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What is the market potential of electric vehicles as commercial passenger cars? A case study from Germany

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Abstract

Commercial passenger cars are often discussed as an early market segment for plug-in electric vehicles (EVs). Compared to private vehicles, the commercial vehicle segment is characterized by higher vehicle kilometers travelled and a higher share of vehicle sales in Germany. Studies which consider commercial passenger EVs less important than private ones often use driving data with an observation period of only one day. Here, we calculate the market potential of EVs for the German commercial passenger car sector by determining the technical and economic potential in 2020 for multiday driving profiles to be operated as EV. We find that commercial vehicles are better suited for EVs than private ones because of the regularity of their driving. About 87% of analysed vehicles could technically be operated as battery electric vehicles (BEVs) while plug-in hybrid electric vehicles (PHEVs) could obtain an electric driving share of 60% on average. In moderate energy price scenarios EVs can reach a market share of 4% in the German commercial passenger car market by 2020 while especially the large commercial branches are important. However, our analysis shows a high sensitivity of results to energy and battery prices as well as electric consumptions.

Contents

1. Introduction

Electric vehicles (EVs) are widely accepted as a promising instrument to reduce greenhouse gas emissions from the transport sector [1]. Germany is an important market for passenger cars and a main player in the traditional automotive industry worldwide [2]. In order to maintain this dominant position also in the market for electric vehicles [3], the German Federal Government set the goal of one million EVs in stock by 2020 [4]. This target is supported by a number of field trials and research programmes [5]. Nevertheless, the number of EVs in today's German passenger car fleet is limited and market share are lower than in other countries [6, 7]. One bearer of hope are commercial passenger cars which are considered as an early market [8].

In general, the characteristics of the commercial sector in Germany are advantageous for the adoption of innovative fuel efficient vehicle concepts such as EVs. The large share of annual first registrations (60% for commercial owners in Germany [9]) provides an important lever for the integration of EVs into the vehicle stock and thus for mass market introduction. High vehicle kilometers travelled (VKT) are advantageous due to the lower operating costs of EVs compared to conventional vehicles. On the other hand, the comparatively high VKT of commercial cars also indicate a similarly high share of CO_2 emissions resulting from final energy consumption which is still rising (24% in 1990 to 37% in 2008) [10]. Hence, the diffusion of electric vehicles in the commercial passenger car sector could significantly reduce final energy consumption and CO_2 emissions and is thus an interesting field of research.

Commercial passenger cars and the operation of electric vehicles therein has received considerable attention in the literature ranging from general works on the commercial vehicle sector, over studies which determine use cases or treat the vehicle purchase behaviour to specific case studies.

General works on the driving behaviour of commercial vehicles do not focus on EVs in particular. They describe [11–14] or model [15] the driving behaviour of commercial passenger cars. Schwerdtfeger (1976) [11] describes the urban delivery traffic by its type and volume, whereas Steinmeyer (2007) [14] or Schütte (1997) [12] use driving data to define commercial passenger traffic. Deneke (2005) [13] developed a method to cluster commercial traffic into different categories depending on the economic sector, the actual driving pattern and the vehicle characteristics. Ruan et al. (2012) [15] underline the potential of analysing interrelationships among individual tours.

A second group of studies tries to identify specific use cases for electric vehicles in the commercial sector based on the driving behaviour [16–24]. For example, Clausen and Schaumann (2012) [16] find plug-in hybrid electric vehicles (PHEVs) as important transitional technology to battery electric vehicles (BEVs) as well as fuel cell electric vehicles (FCEVs) for urban logistics whereas Ketelaer et al. (2014) [17] find well fitting driving patterns in postal services. Feng and Figliozzi (2012, 2013) [18, 19] focus on the replaceability of commercial trucks by electric vehicles. Furthermore, there are several studies with a specific technical focus, like battery swapping for vehicle fleets [20], the public transport sector [21] or energy consumption in companies [22], studies focusing on specific vehicle types as small sized electric vehicles [23] as well as works which analyse the electric driving share of commercial PHEVs in field trials [24].

The vehicle purchase behaviour of commercial vehicles is the research focus of a third group of studies [25–28]. The analysis of purchasing behaviour in the field of psychological research identifies purchase criteria and their importance for the purchase decision. Purchasing behaviour can differ for different fleet purchase structures [26]. The diversity of fleet purchase structures leads to different attitudes with respect to the adoption of recently launched alternative fuel vehicles. The testing of new technologies, besides factors as environmental impact and public image, plays an important role [27]. Analysing preferences of fleet managers for alternative fuel vehicles, [25] find public fleets being most responsive to capital costs and private fleets focusing on ”practical operational needs”. Figliozzi and Feng (2012) [28] identify the key technical and economical factors for electric commercial vehicles to economize against conventional vehicles.

Studies that analyse the market potential for EVs specifically for the commercial sector are rare. When market potentials are calculated, the commercial vehicle market is often not considered (see e. g. [29]) and only some reflect commercial vehicles explicitly as a part of their analysis [30–33].[1] Few studies focus their research on the market potential of electric vehicles in the commercial passenger car sector [17, 25, 35]. Berg (1985) [35] conducted 583 interviews to identify the size of the potential market for electric vehicles in the US based on driving patterns. He does not consider economical factors but analyses several driving and structural characteristics of companies to retrieve market potentials. Golob et al. (1999) [25] perform a survey with 2,000 fleet managers in the US as a basis for a consecutive market potential estimation. Ketelaer et al. (2014) [17] use data from [36] to estimate the market potential of EVs in postal services. A comprehensive analysis on EV market potential in the German commercial passenger car sector is to the best of our knowledge not available at this point.

The aim of the present paper is to analyse the market potential of electric vehicles in the German commercial passenger car sector. We determine market potentials based on an individual EV battery simulation and a consecutive comparison of total costs of ownership for electric and conventional vehicles. This is in accordance with earlier works [33, 37–41] and a useful approach since commercial car buying decisions mainly rely on cost [25, 42]. Our calculations base on more than 500 driving profiles from the commercial passenger car sector collected with GPS-trackers in German companies from 2011 until 2014 [43].

This work differs from previous studies on the potential of EVs as commercial passenger cars. First, we analyze longitudinal driving data with about three

[1] See [34] for a recent review on market diffusion models for EVs.

weeks of observation. This is important to not overestimate market potentials based on the data collections of only one day (see e. g. [41, 44]). Second, this longitudinal data allows us to compare the regularity of daily driving individually. Third, we analyze subsectors of the commercial passenger car sector in detail to identify branches with EV market potential. In this study we focus on plug-in electric vehicles, i. e. battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and range-extended electric vehicles (REEV), without considering hybrid electric vehicles without plugs or fuel cell electric vehicles.

The outline of this paper is as follows: In the following section we introduce the market for commercial passenger cars in Germany and point out some peculiarities. Section 3 holds the methods used to analyse market potentials and the underlying technical and economical assumptions, while the driving profiles are described in section 4. The results are presented and discussed in section 5 and conclusions are drawn in section 6.

2. Commercial passenger cars in Germany

The commercial passenger car sector is very heterogeneous and no unique definition exists for it [13, 14]. We identify four main definitions in the literature: a car is defined as commercial passenger car (1) according to the purpose of the trip, (trip to work vs. a leisure trip) [45], (2) according to the means of transport (goods vs. people) [45], (3) according to the vehicles weight (with vehicles above 3.5 tons being considered as commercial vehicles) [46] or (4) according to the car holder (person vs. company) [47]. Here, we follow the last definition using car holder information: the commercial passenger car sector comprises all trips of vehicles registered to commercial vehicle owners. An advantage of this approach is that car registration data is publicly available [9, 47]. A disadvantage is the impossibility to distinguish between vehicles that are company owned but also privately used (so-called company cars) and purely commercial vehicles (fleet vehicles). However, there is no publicly available data to distinguish between the two.

In Germany, 90 % of passenger cars (with a weight of less than 3.5 tons) in the vehicle stock are privately owned, whereas 60 % of annual first registrations are registered to a company [9, 47]. Compared to the private sector, the commercial sector is characterized by a higher number of vehicle kilometers travelled (VKT), a larger motor size and a shorter holding time, see Table 1.

The high share of commercial passenger cars in registrations in line with a low share in stock results from a shorter holding time (or higher turnover rate) for commercial vehicles and a large second car market that is dominated by private vehicle buyers. However, there are certain industrial branches that dominate the new car registrations and holding times vary between different industries. Table 2 shows the industrial branches according to NACE Rev. 2 sections [50] with their passenger car registrations in 2012, their vehicle stock at the beginning of 2013 and their average holding time (as ratio between the two) sorted by registrations.

Table 1: Privately and commercially licensed passenger cars in Germany

criteria	private	commercial	ref.
Stock (2014-01-01)	39,363,889	4,487,341	[47]
Share of stock	89.8%	10.2%	[47]
Registrations (2013)	1,120,125	1,832,306	[9]
Share of registrations	37.9%	62.1%	[9]
Avg. veh. holding time [a]	6.2	3–4	[48, 49]
Avg. motor size [ccm]	1,638	1,994	[47]
Avg. VKT on weekday [km]	40.1	76.8	[45]
Avg. VKT on Sat./Sun. [km]	28.8	29.3	[45]

We find that about 90% of all commercially licensed vehicles are newly registered in four groups: Wholesale and Trade (G), Manufacturing (C), Administrative and support service activities (N) and Other service activities (S). The holding times in sectors G,C and N are much lower than average (1.1 to 1.7 years). About 89% of vehicles within section G are licensed to companies that work within vehicle trade, with vehicle parts and vehicle maintenance [51]. In section C another 74% of vehicles are registered to vehicle construction while car rentals sum up to 85% of vehicles in section N [51]. Thus in total 63% of all commercial passenger car registrations are directly related to the automotive industry. This is important to know since a large number of these vehicles might be showroom cars that are hardly driven during first registration. Nevertheless a short holding time results in a faster second-car life cycle.

Table 2: German commercial passenger car statistics

NACE Rev.2 - section	registrations 2012	stock 01/01/2013	avg. holding time [yrs.]
G - Wholesale and trade	699,506	742,005	1.1
C - Manufacturing	380,367	658,608	1.7
N - Administrative and support services	357,835	425,946	1.2
S - Other service activities	265,926	1,461,127	5.5
Q - Human health and social work	33,391	187,660	5.6
F - Construction	31,150	227,166	7.3
O - Public admin., defence, social security	28,546	130,429	4.6
H - Transportation and storage	27,269	153,604	5.6
K - Financial and insurance activities	18,582	66,465	3.6
J - Information and communication	16,271	66,020	4.1
M - Professional, scient., tech. activities	12,065	49,913	4.1
D - Electricity, gas, steam, air conditioning	7,452	38,614	5.2
I - Accommodation and food service	5,495	46,254	8.4
L - Real estate activities	4,419	17,420	3.9
E - Water, sewerage, waste, remediation	3,938	24,401	6.2
R - Arts, entertainment and recreation	3,541	19,717	5.6
A - Agriculture, forestry, shipping	2,963	37,934	12.8
P - Education	2,134	10,640	5.0
T - Households and other	1,418	6,856	4.8
B - Mining and quarrying	1,192	7,403	6.2

The fourth largest car registration group is section S which contains about 14% of all commercial registrations. 99% of this group comprise membership organizations, trade unions as well as political and religious organizations [51]. In the further analysis we will put special consideration on these four vehicle groups.

3. Methodology

In the present study we analyze driving profiles of commercial passenger cars. Here and in the following, a driving profile comprises all trips of a vehicle within a defined observation period. To determine the market potential of electric vehicles in commercial passenger car transport, we first simulate each driving profile as electric vehicle and calculate its total cost of ownership (TCO) for different drive trains (section 3.1). Second, a deeper analysis of the real world consumption of the driving profiles by modelling driving forces is given in section 3.2.

3.1. Calculation of market potentials

In the technical analysis we simulate each driving profile to be driven with an electric vehicle. We simulate the batteries of pure battery electric vehicles, plug-in hybrid electric vehicles and range-extended electric vehicles by calculating the battery state of charge (SOC(t)) of a battery for a specific point in time t as follows:

$$\mathrm{SOC}(t+1) = \begin{cases} \mathrm{SOC}(t) - d_{\Delta t} \cdot c_{size} & \text{for} \quad d_{\Delta t} > 0 \\ \min\{\mathrm{SOC}(t) + \Delta t \cdot P_{loc_t}, C\} & \phantom{\text{for}} \quad d_{\Delta t} = 0 \end{cases} \tag{1}$$

The initial value is given by $\mathrm{SOC}(0) = C$. C in kWh describes the capacity of the battery analyzed. As the driving profiles consists of several trips, the distance of each trip in a driving profile between the trip departure t and arrival $t + \Delta t$ is given in $d_{\Delta t}$ (in km), while Δt is the duration of the trip (in hours). With the specific consumption of electricity c_{size} (in kWh/km) which depends on the car size we determine the electricity consumed for this trip by multiplying the specific consumption with the distance. Furthermore, considering t as arrival time after a trip, P_{loc_t} in kW describes the power for charging at the location where the car is parked at time t. If no charging infrastructure is available, we set $P_{loc_t} = 0$. Thus, equation (1) describes that the battery will be discharged by the energy needed for driving distance $d_{\Delta t}$, if the car is driven (case 1). Otherwise (case 2), it will be charged with the power P_{loc_t} for the time Δt if necessary and charging infrastructure is available ($P_{loc_t} > 0$). With this battery simulation, we determine whether the driving profile can be driven completely with a BEV or which fraction could be driven in electric mode with a REEV or PHEV, i. e. the electric driving share. For BEVs we check if all $\mathrm{SOC}(t) > 0$ while the sum of electric kilometers within a profile divided by the total kilometers in the profile determines the electric driving share.[2]

[2]We simulate REEVs and PHEVs both in charge depletion mode regardless of the underlying technical concepts. They differentiate only in battery size (resp. cost) as well as electric

Using the results from the technical analysis, we determine the cost-optimal drive train for each user. We calculate the total cost of ownership (TCO) for five different propulsion systems (Gasoline, Diesel, PHEV, REEV, BEV) for each user and assign the one with the lowest (annual) TCO to the driving profile. The annual total cost of ownership TCO_a consists of capital expenditure a_{capex} and operating expenditure a_{opex}:

$$TCO_a = a_{capex} + a_{opex} \tag{2}$$

We use the discounted cash-flow method with residual values and calculate the investment annuity:

$$a_{capex} = (I \cdot (1+i)^T - SP) \cdot \frac{i}{(1+i)^T - 1} \tag{3}$$

Here the investment is denoted by I (for vehicle and battery), the interest rate by i, the investment horizon by T and the residual value (= resale price) by SP. All parameter values are given in Table 3 and Table A.8. The resale price depends on the annual mileage, the vehicle age and the vehicle list price. We use the results of [52, 53] with $\mathrm{SP} = \exp\left[\alpha + 12 \cdot \beta_1 T_1 + \beta_2 \mathrm{VKT}_i/12\right] \cdot \mathrm{LP}_i^{\beta_3}$ where the parameters $\alpha = 0.97948$, $\beta_1 = -1.437 \cdot 10^{-2}$, $\beta_2 = -1.17 \cdot 10^{-4}$ and $\beta_3 = 0.91569$ have been obtained by regression (see [52, 53] for details) and T_1 denotes the vehicle's age in years at the time of resale.

The operating expenditure (a_{opex}) is calculated as follows:

$$a_{opex} = VKT_a \cdot (s_e \cdot c_{el} \cdot k_{el} + (1 - s_e) \cdot c_{conv} \cdot k_{conv} + k_{O\&M}) + k_{tax} \tag{4}$$

We multiply the vehicle kilometers travelled per year (VKT_a) with the cost for driving in electric mode plus the cost for driving in conventional mode and the kilometer-specific cost for operations and maintenance ($k_{O\&M}$). The cost for electric driving consists of the electric driving share s_e, the electric consumption c_{el} in kWh/km and the cost for electricity k_{el} in EUR/kWh. The same holds for the conventional driving where the share of conventional driving, i. e. $(1 - s_e)$, is multiplied with the conventional consumption c_{conv} in l/km and the cost for conventional driving k_{conv} in EUR/l. Finally the annual cost for vehicle taxes k_{tax} in EUR/yr is added.

By determining the TCO-minimal propulsion system, summing up all drivers for whom this would be an electric vehicle and dividing it by the total number of driving profiles, we obtain the potential market share of EVs in the sample (see also [54]).

For the battery simulation we need the electric consumptions for all EV types, their battery capacities and their depths of discharge. All vehicle consumptions are taken from [55] as this study reflects the additional consumption

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and conventional consumptions.

of devices, e. g. for heating and cooling, but also the effectiveness of charging stations. Besides, the conventional consumptions for PHEVs and REEVs are the pure conventional consumptions when batteries are completely discharged. These values are difficult to obtain from car makers which tend to underestimate the vehicle consumptions. All values for consumptions are given in Table A.8. Battery capacities (Table A.8) and depths of discharge (Table 3) are based on [41, 56–58].

Table 3: Vehicle independent input parameters 2020 (All prices in EUR_{2014} without VAT). Data from [55, 59, 60].

Parameter	Unit	Value
Depth of discharge BEV	./.	90%
Depth of discharge REEV	./.	80%
Depth of discharge PHEV	./.	75%
Battery price	EUR/kWh	280
Electricity price	EUR/kWh	0.181
Gasoline price	EUR/l	1.39
Diesel price	EUR/l	1.33
Interest rate for vehicle and battery	./.	5%
Investment horizon	years	3.8
Depletion rate	./.	35%

For the calculation of vehicle TCOs we use vehicle prices of [58] while the cost increase for conventional vehicles due to CO_2 restrictions is based on [7]. The cost for operations and maintenance of large vehicles directly derives from [61] and is transferred to all other vehicle sizes based on [62, 63] while vehicle taxes derive from the current German vehicle tax legislation [64]. Vehicle list prices, maintenance and operations cost and vehicle taxes are presented in Table A.8.

Moreover, we need a number of vehicle independent parameters for our calculations. While the net battery price is relatively high with 280 EUR/kWh in 2020 [65], a variety of cost parameters derives of one study that is based on several industry experts [58]. The electricity price is a combination of industrial and trade electricity prices deriving of [66], while gasoline and diesel prices are based on the New Policies Scenario in [67]. All values are shown in Table 3.

Furthermore, we assume that: (1) Plug-in electric vehicles are charged with 3.7 kW overnight and when they are within 500 meters of their company location; (2) EVs are only considered for the same vehicle size as the conventional ones in the profiles (no downsizing). (3) PHEVs and REEVs always run in Range-Extender-Mode, i. e. the energy in the battery is used up completely before the conventional propulsion is used. (4) All economical parameters are given without VAT, since commercial car holders can recharge it. (5) Companies can depreciate the cost of their vehicles. We assume a reduction in cost due to depreciation by an average company tax of 35%. (6) We consider four car sizes: small vehicles (cubic capacity (CC)<1,400 ccm), medium vehicles (1,400 ccm<=CC<2,000 ccm), large vehicles (2000 ccm<=CC) and light commercial vehicles (LCV) or transporters with a weight of less than 3.5 tons.

3.2. Analysis of electric consumptions

With the methodology in the previous section we are able to determine potentials of EVs from a technical and economical perspective. The technical analysis is based on assumptions for average electric consumptions, although they can differ significantly between individual vehicles. For example, Neubauer et al. (2014) [68] identify that aggressive driving behaviour can lead to an additional fuel consumption of about 20 %. Based on high resolution driving profiles we are able to simulate whether these assumptions are reasonable by calculating a mean consumption for each driving profile. The consumption of a vehicle results from: (1) overall driving force, that has to be overcome during driving, (2) the efficiency of the vehicle drivetrain η and (3) the consumption of the auxiliaries. Overall driving force is given by the sum of the aerodynamic drag force (F_{air}), the rolling resistance (F_{roll}) and the acceleration force (F_{acc}) [69, 70]:

$$F_D(t) = \underbrace{\frac{1}{2} \cdot c_w \cdot \rho \cdot A \cdot v(t)^2}_{(F_{air})} + \underbrace{\mu \cdot m \cdot g}_{(F_{roll})} + \underbrace{m \cdot a(t)}_{(F_{acc})} \tag{5}$$

The influence of the vehicle type is given by its mass m, its drag coefficient c_w, its front surface A as well as the rolling resistance coefficient μ. Velocity and acceleration are given as v and a; gravitated field strength g=9.81 m/s^2 and air density ρ=1.205 kg/m^3 are assumed to be constant. The respective power needed to move the car is given by:

$$P_D(t) = \frac{1}{\eta} \cdot F_D(t) \cdot v(t) \tag{6}$$

The power losses in the vehicle drive train are accounted for by the total vehicle drive train efficiency η. Integrating driving power over time yields consumption resulting from driving. The energy demand of the auxiliaries has to be analyzed separately and is not subject of this analysis.

Besides the technical assumptions in the previous section, we need several additional parameters for the calculation of real world energy consumption. These are given in Table 4.

Table 4: Vehicle parameters used for calculation of driving forces (all values for 2020)

Parameter	Specification of vehicle type				Reference
	small	medium	large	LCV	
Vehicle mass m [kg]	1,200	1,700	1,900	2,100	
Air resistance coefficient c_w	0.33	0.29	0.29	0.32	[71]
Front surface A [m^2]	2.04	2.24	2.35	4.00	
Rolling resistance coefficient μ	0.015				[70]
Total drivetrain efficiency η	0.73				[70, 72]
Regenerative braking efficiency	0.3				[55]
Gravimetric density of battery [Wh/kg]	116				[73]

The vehicle parameters mass m, air resistance coefficient c_w and front surface A are mean values of the most sold vehicle models per class according to

[71]. For the rolling resistance coefficient μ the maximum value for car on asphalt is assumed [70]. The total drive train efficiency is the product of the drive chain efficiency, the motor efficiency and battery efficiency including charging efficiency. Data is adapted from [70]. Regenerative braking efficiency here describes overall efficiency of energy usable from negative acceleration. The energy demand of auxiliaries is assumed as constant and is in accordance with [55]. We use an energy consumption for auxiliaries of 1.4 kWh/100km for small cars, 1.6 kWh/100km for medium sized cars, 1.8 kWh/100km for large cars and 2.0 kWh/100km for LCVs, although their consumption actually depends on time, temperature and equipping.

4. Real world driving data of commercial passenger cars

In our analysis we use driving profiles which contain all vehicle trips within a certain observation period. To analyse the potential EV market shares in commercial traffic, a relevant number of driving profiles is required. For a large collection of driving profiles in commercial traffic, Motor Traffic in Germany (KiD) is one major German data source collected in 2002 and 2010 [36, 74]. However, the observation period in KiD is only one single day per vehicle. Since the time horizon of the used data collection has a significant influence on the upscale to VKT as well as on the technical feasibility and potential electric driving share, a single day data base might result in a strong bias (see e.g. [41, 75]). For this reason we have been collecting data of conventional vehicles with a time horizon of about three weeks in the on-going project "REM2030" [43]. Table 5 shows the characteristics of the REM2030 commercial driving database.

Table 5: REM2030 driving profiles database

Data collection design	GPS-tracking
Observation period	21.0 days
Total number of vehicle profiles	522 (498)*
Total number of passenger cars	385 (373)*
Avg. VKT per day of passenger cars [km]	71.6 (72.8)*
Total number of passenger car trips	52,672 (52,474)*
Total number of light commercial vehicles (LCV)	137 (125)*
Avg. VKT per day of LCVs [km]	65.5 (66.7)*
Total number of LCV trips	18,570 (18,666)*

*vehicles with more than six days of observation

The REM2030 data is collected with GPS-tracking over 21 days on average and currently contains 522 vehicle driving profiles of which 498 have an observation period more than six days and are analysed in the following. Its 373 passenger cars and 125 LCVs with an observation period of at least one week perform about 53,000 and 19,000 trips which yields an daily average of 6.7 trips and 73 km per day for passenger cars and 6.8 daily trips and 67 km on average for LCVs which is in line with [36]. Regarding the distinction of solely commercially used (fleet vehicles) and partly privately used commercial vehicles (company cars), the REM2030 data mainly contains vehicles of company's fleets which are only used for commercial purposes.

We find advantages of both data sets: the total number of vehicles is much larger in KiD2010 [36] while the observation period is longer in the REM2030 data. The number of passenger car trips is about the same, while the total number of LCV trips is larger by a factor of 9 in KiD2010. Since we simulate every profile solely in the technical analysis the observation period plays a decisive role. We showed that one single observation day tends to strongly over- or underestimate the replaceability by a BEV or the electric driving shares of PHEVs and REEVs of one single profile [75] and the total share of vehicles that could technically be replaced by BEVs in total [41]. Also, the data collection of the REM2030 profiles tries to be representative for vehicle registrations, while KiD2010 is focussing on vehicle stock. Thus, the REM2030 profiles fit best to our requirements.[3]

For the comparison of private and commercial profiles, we use the German Mobility Panel (MOP) data [77]. The MOP is an annual household panel that contains all trips of persons in 1,000 households over one week which can be mapped to vehicles [75]. With all trips collected between 1994 and 2010 we can analyse 6,339 vehicle profiles.

For modelling the driving profile specific consumption (see section 3.2) high resolution data is needed which is available for 207 driving profiles. This data has a resolution of at least one data point every 500 meters. For the simulation, the velocity and the time stamp of each data point are relevant. With this information, the velocity and acceleration vector for each driving profile can be determined.

5. Results: Market potential and influence factors

The results of our analyses are threefold: First we take a look at the driving profiles of commercial passenger cars to determine whether they are better suited for EVs than those of private vehicles. Second, we show results of the technical and economical analysis followed by the last subsection which treats the influence factors.

5.1. Daily distances travelled and regularity of driving of commercial vehicles

The economics of EVs suggest that they should drive many kilometers in order to economize but at the same time not too much because of the limited range of EVs. This discrepancy is resolved by driving behaviour that is very regular with higher than average daily VKT. In the present section we analyse the regularity of driving and daily VKT of German commercial passenger cars and compare it to private passenger car driving.

[3] For a recent analysis of the EV potential with KiD2010 data refer to [17], for a comparison of an earlier version of REM2030 data and KiD2002 see [76].

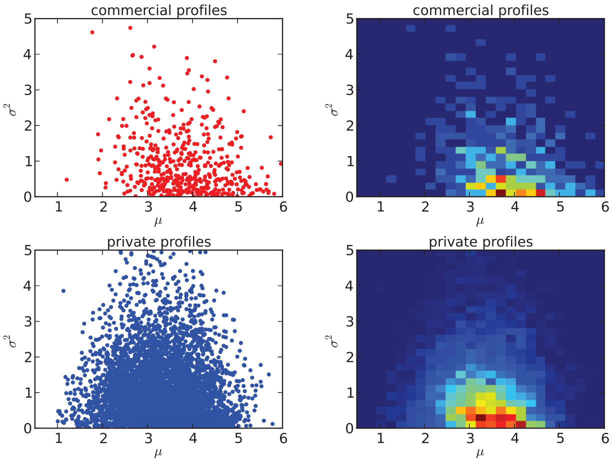

Figure 1: Comparison of regularity of commercial and private users. Shown are μ and σ for each driver (left panel) of a lognormal fit for commercial fleet users (red) and private users (blue) as well as their 2-D-histograms on the right panel. Data from [43, 77].

We measure the regularity of daily driving by the standard deviation of the logarithm of daily VKT. For each vehicle, the daily VKT r_{ij} by vehicle i on day j are analysed. We study the logarithm of these daily VKT $\ln(r_{ij})$ since daily VKT are right-skewed and their logarithms are approximately Gaussian distributed [78]. For each vehicle i, the typical scale of daily driving $\mu_i = \frac{1}{n}\sum_{j=1}^{n}\ln(r_{ij})$ and the variation in daily driving $\sigma_i = [\frac{1}{n-1}\sum_{j=1}^{n}(r_{ij}-\mu_i)^2]^{1/2}$ are calculated. The latter measures the individual regularity of daily driving. The former measures the typical scale of driving since the vehicle's median daily VKT is given by $r_{\text{med},i} = \exp(\mu_i)$ and the mean daily VKT by $\bar{r}_i = \exp(\mu_i + \sigma_i^2)$.

The scales and variances of individual daily driving have been calculated for German commercial and private vehicles. Figure 1 (left panels) shows a scatter plot of the individual scales μ and variances σ^2 for commercial (top panel) and private (lower panel) vehicles together with two-dimensional histogram of these values. The histograms indicate that commercial vehicles show higher average daily VKT. Furthermore, both private and commercial driving behaviour shows a large variation of daily VKT between drivers (the μ_i range from 2 to 5.5) and between the days of one individual driver (the σ_i^2 range from 0 to 4). Please note that several days of observation for each driver are required for the calculation of the individual variance of daily VKT.

We are now able to compare the distances and regularity of daily driving distances between private and commercial vehicles. Table 6 shows the median, mean and standard deviation of the daily VKT for private and commercial vehicle usage. We calculated the μ_i and σ_i for each vehicle from both user groups. We observe that commercial users show higher average daily distances since the median and mean of typical daily VKT are larger for commercial vehicles. However, commercial vehicles show smaller variation in daily driving between different days. The median and mean of standard deviation of daily VKT are smaller for commercial vehicles.

Table 6: Summary statistics for daily VKT of private and commercial vehicles.

	mean of daily VKT μ_i		SD of daily VKT σ_i	
vehicle group	commercial	private	commercial	private
median	3.76	3.31	0.78	0.86
mean	3.68	3.30	0.85	0.91
standard deviation	1.05	0.77	0.53	0.48

We perform statistical tests to measure the significance of these differences. A test for the difference of means and medians of the μ's between private and commercial vehicles is highly significant (t-test with unequal variances and unequal sample sizes for the means rejects the null hypothesis of equal means with p <0.1% and a Wilcoxon rank sum test rejects the null hypothesis of equal medians with p <0.1%). The differences between the standard deviations of daily VKT are also significantly different between private and commercial vehicles (t-test with unequal variances and unequal sample sizes for the standard deviations rejects the null hypothesis of equal mean standard deviations with p=3.9% and a Wilcoxon rank sum test rejects the null hypothesis of equal medians of standard deviation with p=0.3%). We thus conclude that commercial vehicles show higher daily VKT and drive more than regularly than private vehicles.

The higher daily VKT with more regular driving imply that commercial vehicles are on average better suited for EVs than private vehicles. Specific commercial branches could be even better suited than the average commercial vehicle. In particular, some branches show very high annual VKT (cf. Table B.9), for example the branches H (Transport), C (Manufacturing) and N (administrative services). We compared the average annual VKT between the different commercial branches by a t-test assuming log-normal distributed annual VKT. We performed the statistical tests for two data sets of commercial driving (see Table B.9). We find the average annual VKT in branches H, O, A, and D to differ from at least two third of the other branches (two-sided t-test for mean annual VKT with unequal variances and unequal sample sizes significant at p<1%). Furthermore, an analysis of variance shows that the commercial branch and the vehicle size have the highest explanatory power for the variance in annual VKT between different commercial vehicles and these attributes will we studied in the remainder of this work.

In summary, we found commercial vehicles to drive more kilometers per day and to drive more regularly. Their driving profiles are thus better suited for the limited electric driving range of EVs and the fuel economy of EVs.

5.2. Technical and economical potential for EVs

We now turn to the technical and economical potential of EVs in the commercial passenger sector. Results for the technical analysis can be found in Table 7 (distinguished by commercial branches) and Table B.10 (distinguished by vehicle sizes). Both tables use the same columns with the number of driving profiles (first column), the technical results (columns 2–5). The registrations in 2012 (see Table 2) determine the order of Table 7.

Table 7: Technical analysis distinguished by commercial branches

commercial branches	no of driving profiles	no of BEV tech possible	avg. share of feasible trips	avg. PHEV el share	avg. REEV el share
G - Wholesale and trade	45	12	86.5%	53.3%	65.4%
C - Manufacturing	101	18	77.4%	46.1%	54.9%
N - Administrative and support services	43	15	86.1%	57.7%	70.2%
S - Other service activities	51	16	88.1%	58.1%	68.8%
Q - Human health and social work	67	43	94.6%	72.2%	86.6%
F - Construction	38	12	92.3%	67.4%	78.8%
O - Public admin, defence, social security	66	43	97.4%	82.3%	90.0%
H - Transportation and storage	45	2	51.0%	25.6%	34.7%
K - Financial and insurance activities	5	1	93.3%	67.5%	76.4%
J - Information and communication	10	4	90.7%	57.6%	70.7%
M - Professional, scient., tech. activities	4	0	89.3%	41.5%	62.3%
D - Electricity, gas, steam, air conditioning	16	11	97.4%	82.2%	87.2%
E - Water, sewery, waste, remedation	7	4	92.3%	71.0%	74.1%
TOTAL	498	181	87.4%	60.2%	70.8%

For BEV, columns two and three show the number of BEVs which can technically fulfil all the driving of the profile and the average share of feasible trips with a BEV. We find the highest values for possible BEVs in commercial branch Q and O (for branches that contain at least 20 vehicle driving profiles) while there are many commercial branches with a high average share of feasible trips (Q, F, O with more than 90%). This means that high shares of trips are feasible with a BEV in several commercial branches, but some are too long (especially in commercial branch F). Also the average electric shares for PHEVs and REEVs are quite large (especially Q and O) while commercial branch H has the lowest values in all categories. Thus, the majority of vehicles has high electric driving shares and a large number of vehicles are feasible as BEVs (181 out of 498). While commercial branches Q and O are especially interesting, driving in commercial branch H often exceeds the technical limitations of EVs. From a technical point of view smaller commercial vehicles are better suited for EVs than larger ones (see Table B.10).

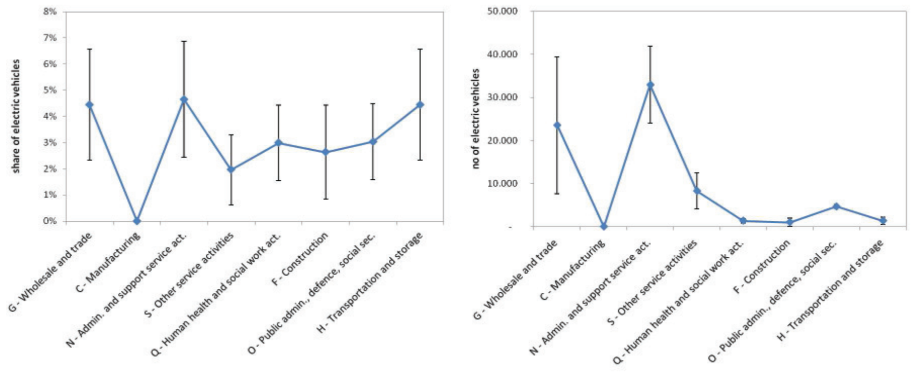

Figure 2: Relative and absolute economic potential of different commercial branches. *Left panel:* The blue line shows the relative economic potential, the whiskers indicate the 50%-confidence-intervals based on an approximation with a binomial distribution. *Right panel:* Same display with absolute potentials and respective 50%-confidence intervals.

The economic results are shown in Figure 2. We only show the eight largest commercial branches ($>$ 20,000 registrations per year) and the relative potentials with the 50% confidence interval (based on a binomial approximation due to limited sample size)[4] on the left panel and the absolute potentials (multiplied with their registrations) on the right panel. In this analysis potentials for vehicle sizes within vehicle branches have been analysed separately and aggregated thereafter.

The highest relative potentials can be found in commercial branches G, N and H with about 4.5%, while most relative potentials are in the range of 2–4% and only commercial sector C has no relative potential. There is no commercial branch that is particularly well-suited for EVs. This result is different from the technical analysis where we found the highest technical potentials in branches Q and O seemed to be the most promising while vehicles of branch H often exceeded the electric range. From an economical point of view, most of the vehicles in branches Q and O are not able to gain a sufficient annual mileage to economize as EV (see also Table 7 that driving in branches O and Q is considerably below average). In branch H instead almost all vehicles that are technically able to perform a high amount of electric driving are economically interesting for EVs, especially because of their high mileage. This illustrates the issue of EVs mentioned in section 5.1: A high amount of driving is necessary to economize, but technical conditions do not allow very high annual mileages. The two restraints define a window in which a techno-economical operation is possible.

[4] We define the relative frequency of EVs as the number of EVs (k) divided by the number of all vehicles (n) as: $p = k/n$. For the 50% confidence interval we use an approximation of the binomial distribution (see e. g. [79]): $\Delta p \approx 0.69 \cdot [p \cdot (1-p)/n]^{1/2}$.

We now turn to absolute EV-potentials in Figure 2. We find the highest economical potentials in branches G (∼24,000 EVs) and N (∼32,000 EVs) followed by branch C (∼10,000 EVs). Those three branches sum up to more than 90% of the total EV potential. This is not surprising if we remember the total vehicle registrations in the commercial sector (section 2). Almost 90% of all new cars are registered every year in commercial branches G, C, N and S. Although there are no EVs in branch C, it is obvious that the largest commercial branches (in terms of vehicles) will register the most EVs. This is different to other studies that focus on very early applications of electric vehicles, e. g. postal services (that account for 10,000 vehicles per year) or nursing services (the corresponding branch Q has about 30,000 vehicles registrations per year). If commercial vehicles shall serve as a trigger for a mass adoption of EVs one should focus on the commercial branches with the most vehicles.

5.3. Analysis of influencing factors

The future market potentials for EVs are influenced by several factors and assumptions. In the present section we determine the influence of energy prices, interest rate and fuel consumptions.

5.3.1. Sensitivity Analysis

In the sensitivity analysis we determine the influence of certain input parameters on results by changing them to a certain percentage and recalculating market potentials. The left panel of Figure 3 shows the changing absolute EV market potential in 2020 (on the ordinate) with respect to changes for several parameters (on the abscissa). We change the following parameters by ±25%: electricity price (solid blue), fuel prices (both gasoline and diesel price, dash-dotted red), battery price (solid green with dots), interest rate (dashed grey) and electric consumptions (all electric consumptions, dotted purple).

We can clearly observe the positive correlation of rising EV market share with increasing fuel prices and a negative correlation for all other parameters. While the interest rate only has a small impact on results, increasing fuel prices by 25% (1.67 EUR/l for gasoline without VAT) or decreasing battery prices or electric consumptions by 25% could increase the total market potential by a factor of four. EV market potential could double if the electricity price was 25% larger (0.34 EUR/kWh). If fuel prices were 10% lower or electric consumptions 10% higher than assumed, the market potential would shrink close to zero. This high sensitivity of market potentials stems from the very close total costs of ownership of conventional and electric vehicles for many users in 2020. Thus, only slight changes to cost parameters could change the most economic vehicle option for a large number of vehicles.

In Figure 3 we show the differences between the cheapest conventional and electrical propulsion system in our analysis on the ordinate and the relative share of users with this or a lower TCO-difference on the abscissa. The vehicles are grouped by vehicles sizes and their market share (without considering the industrial branches) can be found where the curves cross the zero line. We

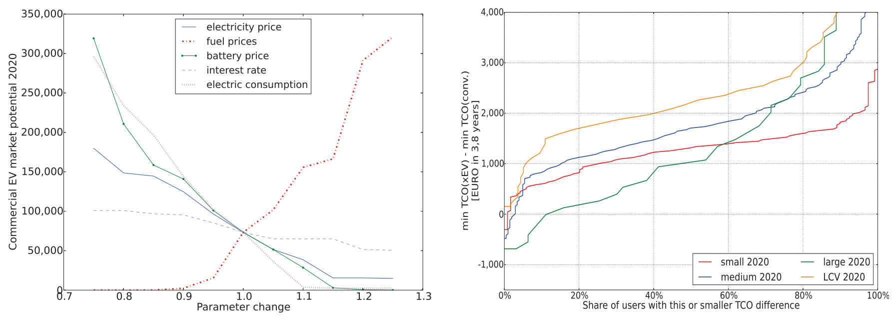

Figure 3: Sensitivity analysis and comparison of total cost of ownership deltas. *Left panel:* Electric vehicles market potential in 2020 (ordinate) over parameter changes of ±25% (abscissa). Changes for electricity price in solid blue, fuel prices in dash-dotted red, battery price in solid green with dots, interest rate in dashed grey and electric consumptions in dashed purple. *Right panel:* Delta of total cost of ownership between cheapest electric and conventional vehicle (ordinate) over the share of users with this or smaller TCO difference (ordinate). Small vehicles in red, medium-sized in blue, large vehicles in green and LCVs in yellow.

observe that there are significant market shares for large vehicles and LCVs (∼10%) since they are able to economize faster because of the large advantages in running cost of EVs while small and medium vehicles' market shares are around 1–3%. Decreasing the TCO for the cheapest electric vehicles by 1,000 EUR, market shares of small, medium and large vehicles would increase by 15%,20% and 25% (LCVs 20%). A change like that could for example result from an increase of the gasoline price by 15% if the gasoline vehicle was the cheapest conventional car.[5] Also commercially licensed vehicles profit from the deduction of VAT and depreciation allowances.[6] Thus, the market share of electric vehicles is very volatile and strongly depends on the assumptions. Especially fuel and battery prices as well as electrical consumptions do have a meaningful impact. We will analyze the probability of the latter in the following subsection.

5.3.2. Energy consumption

Vehicle consumption strongly depends on driving behavior. Neubauer and Wood (2014) [68] find that aggressive driving can increase vehicle consumption by up to 20%,while Mock et al. (2013) [7] support this hypothesis by finding a high variety in real world driving consumption. As fuel or electricity consumption is the main driver of the total operating cost of a vehicle, driving behaviour directly influences TCO. The high effect of consumption on TCO is supported by the high sensitivity of the calculates EV market potential to the variation of

[5] If the gasoline consumption for an average-sized conventional car is 0.06 l/km, its annual mileage is 20,000 km and the initial gasoline price is 1.34 EUR/l, an increase of 15% would be calculated as: $0.15 \cdot 1.34$ EUR$/l \cdot 0.06\ l/km \cdot 20,000\ km \cdot 3.8\ a \approx 1000$ EUR.

[6] In [80] we can compare graphs with the same display of private and commercial vehicles finding that slopes are generally smaller for commercial vehicles which derives from a more regular driving, but also from the deduction of VAT and depreciation allowances.

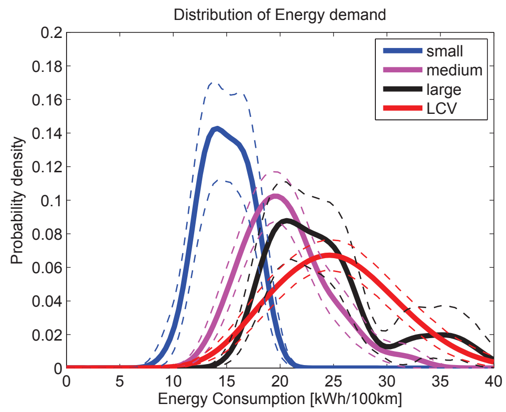

Figure 4: Distribution of real world energy demand in [kWh/100km]. Distributions are shown for the vehicle sizes small (blue), medium (magenta), large (black) and LCV (red) according to [43]. Estimation of the probability density function with kernel density estimation with optimized bandwidth, acc. to [81]. Dashed lines indicate 95% confidence intervals calculated by bootstrapping, acc. to [82].

vehicle consumption (section 5.3.1).

Here, we determine differences in electric consumptions resulting from varying driving behaviour represented in the REM 2030 database. First, we calculate a mean electric consumption for every driving profile by modelling driving forces, including a constant value for auxiliaries (see section 3.2). Second, we calclulate a probability density distribution of all mean values for the different vehicle sizes using kernel density estimation with optimized bandwidth acc. to [81]. The probability density function assigns each energy consumption value, plotted against the abscissa, a probability of occurence on the ordinate. In order to take account of statistical uncertainty resulting from limited sample size, 95% confidence intervals are calculated applying bootstrapping [82] and shown with dashed lines.

As expected, on average we observe higher consumptions for larger vehicles. Weight and front surface increase with vehicle size (see Table 4) leading to a higher driving resistance. For the vehicle sizes small, medium and large, we get probability density functions that are approximately symmetrical. A good accordance of the mean values with the medians support this hypothesis (For small vehicles we receive a mean value of 14.8 kWh/100km and a median of 14.5 kWh/100km, for medium vehicles the according values are 20.5 kWh/100km and 20.2 kWh/100km, for large vehicles the values are 24.3 kWh/100km and 22.9 kWh/100km and for LCVs 25.7 kWh/100km and 25.0 kWh/100km.). These values are in good accordance with the assumed values for the market potential calculation. The probability density function of LCVs a high spreading of consumption up to above 30%. This could be due to the fact, that this category comprises different vehicles with different characteristics. In figures, standard deviation of electric consumption is 2.1 kWh/100km for small vehicles, 3.8 kWh/100km for medium sized vehicles and 5.4 kWh/100km for large vehicles. The high spread also leads to an overlap of the density functions. I. e., a moderately driven medium sized car can have a lower consumption than an aggressively driven small car. Nevertheless, the probability functions are approximately symmetrically distributed around mean values that are in good accordance with the values used for market potential estimation.

The effect of the analyzed differences in driving behaviour on TCO can be interpreted as follows: While aggressive driving with high consumption and thus high operational cost would favour EVs as energy efficient technology, lower driving aggression in turn would favour conventional vehicles. Given the symmetrical distribution of vehicle consumption around the used mean values, the negative effects of low driving aggressiveness on EV market potential on the one hand and the positive effects of high driver aggression on the other hand would cancel each other out. Therefore, we consider the impact of differences in driving behaviour on the results of the market potential calculation to be rather small.

5.4. Discussion

Our results are subject to several assumptions that have to be discussed: The methodology of using TCO to determine the economical replacement potential might be questioned as well as assumptions for driving profile data and technical and economical parameters that are used in the analysis.

We use a TCO-based comparison of different drive trains for every single driving profile to determine the most cost-efficient vehicle option for each profile. The potential market share of EVs is calculated by the share of EV users reflecting the vehicle size and commercial branch. Calculating market shares with total cost of ownership is a common approach [83–85], although the buying decision for a single vehicle is often not solely based on cost [86, 87]. However, since companies take cost as the main argument regarding their vehicle fleet [42, 88], this approach is justifiable. This type of analysis also considers the growing amount of leasing vehicles where full leasing rates reflect the full vehicle TCO. However, some studies indicate a willingness to pay more for alternative fuel vehicles which would increase EV market shares [89–91], other factors that influence the commercial buying decision [35] or specific use cases (like overnight inner city logistics with reduced noise or car-sharing) were not considered in this analysis. We cannot invalidate that company car owners may participate in the buying decision of their vehicle which adds a variety of aspects besides cost therein, but data on company car owners is rarely publicly available in the needed resolution. In an analysis of variance we find that about 70% of annual driving can be explained by commercial branches and vehicles sizes, while company, fleet and city size had minor influence. Thus, considering these two factors explicitly seems appropriate for commercial vehicles. An analysis that did not reflect commercial branches which was performed additionally came to similar results for the overall EV market share.

For our analysis we rely on driving profiles which were collected with GPS-trackers for three weeks since there was no publicly available data for commercial driving exceeding one day (see section 4). A battery profile simulation as performed in our analysis largely overestimates the technical feasibility of BEVs [41], the electric driving shares of REEVs and PHEVs [75] and the market potential [76] since driving varies largely between drivers and days [44]. Although the sample is limited, the ongoing collection tries to cover especially the large commercial branches in terms of registrations [43]. Clustering branches into groups based on their driving behaviour might be interesting for further research which would increase the subsample sizes.

In the calculations we have to make assumptions for technical and economical parameters. These are based on a large study that discussed several other options for parameters [80]. However, we perform a sensitivity analysis and an analysis of real world fuel consumptions in section 5.3 to determine the impact of changes to the assumptions. The analysis of electric consumptions shows that the average values chosen for the market potential analysis reflect the peaks of consumption distributions and are thus well considered. The battery degradation based on intense use is reflected in an auxiliary analysis which shows that all trips performed by EVs are covered [80, sec. 7.8].

In the comparison of driving behaviour of commercial and private vehicles, we did not reflect the vehicle size which is available in the data set. An inclusion could lead to different results and insignificances between commercial and private profiles within the vehicle size classes. However, the focus of this analysis was to determine whether commercial and private vehicles drive differently in terms of distance and regularity; for that reason, the neglect of vehicle size is legitimate. Furthermore, different measures could have been used to compare the regularity and distances.

6. Summary and Conclusions

This paper analyses the commercial passenger car sector of Germany with respect to its market potential for electric vehicles. Our analysis is based on over 500 real world driving profiles from the commercial passenger car sector with an observation period of at least three weeks. This long observation period is decisive for the calculation of individual TCO and overall EV market potential. We perform a battery simulation of each profile to determine the technical potential for EVs followed by an individual calculation of the total cost of ownership for different drive trains. The technical and economical market potentials are ensued by a sensitivity analysis of results. Additionally an analysis of electric consumption based on high-resolution driving profiles determines the probability of changes in electric consumptions.

Electric vehicles face the obstacle that they have to have high annual mileages to economize in comparison to conventional vehicles while their driving range is limited and long-distance trips cannot be performed electrically. While private driving profiles are less regular and long-distance trips occur more frequently, many commercial vehicle profiles show less differences between day-to-day driving. Also annual vehicle kilometers travelled are higher for commercial vehicles. Both conditions favour EVs. Besides, the deduction of VAT and depreciation allowances for commercial vehicles also favour EVs. Thus, we conclude that commercially licensed electric vehicles are better suited for EVs than private ones.

Although postal or nursing services are often proclaimed as early markets for electric vehicles, a much larger number of electric vehicles can be expected in the large commercial sectors. In Germany the four largest commercial sectors account for 90% of annual vehicle registrations: Wholesale and Trade (G), Manufacturing (C), Administration and support service activities (N) and Other service activities (S). While results for technical and economical potentials do not differ considerably between commercial sectors, a significant EV market evolution can only be achieved by considering the large commercial sectors.

Framework conditions such as the oil or electricity prices as well as battery prices are the drivers for EV market potentials. Small changes in these parameters change results largely in positive and negative direction. Although analyses of electric energy consumptions show a wide distribution for the analyzed data, the used mean values reflect the peaks of the distributions reasonably well. Against this background, a consequent monitoring of framework conditions should be prioritized by car makers when decisions about vehicle prices are made or by policy makers when subsidies are discussed.

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Appendix A. Parameters for calculation

Table A.8: Vehicle dependent input parameters 2020 (All prices in EUR_{2014} without VAT). Data from [55, 58, 61–64].

Parameter	Veh. size	Gasoline	Diesel	PHEV	REEV	BEV
Conv. energy consumption [l/100 km]	small	5.5	4.2	5.0	5.9	./.
	medium	6.7	5.1	7.1	6.1	./.
	large	8.9	6.3	7.6	8.7	./.
	LCV	9.8	8.3	9.7	11.3	./.
El. energy consumption [kWh/100 km]	small	./.	./.	15.9	16.9	16.9
	medium	./.	./.	19.6	20.6	20.6
	large	./.	./.	21.3	22.4	22.4
	LCV	./.	./.	31.3	34.0	34.0
Battery capacity [kWh]	small	./.	./.	7	13	20
	medium	./.	./.	10	16	24
	large	./.	./.	13	19	28
	LCV	./.	./.	16	22	32
Net investment w/o battery [EUR]	small	10,699	12,888	15,356	14,223	11,280
	medium	17,698	19,885	21,226	20,983	18,042
	large	31,355	33,587	35,551	34,418	31,432
	LCV	38,600	40,800	43,371	41,631	38,677
Operations & maintenance [EUR/km]	small	0.026	0.026	0.024	0.017	0.021
	medium	0.048	0.048	0.044	0.033	0.040
	large	0.074	0.074	0.069	0.058	0.062
	LCV	0.059	0.059	0.055	0.041	0.049
Vehicle tax [EUR/yr]	small	50	126	26	20	0
	medium	101	209	34	20	0
	large	193	325	46	28	0
	LCV	161	161	161	161	0

Appendix B. Further results

Table B.9: Driving distances distinguished by commercial branches

NACE section	REM2030		KiD2010 (all cars)		KiD2010 (driving)		registr.
	no of profiles	avg, daily VKT	no of profiles	avg, daily VKT	no of profiles	avg, daily VKT	
G - Wholesale and trade	45	64.2	5,348	47.7	2,504	102.0	699,506
C - Manufacturing	101	78.7	4,782	58.6	2,446	114.6	380,367
N - Administrative and support serv.	43	78.6	1,548	56.3	830	105.1	357,835
S - Other service activities	51	62.1	16,321	53.2	8,417	103.1	265,926
Q - Human health and social work	67	51.7	1,237	41.0	740	68.5	33,391
F - Construction	38	47.1	6,381	45.0	3,144	91.2	31,150
O - Public admin., defence, social sec.	66	29.1	3,233	36.8	1,586	75.0	28,546
H - Transportation and storage	45	202.8	3,489	61.3	1,920	111.3	27,269
K - Financial and insurance activities	5	48.8	271	56.8	164	93.9	18,582
J - Information and communication	10	65.6	326	46.9	169	90.5	16,271
M - Professional, scient., techn. act.	4	60.2	18	71.7	11	117.3	12,065
D - Electricity, gas, steam, AC	16	32.5	963	46.1	510	87.0	7,452
I - Accommodation and food service	0	0.0	307	39.8	156	78.3	5,495
L - Real estate activities	0	0.0	22	35.6	17	46.0	4,419
E - Water, sewery, waste, remedation	7	37.8	984	66.7	547	120.0	3,938
R - Arts, entertainment and recreation	0	0.0	178	36.1	74	86.7	3,541
A - Agriculture, forestry, shipping	0	0.0	1,439	34.9	690	72.7	2,963
P - Education	0	0.0	70	54.3	42	90.4	2,134
B - Mining and quarrying	0	0.0	197	49.8	106	92.5	1,192
Total	498	71.5	47,114	50.7	24,073	99.1	1,902,042

Table B.10: Driving distance and technical analysis distinguished by vehicle sizes

	number of profiles	technical analysis 2020			
vehicle sizes	no of driving profiles	no of bev tech possible	avg. share of feasible trips	avg. phev el share	avg. reev el share
small	113	77	96.7%	73.4%	86.9%
medium	198	52	81.2%	51.5%	61.9%
large	55	10	77.0%	51.5%	60.8%
transporter	132	42	84.7%	61.0%	69.3%
Total	498	181	84.9%	59.3%	69.7%

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