two points are particularly significant for the programme design of 'Electromobility on Site'[24].

Starting with the need for high lifetime mileage (bullet point 3 above), the trip data (Figure 4) from the vehicles collected in the ZDM points to low utilisation rates in the operational contexts targeted by the funding guideline. A BEV begins to save GHG emissions compared to a similar ICE vehicle after a 'break-even' mileage point. Using the annual mileage of the 2018-19 period, these 'break-even' points are crossed by BEVs compared to Diesel/petrol ICEs for the operational contexts 'company cars' at 9.2/6.9 years, for 'cars part of company fleets' at 11.1/8.4 years and for 'cars part of communal fleets' at 13.4/10.0 years respectively [28].

The GHG emissions from battery production (bullet point 4 above) depend in large part on the size (capacity in kWh) of the batteries [33]. The larger the production emissions of BEVs, the longer it takes to reach the GHG emissions 'break-even' point. A reduction of battery size (and/or GHG emissions of production) would therefore improve the GHG benefit of BEVs. An analysis of the battery sizes for different passenger cars using data from the vehicles recorded in ZDM has shown an increase in all classes between 2010 and 2019 [28], while the daily recorded mileage between 2015-17 and 2018-19 increased only slightly (section 4.1).

5 Conclusions and considerations for further development of the funding programme 'Electromobility on Site'

Summarising the insights from section 4, collected trip data in ZDM show that electric vehicles currently on the market are suitable for the operational contexts supported by 'Electromobility on Site' to date (short trips and daily mileage, mostly high SOC of the batteries), but also evidence that their annual mileage is too low to provide significant GHG benefit compared to ICE vehicles.

This leads to a few key considerations in the future design of the three pillars (R&D, electromobility concepts and procurement) funding programme 'Electromobility on Site':

In principle, municipal fleet continue to be an important target for funding support. Even though these vehicles do not have high-mileage delivering immediate large GHG reductions, the demonstration character of municipal fleet electrification and valuable insights into the use of EVs in fleets generated in the programme accompanying research continue to support governmental funding support. In addition, these vehicles are mostly used in urban contexts where air pollution is a major concern[25] and therefore deliver environmental benefits beyond reductions in GHG emissions. With the implementation of the EU Clean Vehicles Directive in Germany, local authorities will require continued support to achieve the targets set for low emission vehicles in their fleets.

ZDM data monitoring revealed (as described in section 4), however, that increasing the mileage of the funded vehicles ought to be an important objective to improve the contribution to the reduction of GHG emissions in the transport sector. Current R&D funding and data collection of the programme is targeting the sharing fleet vehicles among organisations to increase individual vehicles' mileage as well as understanding fleet management and charging. Examples are the ongoing R&D projects Smart eFleets[26] [36] and Zukunft.de[27] [37], whose ongoing progress and results are monitored for programme relevance. Future calls for project proposals are expected to

[24] Emissions from electricity generation have to be tackled mostly in the power sector and the programme requires recipients of funding to integrate renewable electricity used to charge vehicles at a minimum by purchasing electricity through 'green electricity tariffs'

[25] In fact, 'Electromobility on Site' has been used as a vehicle to channel Federal funding made available to those local authorities in breach of NOx emissions regulation within the 'Sofortprogramm Saubere Luft' (Immediate Action Programme for Clean Air) in 2017-2020

[26] In Smart eFleets, the public transport operator (BVG), municipal water works and municipal waste management company (BSR) in Berlin are piloting the cross-company sharing of vehicles and charging infrastructure with the goal of reducing vehicle numbers in each of the organisations' fleets and to increase utilisation of the vehicles.

[27] In Zukunft-DE, several last-mile delivery providers share experiences of the electrification and optimisation of their delivery vehicles (mostly light duty).

continue to focus on aspects of large fleet electrification and the sharing of vehicles to support innovation in increasing vehicle utilization rates/mileage.

A potential new funding element under consideration are vouchers for consulting advice on fleet electrification that can be applied for by local authorities and their companies. This is to ensure optimisation of utilisation of vehicles within fleets for example through incorporation of electric bicycles or cargo-bikes to replace trips previously done by car.

In procurement funding continued efforts will be made to identify and target support of high mileage fleets, such as taxi and ride-hailing and sharing companies, and to include these vehicles in the ZDM monitoring. It remains an option to consider limiting funding to smaller battery capacities for certain vehicles, but more conclusive evidence is needed to fully understand optimal battery size for vehicles used in specific contexts and how to integrate this into funding policy.

Finally, and importantly, the data collection and analysis currently performed by the team at NOW has to be intensified, further integrated and expanded to investigate additional aspects of electromobility as well as vehicle types. This includes general market monitoring in Germany and the rest of the world, the analytical modelling for the roll-out of charging infrastructure as part of the Masterplan charging infrastructure as well as the integration of new data sources in the ZDM in order to further understand detailed developments in the use of different types of vehicles, including heavy duty goods transport.

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