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Cost-Benefit Analysis of policies for the development of electric vehicles in Germany: methods and results

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Abstract
Policies toward the diffusion of Electric Vehicles received a lot of attention in the latest years in many developed countries. However evaluation of such policies is still incipient and consistent assessment tools are necessary to avoid that policies are flawed or based on ungrounded a priori. In this paper, we review different existing models and present a simulation tool for the assessment of EV policies in Germany. This model incorporates detailed representation of the various technological, behavioral and economical mechanisms that govern the possible diffusion of EV in Germany. Consistent with most of the literature, our finding suggest that most of EV supporting policies have a negative outcome. These results are strongly driven by the regulatory framework in which EV diffusion could take place and especially the Car Average Fleet Emission regulation EU 443.

Keywords: Electric vehicles, evaluation, cost benefit analysis

JEL Codes: : C53 Forecasting Models; Simulation Method; O33 Technological Change: Choices and Consequences; Diffusion Processes; D61 - Allocative Efficiency; Cost-Benefit Analysis

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1 Introduction

Electric cars as an alternative to conventional internal combustion engines are becoming increasingly popular among policy makers as well as the general public since they appear as a way to address environmental issues as well as rising prices of fossil fuels. In this context, a number of countries are considering ambitious policies in order to foster the diffusion of such technologies. It is however unclear how such policies can represent a welfare improvement i.e. if their social benefits are larger than their costs. This is already apparent considering the high costs of some measures decided in given countries (consider a 5000 € premium proposed in numerous European countries) and the high targets of some policies (consider the target of 1 mln vehicles in the German fleet in 2020 set by the German government). Such high targets and heavy costs should not, in themselves, be a sufficient rationale for rejecting these policies but they strongly suggest that they should be submitted to rigorous assessment.

In order to assess the validity of these policy packages, one needs to establish a consistent evaluation framework based on a realistic representation of the mechanisms leading to the diffusion of electric vehicles and a comprehensive representation of the costs and benefits that accrue to the different actors. Such an ambition was at the origin of the EMOB project, a research project funded by the German Ministry of the environment.

In this paper, we provide a description of the simulation tool developed within this project and show the main results obtained.

First, we review the main existing models for simulation of diffusion and evaluation of electric cars and the main findings of Cost Benefit Analysis and propose a number of guidelines for future developments. In a second section, we provide a brief description of the model. In a third section, we show results of selected policy scenarios. In a last section, we discuss the results and conclude.

2 Existing models and results

The literature regarding the diffusion of electric vehicles consists of several types of approaches: diffusion forecast (which typically provide the foreseen development of electric vehicles in a given context), models (that allow for large scale simulation of various policy scenarios), and evaluations (which provide results about the costs and benefits of policies). While these different materials should theoretically be interlaced, it is often found that they are quite distinct which makes it possible to proceed our examination using this categorization.

2.1 Diffusion forecast

As far diffusion forecast is concerned, the available material mainly consists of simplified market penetration forecasts that are mainly based on the Bass diffusion theory (a methodology defined in (Bass 1969), (Bass 2004) and used recently (Becker, Siduh et al. 2009)) or ad hoc Stated Preferences surveys (Dagsvik, Wennemo et al. 2002; Achtnicht 2008; Mabit and Fosgerau 2011). Some other studies (mainly carried out in a professional rather than a scientific context) rely on the concept of Total Cost of Ownership (TCO), an approach that, sometimes with some more extra complications, substantially assigns the demand to the cheapest technology (for a critic of cost driven decision process see (Turrentine and Kurani 2006)).

Bass diffusion models are a way to model mathematically the speed at which the potential market of a given technology is achieved based on two types of behaviors: *innovation* and *imitation*. Stated Preferences surveys, as far as they are concerned, are based on surveys that propose to consumers hypothetical products (for instance a gasoline car with a given range and fuel costs, together with an electric car with different performances) and obtain information on how much consumer preferences are sensitive to the different features (for instance: range, fuel cost). This information is then used to simulate consumer purchase behavior when products with given characteristics are introduced in the market.

2.2 Models

Another important body of literature relates to models. Table 1 **Errore. L'origine riferimento non è stata trovata.** indicates the most relevant models available to forecast and evaluate the diffusion of electric vehicles. This type of approach can prominently be illustrated by the U.S. project Transition toward Alternative Fuel Vehicles (TAFV: (Greene 2001)) and its successor (AVID, (Santini and Vyas 2005)).

Table 1 – main existing models for the forecast and evaluation of electric car diffusion[1]

Model	Country - Time frame	Type of model	Market diffusion approach	Observation
TAFV (Greene 2001) (and AVID), (Santini and Vyas 2005)	USA	Micro economic welfare maximization model	Discrete choice model. Coefficients derived from microeconomics and, partly, economic data	High level of resolution among technologies and fuel types
VISION (Singh, Vyas et al. 2003) (see also VISION CA)	USA- until 2050	Spreadsheet model	Exogenous market penetration assumption for different technologies	Diffusion pattern is strongly driven by numerous exogenous assumptions
Smart Garage (RMI)	USA 2010-2030	Spreadsheet model	Bass diffusion with exogenous 50 % potential	Strong focus on time pattern of battery reload
AECOM (AECOM Australia 2009)	Australia Until 2040	Market penetration forecast	Synthetic Utility Function	
CalCars (Kavalec 1996)	California 1994-2015	Market and policy simulation model	Nested multinomial logit for ownership and technology choice based on RP and SP data	
IPTS transport technologies model (Christidis, Hidalgo et al. 2003)	20 developed countries: up to 2020	System dynamics	Weibull distribution based on costs, + Wood algorithm to take into account capacity constraints	Implemented in Vensim
Vector21 (Mock, Hülsebusch et al. 2009)	Germany Until 2030	Extended TCO approach	TCO+wtp for "advanced vehicles"	Model includes 9 technologies and 900 customer types. BEV diffusion is exogenously limited (for instance to 50 % for small cars) to reflect range limitation
ASTRA (IWW, TRT et al. 2000)	EU 27: until 2050	System dynamics model integrating macroeconomic transport and environment.	Discrete choice model. MNL	Implemented in Vensim. Discrete choice calibrated on diesel/gasoline competition 1990-2006

[1] Other existing transport models were not considered in this table (for instance Transtools. Tremove) as they offer limited knowledge about.

2.3 Electric car evaluation

Apart from these models, which concentrate on the market penetration, the literature also proposed a number of studies labeled as "cost benefit analysis" of electric vehicles. Most of the studies falling into this category actually use this terminology improperly, at least to our view, as they consider the costs and benefits to car users only (Simpson 2006), or alternatively, the industry, or government agency (Kosub 2010), or sometimes omitting the externality component of the COBA (Draper, Rodriguez et al. 2008) negating the intrinsic holistic view of cost benefit analysis that should instead consider costs and benefits to society as a whole.

Some studies however take a broader view on the topic. Kazimi investigates the effect of electric and alternative fuel vehicles on air quality in the Los Angeles area and provides the $ value of the related benefits (Kazimi 1997; Kazimi 1997). This analysis does, however, not compare benefits against costs. Funk and Rabl analyses the private and social (= private + external) km costs of electric against gasoline and diesel vehicles in France (Funk and Rabl 1999; Rabl 2002). Their findings indicate that while the total costs of EV are higher than diesel, they are not generally lower than gasoline cars. Carlson and Johansonn-Stenman analyze the social costs and benefits of the introduction of Hybrid technology among small cars in Swedish towns (Carlsson and Johansson-Stenman 2003). Their main finding is that, due to the difference in taxation between electricity and fuel, the development of EV will cost more to society than it will benefit (through the reduced environmental externality). Keefe, Griffin and Graham examined the private as well as the total (private + externalities) costs and benefits of new fuels in the US (Keefe, Griffin et al. 2007). The scope of their research for the current policy process is however limited in that they consider hybrid vehicles (parallel to "advanced diesel", and E85) as the only electrified technology. Interestingly, their analysis aims at integrating novel elements in a Cost Benefit Analysis framework like: the impact of reduced oil consumption on US energy security, the rebound effect (increase in vehicle miles travelled when cheaper travelling technologies are made available). Their finding is that "*measured by NPV, the diesel is the most promising alternative*" a statement that would seem provocative in a number of contexts (as, typically, in European ones) and whose scope is limited for the current policy discussion due to the limited set of technologies considered and to the specificity of the Californian context.

PriceWaterhouseCoopers also produced Costs Benefit Analysis of EV fleet deployment in Austria (PriceWaterhouseCoopers 2009). This study takes into account changes in taxation, imports, energy consumption, and infrastructure investments (charging stations, energy plants). While this study provides interesting insights (for instance showing that, in what can be understood as a no policy scenario, the effect of EV diffusion on public budget is substantially neutral), it fails to recognize the fact that COBA should treat as generally neutral transfers between agents[2] and erroneously associate costs and benefits to decrease/increase in general taxation.

In Australia, AECOM performed a simplified Cost Benefit Analysis of various policy scenarios in New South Wales (AECOM Australia 2009). Costs relate to purchase and operating costs of the vehicles. Benefits relate to Green House Gas and mostly, air pollution. The three scenario policies that are considered can strongly increase the net benefits of electric vehicles diffusion, such a result however constitute a remote prospect as the Net Present Value of policies usually becomes positive only in years after 2030.

2.4 Where are we standing?

As can be observed from the survey of previous studies, the number of available analysis is quite reduced when considering the policy relevance of the issues and the number of countries which actually are considering Electric Vehicles policy. Apart from the general need of keeping up with the pace of technological development and to generate results in other contexts than the few investigated areas (Paris, Swedish towns, California, New South Wales, Austria, Australia), the existing results need to be complemented with further investigations.

First, one needs to take into account the linkages of Electric Vehicles development with further economic impacts, and with related (acknowledgly speculative) employment effects. Policy makers have a strong focus on the so-called "indirect effects" and employment effects. In the absence of sound, micro--founded analysis, the policy making process can easily be occupied by fuzzy, policy driven, lobby produced figure which calls instead for more rigorous analysis.

Second, there are some other issues on how "*global*" benefits like CO_2 emissions should be accounted for in a Cost Benefit Analysis with national scope.

Third, more fundamentally, few of these models (Aecom is an exception, Keefe as well but with the narrow perspective of the costs and benefits to a public agency) are really policy valuation tools that would compare the outcomes of policy scenarios with a properly defined reference scenario. Most of them concentrate on examining the impact of an (often exogenous) EV diffusion. So they evaluate the benefits of some (undefined) technology development while arguably, what is relevant is not what is the cost/benefit of the apparition of a new technology, but how a policy can improve welfare by influencing this development. What is needed is a tool that simulates the effects of policy packages based on a set of incentives consistent with the policy currently considered by policy makers (Kley, Wietschel et al. 2010).

[2] With a provision for second order effects as reflected for instance opportunity costs of public costs.

We have reviewed the existing models and results for the forecast of electric and alternative fuel vehicles and the evaluation of related policies. We have found that a number of models are available. They basically relate to three paradigms: TCO, SP surveys and Bass diffusions models with a limited number of additional, heterodox, approaches.

We found that most of the models available for the diffusion of Electric Vehicles relate to the North American context and/or provide limited insights into the relevant policy issues for European countries. Eventually we found that the Cost Benefit Analysis of Electric Vehicle policy is still incipient as, to our best knowledge, notwithstanding the quality and relevance of the works we have quoted in this article none of them constitute a satisfactory and comprehensive evaluation framework for EV policies in European countries.

2.5 Recommendations for future EV models

This picture suggests that the community of applied economists should dedicate efforts to the extension of existing models focusing on a few features. Apart from the need to develop relevant and consistent evaluation tools, it is possible to underline a number of modeling features that should be considered in order to render the diffusion mechanisms, and correspondingly, the policy recommendations, more realistic.

First, there is a general need to develop adequate modeling and evaluation tools for the European context: many of the existing models have been developed for an American context and provide little insights about the evolution that can take place in Europe.

Second, we find that a stronger focus should be made about diffusion mechanisms. In many of the existing models, diffusion is exogenous, which makes it virtually impossible to establish policy assessment. In other models, we find that the adequacy of the behavioral parameters is questionable: whether it is based on a given SP survey that can prove very idiosyncratic, or whether it is calibrated on a very limited set of data (like diesel/gasoline market shares). Additionally, one should consider how the diffusion theory insights should be integrated together with other behavioral paradigms and, especially, Discrete Choice Models. There is a wide discrepancy between the meaning that marketing science gives to SP based market shares estimates and the meaning given to these estimates by transport scientists. The ones tend to see them as long term potential, while the others consider them, to say it briefly, as short term market possible achievements. How these two diverging approaches should be reconciled is still on the agenda of transport modelers and marketing scientists.

Third, one should consider that most of the existing models present limited interactions with other sectors. This relates for instance to the energy sector which will certainly be impacted by the development of EV and, reversely, some policy measures will probably be implemented through the energy sector (consider refueling stations). Similarly to energy sector, we also reckon that more attention should be dedicated to car industry and to the CO_2 emissions standard that this industry will have to face due to EU/443 regulation. Such a change in the regulatory setting is felt by stockholders to be a major change in the car market and may constitute a strong input to EV diffusion. In this context, it is fair to state that the modeling of EV diffusion should explicitly take into account the effects of this regulation on the car industry and indirectly on car market.

Based on these indications, a model has been constructed for the evaluation of EV policies, to respond to the need of policy makers to evaluate EV policies in Germany. The next section of this paper presents the features of this model.

3 Policy simulation and evaluation using EMOB

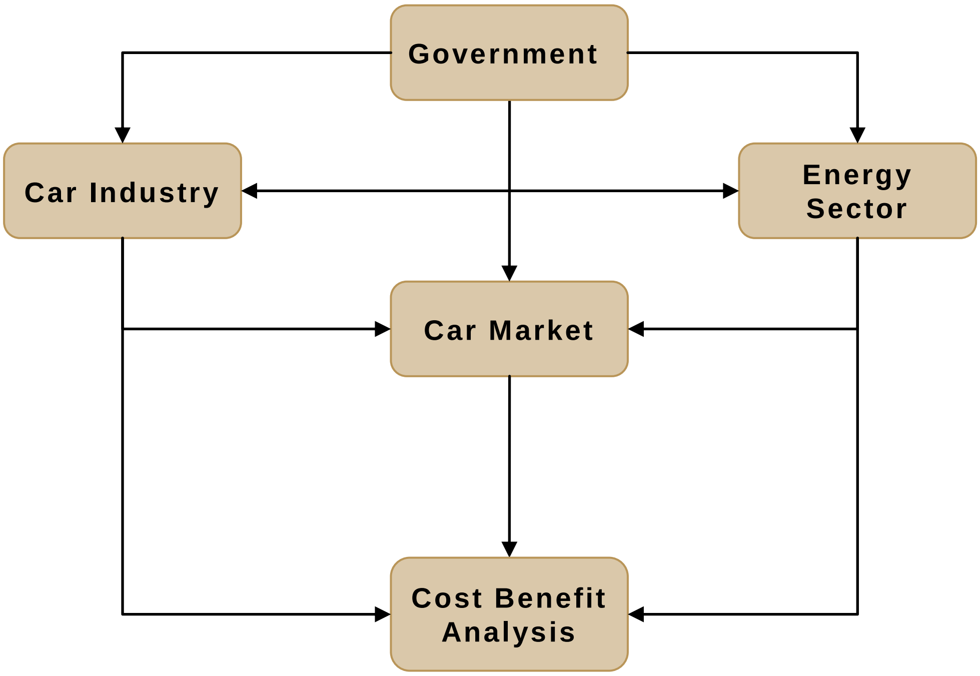
We first provide basic presentation of the simulation tool and then present more in detail its policy evaluation module.

3.1 EMOB in short

EMOB is a simulation model designed to forecast and evaluate policies toward the diffusion of electric vehicles in Germany. EMOB has been developed in the Goldsim simulation package. Results presented in this paper refer to EMOB release 0.1.3.6 developed in Goldsim 10.5.

EMOB includes five main modules: policy, energy sector, car industry, car market, cost benefit analysis together with economic impact analysis. We provide hereafter some more information on car industry and car market and energy sector. Readers interested by a more detailed description of the model can refer to the project-related policy report and the technical report (Gosh, Hemmert et al. 2011).

Figure 1: general structure of EMOB model



Government module, without entering in the details, defines the set of instruments used in a given policy. These instruments relate to actions directly aiming at EV diffusion (typically purchase incentive) and as well to actions directed toward the context (consider for instance a regulation on fuel efficiency) in which EV could develop.

The **car industry module** generates the features of the different car alternatives present on the market. It incorporates the effects of technological progress (for instance the increase in energy density of batteries) and regulatory drivers. In particular a detailed description of Regulation EU/443 on CO_2 emissions is included. Facing this regulation, car producers have to change the optimal fuel efficiency of the vehicle. As will be illustrated below, this latest element is found to be highly influential of the general diffusion pattern and Cost Benefit Analysis results.

EMOB's core component is **a car market** simulation module that is based on a Discrete Choice Model that forecasts the diffusion of different automotive technologies on the German market. It represents vehicle choice with a high level of resolution. Namely: it incorporates 9 competing technologies (Gasoline, Diesel, Hybrid, Biofuels, LPG-CNG, BEV, Range Extender, Plug-in Hybrid, and Fuel Cell). This choice process is run in parallel for 6 submarkets (privately owned household cars, rental cars, car purchased by resellers, cars provided by companies to their employees as a fringe benefit, corporate fleet, and public procurement), which are characterized by differing purchase mechanisms.

Vehicle segments are taken into account, corresponding to different vehicle sizes (mini, compact, etc), with a level of decomposition that is fairly larger than in other existing models and is based on the categorization of the Federal Bureau of Motorization[3] in use in Germany. It includes 11 categories: Minis, small cars, Compacts, Middle range, Higher middle range, Luxury, Sports Utilities Vehicles, Sport cars, Minivan, People carriers and Light Freight Vehicles. The choice of the vehicle segment is endogenous; this means that faced with changing car attributes, people can choose to change segment rather than technology. The model is "dynamic", i.e., the market shares of respective technologies and segments are a function of the time-dependent value of car attributes. The discrete choice model elaborates on a meta-analysis of Stated Preferences surveys and constructs a Synthetic Utility Function based on willingness-to- pay (WTP) and elasticities defined through a literature survey. A separate paper (Massiani) is exclusively dedicated to the construction of this Synthetic Utility Function.

The model also contains a "diffusion" module, which uses the Discrete Choice Model as input data (to be understood as "potential market shares") and computes adjusted market shares based on a Bass-like diffusion model.

The **energy module** allows for a quantitative evaluation of the effects of short-and medium-scale policy measures as well as the representation of long-term interaction between electric cars and the energy sector. It is based on exogenous forecasts of the German generation portfolio and uses Monte Carlo simulation based on observations of German photovoltaic and wind feed-in to represent fluctuating renewable energy supplies.

The model can be run for a reference scenario that represents the most likely scenario. It can also be run for a variety of policy scenarios that activate a series of policy measures (purchase incentive, fuel taxation, etc). Generally speaking, the model provides an evaluation framework for a wide variety of policies and is based on a detailed and micro-founded representation of the choice made by car purchasers among a wide variety of existing cars.

3.2 Cost-Benefit Analysis in EMOB

The Cost Benefit Analysis module collects information on the changes that occur for a number of relevant variables between a reference scenario and various policy scenarios. The computation takes into account different categories of agents: consumers, producers, State, environment. The "rest of the world" is also included in the analysis as it can also be impacted, especially through changes in fuel import/export.

The costs/benefits of each category of agent are then computed considering different categories:

[3] Kraftfahrtbundesamt

- Car purchase costs
- Fuel costs
- Road tax
- Infrastructure costs (refueling, electricity)
- Other fiscal costs (changes in VAT receipt and shadow cost of public funding).

Table 2 summarizes the different costs and benefits taken into account for the different actors.

Table 2 - Overview of stakeholder and impact areas

Impact areas	**Consumers**	**Producers**	**Government**	**Environ.t**	**Rest of the World**
Car purchase	Change in consumer welfare car purchase expenditure	Producer rent car sales	Direct policy funding costs		Foreign producer surplus car purchase
Fuel consumption	Fuel expenditure welfare	Producer rent fuel production	Fuel tax revenues	CO_2 damage costs	Foreign fuel production and sale producer surplus
		Producer rent electricity production	Energy tax receipts	Other pollutants damage costs	
		CO_2 abatement costs	Fine payments		
Road tax	Road tax liability		Road tax receipts		
Infrastructure	Home charging infrastructure	Home charging infrastructure			
	Grid extension	Grid extension			
Other fiscal costs	Shadow costs of public spending	Shadow costs of public spending	VAT receipts		

Consumers are mainly impacted through changes in price and quantity of cars and fuels. The evaluation method for consumer costs/benefits relies on the surplus. For instance, in some policies, it appears that the total expenditure for fuel increases, but quantities decrease. The increase in total expenditure does not however fully represent the real welfare loss of consumers in that they also renounce to some fuel consumptions (and the benefits linked to it): this can adequately be taken into account looking at changes in consumer surplus. Additionally, consumers are impacted through changes in road tax liability (a pro-EV policy could for instance switch demand to vehicle categories that are less taxed). They also ultimately bear the cost of charging infrastructure and grid extension.

As far as **producer**s are concerned, the costs and benefits are represented by changes in the producer surplus. This relates to car producers that are impacted through the changes in price and quantities and to fuel sellers, considering changes in the sold quantity of fuel.

As far as **government** is concerned, cost relate to the direct cost of the policy, the changes in fuel and energy and road taxes income, possible fine revenues (in case car manufacturers exceed CO_2 emissions threshold) and changes in VAT receipts. The shadow cost of public spending is accounted for, but it appears in the cost and benefits of the consumer and producers as it is ultimately them who bear this additional cost.

Benefits and costs for **environment** relate to CO_2 emissions and other pollutants damage costs. There estimation relies on a physical quantification of the emissions and subsequently on their conversion to monetary costs, using well established monetarization guidelines (Maibach et al. 2008).

Eventually, we take into account costs and benefits for **the rest of the world**. This relates to the costs and benefits of foreign car manufacturer who can also take advantage of an expansion of the German market and to the changes in benefits of fuel producers. While one may be interested by providing a cost benefit balance only for Germany, it appears that computing costs and benefits for the rest of the world is instructive. It lets appear interesting phenomenon, when, for instance change in fuel import range among the largest benefits/costs of the project.

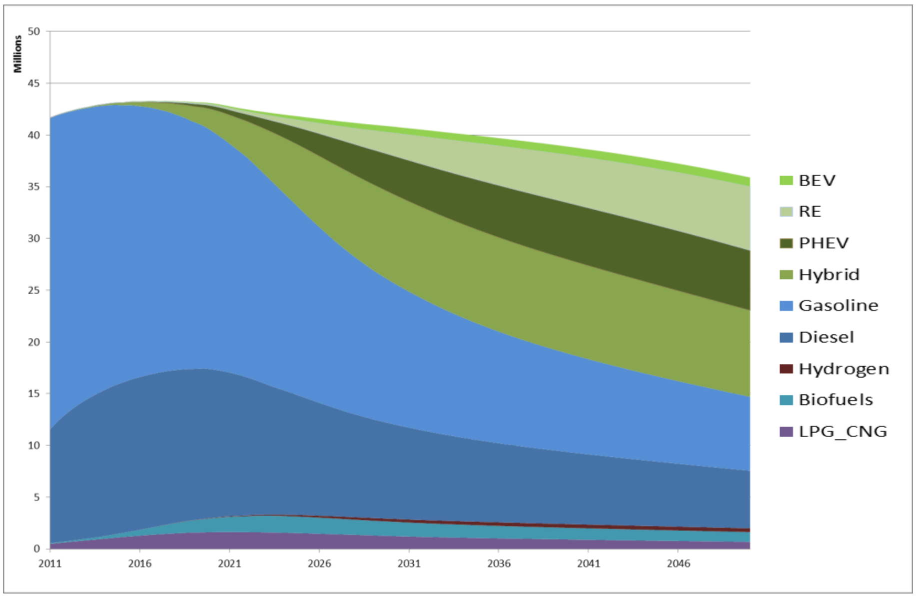
After taking into account the various costs and benefits for different actors, it is possible to summarize the whole effects of the policy by computing Net Present Value (NPV) of the different scenarios for various relevant time horizons (2025, 2030 and up to 2050). This NPV is computed using a 5% discounting rate. We can now move on to the presentation of the policy simulation outcomes.

4 Policy simulation Outcomes

The policy evaluations results are closely linked to the simulated diffusion of EV which, in our results, appears slightly smaller than in many other estimates. We obtain 0.4 million EV (BEV, REV, PHEV) in 2020 and 6 millions in 2030. Interestingly we find that EV's are mainly concentrated on two transition technologies (Plug in Hybrid and Range Extender) while

Battery Electric Vehicles only have a marginal role in the general outcome. The general pattern of the German fleet is depicted Figure 2

Figure 2 Composition of the German fleet for different technologies in the reference scenario



In the subsequent section of this analysis we first present the various scenario policies and subsequently present the outcomes of the policy runs.

4.1 Detailed results for a purchase incentive policy

In this section, we present in detail the results of the model for a policy based on a purchase incentive. Namely it consists in a 2 000 € incentive for 200.000 EV cars. This policy is showcased in that it corresponds to a measure that is often proposed by policy makers.

Table 3 costs and benefits of purchase incentive policy: 2000 € for 200.000 veh. (NPV 2025 in mln €)

	Consumers		Producers		State		Environment		Rest of the world	
Car purchase	Consumer surplus car purchase	1.988	Producer surplus vehicle purchase	- 68	Direct cost of the measure	- 349			Producer surplus	- 781
Fuel expenditures	Consumer surplus	- 997	Producer surplus on fuel distribution	- 62	Fuel taxation	- 484	CO_2 Emissions	157	Producer Surplus Fuel	- 450
			Producer surplus on electricity production and distribution	59	Energy tax	54	Other environmental damages	56		
			CO_2 reduction costs Electricity sector	- 65	Regulation 443 fines	- 3				
Car tax	Car tax	- 417			Car tax income	417				
Infrastructure	Expenditure for refueling stations	- 181	Installation of recharging stations	15						
	Network construction	- 382	Network infrastructure investment	36						
Policy costs	Shadow cost of public expenditures	79	Shadow cost of public expenditure	133	VAT income	- 339				
Total NPV for Stakeholder	Total NPV for consumers	90	Total NPV for producers	48	Total NPV for State	- 705	NPV environment	214	NPV Rest of the world	-1.231
Total NPV	- 353								(not included in total NPV)	

The results of this scenario exhibit some significant patterns. A first element relates to the general negative outcome of the policy. This is explained by the fact that, while the policy is beneficial both for consumers and producers, as well as the environment, it comes at a high price for the State. Interestingly, while consumers benefit from cheaper car (this relates to the price incentive but also to the changes of conventional car prices, as will be illustrated below), they face an increase in fuel consumption and consequently in car taxation. This counterintuitive effect relates to the mechanisms of regulation EU/443 on CO_2 emissions. When the number of EV's increase, the average emissions of a prototypical car manufacturer decreases (this relates to the fact that EV's are accounted for as zero emission vehicles in the computation of car manufacturers average emissions). This makes the efforts for high fuel efficiency of the car less profitable for car manufacturers. In these conditions, the efficiency of cars sold on the market are slightly reduced (but their price as well decreases). While this reduction may seem marginal at the level of each single car, it applies on a very large number of cars, resulting in a strong response of fuel consumption to the increase of EV's.

4.2 Comparison with other scenarios

In this section, we present the outcome of Cost Benefit Analysis for different policy scenarios. The selected policy scenarios rely on the measures that were on the policy agenda during year 2011 in Germany. Generally, they were defined within the National Platform for Electromobility, a stakeholder forum created by the German government for the definition of a national policy. Namely, we consider:

- Purchase incentive of 2 000 € for 200 000 cars
- Bonus-Malus (-5 000 €; +2 200 €)
- Fleet public purchase (by public administration)
- Fleet purchase (by public administration), Dienstwagen fiscal exemption.
- 15 cent electricity for electric vehicles

Table 4 provides the main results of the results

Table 4: costs benefit analysis results for a set of EV policies

Measure	Time frame	Efficiency	Additional EV	Direct cost per additional EV (€)	NPV 2020 (Mio €)	NPV 2025 (Mio €)
Incentive 2000 € (200.000 cars)	until 2014	Very high	130.000	2 615	- 276	- 343
Bonus-Malus	2012-16	Very high	500.000	- 2 000	- 1 000	- 2 400
Fleet purchase	2012-20	Average	70.000	-1 300	161	255
Fleet purchase, Dienstwagen fiscal exemption	2012-16	High	90.000	-900	-452	-272
15 cent/kwh for EV		Average	90.000	833	-207	-800

Generally the various scenarios exhibit a negative NPV, with the exception of fleet purchase.

5 Discussion and conclusion

The outcome of the analysis is found to be distinct, on various aspects, from the general consensus regarding EV policies.

A first outcome relates to the generally low penetration of pure EV's (Battery Electric Vehicles) on the German market even on the long term (up to 2050). In the reference scenario, the Battery Electric Vehicles only represent 0.7 % market share in the German market in 2020. Even aggressive policies, which have been additionally simulated in the model, fail to obtain a significant market share of BEV in the long run. This picture is somehow altered when considering intermediate technologies like PHEV and Range Extender, which perform a much larger penetration than BEV's in the medium to long term (for instance PHEV and RE together are sold 4.5 times more than BEV in 2020). Those technologies appear to be the real vector for EV development in the German market, they however obtain a relatively modest market development in the short medium run (3.2% market share in 2020). Additionally hybrid technology appears to be successful technology and takes a fundamental role reaching market shares of 14% in 2020. All these evolutions take place in a context that is strongly influenced by the strict emission standards imposed on car producers by approved EU regulation 443 which drastically decreases conventional car emissions at the cost of an increase in vehicle purchase price.

It is properly this regulatory context that influences as well the general picture provided by our Cost Benefit Analysis. Contrarily to expectations, policies toward the development of electromobility appear to generally allow car manufactures to relax their emission reduction efforts. This relates to the fact that regulation 443 sets a target (95g/km in 2020) as an average on all vehicles sold. Selling more EV's thus allows increasing emissions of non EV vehicles and the expected benefits of electromobility in terms of emission reductions are usually more than compensated by the general increase of conventional engine emission. This implies that CO_2 emissions are not decreased (for a detailed analysis see (Massiani and Weinmann) and correspondingly fuel expenditure increases. Interestingly, other effects of various EV policies are found to be of limited magnitude compared with this increase in fuel consumption and emission. Consistently, an unexpected outcome of the policy is that part of the benefits is conveyed to oil exporting countries.

Generally our results cast doubts on the validity of EV supporting policy in Germany. While one may object that Cost Benefit Analysis is not in conditions to take into account all the relevant aspects of a given policy – an argument more often expressed when the outcome is negative than when it is positive, we posit it is still useful to provide results. Noticeably, it can help in indicating that if a policy is implemented it is not at least for those of the mechanisms that are included in the analysis. Would anyone consider that EV policies are good for other reasons, say industrial leadership of the German car industry – or any other reason, then Cost

Benefit Analysis could not infirm this assumption. It would however make it necessary for those who claim the supposed industrial benefits of EV policies to come with solid arguments.

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