Chapter 7
Who Are the Early Adopters of Electric Vehicles in Commercial Transport—A Description of Their Trip Patterns

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7.1 Introduction

Several German literatures focused on identifying the potential of EVs on the German market or try to characterize the potential early adopters (see e.g. Plötz et al. 2014).

Previous studies focusing on the use of electric vehicles try to describe users primarily on the basis of socio-demographic characteristics and to analyze the factors that have influenced the decision to purchase. In the German-speaking countries most studies based on stated-preference surveys of potential users or on surveys of test users within scientific pilot projects or derive the potential out of large traffic and transport data sets (see e.g. Globisch and Dütschke 2013; Trommer et al. 2013; Wietschel et al. 2012; Götz et al. 2011). In Germany, only few studies focusing buyers of EVs were conducted. But these studies include relatively small sample sizes with less than 100 participants (see e.g. Peters et al. 2011). Their results are limited generalizable. Especially studies focusing the commercial users of EVs in Germany are relatively rare. Nevertheless, there are nearly 20,000 registered EVs in Germany already and thus a notable number of private and commercial users integrating EVs in everyday life (KBA 2015). This target group and their experiences need to be analyzed. Regarding the usage of EV technologies, the influence on the current organization of commercial transport and traffic is one important topic. The paper is therefore focusing on the usage of EV technologies

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and the influence on the current organization of commercial transport and traffic. The main questions within this topic are addressed:

- How is the target group characterized?
- How are EVs implemented in (present) fleet?
- Is the logistical organization of companies restructured by using electric vehicles in comparison to conventional vehicles, and how is thus done?

To answer these questions the paper presents extracts from a conducted study of current electric vehicle users in Germany. Focusing on commercial early adopters the paper will first give an overview of their profile and second describe their trip patterns like distances and trip planning behavior. Finally the paper will give insights into replacements of ICEVs and its effects.

7.2 Data and Methodology

7.2.1 Methodology of the Survey

To describe the status quo of the usage of electric vehicle, and to get an impression of the early adopter and their user behavior for the first time, the Institute of Transport Research of the DLR e.V. (German Aerospace Centre) conducted a survey across all owners (private and commercial) of electric vehicles in Germany. The survey took place between December 2013 and February 2014. Over 9,200 persons were addressed (gross-sample). One third (n = 3,111) of them answered, while the commercial electric vehicle user constitute 37 % (n = 1,165). This proportion corresponds to the one in the gross-sample.

The target group of respondents included owners of all kinds of electric vehicles with an external charging option registered in Germany. These include BEVs, which are equipped purely with a battery electric drive, and so-called plug-in hybrids (PHEVs), which are equipped with an internal combustion engine (ICEV) in addition to the electric motor. No further distinction between PHEVs and so-called range extended vehicles (REEV) was made. On account of the comparatively widespread use of electric light vehicles (e.g. the Renault Twizy), these were also included in the sample, provided that they satisfied the requirement of being a three- to four-wheeled vehicle with at least 300 kg gross vehicle weight. Two-wheeled vehicles were excluded because part of this vehicle group contains of electrically driven wheelchair. Those were not originally targeted. Another limitation regarding the sample refers to the branches. Registered vehicle owners of branches like car manufacturing, wholesale or trade or repair of motor vehicles or car rental as well as car sharing were also excluded. The survey aimed at analyzing the usage of EVs and therefore addressed the users. It was assumed that companies of the mentioned branches do not use electric vehicles themselves in most cases. As a result the actual users of the electric vehicles cannot be determined. Due to these exclusion criteria the finally addressed persons are described as gross-sample and the respondents[1] as net-sample.

The survey was conducted using standardized online questionnaires. These asked not only multiple-choice questions, but also quite deliberately open ones. In co-operation with the Federal Motor Transport Authority (KBA), the target group was contacted by mail and was thus made aware of the online survey. Due to data-protection provisions no personal data were recorded and therefore a non-response-analysis had to be renounced.

The survey contained questions on the following subjects:

- characteristics of the electric vehicle
- motivation for vehicle purchase
- use of vehicle
- charging pattern
- general information about companies using electric vehicles

Generally, the aim of the study was to analyze the actual utilization of electric vehicles in everyday life. Thus, to control the goal been achieved the commercial questionnaire first asked whether the respondents have taken the decision to buy an electric vehicle themselves; and whether they are the vehicle user. If they are not one and the same person, the actual vehicle user should answer the subsequent questions. A solid majority of the respondents (72 %) identified themselves as being both decision-maker and user or the person planning the disposition of the electric vehicle. One reason for this coincidence is the large proportion of small-sized companies among the commercial users of electric vehicles (see next sector). Further 19 % are just user or planning persons and only a minority (9 %) just decided the EVs purchase.[2]

7.2.2 External Data for Comparison

To figure out whether and to what extent the commercial EV users perform differently from general commercial traffic behavior, the survey results are compared to information given by a major data source of commercial road transport in Germany called Motor Traffic in Germany (KiD) (WVI 2010). The KiD was conducted in 2010 and collected a large number of driving profiles in commercial traffic. The observation period of these survey covers one day. The data set of KiD 2010 therefore consists of vehicles with and also without movements on the survey day.

[1]This paper concentrates on the description of commercial EV users. Net-sample therefore means commercial respondents. Unless there is no other indicated amount the net-sample constitutes of 1,165 commercial respondents.

[2]At this point no filtering will be executed. It cannot be assumed that the decision-maker are unable to give statements regarding EVs usage.

All references to ICEVs in the following text are own calculations based on the KiD 2010 data set and refer to car-sized and light-duty vehicle up to 3.5 tons gross vehicle weight powered by internal combustion engines. The analyses regarding ICEVs are restricted to these vehicle sizes in order to improve a certain comparability to the EVs data. An inclusion of vehicle sizes of 3.5 tons gross vehicle weight and more would lead to distortions because there are no comparable sizes of EVs available and recorded in the survey. Furthermore analyses of the KiD 2010 data set in this paper exclusively involve vehicles which were used during the observation period.

Both studies differ regarding their survey styles. Meanwhile the KiD collects trip profiles through protocols for the survey day, the survey of electric vehicle users asked of experienced averages. A comparison of groups from both studies therefore can be seen as a first approach only, since “before and after” data are not yet existing to this extent and context.

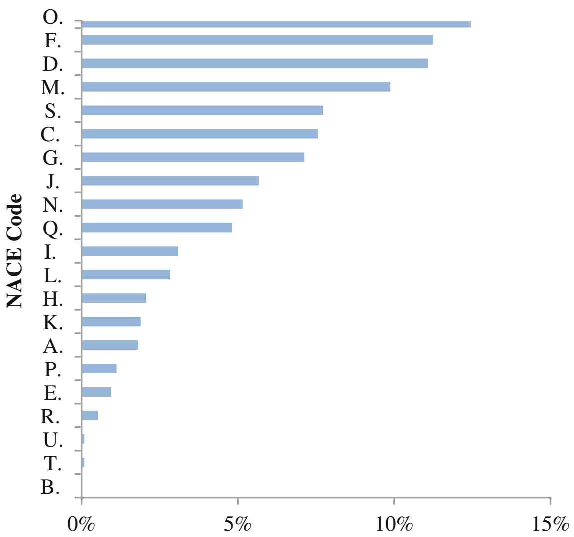
7.3 Profile of the Commercial Users of Electric Vehicles in Germany

First, a short description of the current commercial users of electric mobility will give an impression of their characteristics. Such users primarily (two-thirds) work in small companies[3] with one establishment employing 49 persons and operating a fleet of up to nine vehicles, including one electric vehicle. The main sectors practicing electric mobility are public administration (13 % of commercial users), construction industry (12 %) and energy supply (electricity, gas, steam etc.) (11 %) (see Fig. 7.1). No branch distinguishes itself as having a special affinity for electric mobility. But by combining all its defined branches,[4] the service sector constitutes the largest number of commercial electric vehicle users, at 25 %.

Commercial electric mobility must not only be seen as a phenomenon of major cities (with at least 100,000 inhabitants). In fact it is almost equally present in small-sized towns with at least 5,000 up to 20,000 inhabitants (32 %) and major cities (34 %) (see Fig. 7.2). Due to similar distributions regarding spatial patterns, it can be assumed that the net-sample is approximately equivalent to the gross-sample. A comparison of gross- and net-samples regarding branches shows different distributions. While, as described, the main branches in the net-sample are public administration, construction industry and energy supply, the main part of the gross-sample are other services activities (37 %).

[3]The categorization of companies is along the lines of the NACE classification 2008 from the European Commission (Eurostat 2008).

[4]That includes the NACE Codes K, M, N, S.



Legend
O. Public administration and defense; compulsory social security
F. Construction
D. Electricity, gas, steam and air conditioning supply
M. Professional, scientific and technical activities
S. Other services activities
C. Manufacturing
G. Wholesale and retail trade; repair of motor vehicles and motorcycles
J. Information and communication
N. Administrative and support service activities
Q. Human health and social work activities
I. Accommodation and food service activities
L. Real estate activities
H. Transporting and storage
K. Financial and insurance activities
A. Agriculture, forestry and fishing
P. Education
E. Water supply; sewerage; waste management and remediation activities
R. Arts, entertainment and recreation
T. Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use
U. Activities of extraterritorial organizations and bodies
B. Mining and quarrying

Fig. 7.1 EV users differentiated by branches (n = 1,131)

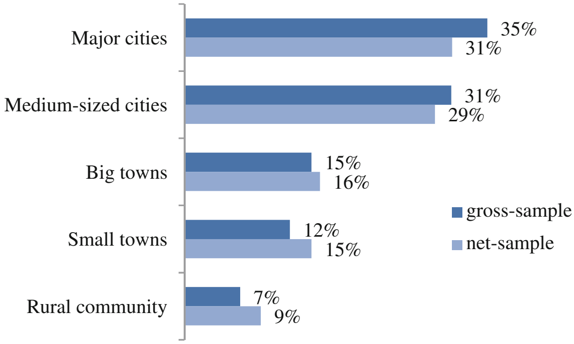


Fig. 7.2 Distribution of EV users' sites within the gross-sample (n = 3,710) and net-sample (n = 1,085). The spatial levels are taken from the Federal Institute for Research on Building; Urban Affairs and Spatial Development (BBSR). Major cities are defined as municipalities with at least 100,000 inhabitants. Medium-sized towns are municipalities with at least 20,000 up to 100,000 inhabitants. Small-sized towns are defined as municipalities with at least 5,000 up to 20,000 inhabitants. Smaller units are defined as rural communities (BBSR 2003)

7.4 Descriptive Analysis of Trip Patterns

7.4.1 Usage Restrictions

Regarding usability, the commercial users were asked which purpose their electric vehicles should serve but are restricted by technical properties. One third answered that they are able to use the electric vehicle without feeling any restrictions to their purpose. The underlying causes of restrictions—if perceived as such—are the low range (41 %) and the long charging duration (28 %).[5]

In the following, the paper will go into more detail regarding aspects like daily driven distances, EV trip planning and whether the EVs replaced an ICEV and the resulting impacts.

7.4.2 Distances

Half of the respondents (52 %) report daily tours[6] of up to 30 km per trip on average across the entire fleet. A further 31 % state the tours of the company fleet differ between longer and shorter distances and longer and shorter stops. The remaining 17 % are driving more than 30 km per trip on average. The daily distance covered by the electric motor of plug-in hybrids is 47 km, and of BEVs (battery electric

[5]Within the question concerning usage restrictions multiple answers were possible.

[6]A tour is understood as a sequence (linkage) of several trips. A tour has the same start and end point (Clausen 2009, p. 155).

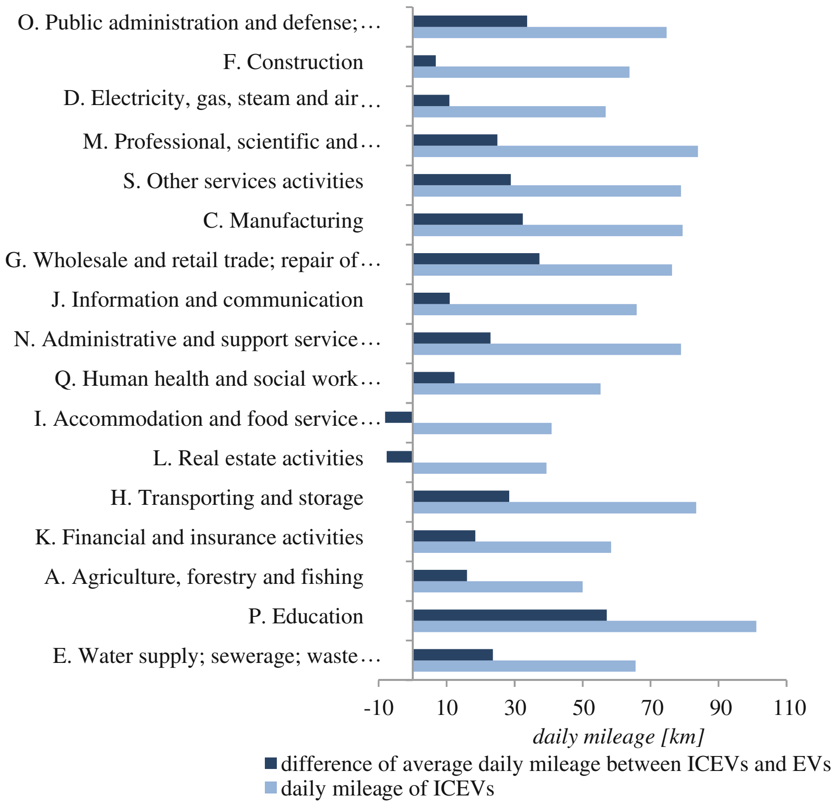


Fig. 7.3 Average daily mileages of ICEVs and the differences between average daily mileages of ICEVs (n = 26,199) and EVs (n = 1,131) in kilometers sorted by branches frequency. The information regarding the daily driven distances of ICEVs are the author's own calculations based on the KiD 2010 data set and refer to mileage for the purpose of commercial transport (WVI et al. 2010). As mentioned, the group of ICEVs considered consists of car-sized and light-duty vehicle with up to 3.5 tons gross vehicle weight. Information about the daily mileages of EVs is calculated based on the survey data. The respondents were requested to specify their average daily electric-driven kilometers for commercial purposes. Sectors which were mentioned by less than 10 respondents are unconsidered in this figure

vehicles) is 49 km. Every fourth commercial user drives even shorter electrical distances per day of up to 25 km. To get an impression whether EV usage differs from ICEV usage a comparison with trip data out of the KiD 2010 will be given in the following.

When considering the commercial daily mileage separated by type of vehicle propulsion and branches, it is recognizable that the majority of electric daily driven distances are between 40 and 60 km, whereas in more than half of the branches (13 out of 21) ICEVs' daily mileages are over 60 km in average (see Fig. 7.3). But only three sectors (P. Education, M. Professional, scientific and technical activities and H. Transporting and storage) drive on average more than 80 km per day.

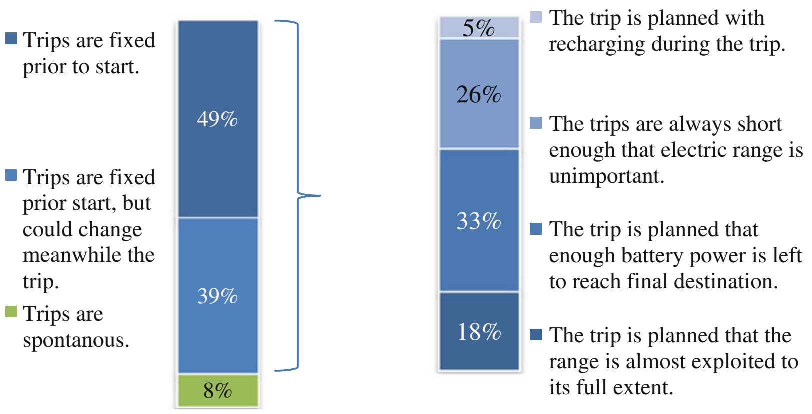


Fig. 7.4 Trip planning profiles. The remaining percent to 100 % are accounted for the answers "do not know" and "not specified". And the importance of electric range within trip planning

Further information is gained by an analogy of the daily mileages of electric powered vehicles and those powered by internal combustion engines, demonstrated by their differences per branch.[7] The majority of commercial EV users drive fewer kilometers per day on average compared to their ICEV counterparts. Deviations are varying from 11 up to 56 % of the ICEVs average daily mileage per branch. Focusing on the top three most common represented sectors within the EVs (see also Fig. 7.1), differences vary between 7 km (F. Construction) which means a deviation of 11 % and 34 km (O. Public administration and defense; compulsory social security) which means a deviation of 45 %.

7.4.3 Trip Planning

Currently, the majority (88 %) of commercial electric vehicle users plan their trips in advance (see Fig. 7.4). Almost half of them (45 %) use manual trip planning.[8] Only a minority of 9 % of plans are software-based. Note that an additional 19 % of those planning their trips are not integrating their EVs in these processes. The proportion of trip planning by users of EVs is, however, higher compared with car-sized and light duty vehicles powered by internal combustion engines in Germany (WVI 2010). Trips are manually planned in 24 % of ICEVs. The amount of non-planned trips is 40 % within ICEVs. Unexpectedly, considering the fact of

[7]The calculation of the differences based on the ICEVs' average daily mileages subtracted with those of the EVs.

[8]Within the question concerning the usage of trip planning technologies multiple answers were possible.

limited range and long charging duration, it seems unnecessary to strictly regulate EV usage for every fifth user. But those who are planning their trips with an EV are aware of its limited range. One third of planned trips are prepared in a way that enough battery power is left when finished. Even 18 % almost exploit the electric range. This applies to PHEVs (27 %) and BEVs (17 %) as well.

Distinguishing between users who plan their trips and those who do not shows only small differences in electric daily driven distances. Planned trips cover 46 electric driven kilometers on average per day. Meanwhile, spontaneous trips reach 44 km daily. It is interesting that users, who have planned trips which may change during the trip, drive electrical on average 54 km. That is on average 8 km more than exclusively planned trips and 10 km more than spontaneous trips.

EV usage in branches with less differences, such as the construction industry, is more planned and thus there is a greater awareness of the length and duration of their trips. However, such assumptions cannot be confirmed by the data. The construction industry plans its EV usage less compared to the average of EV users. Only 35 % of users of this branch plan their EV trips in advance, whereas a branch recording large deviations between the daily mileages of ICEVs and EVs, such as in sector O (Public administration and defense; compulsory social security) plan their EV trips more often (59 %).[9]

Even if the differences are quite large when looking at the average daily mileages of ICEVs, it seems unnecessary to be aware of restrictions in electric range, which would be sufficient to cover the daily mileage directly even without recharging. A further look at Fig. 7.4 shows that, only a minority (5 %) is integrating recharging into their trip planning. That means few commercial users are taking f.e. the usage of public charging infrastructure into account while preparing their EV trips. That en route recharging is rare, is also evident in the question of charging places and times. The majority (77 %) start charging in the afternoon and evening hours between 15:00 and 22:00. The preferred place for charging is the own premise. 62 % uses this charging place (almost) daily.

7.4.4 Replacement of ICEVs by EVs and the Impact on Transportation Processes

Due to the reduction of transport-related CO_2 emissions, it is relevant whether the electric vehicle was purchased by the company in addition to the already existing vehicles powered by internal combustion engines or if vehicles were replaced. Forty percent of the commercial respondents indicated that they have replaced another vehicle since the purchase of an electric vehicle. Another 9 % plans to replace it within the next 12 months. This shows that almost half of the respondents (plans to) exchange an existing ICEV for an EV. The question of whether such abolition has a

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[9]For the average of trip planning behavior see Fig. 7.4.

causal relationship to the purchase of the EV was confirmed by 89 % of the commercial respondents.

The EV mostly replaced the other vehicle directly. Only a relatively small proportion (9 %) of commercial electric vehicle users used the vehicle temporarily in parallel with the subsequently replaced vehicle, and decommissioned the latter only within the first 12 months after the purchase of the EV. There were a variety of reasons: the users wanted to test the reliability of the EV, gain confidence, and in case of malfunctions, be able to replace the electric vehicle with a conventional vehicle, or they just generally wanted to experiment with using the electric vehicle.

In distinguishing between BEVs and PHEVs, it can be seen that since the EV's purchase already more than half of the PHEVs (57 %), though only 41 % of BEV users, replaced an ICEV. This suggests that using a BEV is perceived as more restrictive and therefore in the event of a default hold a replacement ICEV.

The analysis shows that almost every fourth commercially used EV is a small car (e.g. VW Polo). Another 20 % are EVs with 3.5 tons gross vehicle weight. In 32 % of all cases, the electric vehicle replaces another vehicle (50 % diesel, 42 %

Vehicle segment of the substituted vehicle

Vehicle segment of the EV	Light vehicle	Very small cars	Small cars	Compact cars	Medium-ranged cars	Luxury cars, Sportswagon	Light-duty vehicles
Light vehicle	4	4	13	5	7	5	0
Very small cars	0	18	18	9	5	5	3
Small cars	0	5	36	25	10	8	14
Compact cars	1	0	7	31	34	18	11
Medium-ranged cars	0	0	0	2	4	5	0
Luxury cars, Sportswagon	0	0	1	1	5	16	2
Light-duty vehicles	0	1	7	6	4	2	62

Legend

0 respondents
1-10 respondents
11-20 respondents
21-30 respondents
31-40 respondents
over 40 respondents

Fig. 7.5 Comparison of vehicle segments of the EV and the substituted vehicle (n = 414)

gasoline). A closer look at cases where the EV replaces a car refutes the thesis: a trend towards smaller sizes is recognizable (see Fig. 7.5). Almost every second (49 %) user who replaced another vehicle chose a smaller sized EV. This fact indicates that commercial users partly have to choose smaller EVs because of the limited number of models available at the moment. This is at least confirmed by analyzing the usage restrictions of commercial EV users. The data show that low possible payload is a central reason for non-usage especially regarding the transportation of goods. In other words, the limited options of EVs with larger payload limit the amount of users.

To answer the question whether a replacement of an ICEV and the usage of an EV influences transport organizations, the survey asked if the yearly driving performance of the fleet changed after the introduction of the EVs.[10] Nevertheless the majority (70 %) of these users who replaced a vehicle by an electric one quotes no change, neither increasing nor decreasing, in the annual driving performance of the company's fleet. A separate analysis—of cases in which the EV replaced another and those who do not—shows no differences in the response towards annual mileage.

Further, the users were asked whether the payload has changed through the use of the EV instead of the substituted Diesel or gasoline engine. The results given by Fig. 7.5 are confirmed within the question asking about a possible change regarding their payload. One third of users who replaced a combustion engine vehicle by an electric vehicle report a diminished payload capacity. The majority (59 %) feels no changes in point of payload.

7.5 Conclusions

The analysis first shows that a majority of smaller companies are the early adopters of electric mobility. They are driving electrical distances of 49 km on average per day. The commercial early adopters in Germany are mainly to be found in branches realizing mainly business passenger transport (f.e. public administration, energy supply or service sector) in small-sized towns as well as in major cities.

It is conceivable that EVs cannot operate all kind of trips, due to their limited range. The restrictions and possibilities associated with the electric vehicle technologies (e.g. range, charging time and emission-free usage) and the type of implementation in fleets could affect the organization of commercial transport and traffic and the demand of adjustments. Therefore, it seems reasonable to assume that trips are recreated while implementing EVs in present fleets. This could have an impact on the driving performances of fleets. However, the results are giving no indications to confirm this thesis. Only 40 % of the commercial EV users substitute another Diesel or gasoline engine within the purchase. That means the majority

[10]At this point only companies owning two and more vehicles are considered.

integrate EVs as additional vehicles in their fleets. Half of the substitutions were connected with a reduction in vehicle sizes. That influenced partly the impact on the payload. Every third user remarks a diminished payload. In addition, constraints mentioned by the commercial users are rather seen in the transportation of goods and materials due to insufficient payload. It could be assumed that the down-scaling while substituting an ICEV can be explained by a limited variety in electric vehicle models. Particularly when it comes to transport loads larger vehicle sizes of EVs are required.

One major result is that the commercial early adopters have trip structures matching the range and charging characteristics of EVs. So they have therefore trip-profiles which allow usage without any adjustments or adaptations regarding technical conditions. The analysis regarding distances further shows that the EV usage varies thereby from sector to sector partially immense from those of the ICEVs used in Germany. Few branches seem to use their EVs similar to their ICEVs with respect to daily mileages, while others are rather cautiously and drive less kilometers electric than with combustion engines. The results indicate that the commercial early adopters are not restructuring It therefore seems that the commercial early adopters of EVs are not representative for their branch in this point.

In addition regarding the topic of logistical organization it is noticeable that compared to the German average EV using companies are planning more frequently their trips in advance. One could be forgiven for thinking that trip planning behavior has an impact on the willingness to integrate EVs in the company fleet. But a test of correlation between these two aspects cannot be given by the study. Furthermore whether these variations in daily mileages and downscaling (within replacements) are leading to logistical conflicts is a matter of speculations. To gain insights into this topic it is necessary to examine the whole heterogeneous fleet and ideally to select before/after data.

A further interesting result of the analysis of trip planning behavior is that recharging during trips is rarely planed by the commercial early adopter and the majority charges on their own remises. An expansion of public charging infrastructure seems not necessarily to be a solution to increase the attractiveness of electric vehicle for potential commercial user.

The paper describes results of a study of commercial early adopters of electric vehicle with a special focus on their trip patterns. As mentioned due to data-protection provisions a non-response-analysis had to be renounced. A representative status of the study therefore had to be verified by sample characteristics. A closer view on electric users company locations described by postal codes first shows an almost similar distribution within the gross- and the net-sample. Meanwhile a second comparison of branch distributions shows variations. But because of different survey methods, however, industry classification cannot provide guidance towards representative status. In the gross-sample, employees of the Federal Motor Transport Authority (KBA) categorized the vehicle-owning companies into branches. The respondents, in contrast, were requested to specify the branch of their company themselves. In terms of categorizing their company with respect to the branches of NACE classification, respondents often deviate from the categorization given by official authorities (WVI 2012, p. 288ff.). The self-specification on the level of sections (A to U) may lead to inaccurate information. Further characteristics for testing representativeness are unavailable due to a lack of information within the gross-sample.

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