THE IMPACT OF POLICY MEASURES ON THE DEMAND FOR PRIVATELY-HOLD ELECTRIC VEHICLES: A SOCIO-ECONOMIC ANALYSIS FOR FRANCE

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ABSTRACT

So far, demand forecasts for electric vehicles (EVs) providing decision support for policy makers as well as market projections for vehicle manufacturers have been largely based on either large scale macro-economic models or on disaggregate models derived from stated preference surveys. Both of these approaches neglect important and decisive factors influencing future demand. This study introduces an empirical methodology based on the French National Transport Survey 2007/08 and on detailed total costs of ownership calculations in order to project private EV demand until 2023. Several realistic policy, market and vehicle development scenarios are analyzed in order to derive the possible impact of these factors on final EV demand. Recommendations for policy measures are derived. The focus of the study is the Paris region. Aggregate results for France are obtained.
Results of the scenario analysis show that the maximal percentage of EV-qualifying households lies in the vast range of 2-25% of French households. This signifies an overall EV demand of 0.5 - 6.7 million vehicles until the year 2023. The exact percentage depends on the specific scenario setting. Fiscal policy measures show to become less important with time thanks increasingly EV-favourable market conditions and advancing vehicle technologies.

Keywords: Electric vehicles, demand forecast, market analysis, total costs of ownership (TCO), constraints analysis

1 INTRODUCTION

1.1 Context and Objective

Recent years have been showing increasing public interest in electric mobility. Electric mobility is seen as one of several promising means to achieve resource-efficient and decarbonised future transport systems, increased energy independence of nations and an upturn of the car industry after the years of crisis.

Within the portfolio of electric vehicles, battery electric vehicles (that solely run on electricity - they constitute the subject of this study and are in the following abbreviated as EVs – Electric Vehicles) are especially thought to find use in company car fleets and as shared vehicles of transport providers. Here, thanks to increased vehicle usage, a financial advantage of this type of vehicles is expected to be achievable, while restrictions concerning infrastructure needs and limited range do not necessarily pose constraining factors. Private households are seen to create potential demand for an EV only under specific conditions. This appear to be threefold: i) appropriate recharge infrastructure is cost-effectively accessible ii) mobility needs of a given household can be met by the restricted range of available EV models, and iii) the overall financial equation which is heavily influenced by purchase prices, vehicle usage patterns and economic framework conditions favours the acquisition of an EV rather than the one of a conventional vehicle (CV).

The objective of this study is to explore the potential demand for electric vehicles under the light of these three conditions. For this purpose, a disaggregate approach that allows exploring the characteristics of single households is applied. Literature review shows that such an approach has rather been the exception for EV demand forecasts. We argue, however, that it is specifically such disaggregate information on households' infrastructure needs and mobility patterns as well as on (local) policy measures that allow most reliable predictions on future EV demand. In order to account for many remaining uncertainties related to the introduction of EVs (such as the development of market trends and future vehicle specifications) as well as different policy packages, the study explores various realistic scenarios. The developed methodology is applied to France and puts specific focus on the metropolitan area of Paris. It explores the potential demand evolving throughout the upcoming 10 years (from 2012-2023).

1.2 A brief review of literature

Various types of EV-forecasting methodologies have been developed that each shall cover the need of a certain demanding body. Each forecasting approach comes with its deficiencies. In the following a categorization of reviewed literature on forecasting the demand of alternative fuel vehicles is proposed.

Type 1: Aggregate demand forecasts

Aggregate demand forecasts mainly serve national or even international policy makers to define cost-effective high-level policy measures that help push the development of EVs. Car manufacturers use outcomes of such studies in order to forecast their potential sales and to define their prices and production strategies; utility companies and energy providers are interested in order to forecast the impact of EVs on the electricity grid and on potential future energy demand.

For the large interest in this type of forecasts, aggregate demand forecasts appear to be dominant. Examples of such studies are Funk and Rabl (1999), Delucchi and Lipman (2001), Carlsson et al. (2002), Draper et al. (2008), BCG (2009), Becker (2009), Deutsche Bank (2009), EDF (2009), Figliozzi et al. (2010), Nemry et al. (2010), Brady et al. (2011), CE Delft (2011) and CDGG (2011). Most of these studies are based on cost comparisons of an EV with a CV, which differ in their level of detail. Taking hypotheses on technological advancements of vehicles and price developments allows conclusions on if, when and by what magnitude EVs have the potential to replace CVs. Working on an aggregate level, household characteristics that seem to be important for vehicle purchase decisions are not taken into account. Local policy measures are usually neglected.

Type 2: Disaggregate demand analyses based on stated preference (SP) data

This category of studies allows exploring the willingness-to-pay of vehicle purchasers for certain technologies and/or vehicle features. Results mainly serve car manufacturers to identify the technological improvements most desired by potential customers. Also utility companies or policy makers can be interested in this type of studies for identifying, for example, purchase behaviour that is determined by the density of the recharge/refuel network or specific policy measures. Examples of such studies are Brownstone et al. (1999), Page et al. (2000), Brownstone et al. (2002), Dagsvik et al. (2002), Choo et al. (2004), Hess et al. (2009), Deloitte (2010), Hidrue et al. (2011), Jordal-Jorgensen (2011), Maness et al. (2011), Mabit (2011), Saphores et al. (2012), Anastasopoulos et al. (2012) and Molin (2012).
This type of study is meaningful when exploring vehicle choice behaviour in response to certain vehicle features or framework conditions. Their potential to forecast actual vehicle demand appears to be limited - especially so since stated preference surveys come with many uncertainties with regards to the actual purchase behaviour of respondents.

Type 3: Disaggregate demand analyses based on socio-economic data

This type of studies serves to forecast demand on a disaggregate level. E.g. by using the results of type 2 studies, most important characteristics of so-called ‘early adopters’ of alternative fuel vehicles are identified. By the means of an available data source, these early adopters are counted and, if possible, even geographically located within a specific region. Local policy makers and infrastructure providers are then in the position to decide on policy measures that target these first user groups. In case the data source covers a large region, also aggregate results can be obtained. Probably due to the lack of data availability, studies of type 3 appear to be the scarcest. Campbell et al. (2012) gives an example of such a study by exploring household characteristics of households in Birmingham, UK. Thanks to the level of detail, identified likely early adopters of EVs can be localized within the area of Birmingham. Chlond et al. (2012) takes a similar approach by using the data of the German Mobility Panel. Vehicles that ‘qualify’ for an EV are identified; socio-economic characteristics of concerned households are explored thereafter. Biere et al. (2009) defines vehicle user groups by their employment status and identifies those who are likely to benefit financially from preferring an EV over a CV. Finally, only multi-motorized households that dispose of private parking facilities are seen to qualify for an EV. The methodology is applied to the whole of Germany and forecasts that more than 30% of Germany’s (private) vehicle fleet qualifies for EVs by 2020. This potential is put into question: only elevated vehicle usage (high mileage or long ownership periods) will actually render the EV profitable over the CV.

Conclusions on the literature review

We argue that type 3 studies are the most promising for forecasting EV penetration in a reliable way. If data availability allows, they have the potential to take into account most 'rational' parameters influencing the purchase decision of a certain type of vehicle. In case the data source covers a large enough region, such studies can be aggregated to meaningful geographic levels while not leaving important household characteristics or vehicle usage patterns aside.

1.3 Paper outline

The methodology section (section 2) of this paper first introduces the study area and the available data source. It then describes how 'EV-qualifying' households that will potentially create EV demand are identified, and which specific scenarios are explored. The results section (section 3) then shows i) the incremental application of household selection criteria for a specific scenario and region, and ii) final results per defined scenario and geographic area. Finally, the concluding section (section 4) gives a comprehensive summary of results and draws conclusions on most significant EV-supportive policy measures. Shortcomings of the applied method giving directions for further research are discussed.

2 METHODOLOGY

2.1 Study area and data availability

The focus of this study is the Paris region (or the Île-de-France, IDF, region). The region is divided into the 3 residential zones Paris, the 'Petite Couronne' and the 'Grande Couronne'. Differences between these sub-regions are remarkable. Whereas Paris can be perceived as extremely dense urban area that is very well served by PT (public transport), the 'Petite Couronne' shows typical suburban characteristics of a periphery. Accessibility is mainly assured by suburban trains and bus services. The 'Grande Couronne' area, on the other hand, shows a mix of pre-urban and almost countryside-like characteristics. The PT network is much less dense and mainly relies on buses and few connecting train lines. These different land use structures entail quite diverse mobility needs of the sub-regions' inhabitants. The IDF region therefore allows exploring the potential EV demand for quite diverse settings.
The French National Transport Survey (the ENTD) 2007/08 serves to explore household and vehicle usage characteristics of over 20 250 French households. The number of surveys successfully carried out in the Paris region amounts to 5 887 (approximately 20% of these are located in Paris, 30% in the Petite Couronne, and 50% in the Grande Couronne). The data source of the ENTD gives vast information on socio-economic characteristics of households, on vehicles of a household, on households' access to transport and parking infrastructure, as well as on households' vehicle usage patterns. Aggregations for the whole of France are made by applying the territorial characteristics (such as parking costs) of the Grande Couronne to the national level.

2.2 Identifying EV-qualifying households

Given the data availability and findings of previous studies (see Biere et al., 2009; Deloitte, 2010; Campbell, 2012 and Chlond, 2012), a list of criteria was established that allows verifying whether, from a 'rational' perspective, a given household qualifies as potential EV-household. While previous studies often focus on identifying likely early adopters by their income or by certain lifestyle characteristics, this study focuses on households that are conform to all constraints, limitations and specifications of EVs – in a practical, technical as well as in a financial sense.
Table 1 gives the set of criteria that was established. Households (HHs) complying with the whole set of criteria constitute what we define as 'EV-qualifying' households. The table shows 3 categories of criteria that refer to the threefold condition under which a private household is seen to be a likely EV adopter (as stated in the introduction).

TABLE 1 - Set of criteria defining EV-qualifying households

Criterion Category	#	Variable	Necessary setting for an EV-qualifying HH	Concerned HH type
Vehicle Ownership	1	Car ownership	at least 1 car in the HH	all (mono- and multi-motorized HHs)
Infra-structure	2	Private parking space	at least 1 private parking space accessible	
	3	Type of private parking space	at least 1 private parking space that is either covered, or, alternatively, is close to the single detached home of the HH	
	4	Parking space at frequent destination	at least 1 available parking at frequent destination (if the vehicle is used for this type of trips)	
Vehicle Usage	5	Regular return-trips carried out with the vehicle (e.g. home-work-home)	in the range of the EV	
	6	Home-secondary home trips by car	in the range of the EV	mono-motorized
	7	Home-occasional home trips by car	in the range of the EV	
	8	Holiday trips	not made by private car	
Economics	9	Total Costs of Ownership (TCO)	TCO of an EV are less than the TCO of the comparable CV	all (mono- and multi-m.)

The last column of Table 2 shows to which type of household each criterion is applied. A differentiation into mono-motorized households (that dispose of only one car) and multi-motorized households (that dispose of more than one car) is made.
The first criterion (applied to all households) reflects the assumption that only motorized households are seen as potential EV purchasers.
The set of infrastructure criteria reduces the number of potential EV-qualifying households to those with access to private parking infrastructure (criterion 2) that can be easily equipped with EV recharge infrastructure (criterion 3). Criterion 4 is a supplementary, quite stringent criterion to assure that the EV user has access to recharge infrastructure throughout the day in case the vehicle is used for frequent trips to the same destination (such as to work). It is assumed that such parking spaces will be increasingly equipped with recharge infrastructure.

In contrast to previous studies (e.g. Biere et al., 2009; Deloitte, 2010; Campbell, 2012) that only see multi-motorized households as potential EV adopters, this study also considers mono-motorized households as potential EV households. However, mono-motorized households are subject to the more stringent set of vehicle usage criteria containing also criteria 5-8. The assumption that members of multi-motorized households can fall back onto a CV within their household's vehicle fleet in case the range of the EV is not sufficient for a certain trip allows relaxing criteria 6, 7 and 8 for this latter type of households.
Criterion 9 is an economic criterion that assures that only households for which the acquisition of an EV is financially interesting (compared to a CV) qualifies as potential EV household. This criterion is seen as a major advancement compared to previous studies following a similar approach: a detailed total cost of ownership (TCO) approach, which accounts for purchase and usage costs of the vehicle over its whole ownership period, is applied. TCO for each single household are calculated by taking into account the household's specific characteristics. Necessary information on households is obtained from the ENTD. It mainly refers to the residential zone of the household, the yearly mileage of the household's most used vehicle, and the fuel type of this vehicle. The application of criterion 9 demands extensive cost calculations. The exact methodology followed and a description of the calculation model are given in Windisch (2011). Certain household and vehicle usage specific information that is necessary for TCO calculations could be retrieved from the ENTD 2008/09. The most important items of such retrievable information refer to i) the yearly driven distance of the vehicle likely to be replaced next (assumed to be the oldest vehicle in the household), ii) yearly incomes (necessary for calculating tax reductions), and iii) the preferred vehicle type of the vehicle to be purchased (either compact or sedan – assumed to be the vehicle type of the vehicle to be replaced), and iv) the residential area of the regarded household. Household or vehicle usage specific information that could not be retrieved from the available database were assumed to be in line with the 'reference' scenario. (See the tables in the annex for an overview of this scenario and further assumptions necessary for calculating the TCO for different vehicle types and usages).

2.3 Scenario Analysis – Attempting a look till 2023

Forecasting the potential demand for EVs comes with many uncertainties. These mainly relate to i) (changing) public policy packages on national and local level, ii) (changing) economic framework conditions, and iii) technological advancements of batteries and vehicles over time. In order to account for these uncertainties, reliable demand forecasts necessarily need to work with scenario analysis.
In order to account for changing framework conditions over time, two time intervals within which EV-qualifying households are likely to purchase their new (supposedly electric) vehicle are defined. The first time interval covers the years 2012 – 2016. The second time interval covers the years 2016 – 2023. Households whose oldest vehicle (meaning the vehicle that has been the longest time in use by the household) has been owned for more than 7 years are supposed to purchase a new vehicle in the first time interval; households whose reference vehicle has been owned for less than 7 years are supposed to purchase a new vehicle in the second time interval. This assumption is rather conservative given the average vehicle ownership period of 5 years that was found in the ENTD and is consistent with INSEE (2010). Making this assumption entails the supposition that every household owning

a vehicle will purchase a new vehicle until 2023 the latest. The fact that almost 60% of privately owned vehicles in France are bought 2nd-hand has to be kept in mind (INSEE, 2010). The option of 2nd-hand purchases is not accounted for in the underlying study.

The following table gives information on possible scenario settings for each of the three defined factors of uncertainty for the defined time intervals (see the following section for more precise information on assumptions behind each scenario). Within time intervals the settings are assumed to be constant. The exception is the parameters describing the economic trends which are subject to change each year (according to the selected scenario).

TABLE 2 - Possible scenario settings per category of uncertainty

	Time Interval	
Uncertainty factor	2012-2016	2016-2023
Policy Package	reference	reference/reduced
Economic Trends	base/optimistic	base/optimistic
Vehicle development	reference	reference/improved

For the time *interval 2012-2016*, only the reference setting for the policy package and the vehicle development are foreseen. The settings refer to the framework conditions as of 2012. Vehicle characteristics and prices refer to the EV and CV models of the French car manufacturer Renault; public policy settings refer to the package that has been put in place in France (and more specifically in the Paris region) by 2012. Neither the public policy nor the vehicle characteristics are assumed to change till 2016. Alternative scenarios are therefore not accommodated. For the development of economic trends two different scenario settings are accommodated in the forecasting tool. They mainly refer to the development of fuel and electricity prices.

Looking into the future, to the time *interval 2016-2023*, none of the uncertainty factors is restrained to one single scenario. It is neither entirely certain how the policy package will develop nor how vehicle development will progress (and how this will impact the final sales prices of vehicles and their batteries). For each category of uncertainty there are two possible scenario settings. The policy package is assumed to stay at most at the level of 2012. However, it is likely that it will be reduced due to an increasing budgetary burden coming along with increasing EV sales. For this reason, the alternative scenario to the reference scenario is the ‘reduced’ scenario. Concerning the economic trends, again a base and an optimistic scenario are accommodated. Vehicle development is supposed to advance with increasing EV demand. The alternative scenario to the reference scenario is therefore the ‘improved’ scenario. The different scenario settings for the first and second time intervals can be combined in various ways, giving a total number of 16 possible scenarios. It was decided to restrain the study to the 6 scenarios as shown in table 3. They are considered to be the most likely scenario combinations.

TABLE 3 - Modelled scenarios

Scenario	1	2	3	4	5	6
Naming	***Technology***	***Technology +***	***Cost-Decrease***	***Cost-Decrease +***	***Policy***	***Policy +***
Economic Trends 2012-2016	base	optimistic	base	optimistic	base	optimistic
Economic Trends 2016-2023	base	optimistic	base	optimistic	base	optimistic
Policy Package 2016-2023	reduced	reduced	reduced	reduced	reference	reference
Vehicle Development 2016-2023	improved	improved	reference	reference	reference	reference

Settings for the policy package and the vehicle/battery development in 2012-2016 are not shown since only the reference scenario is available. It can be seen that only scenarios with a stable market development (either base or optimistic) over the two time intervals are modelled. Further, it is assumed that policy packages will most likely be reduced in the second time interval (scenarios 1-4). Only 'Policy' scenarios (5 and 6) assume strong policy support also in 2016-2023. 'Technology' scenarios (1 and 2) assume that vehicle specifications improve over time (which comes along with price increases); 'Cost-Decrease' scenarios, on the other hand, assume constant vehicle specifications (allowing for price decreases). The '+' sign indicates scenarios that assume 'optimistic' economic trends, while the ones without further specification assume 'base' economic trends. More specific settings that are assumed behind each scenario are given in the following section.

2.4 Assumptions behind the scenario analysis

Table 4 gives a more detailed description of defined scenario settings. The first part describes the two scenario settings for the development of the economic trends (NB: it is assumed that the scenario setting remains the same over both time intervals). The second and the third part give the settings for the policy scenarios and the vehicle development scenarios for the two time intervals. Vehicle development scenarios change the settings of cost, consumption and range specifications of the EV and CV vehicle types.

TABLE 4 - Scenario Settings[1]

Economic Trend Scenarios	**Base**	**Optimistic**
Fuel Price	medium	high
Electricity Price (% increase/year)	7	4
EV Maintenance Share (in %)	80	50
EV Insurance Reduction (in %)	20	20
Market Interest Rate (in %)	6,5	5,5
Inflation Rate (in %)	1,7	1,4

Policy Scenarios	**Reference 2012**	**Reference 2016**	**Reduced 2016**
Purchase Subvention EV (Euro)	5000	5000	0
Registration Tax Exemption EV	yes	yes	no
Fuel Taxation (TICPE increase in %)	5	5	2
Electricity Taxation (% increase/year)	0,5	0,5	0,3
Parking Policy Scenario	2	2	1
Infrastructure Usage Costs Exemption	no	no	no
Infrastructure Installation Costs	yes	yes	yes

Vehicle Development Scenarios	**Reference 2012**	**Reference 2016**	**Improved 2016**
EV			
Battery Purchase Costs (in % of current price)	100	85	110
Battery Hire Costs (in % of current price)	100	100	110
Vehicle Purchase Costs (in % of current price)	100	85	85
Range (in km)	120	120	250
CV			
Vehicle Purchase Costs (in % of current price)	100	85	110
Petrol Usage (in % of current usage)	100	100	85
Applied household selection criteria	all	all	skip # 4

Scenarios referring to economic trends and the underlying policy package only show impact on the economic 'TCO' criterion (criterion 9 as shown in table 1). However, settings of the vehicle development scenarios have impact on more selection criteria as defined in table 1. The setting of the range of the EV impacts criteria 5, 6 and 7. Also, increased range is assumed to come with less range anxiety. Criterion 4, that claims the necessity of having access to parking infrastructure at work, is therefore skipped for the 'improved 2016' scenario.

3 RESULTS

Given the successive application of selection criteria and the carried out scenarios analyses for altogether 4 distinct geographic areas (Paris, Grande Couronne, Petite Couronne, France total), results are manifold. First, the results of the successive application of the selection criteria as shown in table 1 are presented. The set of criteria is applied to all households in France under a specific scenario setting. The second section then shows final results (after having applied the whole set of criteria) for all 6 different scenarios modelled and makes the distinction into each defined geographic zone.

[1] Fuel price scenarios are based on EIA, 2011 (see annex); Parking policy scenarios refer to: 1 – no EV policy, 2 – free public parking for EVs (see annex); insurance cost decreases for EVs are currently offered on the French market (see annex). Ad battery hire cost scenarios: Since currently offered battery hire prices appear to be a (even more) costly business model for the offering car manufacturer than the battery purchase business model, battery hire prices are assumed to remain or even increase in future scenarios. Ad CV development scenarios: It is assumed that either similarly fuel-efficient models will be available for a reduced price or more fuel efficient models will be available for an increased price.

3.1 Successive application of selection criteria

For interpretation reasons, the results of the successive application of the selection criteria are given for scenario 3 (“Cost-Decrease”), which assumes a reduced policy package from 2016 onwards, while no major technological improvements in vehicle/battery technology have been achieved until then (which, in turn, allows for purchase price reductions for the modelled time interval 2016-2023). Looking at this scenario eases the analysis since for both time intervals (2012-2016 and 2016-2023) the same selection criteria are applied in the same form. A single table gives all results. Looking at the successive results allows analyzing which criteria are more or less stringent when applying them incrementally.

TABLE 5 - Results for France under Scenario 3 (“Cost-Decrease”)

France *(Scenario 3)*

Set of household selection criteria			HHs complying with criteria 1 to n (if applied to the defined HH type)	
Criterion Category	Criterion *n*	Criterion Description	mono-motorized *(all in % of the total household population*)*	multi-motorized
Vehicle Ownership	1	Household motorized	47,0	33,2
Infra-structure	2	Private parking at home available	30,3	26,0
	3	Home recharge infra. installation possible	25,9	24,9
	4	Parking at work available	23,4	22,6
Vehicle Usage	5	Return-trips to frequent destination within EV range	23,1	22,4
	6	Trips to secondary residences within EV range	21,9	n.a.** ↓
	7	Trips to occasional residences within EV range	21,7	
	8	Holiday trips not carried out with the private vehicle	12,3	
Economics	9	TCO EV < TCO CV (Battery purchase | Battery hire)	0,1 | 0,5	0,1 | 0,9
Total EV-qualifying HHs till 2023 (in % of total HH pop.*)			**0,2 | 1,4**	
Total EV-qualifying HHs till 2023 (in households)			**53 250 | 372 751**	

Reading aid : Taking the line of criterion *n* =5: 23,1% of the total household population in France complies with criteria 1 to (including) 5 and is mono-motorized; 22,4% complies with the same set of criteria and is multi-motorized. 0,2% of the total household population corresponds to all selection criteria. This percentage rises to 1,4% in case the vehicle's battery is hired.

* 26 625 086 HHs according to the survey (weighted)

** n.a. - not applied (previously found %-value is immediately subject to criterion 9)

Source: ENTD 2007-2008 and the author's calculations based on the conceived TCO model

Table 5 shows the results for single- and multi-motorized households separately before aggregating them to a single total. The application of the first criterion gives information on vehicle ownership of households in France: 47.0 % of households are single-motorized, 33.2 % are multi-motorized. The availability of a private parking space at home is more likely for multi-motorized households than for single-motorized households. In case a household has access to such a private parking, the household is likely able to equip it with EV recharge infrastructure. The criterion of having access to a parking place at the frequent destination of the vehicle (e.g. at work) does not appear to be very stringent. With the exception of criterion 8 (the holiday criterion), vehicle usage criteria do not reduce the potential number of EV households significantly. Since criterion 8 is not applied to multi-motorized households (neither are 6 or 7), the overall reduction of EV-qualifying households due to vehicle usage criteria can be seen as low. The TCO criterion, criterion 9, comprises the effects of the selected 'Cost-Decrease' scenario. Two different sub-scenarios are modelled. The first sub-scenario refers to a TCO comparison of an EV with a CV where the vehicle battery is purchased up-front with the vehicle. The second sub-scenario refers to the business model of the French car manufacturer Renault: the battery is hired during the ownership period of the vehicle and remains in the ownership of the car manufacturer. It can clearly be seen that the hiring of the battery is financially more interesting for the vehicle buyer under all taken assumptions. In this scenario much fewer households are excluded from the pool of potential EV-households due to the economic (TCO) criterion. In general, the TCO criterion is very stringent: a large potential of EV-qualifying households is lost due to a missing TCO advantage for the households. (The following section gives an idea of the sensitivity of the market potential to the economic criterion.)
The total resulting numbers show that 1.4% of households in the Paris region qualify for an EV in case they are willing to hire the battery of their vehicle. This percentage signifies a total of approximately 373 000 households that are potential EV buyers until 2023. In case only the battery purchase option is considered, these numbers drop to 0.2 % and 53 000 respectively.

3.2 Final results per scenario and region

Since table 5 does not give information on when vehicles are actually bought, neither on which geographic area counts most EV-qualifying households, this section now shows results per defined scenario, per time interval and per area (France, Paris, Petite Couronne, and Grande Couronne). Only final results per scenario are shown. The distinction into single- or multi-motorized households is omitted. Only results for the battery hire option are shown, being the prevailing business model currently in France (and the only one offered by Renault). Further, in order to investigate the sensibility of results with regards to the economic criterion, a supplementary scenario is modelled that assumes an increase of the EV purchase subsidy by 2 000 Euro (resulting in a total purchase subsidy of 7 000 Euro). This increase is in line with the augmentation of the French purchase subsidy as in place since late July 2012 (see Ministère du Rédressement Productif, 2012). However, contrary to the assumption that any modelled purchase subsidy remains in place until the end of 2015, the French EV purchase subsidy is so far only guaranteed until the end of 2013.

TABLE 6 - Results per geographic area, scenario and time interval

France

Scenario	*Techn.*	*Techn. +*	*Cost-Decr.*	*Cost-Decr. +*	*Policy*	*Policy +*
% of total HHs	1,5	10,4	1,5	9,1	5,6	25,4
Total HHs till 2023 (in 1000)	389	2 769	389	2 434	1 478	6 763
% of HHs till 2016	96	83	96	94	25	34
% of HHs after 2016	4	17	4	6	75	66
+ 2000 Euro subsidy	*+ 9,8 %*	*+ 3,8 %*	*+ 9,8 %*	*+ 3,8 %*	*+ 25,0 %*	*+ 7,5 %*

Paris

Scenario	*Techn.*	*Techn. +*	*Cost-Decr.*	*Cost-Decr. +*	*Policy*	*Policy +*
% of total HHs	2,9	3,2	2,9	3,1	6,9	6,9
Total HHs till 2023 (in 1000)	34	38	34	35	81	81
% of HHs till 2016	100	89	99	95	42	42
% of HHs after 2016	0	11	1	5	58	58
+ 2000 Euro subsidy	*+ 0,0 %*	*+ 0,0 %*	*+ 0,0 %*	*+ 0,0 %*	*+ 0,0 %*	*+ 0,0 %*

Petite Couronne

Scenario	*Techn.*	*Techn. +*	*Cost-Decr.*	*Cost-Decr. +*	*Policy*	*Policy +*
% of total HHs	0,7	4,4	0,7	4,1	2,5	10,5
Total HHs till 2023 (in 1000)	12	80	12	76	45	193
% of HHs till 2016	92	91	92	96	25	38
% of HHs after 2016	8	9	8	4	75	62
+ 2000 Euro subsidy	*+ 5,3 %*	*+ 2,0 %*	*+ 5,3 %*	*+ 2,0 %*	*+ 12,7 %*	*+ 4,9 %*

Grande Couronne

Scenario	*Techn.*	*Techn. +*	*Cost-Decr.*	*Cost-Decr. +*	*Policy*	*Policy +*
% of total HHs	1,3	8,6	1,3	7,6	4,6	22,2
Total HHs till 2023 (in 1000)	25	170	25	149	90	435
% of HHs till 2016	100	81	100	93	28	32
% of HHs after 2016	0	19	0	7	72	68
+ 2000 Euro subsidy	*+ 7,5 %*	*+ 2,9 %*	*+ 7,5 %*	*+ 2,9 %*	*+ 22,8 %*	*+ 7,4 %*

Model results are significantly dependent on the general economic trends. EV-favourable market trends (all scenarios indicated with a "+") constitute a significant lever for the profitability of EVs. The only exception appears to be Paris when regarding the policy scenarios. This is to be explained by the fact that the total remaining potential of EV-qualifying households after having applied household selection criteria 1-8 (which amounts to 6.9 %) is already attained by the sole 'Policy' scenario.

A difference between the 'Technology' and the 'Cost-Decrease' scenario is not noticeable. Assumed improvements in technical specifications of the vehicles in the first scenario and reductions of purchase prices assumed for the latter scenario appear to have the same, rather negligible impact. This is likely to be due to the fact that both scenarios also assume vehicle advancements or price reductions for the CV. As a consequence, the TCO comparison between the CV and the EV does not result in any remarkable increase or decrease of the number of EV-qualifying households.

The policy scenarios show that maintaining supportive policy measures also during the second modelled time interval is an important lever – however, in a minor magnitude than EV-favourable market trends (compare the 'Cost-Decrease' with the 'Cost-Decrease+' scenario, on the one hand, and the 'Cost-Decrease' with the 'Policy' scenario, on the other hand). The largest potential of EV-qualifying households is found when both, EV-supportive policy measures and EV-favourable market trends are assumed for both time intervals.

An increase of the purchase subsidy by 2 000 Euro (to a total of 7 000 Euro) shows to have significant, but area-depending impact. The sensitivity of results to the TCO criterion becomes evident. The impact of an increased purchase subsidy is lower in scenarios that assume EV-favourable market trends. This speaks for a decreasing sensitivity of results to an increasingly EV-favourable TCO comparison. The most obvious example supporting this observation is the policy scenarios: In case of EV-favourable market trends, the increased purchase subsidy can 'only' add 7.5% to the total potential of EV-qualifying households in France. It then sums to 32.9% (7.5% + 25.4%) and is close to the attainable potential of 33.7%, which remains after selecting households according to criteria 1-8 (as can be derived from table 5 by adding 12.3% and 22.4%). In case EV-favourable market trends are not assumed, the subsidy adds 25% (!) to the total potential of EV-qualifying households. It then sums up to 30.6%.

The dominant share of identified EV-qualifying households until 2023 is found to materialize in the first defined time interval – the time interval when policy measures are assumed to be in place. In case policy measures are also maintained during the second time interval (as this is the assumption behind the policy scenarios), the dominant share is found during this latter time interval. Here, the leverage of continuously increasing fuel prices shows more effect on the resulting potential of EV households than in the first time interval.[2]

Comparing different geographic areas with each other reveals that no uniform picture can be obtained: none of the areas persistently shows the highest percentage of EV-qualifying households. However, the Grande Couronne area reveals the highest percentages for all "+"-scenarios. This is certainly due to the fact that infrastructure constraints, as imposed by selection criteria 1-4, are less stringent in the Grande Couronne than in Paris or the Petite Couronne. In the Grande Couronne area, a higher percentage of households is subject to selection criterion 9 than in these latter, denser areas. However, when regarding scenarios that do not assume EV-advantageous market trends, the highest percentages of EV-qualifying households are found in Paris. This is probably due to the higher (financial) effect of assumed parking policies in Paris than in its suburban areas.

Generally it can be concluded that the effect of financial policy measures on potential EV demand is significant. In 'base' case conditions, their impact appears to be more significant than in scenarios that already assume EV-favourable framework conditions. The TCO difference of an EV and a CV is often marginal and can be easily surmounted to the advantage of the EV. The prospects of EV-favourable economic trends are, however, even more promising for the potential demand for EVs.

4 SUMMARY AND CONCLUSIONS

4.1 Summary of study approach

This study showed a new methodology for forecasting electric vehicle (EV) demand on a disaggregate level that allows the inclusion of crucial household-, vehicle user/usage-, and

[2] NB: According to the hypotheses as presented in section 2.3, approximately 40% of households that are subject to selection criterion 9 are assumed to carry out their vehicle purchase in the first time interval. The remaining 60% are therefore supposed to purchase a new vehicle in the second time interval.

territorial characteristics. The shown methodology is applied to France, and more specifically, to the Paris region (the Ile-de-France). Based on results of previous studies, a set of criteria is established referring to a household's vehicle fleet, to its parking infrastructure and to its vehicle usage patterns. Finally, also an economic criterion based on comprehensive total costs of ownership (TCO) calculations is applied. Only households that comply with the whole set of criteria are seen to be potential EV purchasers that will be likely to create first private EV (electric vehicle) demand.
The detailed and vast set of criteria, combined with the disaggregate (household-specific) and thorough calculation of TCO is seen as advancement to previous studies. In order to account for many uncertainties concerning the introduction of EVs, a scenario analysis is carried out. Assumptions on the development of the general market trends, of fiscal public policy packages and of vehicle/battery technology (and their prices) are varied. This allows a look forward until 2023 – assuming that (i) each household owning at least one vehicle will have replaced one of its vehicles until then, and (ii) individual household characteristics and vehicle usage patterns remain unchanged over time.

4.2 Results and conclusions

Results show that most stringent conditions for the acquisition of an EV are i) the access to private parking infrastructure that can accommodate vehicle recharge facilities ii) the non-usage of the private vehicle for holiday reasons (in case of single-motorized households) and, especially iii) the financial advantage of an EV compared to a CV (conventional vehicle), especially so if the battery is to be purchased up-front with the vehicle. On average, the greatest potential for EV-households in the Paris region is found in the Grande Couronne, which shows pre-urban and partly countryside-like characteristics due to comparatively low population densities. While being more constraint due to the lack of infrastructure accessibility (such as parking spaces), households in the city of Paris show to profit the most from financial parking policy measures. Additional financial supportive policy measures seem to have here little effect. While the analysis of the whole of France shows that the increase of the purchase subsidy from 5 000 to 7 000 Euro can have significant impact on EV demand, the analyses of specific regions show that the effect depends on local framework conditions. For this reason, area-dependent purchase subsidies appear to be the most adequate way for supporting EV uptake. Further, they should be in best possible accordance with prospective market trends.
Results of the scenario analysis show that the potential EV demand can attain over 30% of private vehicle demand until 2023. Attaining such a level implies favourable market conditions and asks for sustained strong fiscal policy measures. Also the provision of parking infrastructure or alternatives to the private vehicle for holiday purposes can significantly increase the identified potential. Such latter measures are likely to provide more cost-effective solutions for attaining a similar EV potential.
For assuring that purchase decisions are based on thorough economic considerations, a focus of policy measures should be put on making the TCO approach to a common decision criterion. 'Soft' policy measures (that were not discussed in this work), such as the increase of familiarity and awareness of new vehicle technologies, are undoubtedly still essential measures. Only this way the full potential of here-identified found EV-qualifying households can possibly be exploited.

4.3 Critical review of results

The applied methodology is based on several important assumptions. First, the here identified potential EV demand constituted by the defined 'EV-qualifying' households relies on *rational* decision makers that base their choice solely on technical, practical and financial considerations. EV (non-) purchase that is likely to evolve due to reasoning that is not accounted for in this study, is neglected. Further, the underlying choice universe of the decision makers is restrained to 5 vehicle models whose specifications refer to currently (or soon to be) available vehicles on the French market. The fact that decisions makers can actually choose from a much larger choice universe, including various other vehicle technologies is ignored. With this comes the negligence of the whole 2nd-hand vehicle market that constitutes around 60% of privately owned vehicles in France (INSEE, 2010). A financial advantage of a newly bought EV over a 2nd hand CV is hardly attainable from today's point of view. For this reason, the here identified potential EV demand certainly overestimates actual demand. Finally, TCO calculations neglect likely differing residual values of the different vehicle types after the assumed ownership period of 7 years. While the assumption that similar residual values of EVs and CVs might actually well reflect the reality within the next decade (none of the reviewed studies takes a significantly different approach), the assumption that the two EV business models (battery hire or battery purchase) result in similar residual values of the vehicles is unrealistic. From the private vehicle owner's perspective, the residual value of the battery hire option is likely to be inferior to the one of the battery purchase option. This latter case allows the vehicle (and battery) owner to make use of the EV battery's 2nd life value. In subsequent studies, the here discussed assumptions should be treated in more detail and in a more realistic way. Further, sensitivity analysis on most important TCO-decisive parameters, such as the yearly mileage, fuel prices, and vehicle purchase costs, should be carried out. Scenarios that relax one or more household selection criteria should be envisaged, especially so when taking a look in the even farther future.

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ANNEX

Values and assumptions for TCO Calculations

Table A1: Vehicle-type-specific data

Vehicle/Battery Type Options					
Engine Type - Model Type	CV - Compact		CV - Sedan	EV - Compact	EV - Sedan
Fuel Type	Petrol	Diesel	Diesel	Electricity	Electricity
Battery Purchase Type	-	-	-	purchase/hire	purchase/hire
Reference Vehicle	**Renault Clio** Clio iii Live 3P 1.2 16V (75ch)	**Renault Clio** CLio iii 3P dCi (90ch) eco2	**Renault Fluence** FLUENCE dCi (110ch) eco2	**Renault ZOE Z.E.**	**Renault Fluence Z.E.**
Vehicle/Battery Specifications					
Engine Power (max. kW) (1)	55	65	81	65	70
CO2 Emissions (g/km) (1)	135	106	120	0	0
Range (NEDC) (km) (2)		1375	1364	200	185
Energy Consumption per vehicle usage area (in kWh/100km or l/100km) (3)					
urban	7,6	4,9	5,6	13,9	14,3
ex-urban	4,9	3,5	4,0	17,0	17,5
mix	5,8	4,0	4,6	15,5	15,9
Battery Capacity (in kWh) (4)	-	-	-	22	22
**according to EU-approved UN ECE R101 carbon dioxide emission rating*					
Vehicle/Battery (+Registration) Costs					
Vehicle Purchase (in Euro) (4)	16 650	17 450	22 850	20 700	26 300
Battery Purchase* (in Euro)	-	-	-	9 900	9 900
Bonus/Malus (in Euro) (5)	0	0	0	5 000	5 000
Registration Fees (in Euro) (6)	330	237	376	0	0
Battery Hire Costs (in cEuro/km) (7)	-	-	-	6-10	6-10
**based on 450 Euro/kWh assumption (EVs only offered with battery lease / PHEV only offered with battery purchase)*					
Maintenance Costs (in cEuro/km) (8)					
Total	4,3	4,3	5,6	4,0	5,4
Tire Costs	2,0	2,0	3,0	2,2	3,3
Service Costs	2,3	2,3	2,6	1,8	2,1
Insurance Costs per residential zone* (in Euro/year) (9)					
Paris / Petite Couronne	536	548	548	429	438
Grande Couronne / Rest of France	430	460	460	344	368
** 13% decrease in case private parking available*					

(1) Values for EV obtained from http://www.renault.fr/gamme-renault/vehicules-particuliers/index.jsp; values for CV and PHEV obtained from ADEME (2012); CO2 emissions refer to tank-to-wheel emissions (sources accessed in June 2012)
(2) Values for CV and EV according to the New European Driving Cycle from http://www.renault.fr/gamme-renault/vehicules-particuliers/index.jsp, values for PHEV based on http://www.opel.fr/flash.html (sources accessed in June 2012)
(3) Values for CV and PHEV according to ADEME (2012), values for EVs based on http://www.avem.fr/actualite-les-resultats-des-rallyes-du-challenge-bibendum-2011-a-berlin-2304.html (accessed June 2012)
(4) As advertised on http://www.renault.fr/gamme-renault/vehicules-particuliers/index.jsp (EVs + CVs) and http://www.opel.fr/flash.html (PHEV).
(5) see http://www.service-public.fr/actualites/00694.html, 'Bonus pour les véhicules propres' and 'Malus pour les véhicules polluants' (accessed June 2012)
(6) Including (i) regional fees as in the IDF region (46 Euro * 'Puissance fiscale' of the vehicle in case the vehicle emits tank-to-wheel emissions), (ii) 'frais de gestion' and (iii) 'frais de port'.
(7) Here shown prices are average value ranges of Renault's tariffs that are dependent on the yearly distance driven and the duration of the hire contract. The underlying TCO model is based on Renault's business model: Battery hire costs increase incrementally with an increasing yearly driven distance and an increasing vehicle ownership period. Values were obtained from http://www.renault.fr/gamme-renault/vehicules-electriques/fluence-ze/fluence-ze/ze-battery/ (accessed June 2012). Not yet advertised battery hire costs for the ZOE Z.E. model are assumed to be the same as for the Fluence Z.E. model.
(8) Costs comprise service and car tyre costs. Service costs for CVs are based on a study recording the costs of over 5000 vehicles in France (Carnet d'entretien en ligne, http://www.entretien-auto.com, accessed June 2012). Service costs for EVs are assumed to be 20% less than for CVs (according to discussions with Renault). Costs for PHEV assumed to be the same as for CV sedan model. Car tyre costs for CVs are based on http://www.linternaute.com/auto/entretien-voiture/les-couts-moyens-d-entretien-automobile/changement-de-pneus.shtml (accessed June 2012). Tyre costs for EVs (PHEV) assumed to be 110% (112%) of those of the comparable CV (the sedan model), due to increased vehicle weight.
(9) Reference values for CV obtained by an online calculation template, see http://www.caradisiac.com/service/assurance-auto/ (accessed June 2012), prices simulated for an all-risk insurance.

Table A2: Vehicle-user-specific data
NB: Due to the definition of the household selection criteria, all households to which TCO calculations are applied dispose of a private parking at their home.

Vehicle User Categorization								
Residential Area	Paris		Petite Couronne		Grande Couronne		Rest of France	
Parking Availability	yes	no	yes	no	yes	no	yes	no
Parking Costs per parking policy scenario (in Euro/year) (1)								
CV	902				221			
EV								
1 - No parking policy	902	2342	902	2342	221	1001	221	1001
2 - Free public parking	0	1440	0	1440	0	780	0	780
3 - Free public parking incl. overnight infra.	0	0	0	0	0	0	0	0
Income (2) (3)								
in Euro/year	25 643				23 854			
Yearly Driven Distance (3) (4)								
in kkm	12 - 19		11.5 - 19		15 - 20		15 - 20	
Usage Purpose (all user categories) (3)					Vehicle Usage Period (3)			
0 - 100% professional usage					7 years			

(1) Based on own estimates and parking tariffs in the ÎDF region
(2) Average salaries in the ÎDF region for the year 2008, INSEE (2009)
(3) Exact values in accordance with characteristics of the household to be simulated (information retrieved from the ENTD or according to the reference scenario – see table A5)
(4) Value ranges give indications on typical yearly distances as found in the EGT (Enquête Globale de transport) 2001 for the ÎDF region

Table A3: Energy price forecasts per scenario

Energy Prices (1)								
	Fuel Price (€/l)						Electricity Price (c€/kWh)	
Scenario	Low Oil Price		Medium Oil Price		High Oil Price		Medium	High
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	*(+4%/year)*	*(+7%/year)*
2013	1,22	1,00	1,40	1,30	1,66	1,73	15,14	16,02
2014	1,22	1,01	1,42	1,35	1,71	1,81	15,83	17,24
2015	1,22	1,01	1,45	1,39	1,74	1,88	16,55	18,55
2016	1,22	1,00	1,47	1,43	1,80	1,98	17,31	19,95
2017	1,22	1,01	1,51	1,48	1,85	2,06	18,10	21,47
2018	1,23	1,02	1,54	1,53	1,90	2,14	18,92	23,09
2019	1,24	1,03	1,57	1,58	1,95	2,22	19,79	24,84
2020	1,24	1,04	1,60	1,64	2,00	2,30	20,69	26,72
2021	1,25	1,05	1,63	1,69	2,05	2,38	21,63	28,75
2022	1,25	1,07	1,66	1,73	2,09	2,46	22,62	30,92
2023	1,26	1,08	1,68	1,78	2,14	2,53	23,64	33,26

(1) All shown values comprise energy tax forecasts of the reference scenario (see table A4)

Table A4: Other assumptions necessary for TCO calculations

OTHER	
Infrastructure Usage Costs per scenario (EV)	0,26 cEuro / 0,0 (1 - No policy / 2 - Free infra. Use Scenario)
Infrastructure Installation Costs (EV)	590 Euro (for 1 wall-box at the household)
Tax Allowance	according to French barème kilométrique (DGFP, 2012)
Discount Rate	Nominal: 6,5 % Real: 4,8 % (assumed constant inflation rate: 1,7% (2))
Depriciation Costs / Residual Value	Not considered (ie the same for all vehicle models)

(1) Assumed to be constant over the vehicle ownership period
(2) Average inflation rate in France throughout the last 20 years
(3) In line with the assumption that the depreciation costs are the same for all vehicle types (assumption defended by Renault)

Table A5: Settings of the reference scenario (assumed values in case according information is not stated in the ENTD for the regarded household)

Vehicle type to compare	
Model Type	compact
Fuel Type	petrol
Vehicle User (Household) Characteristics	
Residential Zone	GC
Recharge Infra. Availability	no
Vehicle Usage Characteristics	
Yearly Driven Distance (km)	18 000
Vehicle Usage Period (years)	7
Main Usage Area	mix
Share Professional Usage (%)	30