Policy driven demand for sales of plug-in hybrid electric vehicles and battery-electric vehicles in Germany

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1. Introduction

In Germany road traffic accounted for 17% of overall CO2 emissions in 2007. While the grand total of CO2 emissions decreased by 15% since 1991 emissions from road transport declined only by 8% in consequence of increased car ownership and trip distances (BMVBS, 2010). Technological progress in reducing fuel consumption of internal combustion engines vehicles (ICEs) was not able to compensate changes in mobility behaviour of individuals until now.

The possibilities to reduce CO2 emissions of car traffic by pushing electric vehicles into the market are a popular topic of discussions among politic parties, car manufacturers and NGOs. Furthermore municipal administrations are keen to get electric vehicles on their streets to reduce direct emissions like noise and particulates which concentration regularly exceeded limit values in Germany's densely populated areas in the past.

While technology issues were increasingly overcome, the economic viability of electric drive trains remained harshly constrained by high prices of batteries. Nevertheless, in the recent past these prices decreased significantly and made it very interesting to estimate a sale potential for partly and fully electrified drive trains under different economic and regulatory conditions.

2. Objective

The research presented in this paper shows an approach for analyzing the German car market's potential of electric vehicles (EVs). The aim was to develop a methodology that allows calculating the impact of different incentives, taxes and other regulatory scenarios on the maximum EV sales potential. The goal of this analysis is not a sales forecast, which would require also modelling the supply side. But this comes with even bigger uncertainties like battery and vehicle production capacities or the actual vehicle availability on the market. However this instrument can provide valuable insights for car manufacturers and policy design assessing the possible market size under different circumstances.

This paper distinguishes two concepts of EVs: Plug-in Hybrid EVs (PHEVs) and Battery EVs (BEVs) as their driving patterns and costs will differ significantly. Serial and parallel PHEVs concepts are not differentiated.
Moreover, different ownership approaches are considered to illustrate how they influence the market potential. Technical, socio-demographic and economic limitations are modelled to derive possible sales potentials for electric passenger cars. The analysis covers the timeframe of 2010-2030.

3. Applied method and database

3.1. Overview

The procedure to determine the market potential of EVs included two steps: First the current *total vehicle stock* and new car sales distributions were analyzed and potential EV buyers were filtered using household characteristics and trip data forming an *EV Framework Potential*.

The second step was performed on the basis of the EV framework potential and applied the subsequent constraints of economic profitability for potential buyers to replace their conventional ICEs. This depends mainly on the driven annual mileage. Furthermore the competition of PHEVs and BEVs was integrated as the modelled potential customers select the most profitable single option. This results in an *Economic EV potential.*

Nevertheless a *Realized EV potential* would be significantly lower than the calculated Economic EV potential because of two key factors: First, the model assumed that all cars on the market are also available as EV in a PHEV or BEV version. Second, ‘soft factors’ like user acceptance, technology scepticism and adaptation as well as development delays or R&D profitability issues in industry are not considered. Modelling these elements would be subject to large uncertainties. But since policy and tax design mainly influence an economic EV potential, they strongly benefit of the derived results. Figure 1 shows an overview of the described potentials and the constraint methodology.

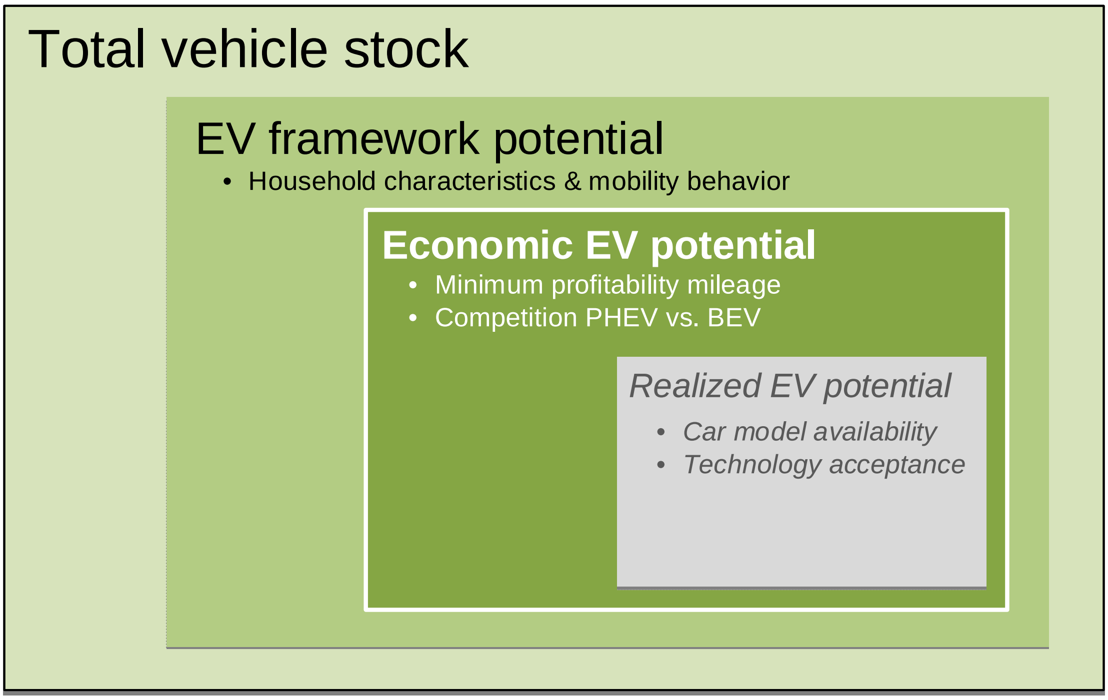

Figure 1: Distinction of EV potentials and methodology steps

3.2. Database

In the model the authors assumed constant sales figures and vehicle category distributions based on the sales and inventory data of the German Federal Motor Transport Authority (KBA, Kraftfahrt-Bundesamt) as of 01/01/2009

(Kraftfahrt-Bundesamt, 2009). Since sales data of 2009 were subject to heavy changes due to the scrapping premiums, the authors used for modelling purposes the values of 2008 shown in Table 1.

	Sales 2008	Total vehicle stock 2008
Private passenger cars	1,356,528	37,168,026
Company cars	1,733,512	4,153,145
Total	3,308,415	43,123,728

Table 1: Total car sales and vehicle stock in Germany in 2008

The analysis was separately performed for three ownership segments due to their different usages and financing model: private passenger cars and business passenger cars with and without private usage.

The data basis of the car fleet structure was derived from two comprehensive National Travel Surveys: “Mobiliät in Deutschland” 2008 (BMVBS, DLR, infas, 2010) for the private passenger cars and “Kraftfahrzeugverkehr in Deutschland” 2002 (KiD) for commercial cars (BMVBS, 2002). Their respective characteristics are shown in Table 2.

	KiD 2002	MiD 2008
Type of survey	National Travel Survey	National Travel Survey
Enquiry period	2001/2002	2008
Object of investigation	Vehicles	Households
Sample size	~77,000 vehicles	~50,000 households
Day-trips	~119,000	~300,000
Focus	Commercial transport	Private transport
Traffic modes investigated	Individual motorized traffic	Public and individual motorized and non-motorized traffic
Vehicle size classification	By kerb weight	Predefined classes (small/medium/large)
Additional information used for market modelling	Availability for private usage	Parking site, general travel behaviour

Table 2: Characteristics of datasets used for modelling

MiD 2008 is the current successor of the “Continuous Survey on Travel Behaviour” (KONTIV) carried out in the former West Germany in 1976, 1982 and 1989 by the Ministry for Transport and the following MiD 2002. The main focus of MiD is to collect reliable information about individuals (socio-economic, demographic, etc.) and households (size, structure) as well as their daily travel behaviour (e.g. trips made according to purpose and means of transportation used, etc.) on a reference date. MiD also provides information about the household’s vehicles (brand, size, engine, etc.). Once it has been weighted and expanded, the information serves as a framework for and supplement to other travel surveys, such as traffic surveys in individual cities, cross-sectional censuses of traffic loads and the mobility panel. MiD is also the basis for a number of transport models by providing reliable contemporary data on important mobility variables (e.g. average trip lengths, share of drivers licences etc.). The results of the study are not only important for transport planning, research and academic interest; they also provide quantitative background information for concrete political decision-making.

KiD was conducted in 2001 and 2002 and focuses on commercial vehicles, i.e. the craft is registered by industry. By doing so, the KiD 2002 is the first nationwide data set available to access the characteristics and travel patterns of commercial motorized vehicles, including motorbikes, passenger cars as well as light commercial vehicles and heavy-duty trucks. The questionnaire of KiD 2002 which mainly appears as a driver's log addresses the keeper of a vehicle and records a one day activity of the surveyed vessel, e.g. time of departure, destination and purpose of the trip. In addition to those data detailed information of KBA about every vehicle were added, e.g. kerb weight and fuel type. The KiD 2002 comprises almost 77,000 vehicles and nearly 119,000 trips (cf. Table 2). That sample is representative to the whole German market in 2002. Thus KiD 2002 is a favourable source to analyse the market's development towards electric mobility regarding the commercial transport. Due to the calculation base of vehicle sales and stock (as of 2008, cf. Table 1) we adjusted KiD data (as of 2001/2002) accordingly and generated a common modelling basis. In this paper only commercial cars up to an overall weight of 2.8 tons were integrated in the study. A possible future extension could be the inclusion of light commercial vehicles. At the time of this publication the model is being adapted to their distinctive technical and trip properties.

According to the MiD approach of private transport commercial vehicles were also allocated into three classes (small, medium, large). In contrast to MiD where the vehicle class is available in the data, KiD vehicles have been distinguished by their kerb weight. Therefore weight classes have been deduced from European statistics (Eurostat, 2009). Furthermore a distribution between diesel and gasoline powered vehicles was applied. Hence, for modelling purposes the authors used in all 36 categories and 5 time periods (2010, 2015, 2020, 2025 and 2030) by combining type of vehicle registration, vehicle size, engine type and EV replacement technology (BEV or PHEV) to represent a disaggregated approach to analyse the market potential towards electric mobility.

3.3. EV framework potential

The conditions for a household to become incorporated into the EV framework potential comprise of some principle preconditions. Therefore characteristics like parking space availability at home, the number of cars in the prospective household, its mode choice behaviour for long distance travels as well as the maximum daily trip length of the current conventional car forming the base filter criteria in data analysis.

Until 2020 the restrictions for private car buyers are numerous: The household must be able to provide a parking space on site and in case of a BEV it cannot be the only vehicle if more than two persons live in the household. This follows the supposition that families with kids would not accept a car with a limited range as their only car in the household. Furthermore the total daily trip length as well as the overall household's long-distance travel behaviour by car is limited with an all-electric car. These restrictions were loosened until 2030.

For company cars the only constraint for EV adoption is the total daily trip length, this is mainly due to data availability but also non-applicability of household criteria for the commercial sector.

To represent an increasing availability of charging infrastructure and faster recharge technologies, a rise of the possible trip length over time was implemented for potential private and commercial vehicles. The described constraints lead to an EV framework potential, which represents the theoretical maximum adaptation level of electric vehicles in the private and commercial market.

3.4. Economic EV potential

Based on the EV framework potential a crucial constraint was applied: The economic profitability for these potential customers for the replacement of the currently used conventional vehicle by a PHEV or BEV. Therefore the net present value (NPV) of the electric versions' extra investment for the whole car holding period was computed. Since all variable cost elements depend on the annually driven kilometres, the minimum driven kilometres to achieve NPV=0 was seen as the profitability limit. The series of cash flows consists of the following values:

1. The initial investment for the PHEV/BEV surcharge compared to a conventional vehicle: This value integrates all incentives and discounts.
2. Variable annual cash flows through consumption savings: This value depends on the scenario's fuel and electricity cost evolution as well as on assumptions for the specific energy consumption of the cars. However, the most important input for the cash flows are the annually driven kilometres.
3. Fix annual cash flows from tax differences: Here the current and assumed future tax legislation is modelled. This integrates CO2 limits, displacement differences between PHEV and conventional engines as well as possible flat taxes for BEVs, which cannot be taxed by engine displacement. Since around 60% of new registered cars in Germany are company cars two special conditions are taken into consideration here: For all company-owned vehicles all affected values are calculated without their respective value added taxes (Kraftfahrt-Bundesamt, 2009; Verkehrsclub Deutschland, 2008; AKA, 2008). Furthermore the German company car tax is integrated (see below).
4. Fixed annual revenues from "Vehicle to Grid" power sales.
5. In the last period the resale value of the electric drive train is considered due to its special depreciation over holding period and usage (Duvall, 2004). This value depends on the assumed holding period and the total driven kilometres and is expected being floored at a residual material value, especially of the battery. This calculation will be explained below in more detail.

The respective necessary yearly kilometres to reach profitability for each segment, vehicle category and concurring conventional engine was calculated in the model for all time steps and applied as an additional filter to the above mentioned EV framework potential. Thus all potential customers derived from the datasets would achieve profitability of their investment due to their driven mileage.

In case of households or companies being potential customers for both PHEVs and BEVs the more profitable option (with less necessary annual mileage) was chosen in order to avoid double count.

Input parameter

During extensive research the authors encountered high spreads for several key input values of the model. In most cases these values were averaged from literature, in others estimations had to be made. The main assumptions and input data used for calculating the EV potential are described in the following.

The surcharges for PHEVs and BEVs compared to conventional vehicles are consequentially influenced by the price per kWh of battery capacity as it forms the most expensive part of the drive train. Averaged from multiple recent sources (Duvall et al, 2004; Anderson, Patino-Echeverri, 2009; Kalhammer et al. 2007; Offer et al, 2009; EIA, 2009; General Motors, 2009; Thomas, 2009) the battery price values for mass production shown in Table 3 are assumed for a constant exchange rate of 1.30 $/€.

	2010	2015	2020	2025	2030
€/kWh	615	440	323	269	227

Table 3: Battery price for both PHEV and BEV technology

Another central input factor is the desired electric range of the respective vehicles. Based on OEM announcements the authors assumed the values shown in Table 4. Regarding the distribution of driven mileage within the current fleet and to meet consumer expectations this range differs between the vehicle size categories. It was furthermore assumed that these ranges stay constant in the future since lower purchase prices resulting from increased efficiency are supposed to attract more customers than increased ranges at maintained purchase prices.

Vehicle size	Electric range
PHEV small	30km
PHEV medium	40km
PHEV large	50km
BEV small	120km
BEV medium	150km
BEV large	200km

Table 4: Electric range of modelled PHEVs and BEVs

Electricity consumption values and the electric range of BEVs and PHEVs can be combined to calculate the required battery size and therefore battery prices for each vehicle segment. Together with drive train costs and a fix 500€ for charging infrastructure in households resp. companies (Biere, Wietschel, Dallinger, 2009) these values led to surcharges for electric vehicles to calculate the economic potential. To include an ecologic willingness-to-pay into the model a general discount was implemented on the final price. From literature on consumer behaviour when selecting a green electricity provider a conservative surcharge value of 7% has been derived (Gerpott, Mahmudova, 2008; Christ, Bothe, 2007; Menges, 2004; Sunderer, 2006; management tools ag, 2008). The final surcharges are depicted in Table 5.

Surcharge in €		2010	2015	2020	2025	2030
PHEV vs. Gasoline	small	5,524	4,328	3,555	3,174	2,884
	medium	8,744	6,677	5,346	4,710	4,225
	large	12,753	9,585	7,542	6,555	5,802
PHEV vs. Diesel	small	4,601	3,406	2,633	2,252	1,962
	medium	7,426	5,360	4,028	3,392	2,907
	large	11,039	7,872	5,829	4,841	4,089
BEV vs. Gasoline	small	15,143	10,360	7,268	5,744	4,584
	medium	24,036	16,286	11,293	8,907	7,089
	large	39,301	26,629	18,460	14,509	11,500
BEV vs. Diesel	small	14,391	9,608	6,516	4,992	3,832
	medium	22,962	15,211	10,218	7,833	6,014
	large	37,903	25,232	17,062	13,111	10,103

Table 5: Surcharges of PHEV/BEV versions on vehicle prices

These values of the electric drive train components were assumed to depreciate faster than the ones of the conventional car parts and also correlate more with the driven mileage (Concawe, 2007). Based on OEM announcements on durability and warranty issues, the following depreciation formula was formed:

Depreciation_E_Parts = 20 + 5 / year + 0.4 / 1,000km [%]

Another crucial element for EV profitability in the future are revenues from V2G. Concrete values largely vary in literature, but there is visible consensus about proportionality to the battery size (USPS, 2009; Schürmann et al, 2009; Staschus, 2007). Mainly based on expected off-peak recharge savings, the values depicted in Table 6 were determined with a linear growth over time.

Technology	Size	V2G €/a 2010	V2G €/a 2015	V2G €/a 2020	V2G €/a 2025	V2G €/a 2030
PHEV	small	20	40	60	80	100
	medium	30	60	90	120	150
	large	50	100	150	200	250
BEV	small	30	60	90	120	150
	medium	80	160	240	320	400
	large	140	280	420	560	700

Table 6: V2G revenues in different time periods

Since an important share of new car sales in Germany is marketed in terms of leasing towards commercial owners as an incentive for their employees, it was assumed as a simplification that all such mixed business/private passenger cars are leased (AKA, 2008). Furthermore, these vehicles were all supposed to allow private usage and their drivers must pay the German corporate car tax. Based on a market review over the largest German car leasing companies the following contract conditions were considered:

- Leasing factor (monthly rate as percentage of list price): 1.3%
- Mileage_accounting = (20,000 – yearly_km) * list_price / 90,000 [€/year]

In addition, private use of corporate cars in Germany is subject to income tax based on a fringe-benefit of monthly 1% of the car's list price plus 0.03% of the distance between home and workplace (German Federal Government, 2009). For the tax calculations an average income tax rate of 20.9% was used and an average way to work of 15 km (Statistisches Bundesamt, 2004). To compensate the share of such cars not being leased, all company cars with business use only were in turn assumed to be purchased.

4. Results

The model described in Chapter 3 was used to first calculate a general EV framework potential on sales for all periods based on the travel surveys. Subsequently, four different scenarios about the economic market potential for the period from 2010 to 2030 have been computed:

- A "base" scenario of EV representing current policy conditions
- A "bonus" scenario with different bonus payments
- A "new corporate car tax" scenario modelling a modified car taxation for corporate cars
- An "EV-Tax" scenario demonstrating the impact of reclaiming losses of mineral oil tax through potential EV sales

4.1. EV framework potential result

The maximum yearly potential for electric powered vehicles regarding EV framework limitations shown in chapter 3.3 are summarised in Table 7 and 8. The EV framework potentials of PHEVs and BEVs may not be regarded independently but rather with BEVs being a competitive subset of the PHEV potential. Therefore the number of potential PHEVs can be seen as the overall EV framework potential.

Hence, it can be observed that from beginning 2010 around 60% of the German new car sales could theoretically be replaced by EVs not considering economic issues and assuming the availability of an EV version for every car. It is striking that the highest rise in EV potentials is between 2015 and 2020 with especially medium-sized BEVs. Afterwards only slight additional potentials enlarge the market. This is mainly due to the loosened parking and travel restrictions and the fact that BEVs are assumed to be able to fully replace an increasing number of conventional cars in terms of usability.

Overall it is noticeable that company cars account for a large amount of the EV framework potential. This is especially applicable for BEVs. The reasons are mainly fewer restrictions on the diversity of usability of EVs in this sector and a high share of commercial vehicles, which performs daily trip lengths less than the electric range of BEVs. Moreover within company cars, unvarying three quarters are used for both business and private trips. Since these cars are more often used for longer trips the share of PHEVs is higher than for BEVs.

	Vehicle size	2010	2015	2020	2025	2030
PHEV	small	436,454	443,550	553,093	556,393	562,378
	medium	811,866	824,915	966,250	970,927	983,145
	large	477,507	481,407	508,607	509,900	512,037
	total	**1,725,827**	**1,749,872**	**2,027,951**	**2,037,220**	**2,057,560**
Share of company cars		46%	45%	39%	39%	38%
- thereof mixed usage		77%	77%	77%	77%	77%

Table 7: PHEV framework potential modelled vehicle and registration categories (sales per period)

	Vehicle size	2010	2015	2020	2025	2030
BEV	small	273,352	283,192	353,490	360,244	366,363
	medium	396,573	402,416	612,984	626,310	643,904
	large	362,500	363,702	376,350	383,168	421,061
	total	**1,032,425**	**1,049,310**	**1,342,824**	**1,369,721**	**1,431,328**
Share of company cars		71%	70%	58%	57%	55%
- thereof mixed usage		77%	77%	77%	77%	77%

Table 8: BEV framework potential of modelled vehicle and registration categories (sales per period)

The EV framework potential underlines the high share of cars with short trip lengths and suitable characteristics for electric mobility within the current German vehicle stock that is represented by the high amount of BEVs. Nevertheless, integrating the economic constraints will reduce these sales potentials significantly since short trip length and limited usage of the identified conventional cars to be replaced also influences the minimum annual driven mileage necessary for the profitability of the electric vehicles. In the following the previously introduced scenarios have been calculated.

4.2. Economic potential

Base scenario

Starting from the EV framework potential the share of EV being profitable for the respective customer was calculated for PHEVs and BEVs. Initially, a base case scenario was calculated assuming the continuation of the current regulations without any changes. The results are depicted in Table 9 and Figure 2.

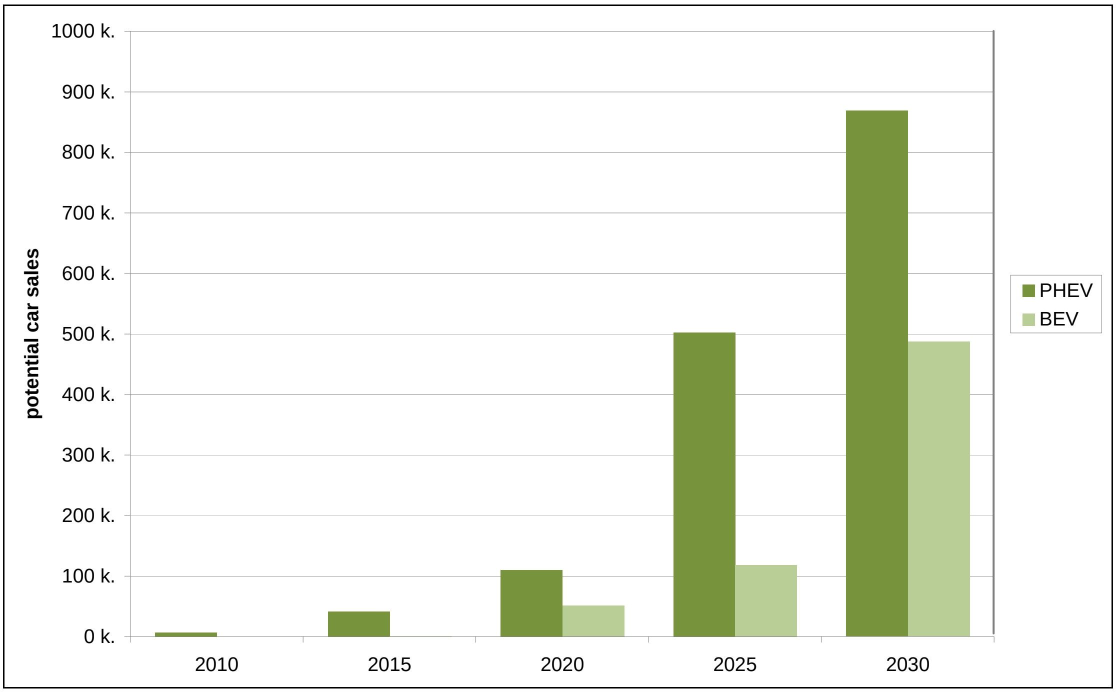

Figure 2: Electric vehicle sales potential in the "base scenario"

The base scenario shows with up to 42,000 vehicles sold per year in 2020 a slow increase of the EV sales potential with a strong upward trend from 2020 until 2030 with already around 1,400,000 vehicles. Thereby potential PHEV registrations are significantly higher than for BEVs for the entire timeframe with a growing trend towards BEVs from 2020 on. Within the first 10 years both technologies play only a minor role in potential car sales. Compared to the EV framework potential the economic sales potential of EVs does only obtain a share of around 8% in 2020 onto a high share of 42% for PHEVs and 34% for BEVs in 2030.

Technology	Size	2010	2015	2020	2025	2030
	small	151	8,112	24,922	44,459	78,084
	medium	0	10,454	36,970	205,231	362,635
	large	6,629	23,244	48,290	252,775	428,570
PHEV (base)	**total**	**6,779**	**41,810**	**110,182**	**502,466**	**869,289**
Share of company cars		100%	97%	76%	60%	49%
- thereof mixed usage		100%	94%	93%	84%	77%
	small	0	244	13,519	100,447	244,552
	medium	0	0	30,914	17,654	242,796
	large	0	0	6,871	0	0
BEV (base)	**total**	**0**	**244**	**51,304**	**118,101**	**487,348**
Share of company cars		0%	0%	89%	51%	31%
- thereof mixed usage		0	0	86%	59%	72%
Total number of EVs		**6,779**	**42,054**	**161,486**	**620,567**	**1,356,637**

Table 9: Economic potential of electric vehicles in the base scenario by segment (sales per period)

There are several other striking observations in the development of the PHEV and BEV potential: First, the competition between the two EV types is mainly decided by vehicle size – small electric vehicles are mostly BEVs while large ones are mostly PHEVs. Profitable large and medium sized EVs are expected to be only PHEVs until 2020. Afterwards especially the profitability of medium sized BEVs is strong rising and BEVs gaining a share of 40% of potential EV sales in 2030. The market for small EVs is already in 2025 dominated by BEVs. Only large EVs are without exception PHEV due to comparatively high surcharges.

Second, company cars play a special role in the sales potentials until 2020. Most sectors and periods with strong market growth show a high share of company cars, in many cases higher than in the general framework potential. The reason for the (especially for early PHEVs) lies in their generally higher driven mileage, amortizing even cars which are unprofitable for private customers.

Third, it can be observed that a high share of company cars goes along with a high share of mixed business-private usage within them. Since this sector is subject to the most unattractive regulation of the three investigated categories towards high-investment, high efficiency vehicles, the reasons for such high potentials lie in their market shares and their high annual driven mileages. The effect of company car taxation will be further discussed in the respective scenario below. It has to be recalled that the result should not be seen as a forecast for vehicle sales, but as a maximum market size in case of full model availability (every car model replaceable by a corresponding PHEV/BEV version) and user acceptance.

Also note that differences in value added tax income are not expected to occur by the modelled sales behaviour. We calculate a break-even mileage between the old low-investment, high-consumption alternative (conventional cars) and its high-investment, low-consumption alternative (EVs). But since both investments and consumption are subject to 19% value added taxes (in case of companies: 0%), any composition of them should lead to equal public income.

Bonus scenario

Currently several countries are planning or already have decided to support the purchase of electric vehicles with a one-time bonus payment by federal and/or municipal authorities. This bonus is usually related to requirements the car has to comply with such as a minimal electric drive range or attainable speeds in electric drive mode. It is assumed that all configurations of EVs within this paper would qualify for such bonus payments.

Such bonus only influences directly the sales period where it is paid (regardless possible effects like mass production enablement or employment creation which is beyond the model's scope). Regarding current announcements this period will be rather early. The calculation will show the effect of the amount of a possible bonus, a differing amount between PHEV and BEV and the year when it is granted. Two bonus arrangements have been calculated for two time periods.

Scenario 1 pictures a split bonus of 1500€ for potential PHEV buyers and 3000€ for BEVs in 2010 and 750€ resp. 1500€ in 2015. Scenario 2 on the other hand implies that buyers of both technologies would receive the same amount: 2000€ in 2010 respectively 1000€ in 2015. Figure 3 shows the impact of a bonus payment to lower the surcharges of EVs within 2010 and 2015.

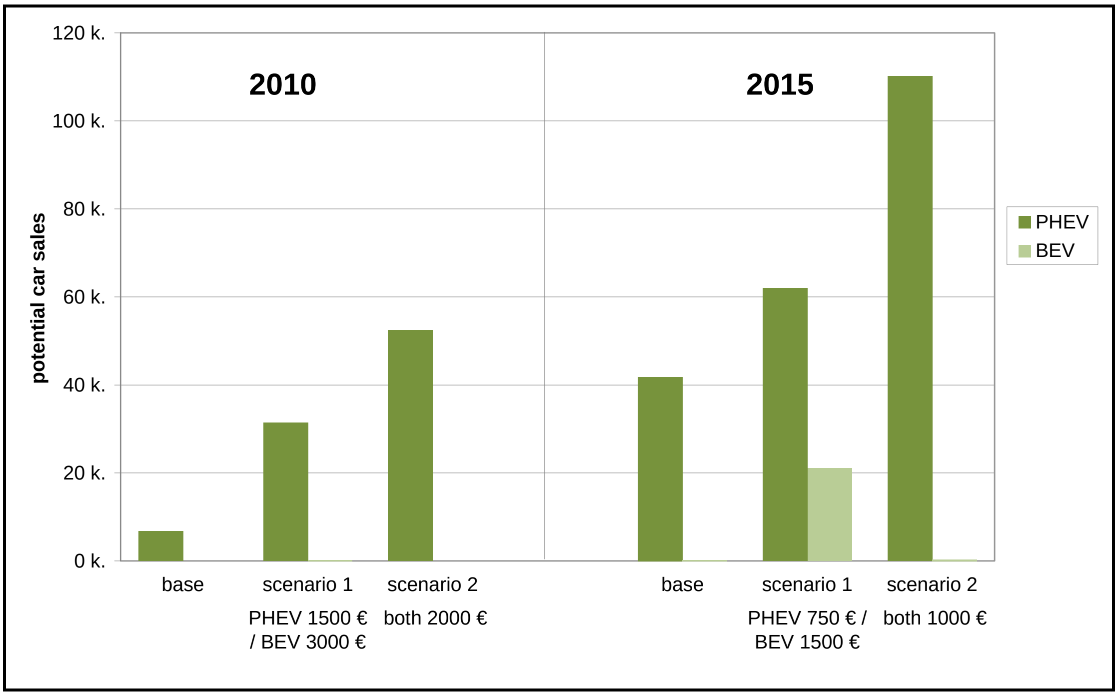

Figure 3: Sensitivity of sales potential for bonus payments in 2010 and 2015

As depicted in Scenario 1 a split bonus in 2010 would increase the sales potential of PHEV by more than 400% compared to the base scenario. But it also outlines that there is no effect in enhancing the economic potential of BEVs. BEVs are not yet economic competitive to PHEVs in 2010 even with a higher bonus payment. Scenario 2 strengthens the findings of Scenario 1. Increasing the bonus to 2000€ for PHEV leads to a further increase of potential sales and with no effect to potential BEV sales. Further calculations have shown that even payments of 5000€ for both technologies or a split payment of 5000€ for BEVs and 3000€ for PHEV only affect the economic potential of PHEVs in this early period of time. The reason is mainly due to comparatively low battery prices for PHEV which are e.g. for a small PHEV only a quarter of the costs for a comparable BEV.

A further calculation for 2015 was performed to show that also in the mid term future a bonus payments will have a high impact on the sales potential of EVs. The results follow the general findings for the calculation of 2010. But beyond that it can be shown that a split payment in Scenario 1 leads to first economic substitutions of PHEVs in favour of BEVs. Scenario 2 in turn shows the sensitivity of that substitution potential resulting in a slump of the economic potential of BEVs.

This leads to the conclusion that even in 2015 the effect of a relatively low bonus leads to a significantly higher economic potential and that it should be considered to split the grants for both technologies to help getting first BEVs earlier into the market to support the long term objective.

New corporate car tax scenario

Another policy option to support the Economic sales potential of EV would be the restructuring of the corporate car tax regulation in Germany. Originally aiming to allow employees the private use of their corporate car (often used as an incentive instead of a rise in pay), its current design may actually hinder them in ordering more expensive but fuel-efficient cars. While the employee's monthly car fringe-benefit subjected to taxing is directly proportional to the car's list price (and the employees income tax rate), the fuel expenses are paid by the employer and can therefore be seen like tax-free salary. Furthermore, the employer can deduct the value added tax on fuel expenses (Verkehrsclub Deutschland, 2008). To model a more eco-investment-friendly alternative, the scenario "New corporate car tax" assumes that the current corporate car tax is dropped entirely. In the same time employees benefiting of private usage of their corporate car must pay all fuel expenses on their own and including all fuel taxes. Mixed-use corporate cars are therefore treated like private cars (even though paid by the company as an incentive) and their usage for business trips is to be billed separately between the employee and the company. The results of the company car tax scenario are shown in the figure below.

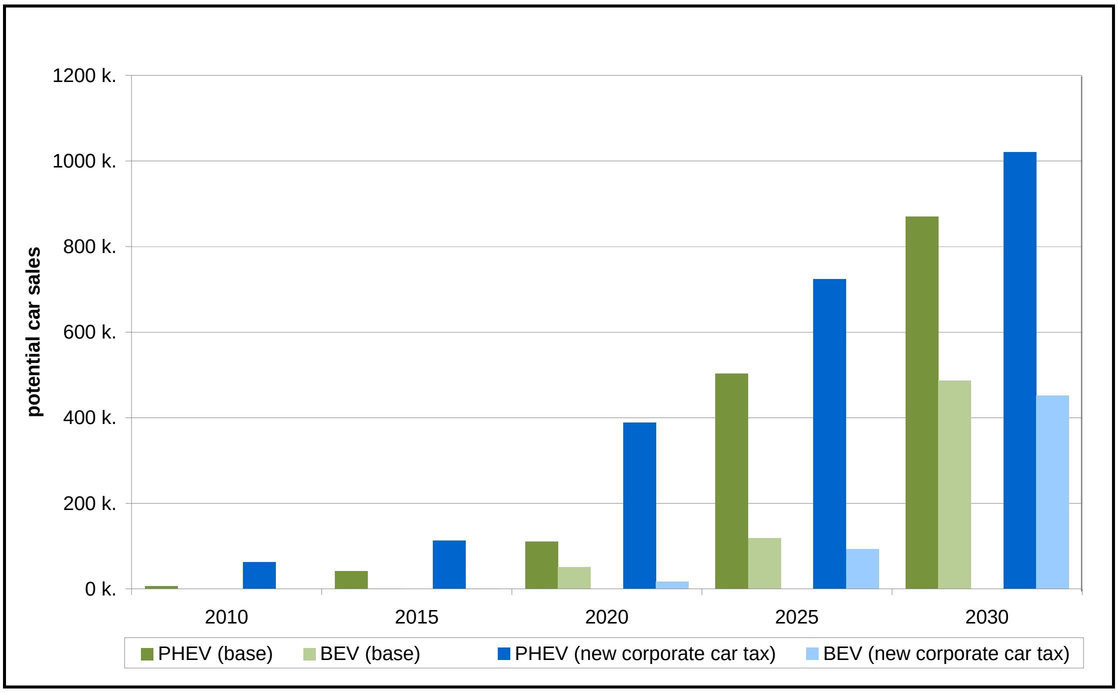

Figure 4: Potential sales of EVs in the new corporate car tax scenario

It can be demonstrated that a revised corporate car tax would positively affect the economic potential of EVs over all periods. Especially potential sales of PHEVs in the near future are significantly higher because of their high yield of fuel savings per investment and the generally high share of mixed-use company cars in this segment and time (as already demonstrated in the base scenario). This negatively affects the share of BEVs due to comparatively low profitability. The effect is subsequently decreasing until 2030. This underlines how the new annual cost structures incite the purchase of fuel-efficient and therefore electrified vehicles.

The new corporate car tax regulation would lead to both positive and negative public income effects:
While the monthly fringe-benefit taxation is entirely dropped, the public income on energy tax as well as the value added tax on fuel is increased. The concrete balance of these two factors depends on the actual fuel consumption. But regarding the sales effect even a negative balance represents a very cost-efficient incentive compared to cash premiums.

Electric vehicle tax

The tax on energy (former mineral oil tax) is the most important consumption tax in Germany. According to the Federal Ministry of Finance the share for fuel accounted in 2008 for an income of 35 billion € (BMF, 2009). Assuming that a growing share of vehicles on the road will be electric vehicles the absolute energy tax income will decrease. The following table illustrates the deficit caused by potential EV car sales building on the base scenario.

		2010	**2015**	**2020**	**2025**	**2030**
Potential EV sales per year in the 'base scenario'		6,779	42,054	161,486	620,567	1,356,637
Energy tax losses per year if every potential EV is sold (in million €)		16	64	190	425	628
Required EV tax for compensation of energy tax losses (per kWh)		0.27€	0.25€	0.19€	0.18€	0.18€
After Iteration	**Potential sales**	-*	-*	914	17,759	315,564
	Energy tax losses (in million €)	-*	-*	2€	37€	375€
	Required EV tax for compensation (per kWh)	0.16€*	0.21€*	0.25€	0.24€	0.17€
* Market breakdown before tax balance is reached						

Table 10: Impact of an EV tax on potential EV sales numbers

It can be shown that an increasing number of potential EV sales accounts for up to 628 million € in tax losses in 2030. The third row depicts a necessary tax per kWh to compensate these losses. Assuming average recharging costs of 0.21€/kWh, the final price including an EV tax would more than double. The decreasing amount of EV tax per kWh over time is justified by a decreasing average yearly mileage per car from 2010 to 2030.

To visualize the effect on the economic potential of EVs the EV tax was implemented into the model. After several iterations it can be found that an EV tax would lead to a collapse of the economic potential of EVs until 2020 and only a very slow recovery until 2030. These findings lead to the conclusion that an EV tax of this type is not practicable. Within the first years of market penetration it is not possible to compensate the losses of tax income trough a reallocation at the expense of EVs. Because of the high investment costs within the next ten years it is crucial to make the purchase of an electric vehicle as attractive as possible to support market development. But since energy tax is an important income federal governments have to find a solution in the medium term.

Conclusive an alternative approach is calculated by raising the energy tax by the value of losses due to potential EVs. Table 11 shows that only a marginal increase per year is necessary for compensation which sums up to a total of around 14% until 2030 compared to the year 2010. The allocation of energy tax losses on conventional ICE vehicles is a beneficially strategy to support the long-term objective to reduce harmful emissions caused by road traffic.

	2010	2015	2020	2025	2030
Energy tax increase in % per year	0.05%	0.18%	0.54%	1.21%	1.79%
Energy tax increase in total	0.05%	0.46%	1.92%	5.84%	13.71%

Table 11: Energy tax increases to compensate losses due to potential EVs

5. Conclusion and outlook

The sales potential for electric drive trains in Germany is not only restricted by infrastructural and technical constraints but also strongly by the economic conditions for the prospective customers.

The results for the base scenario clearly show a growing potential for market diffusion for both PHEV and BEV until 2030. Nevertheless additional policy measures are needed to reduce the actual economic drawbacks of EVs. These measures may consider the important differences between private and company cars to promote electric mobility equally towards all actors.

Results of the scenario analysis show intensive changes in the economic potential especially for two scenarios: A bonus paid on EVs can accelerate the market entry of such vehicles depending on the amount of bonus and the timeframe within it is granted. Also a redesigned corporate car tax could encourage employees to choose more fuel-efficient vehicles. In contrast the calculation of an EV tax to compensate losses from energy tax income should be disregarded. The analysis also revealed that PHEV and BEV markets interact strongly with each other. Hence, policy measures targeting only one market will have certain influence on the other one as well.

Policies to drive EVs into the market may consider these results to design combined solutions of inciting with bonuses and new taxing approaches. However, there is further need for research as the actual realized share of the potential also depends on EV acceptance and actual user behaviour. Therefore, fleet tests and surveys are crucial to understand the demand side – in order to encourage car manufacturers to develop a broad range of electric vehicles in a required quantity.

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