WCTR 2013 RIO

SELECTED PROCEEDINGS

USER ACCEPTANCE OF ELECTRIC VEHICLES IN THE FRENCH-GERMAN TRANSNATIONAL CONTEXT

ENSSLEN, AXEL
JOCHEM, PATRICK
SCHÄUBLE, JOHANNES
BABROWSKI, SONJA
FICHTNER, WOLF
KARLSRUHE INSTITUTE OF TECHNOLOGY, INSTITUTE FOR INDUSTRIAL PRODUCTION, 76131 KARLSRUHE, GERMANY

This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013
Rio de Janeiro, Brazil

unicast

USER ACCEPTANCE OF ELECTRIC VEHICLES IN THE FRENCH-GERMAN TRANSNATIONAL CONTEXT

RESULTS OUT OF THE FRENCH-GERMAN FLEET TEST 'CROSS-BORDER MOBILITY FOR ELECTRIC VEHICLES' (CROME)

ENSSLEN, Axel; JOCHEM, Patrick; SCHÄUBLE, Johannes; BABROWSKI, Sonja; FICHTNER, Wolf
Karlsruhe Institute of Technology, Institute for Industrial Production, 76131 Karlsruhe, Germany

ABSTRACT
Within the framework of the project CROME (Cross-border Mobility for Electric Vehicles) there is an accompanying scientific research on a fleet test of about 100 Battery Electric Vehicles (BEV) in the French-German border region taking place. A user acceptance study is accomplished with the focus on transnational trips. The observed BEV are predominantly company fleet vehicles and are used by several persons. This increases the potential number of BEV users taking part in the accompanying research activities of the fleet test significantly. During the survey period cross-border mobility with BEV has hardly been possible due to different standards concerning hardware and software components, especially concerning components of the charging infrastructure. The idea of CROME is to demonstrate seamless cross-border mobility between France and Germany and to give recommendations to the European standardization process on infrastructure components. Key findings of the first online questionnaire filled out by BEV users and fleet managers indicate that the acceptance for BEV is highest for people that live in communities with less than 5,000 inhabitants, with two or more cars in the household, a higher annual mileage and a high commuting distance.

Keywords: electric vehicle, infrastructure, user acceptance, standardisation

INTRODUCTION
According to governments' plans in European countries like France and Germany mobility with Electric Passenger Vehicles (EV), i.e. Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV), will become more and more important. Increasing the market share of EV in passenger transport is supposed to reduce CO_2 emissions, to make individual transportation with passenger cars less dependent on fossil fuels and to better integrate fluctuating renewable energy sources (Jochem et al. 2012). Individual transportation with Internal Combustion Engine Vehicles (ICEV) has been continuously developed during the last century, whereas the development of EV has just recently been reactivated with government support and political willingness, motivated by the global challenges of decreasing availability of fossil fuels and globally rising CO_2 emissions. In general, basic

infrastructure for electric mobility is already available in most European countries. EV can be charged at domestic socket outlets or on one of the few existing public charging stations. But the challenges for the EV diffusion process are that they have to compete with the technically mature ICEV in terms of consumer habits, conveniences, attitudes and prices. Potential customers need to see an advantage in using an EV during the purchase or leasing decision making process. The lack of public charging infrastructure is one of the concerns that people mentioned when they had been asked about their purchase intention of vehicles running on Liquefied Petroleum Gas (LPG) or Compressed Natural Gas (CNG). They have some comparable characteristics with EV (Dütschke et al. 2011). Increasing diffusion of EV will consequently lead to an increasing number of public charging stations equipped with adequate sockets that fulfil customers' requirements concerning safety and reliability standards as well as standards concerning charging time.
This paper is structured as follows: The first chapter describes the current situation of EV charging infrastructure and services in Europe followed by a chapter describing the binational project CROME which has been set up in order to make cross-border mobility with EV in the French-German context possible. Afterwards a literature review on user acceptance of EV is provided and the evaluation concept for EV user acceptance in CROME is presented. Furthermore, results and key findings of the first online questionnaire within the CROME project are presented and implications and deductions for stakeholders and policy development are derived.

THE CURRENT SITUATION OF EV CHARGING INFRASTRUCTURE AND SERVICES IN EUROPE

EV are predominantly charged at the premises or at home (cf. Ensslen et al. 2012) at common domestic socket outlets. It is widely acknowledged that the charging process should provide some kind of smartness, i.e. communication between the charging infrastructure and the vehicle, in order to allow a faster charging (at higher charging rates) without jeopardizing the physical integrity of the vehicle users and to allow an intelligent integration into the electricity grid. Therefore, the domestic socket outlet (Mode 1 or 2 charging) is inappropriate and the so-called Mode 3 charging is going to be established as the standard EV charging mode (cf. Nationale Plattform Elektromobilität 2012). Mode 3 charging is characterized by additional protection measures (IEC 61851-1), i.e. a standardised communication between the charging infrastructure and the EV (ISO 15118), to ensure that power is only delivered when a vehicle is connected to the socket-outlet, the plug is correctly inserted and the earth circuit is proved to be sound (Van den Bossche et al. 2012). All modes are specified in IEC 62196. There are two different plug-and-socket systems that are used for Mode 3 charging in Europe which have been installed in different pilot projects and have been in discussion of becoming the standard for domestic and public EV charging infrastructure. The Type 2 plug-and-socket system on the one hand (cf. Figure 2) is favoured by the European Commission (European Commission 2013a and 2013b), used in most European countries and has initially been developed by the German company Mennekes (Van den Bossche et al. 2012). It has early been favoured by several institutions (e.g. ACEA 2010 and German-French Working Group "Electric Mobility" 2010). The Type 3 plug-and-socket system (cf. Figure 3) on the other hand is based on a design by the Italian company SCAME and is a further development of a plug that is widespread in Italy where it is especially used for charging light

EV such as two wheelers (Van den Bossche et al. 2012). In France Type 3 sockets are majorly used at public charging installations. The major difference between these two sockets has been the “shutter” available initially only at the Type 3 shutters fulfilling additional protection standards necessary in France and Italy (IEC 2010). Recently, Mennekes has announced that Type 2 plugs are also available with shutters (Mennekes 2012). In Figure 1 the different Mode 3 plug-and-socket systems that have been installed in different European countries are sketched (cf. LeGoy and Buckley 2012 and Theisen et al. 2012).

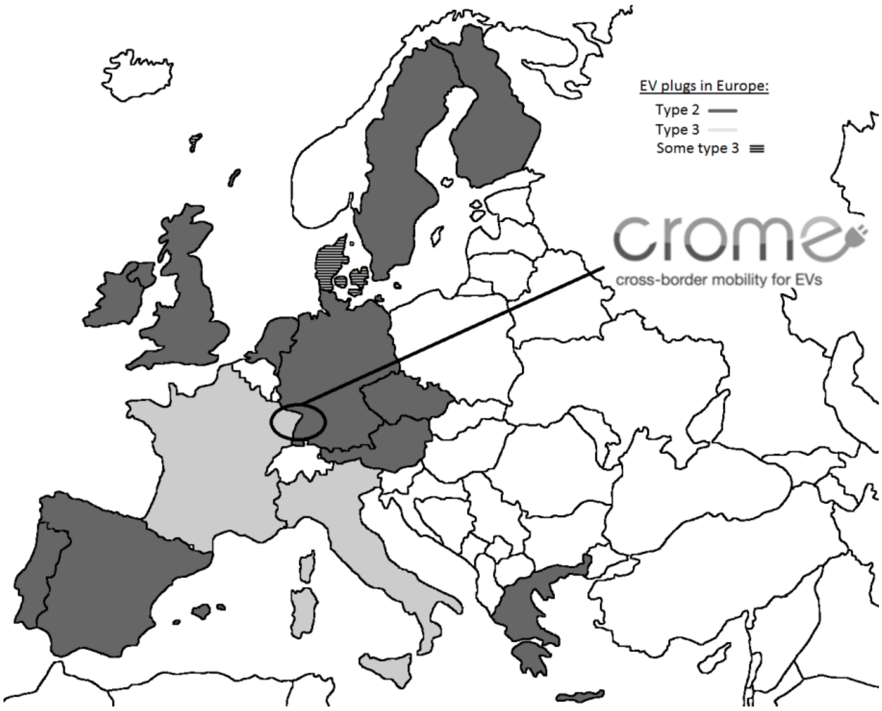

Figure 1 – EV plug types in Europe (based on sources: LeGoy, Buckley 2012, van den Bossche et al. 2012, Theisen et al. 2012)

Figure 2 – Mode 3 Type 2 plug and socket

Figure 3 – Mode 3 Type 3 plug and sockets

According to Figure 1, Type 2 plugs have been favoured in Portugal, Spain, Ireland, the United Kingdom, the Netherlands, Austria, the Czech Republic, Sweden, Finland, Greece, and Germany. Type 3 plugs have been installed majorly in France and Italy and some in Denmark. According to LeGoy and Buckley (2012) there is a trend towards Mode 3, Type 2 plugs for public charging infrastructure and home charging points in Europe.
According to Theisen et al. (2012) countries like Switzerland, Belgium and Norway are rather resistant to start the roll-out of electric mobility infrastructure as long as no agreement on connector types has been achieved. Recently similar developments can be observed

concerning the plug / socket systems for Mode 4 charging ("fast charging")[1]. The CHΛdeMO quick charging technology, having its origin in Japan competes with the combined charging system that assembles the Type 2 plug-and-socket system with two additional contacts for DC energy supply (Combo2). Combo2 has been favoured by ACEA (2011) to become the standard for Mode 4 charging in Europe. In January this year the European Commission has released a proposal for a directive defining that charging stations with alternating current should be equipped with Type 2 sockets and high performance charging stations with direct current should be equipped with Combo2 sockets (cf. European Commission 2013a).

Not only the different sockets used at public charging stations in France and Germany currently make cross-border activity with EV complicated. Additionally, software interoperability is not yet fulfilled. This means that identification, authentication and billing for the purpose of charging at public charging stations abroad are currently not possible. This is due to the fact, that most European charging stations require the ownership of a personalised club card, generally a Radio-Frequency Identification (RFID) card. Consequently it is not possible to charge, if the RFID card of the corresponding charging service provider is missing for authentication.

The obstacles for charging EV at public accessible charging infrastructure in the cross-border context are high. Services that reduce existing barriers and make convenient charging infrastructure usage in the transnational context possible (especially roaming) have not been realized yet. In order to permit cross-border charging activity at public accessible infrastructure, adequate interoperable solutions are of key interest.

THE CROME PROJECT

The situation described above implicates the necessity and delivers the motivation of a working group composed of different stakeholders from industry (original equipment manufacturers of EV, charging infrastructure component suppliers, charging infrastructure operators and research institutions) to cooperate in the project CROME[2]. Hence, the main objective of the project is to first design and then allow and analyse a safe, seamless, user-friendly and reliable use of EV between France and Germany by carrying out a fleet test in order to give recommendations for the European standardization process for EV infrastructure (plugs / sockets, cable, etc.) and services / regimentations (identification, authentication, billing, reservation, localisation of charging stations etc.).[3] The project's accompanying scientific research includes judicial, economical, informatics, as well as vehicle technical aspects concerning the EV and their impact on society.

To analyse the characteristics of cross-border mobility with EV between France and Germany a user acceptance study integrating an EV fleet consisting of more than 100 BEV is conducted. The vehicles are mostly part of commercial or public authorities' fleets and used by multiple persons. Additionally, more than 40 public charging stations have been installed.

[1] Mode 4 charging is the only DC charging mode with currents from 63 A up to 400 A.
[2] Further information available at www.crome-project.eu
[3] Besides CROME the HUBJECT platform (www.hubject.com) and the Green eMotion project (www.greenemotion-project.eu) have a similar objective. Some partners of these projects are in all three consortia.

The model region of CROME is located in the Upper Rhine region, between Karlsruhe in the north, Freiburg and Colmar in the south, Stuttgart in the east and the department Moselle in the west (cf. Figure 4).

Figure 4 – Distribution of respondents to the first online questionnaire within the CROME project

As long as no common standard for EV plugs was determined for Europe, the consequent recommendation was to equip public charging stations with the existing different socket types in order to make cross-border traffic with EV possible from the hardware perspective. Common solutions for services like identification, authentication, billing, (e)Mobility Brokering Services, the localisation or even the reservation of charging stations need to be found to facilitate cross-border traffic with EV.

In order to allow communication between information systems of different charging service providers and to organize data streams, similar to the telecommunication roaming for mobile phones – an (e)Mobility Brokering Services has been developed by Bosch Software Innovations GmbH (Bosch) and tested within the CROME project. The general idea is that EV users should be able to charge their EV at any public charging station, independent from the charging service provider operating it. Therefore, a service that makes communication between the different charging service providers' information systems possible is necessary. Bosch's (e)Mobility Brokering Services delivers the technical basis to perform the following interoperable operations:

- Asking the user's service provider for authorization to charge.
- Deliver information about the consumption during the charging process to the user's service provider.
- Deliver geographical and online status information about charging stations not belonging to the user's service provider.

- Locking and unlocking the charging spot of another service provider.
- Start and stop charging process at another service provider's charging station.

Bosch's (e)Mobility Brokering Services therefore deliver the technical basis, so the main service operations can be performed in order to make interoperable, convenient and user-friendly charging in the cross-border context possible. User acceptance of public charging infrastructure and corresponding services is further evaluated during the bilateral evaluation in the CROME fleet test.

A BRIEF LITERATURE REVIEW OF EV USER ACCEPTANCE

Götz et al. (2012) base their analyses on user acceptance of EV on focus groups as well as on standardized surveys with 1,478 persons who want to buy a new car within the next two years in order to derive market potentials of EV depending on scenarios considering the technical and economic development of EV until 2020 and 2030. Results indicate that 60% of the respondents would decide to buy an EV (Plug-in Hybrid or BEV) considering the scenario for 2020. For the scenario taking into account further technical and economic developments of EV until 2030, the number of respondents deciding to buy EV slightly further increases. Furthermore, cluster analysis is performed in order to derive segments of new car buyers. Eight clusters have been identified: EV fans, cost sensitive EV supporters, purchase price oriented persons, generally cost oriented respondents, consumption oriented persons with a high mileage, the horse power oriented respondents, EV sceptics and EV opponents. Götz et al. conclude that there is remarkable potential for acceptance of EV. Range and charging time hardly impact the overall potential of EV in general, whereas further technical and economic developments of EV improve range and charging time which results in a reduction of the share of PHEV and an increase of the BEV share. Analysing the discussion during two focus groups with potential car buyers indicate that there are substantial information gaps and uncertainties of potential car buyers when they are confronted with electric mobility issues. Götz et al. conclude that communicating important facts about electric mobility is a crucial preliminary condition so potential car buyers also consider EV during the decision making process. According to Rogers (2003) communication is crucial for diffusion of innovations and the degree to which an innovation can be experimented as well as the degree to which an innovation is visible to others impacts the adoption rates of innovations. Field tests of EV, such as the one conducted within the CROME project, can be justified by considering Rogers theory (Rogers 2003).
Dütschke et al. (2011) compare consumer acceptance of LPG and (CNG) vehicles to EV, as consumer perceptions might be similar. Interviewees during this study reported that they had concerns regarding infrastructure and the reliability of the technology before using LPG and CNG cars, but their experiences showed that infrastructure drawbacks in reality were relatively low and that interviewees reported high levels of satisfaction. Conclusions from the study aim to derive recommendations on how to support the market penetration of EV. Concerns need to be overcome by improving the perceived reliability and safety of EV and it seems to be necessary that policy makers provide further incentives to start the ball rolling (Gomez-Vilchez et al. 2013). Wietschel et al. (2012) identify early adopters of EV in Germany until 2020 on the basis of surveys and group discussions with EV users that have been conducted to broach the issues of economic, psychological and socio-demographic backgrounds of EV users. Analyses indicate that the probability of privately purchasing an

EV among current users of EV is highest for men in the beginning of their 40s, with a higher socio-economic status and most likely having a technical profession. This potential customer group is likely to live in multi person households with several vehicles, which tend to be in rural areas or in the outskirts. However, selling EV only to this group of early adopters is not going to be sufficient in order to reach the political goal of one million EV until 2020 in Germany.

Pierre et al. (2011) base their analyses on about 40 semi-open interviews carried out with EV users each lasting about two hours between 2006 and 2008 intending to determine in which ways EV are used within specific ways of life. Pierre et al. (2011) point out that all users agree on EVs' characteristics to be pleasant to drive and to be practical. Two groups of EV adopters are identified, notably innovators characterized by a pioneering-ecological spirit who want to display and defend their values and people who adopted EV due to specific advantages almost by chance. Both groups agree on the fact that EV increase their sensitiveness to transport issues, to energy savings and to environmental questions. They search to increase the security of their journeys. Interviewees criticized the lack of public accessible charging infrastructure. Pierre et al. (2011) conclude that the presence of public accessible charging infrastructure is important in order to further develop electric mobility (also cf. Achtnicht et al. 2012).

Windisch (2012) tries to analyse the potential for EV demand in the region of Paris by using disaggregate demand analysis based on socio-economic data. Different scenarios of political and economic developments until 2023 are analysed in a model that has been constructed by taking the French National Transport Survey (ENTD) as data basis. A set of criteria like the households' vehicle fleets, parking possibilities as well as vehicle usage patterns and total cost of ownership are considered. Conclusions indicate fiscal measures that already have been put in place in France, contribute to a large part to the economic advantage of an EV over an ICEV. Furthermore, providing public charging infrastructure appears to be an important lever. Scenario analyses indicate that maximal future demand for EV in the Paris region is in the range of 4-21% of households, what signifies an overall EV demand of 0.2 to 1 million vehicles until 2023.

Deffner et al. (2012) base their analysis on survey data collected from drivers of commercial fleet EV. Cluster analysis is performed in order to find out different groups' acceptance potential for EV. Three clusters have been determined: (1) Enthusiastic supporters of EV see their environmental beliefs fulfilled by the EV and who regard themselves as pioneers for a sustainable future technology. They are willing to tolerate certain limitations like having to plan trips in advance. (2) The critical sceptics rather want to watch the market development of EV. For one week they had the possibility to test an EV, but they had disproportionately high problems with it and therefore have been disappointed with its reliability. (3) Respondents who clearly deny accepting limitations in their own car usage are somewhat younger than the other two types. One person households and households without children are overrepresented in this cluster and these households can be characterized by only having one car. Limited range and associated limited independence are characteristics that make the EV unattractive to them.

EVALUATION CONCEPT FOR USER ACCEPTANCE OF BEV IN THE FRENCH-GERMAN TRANSNATIONAL CONTEXT

The accompanying scientific research of the CROME project is based on an interdisciplinary analysis[4]. Computer scientists, energy economists, automotive engineers, jurisprudents and electrical engineers are working together in order to give responses to questions arising from different disciplinary origins. The acceptance analysis as part of the evaluation concept consists of repeatedly questioning the users and fleet managers[5] of the BEV by online surveys with different focuses (expectations, first experiences and BEV adoption), as well as of face-to-face interviews[6] of some users and workshops with fleet managers. Additionally, technical data on trips such as speed and acceleration is collected by using data loggers and smartphones (cf. Figure 5). The latter additionally allows to track the GPS signal and to conduct a short survey before each trip, asking e.g. for trip purpose, number of passengers, etc.

All these data samples can be anonymously reunited by a unique user ID which allows a comprehensive impression on first user experiences with BEV and potential anxieties concerning cross-border trips. Economic issues like prices and profitability are considered as well as sociological and cultural aspects that permit to identify national particularities concerning user acceptance of BEV.

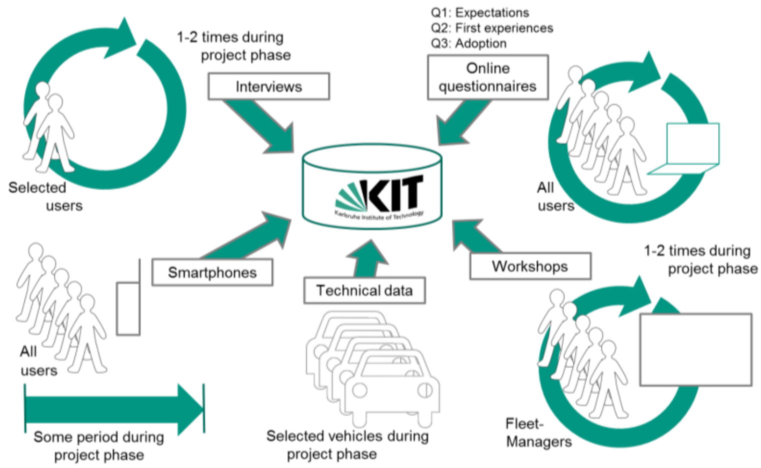

Figure 5 – Evaluation concept for BEV user acceptance in the CROME project

ANALYSIS OF THE FIRST CROME ONLINE QUESTIONNAIRE

115 valid responses to the first online questionnaires on expectations distributed to users and fleet managers in France and Germany participating in the CROME project have been collected between October 2011 and July 2012. About half of the survey participants already had experiences with BEV, about 30% experienced BEV during one or two trips and 20% of

[4] The accompanying research is undertaken by Karlsruhe Institute of Technology (KIT) with the support of Electricité de France Research and Development (EDF R&D), European Institute for Energy Research (EIFER) and Institut français des sciences et technologies des transports, de l'aménagement et des réseaux (IFSTTAR).
[5] Fleet managers are in charge of the electric vehicles in the companies and have partly been involved in the decision making process to acquire EV.
[6] The interviews have been carried out by EDF R&D and EIFER. Further support has been granted to design and elaborate the CROME online surveys.

them didn't have any experiences. Valuable information about the expectations of users and fleet managers concerning BEV, infrastructure usage and linked services has been provided. In order to put these findings in context, the background in terms of the current political, technical, economic and sociological situation in the two countries and, more specifically, in the model region needs to be explored. Since the project's model region is located partly in France and partly in Germany, the evaluation has its special focus on comparing BEV user acceptance between participants of the French and the German parts of the model region.

Potential barriers concerning transnational electric mobility, considering charging infrastructure and corresponding services as well as acceptance issues concerning the BEV themselves are to be identified. Preliminary findings of the first CROME online questionnaire show that the objective to buy a BEV is mostly based on “green reasons”. Hence, BEV have in both countries a green and environmental friendly image. The second and third questionnaire about users' and fleet managers' experiences with BEV will be analysed in 2013.

The hyperlinks to the online questionnaires have been sent out to fleet managers of 67 potential BEV. Between October 2011 and July 2012 users and fleet managers of 43 BEV have participated in the questionnaires. Overall 153 answers could have been collected. After deleting responses from survey participants that have not finished the questionnaires or responded more than one time according to the user ID mentioned, 115 valid responses remained. Of these responses 101 users could have been identified, 14 of the IDs given by the respondents are invalid. During the analysis, the sample of these n=115 responses consisting of 87 users and 28 fleet managers is used. 45 of the respondents completed the French, 70 the German questionnaire (cf. Figure 4).

Major socio-demographic characteristics of the sample are that 72% of the respondents are male (71% of the French and 73% of the Germans), only 15% of the French and 10% of the Germans live in one person households and the average net household income of people responding to the CROME questionnaires is 3,588 € for the French respondents and 3,766 € for the Germans. Compared to representative samples for France and Germany, less of the CROME respondents live in one person households, respondents that are between 40 and 60 years old are overrepresented, whereas respondents younger than 30 and older than 60 are underrepresented. In general people in France live in smaller cities than people in Germany and the population density in France is lower than in Germany[7] (Eurostat 2010) (cf. Table 1).

63.8% of the French live in towns or villages with less than 20,000 inhabitants whereas only 37.8% of the Germans do so. Respondents of the CROME sample reflect this relation. 46.7% of the French respondents live in small towns or villages whereas only 22.5% of the German participants do so. In Germany (France) 72.2% (36.2%) of the population lives in towns larger than 20,000 inhabitants. CROME participants reflect this relation again, even though German CROME respondents living in medium sized towns (between 20,000 and 100,000 inhabitants) are overrepresented. German CROME participants living in cities with more than 100,000 inhabitants are underrepresented.[8]

[7] 102 people/km² in France and 229 people/km² in Germany.
[8] This is due to the fact, that on the German side only Freiburg and Karlsruhe have more than 100,000 inhabitants.

Table 1 – Socio-demographic characteristics of people living in France and Germany out of the CROME project survey and official statistics (Data sources: First CROME online survey, INSEE, DESTATIS)

Attribute	**France**	**French CROME respondents (n_1 = 45)**	**German CROME respondents (n_2=70)**	**Germany**
Household size				
One person household	33.3%	15.2%	10%	40.4%
Multiple person household	66.6%	84.8%	90%	59.6%
Monthly average net income of the household				
Households' average net income	2409 €	**3588€**	**3766€**	2922€
Place of domicile size				
Village (less than 5,000 inhabitants)	40.5%	**35.6%**	**7%**	13.4%
Small town (between 5,000 and 20,000 inhabitants)	23.3%	**11.1%**	**15.5%**	24.4%
Medium-sized city (between 20,000 and 100,000 inhabitants)	24%	28.9%	**76.1%**	37.3%
City (over 100,000 inhabitants)	12.2%	24.4%	1.4%	34.9%
Gender				
Female	51.6%	28.9%	27.1%	51%
Male	48.4%	**71.1%**	**72.9%**	49%
Age				
20 – 29	19.8%	8.9%	12.7%	18.6%
30 – 39	21.2%	**35.6%**	11.3%	18%
40 – 49	22.3%	**37.8%**	**29.6%**	24.8%
50 – 59	21.2%	17.8%	**39.4%**	21.7%
60 – 69	15.5%	0%	7%	16.8%

Findings of the preliminary evaluations (Ensslen et al. 2012) show that availability of public charging infrastructure close to respondents' homes is more important to the German respondents than to the French. A reason for that could be the different urban frameworks since correlations between the respondents' community sizes and the way they have been answering this questions could have been worked out. In general, public charging stations are more important to people living in towns with more than 20,000 inhabitants (as private parking space decreases), thus more important to people living in Germany. However, this cannot be verified with the CROME sample, because almost all participants indicated that they have a private parking place at home where the vehicle can be charged (100% of the French survey participants said so and 93% of the Germans). In general private parking possibilities for people living in cities are less available than for people living in smaller towns or villages. Since most of the respondents stated that they have at least one car at home (104 of the 107 persons answering this question) private parking space might already be used by other cars available in the households[9]. Consequently, the BEV does not have a place to be recharged, if the parking place available is exclusively used by the other car, moving this car to the kerbside in order to charge the BEV is not an option on the long run and if there are no public charging stations available near the respondents' homes.

DEPENDENCY BETWEEN COMMUNITY SIZE AND PARKING SPACE

Dependency between community size and availability of private parking places can be assessed by analysing data from the German mobility panel from 2009. Survey participants were asked how many cars they have at home and where they park their cars, on a private

[9] Fleet test participants would be willing to move their car in order to charge the BEV at home during some period of time of BEV testing in the private context (cf. qualitative interviews that have been carried out by EDF R&D during the CROME project).

parking spot or on the kerbside. Cross tabulation and χ²-tests have been applied in order to find out about potential dependencies between the community size of the respondents' homes and the availability of a first and second car as well as parking possibilities for these cars (cf. Table 2).

Table 2 – Results of χ²-tests for independence about car availability and parking possibilities in households (Data source: German Mobility Panel 2009)

Characteristic values for community size (X)	Characteristics of the second attribute (Y)	N	χ^2 Test statistic	$\chi^2_{(1-\alpha;(m-1)(n-1))}$	Contin-gency coeffi-cient C	Rejection of independency hypothesis?
X_1 ≙ Less than 5,000 inhabitants X_2 ≙ Between 5,000 and 20000 inhabitants X_3 ≙ Between 20,000 and 50000 inhabitants X_4 ≙ Between 50,000 and 100,000 inhabitants X_5 ≙ Between 100,000 and 500,000 inhabitants X_6 ≙ Over 500,000 inhabitants	Y_1 ≙ No car available in household Y_2 ≙ First car available in household	982	84.144	$\chi^2_{(0,95;5)}$ = 11.02 $\chi^2_{(0,999;5)}$ = 20.52	0.281	Yes, highly significant rejection (α = 0.001)
	Y_1 ≙ No second car available in household Y_2 ≙ Second car available in household	982	46.087		0.212	Yes, highly significant rejection (α = 0.001)
	Y_1 ≙ First car is parked on the kerbside Y_2 ≙ First car is parked in a garage or on a private parking place	810	63.252		0.279	Yes, highly significant rejection (α = 0.001)
	Y_1 ≙ Second car is parked on the kerbside Y_2 ≙ Second car is parked in a garage or on a private parking place	258	9.319		0.187	**In this case, hypothesis of independence cannot be rejected**

χ²-tests indicate, that correlations between community size and the availability of a first and a second car as well as between community size and private parking possibilities of the first car can be observed. These results are highly significant. This implicates that the smaller the community, the more likely are people to have a first as well as a second car available in the household. The smaller the community, the more likely it is that people who have a first car also have a garage or private parking place. The bigger the community, the more likely it is that people park their first car on the kerbside. Additionally binary logistic regression analysis has been carried out in order to explain the relation between community size and availability of a first and second car as well as the availability of a parking place for the different categories of communities (cf. Table 3 and Figure 6). The following equations could have been derived:

- Probability that a first car is available in the household and parked in a garage or on a private parking place depending on community size.

$$P_1(Y=1)=\frac{\exp(3.363-0.518\cdot X)}{1+\exp(3.363-0.518\cdot X)}$$ (Equation 1, cf. Table 3 and Figure 6)

- Probability that a second car is available in the household and parked in a garage or on a private parking place depending on community size.

$$P_2(Y=1)=\frac{\exp(0.165-0.33\cdot X)}{1+\exp(0.165-0.33\cdot X)}$$ (Equation 2, cf. Table 3 and Figure 6)

Wald tests' p-values show (cf. Table 3) that community size influences availability of parking space for the first and second car to a statistically significant degree. The constant is only statistically significant in the first model. Model 1 (2) classified 73.2 % (77.6 %) of the respondents' answers about availability of private parking places for the first (second) car correctly.

Table 3 – Results from binary logistic regression analyses concerning parking possibilities for first and second cars in households (Data source: German Mobility Panel 2009)

Equa-tion	Characteristic values for community size (X)	Characteristics of the second attribute (Y)	N	Percentage of correctly classified values by model	Nagel-kerke R²	p-value of Hosmer and Lemeshow test	p-values of Wald test for predictor variables
1	X=2: Less than 5,000 inhabitants X=3: Between 5,000 and 20,000 inhabitants X=4: Between 20,000 and 50,000 inhabitants X=5: Between 50,000 and 100,000 inhabitants X=6: Between 100,000 and 500,000 inhabitants X=7: Over 500,000 inhabitants	Y=0: First car is either not available or if available, parked on the kerbside Y=1: First car is available and parked in a garage or on a private parking place	976	73.2	0.196	0.933	Constant: 0.000 Community size: 0.000
2		Y=0: Second car is either not available or if available, parked on the kerbside Y=1: Second car is available and parked in a garage or on a private parking place	976	77.6	0.077	0.143	Constant: 0.436 (not significant) Community size: 0.000

Nagelkerke R² shows that about 20 % of the first model's variance, what is acceptable (cf. Backhaus et al. 2008) and 7.7% of the second, what is not acceptable, can be explained by the respondents' community size. Hosmer and Lemeshow tests show for the first model that no difference between forecasted and observed values can be determined (p-value of 0.933 exceeding 0.7, cf. Backhaus et al. 2008) whereas this is not the case for availability of a private parking place for the second car. The two equations that could have been determined as well as corresponding empirical data are visualized in Figure 6.

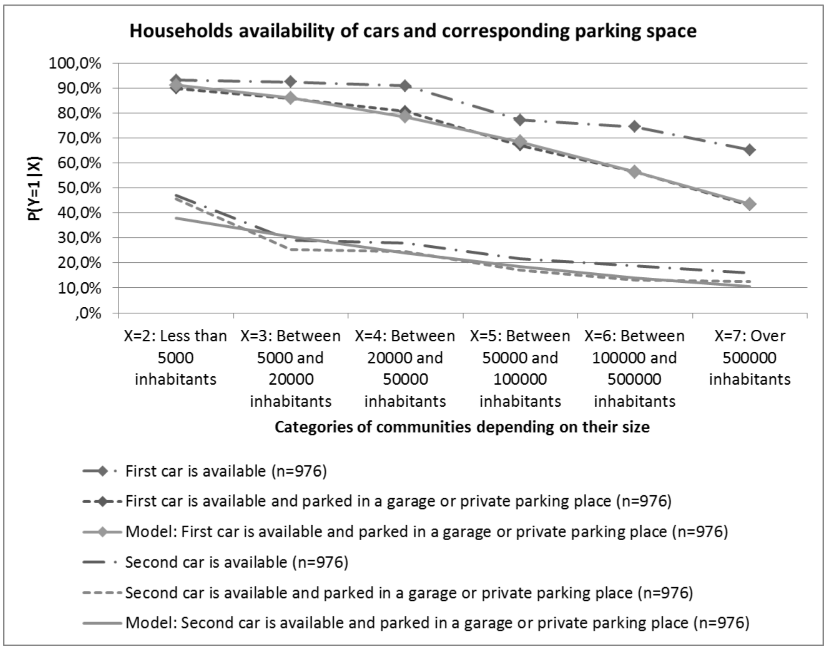

Figure 6 – Availability of first and second cars and availability of garages or private parking places depending on community size (Data source: German Mobility Panel 2009)

Over 90% of the households in communities with less than 50,000 inhabitants have at least one car. In villages with less than 5,000 inhabitants almost all of them have a private parking place for their first car. In communities with more than 50,000 inhabitants the probability of not having a garage or private parking place for the first car increases and the number of households without a car increases rapidly, too. In communities with between 50,000 and 100,000 inhabitants less than 80% of the households have a car. Availability of private parking space gets more restrictive with increasing community size. In big cities with more than 500,000 inhabitants, only about 65% of the households have a car. Only about 68% of these households have a private parking place or a garage. This situation is similar for private parking space for the second car. For third cars in the households analysis is difficult to perform, as only 3% of the households in the German Mobility Panel 2009 have a third car.

RESULTS AND KEY FINDINGS OF THE FIRST CROME ONLINE QUESTIONNAIRE

These outcomes support the derived hypothesis of the CROME project questionnaires that the bigger the community becomes, the more relevant are public charging stations for BEV users, because less private parking possibilities are available in households for the first and the second car. Lack of adequate parking possibilities to charge BEV will consequently restrain their diffusion, particularly in cities.

Furthermore, CROME survey data has been evaluated more profoundly by carrying out a cluster analysis in order to find out more about different groups of BEV users. The idea behind this cluster analysis is to pool those respondents in one cluster, whose characteristics are as similar as possible, whereas the clusters identified should be as heterogenic as possible. Since cluster analyses are explorative methods of multivariate data analyses, it is not possible to determine in advance what clusters will be identified (Backhaus et al. 2008).

In order to find out about the similarities of respondents to the online questionnaire, distances between different respondents' answers have been measured. Euclidian distance has been chosen as distance measure, since it is widely used in empirical applications (Backhaus et al. 2008). After finding out about the respondents' distances, the Ward procedure has been applied as fusion algorithm in order to group the respondents that are similar in one cluster and to identify different clusters that are as heterogenic as possible. According to Bergs (Bergs 1981) the Ward procedure determines good partitions in most cases and correctly assigns the elements to the different groups. Other studies (Deffner et al. 2012 and Götz et al. 2012) that have been analysing user acceptance of BEV by using cluster analyses also used the Ward procedure. After preparing the raw data by transforming the data that have been predominantly collected as discrete, quasi-metric values in different categories, missing value problems have been compensated by substituting the missing values with the attributes' arithmetic averages. Table 5 in the Annexure illustrates the variables that have been used during cluster analysis and illustrates the corresponding transformations that have been performed before cluster analyses have been conducted. In order to balance the different variables' impact on the outcome of the distance measure, the different variables have been z-transformed. Outliers, i.e. respondents who answered very different from other respondents, have been identified. A cluster analysis with a single linkage fusion algorithm has been carried out (cf. Götz et al. 2012). Thus 12 of the 115 responses were excluded from further analysis[10]. Even though the interpretability of the clusters is not always straightforward, it improves the comprehensibility considerably. In the CROME analysis the question about the respondents' general intention to buy a BEV within the next ten years has been central for the interpretability of the results. A four cluster solution has been chosen. The four clusters can be characterized as follows: Frequent car drivers (n_4=13) who use conventional cars on a regular basis, occasional car drivers (n_2=17) and rather undecided and young respondents (n_3=10). The fourth cluster is represented by most of the respondents (n_1=63) and does not show big differences to the whole sample's attributes averages.

These results are neither representative for Germany nor France, since over 70% of the respondents are male, average household income of French and German respondents is higher than the French and German average and more of the respondents work full-time than the average person in France and Germany. The sample size of n=115 respondents that has been further reduced to n=103 during cluster analysis as well as missing value problems additionally limit the precision of the findings.

The cluster of the **frequent car drivers** is characterized by high willingness to adopt BEV. 11 of 13 (85%) respondents answered that they can imagine buying a BEV within the next 10 years. This cluster is characterized by high monthly usage patterns of cars and by higher daily distances travelled by car. Respondents live almost twice as far away from their workplace as the sample average and they majorly have three cars at home (cf. Table 4). Nine of them stated to have a garage. None of them answered not to have a private parking place. For ten (77%) of them the distance from the parking place to the next power socket is less than 10 meters away. The average household net income in this cluster is remarkable. With 4,600 Euros it is by far higher than the whole sample's average household net income of about 3,800 Euros. Respondents of this cluster tend to live in villages or little towns (with less than 20,000 inhabitants). Seven (54%) of this cluster's respondents do so (compared to 35% of the whole sample). All the respondents in this cluster are male and they predominantly live in France (62%) which is remarkable, as in the whole sample French participants are underrepresented (39%). The higher annual car mileage and the higher commuting distances make the respondents of this cluster more sensitive towards variable costs like e.g. electricity prices compared to fuel prices of ICEV, what makes BEV favourable to them.

The cluster of **urban occasional car drivers** (n_2=17) is characterized by a lower car mileage than the average and is only represented by German respondents. Public charging stations in the scope of their homes are more important to them as to respondents of any other cluster. As shown above, this result is linked to the fact that 15 of the 17 respondents (89%) live in medium sized cities (with between 20,000 and 100,000 inhabitants). Respondents of this cluster show a higher interest in the electricity mix by which the BEV is charged than respondents in all the other clusters. They use their cars only occasionally - on average 12 days a month (average value for the whole sample is 19 days a month).

At the same time they can be characterized by higher bike and public means of transportation usage patterns than respondents in the other clusters (bike usage: 13 days a

[10] In Table 6 in the annexure you will find these 12 respondents including justifications for their exclusion.

month compared to 5 days a month in the whole sample and use of public transportation 12 days a month compared to 3 days a month in the whole sample).

Table 4 – Clusters and characteristics of BEV user groups identified by cluster analysis of respondents to the first CROME online survey.

Attributes \ Cluster	Cluster where a major part of the respon-dents has been grouped (n_1=63)	Urban occasional car drivers (n_2=17)	Rather young / undecided concerning purchase intention (n_3=10)	Positive attitude towards BEV / people who travel a lot by car (n_4=13)	Average for all respondents (n=103)
Monthly net income of household	3,700 €	3,500 €	3,900 €	**4,600 €**	3,800 €
Community size					
Village (less than 5000 inhabitants)	19%	6%	40%	**31%**	20%
Small town (between 5000 and 20000 inhabitants)	13%	6%	30%	**23%**	15%
Medium-sized city (between 20000 and 100000 inhabitants)	54%	**89%**	30%	39%	55%
City (over 100000 inhabitants)	14%	0%	0%	8%	10%
Questionnaires completed by survey language					
French	41%	0%	60%	**62%**	39%
German	59%	**100%**	40%	38%	61%
Can you imagine privately buying an EV within the next 10 years?					
Yes	25%	24%	20%	**85%**	32%
Maybe	46%	47%	80%	15%	46%
No	29%	29%	0%	0%	22%
How important to you are public charging stations within the range of your home / your workplace? (1 = not important at all, … , 5 = very important)					
Arithmetic means in cluster	3.2 / 3.7	3.5 / 3.8	**2.6** / 4.4	**2.7** / 4.1	3.2 / 3.8
Would you be willing to pay more for charging your EV with energy from renewable sources only?					
Yes	32%	**53%**	10%	39%	34%
Maybe / Don't know / No answer	49%	35%	**60%**	30%	46%
No	19%	12%	30%	31%	20%
How many days per month do you use a car as means of transport?					
Arithmetic mean in cluster	At 21 days	**At 12 days**	At 20 days	**At 22 days**	At 19 days
How many days per month do you use a bicycle as means of transport?					
Arithmetic mean in cluster	At 3 days	**At 13 days**	At 2 days	At 4 days	At 5 days
How many days per month do you use means of public transportation in the region?					
Arithmetic mean in cluster	At 1 day	**At 12 days**	At < 1 day	At < 1 day	At 3 days
How many days per month do you use car sharing offers or you do carpooling					
Arithmetic mean in cluster	At < 1 day	At 1 day	**At 11 days**	At 1 day	At 2 days
How many kilometers do you on average travel by car on workdays?					
Arithmetic mean in cluster	44 km	**10 km**	36 km	**72 km**	41 km
How many kilometers do you on average travel by car annually?					
Arithmetic mean in cluster	14,900 km	**12,500 km**	16,700 km	**17,500 km**	15,000 km
How far away is your workplace from home?					
Arithmetic mean in cluster	15 km	13 km	15 km	**31 km**	17 km
How many cars do you have in your household?					
Arithmetic mean in cluster	1.9	1.5	1.5	**2.8**	1.9
Do you have a private parking space at home? If yes, where is it located?					
Yes, in a garage	49%	53%	60%	**69%**	53%
Yes, outside but roofed	3%	12%	0%	8%	5%
Yes, outside in the open	11%	29%	30%	8%	16%
No, I do not have a private parking space	5%	6%	0%	0%	4%
No answer	32%	0%	10%	15%	22%
How far away is your parking space from the next power socket?					
<2 m	19%	35%	20%	**46%**	25%
2 – 5 m	19%	6%	30%	0%	16%
5 – 10 m	5%	6%	20%	31%	10%
>10 m	6%	12%	0%	8%	7%
Don't know / No answer	51%	41%	30%	15%	43%
Age	44.1	47.4	38.9	46.8	43.7

Respondents in this cluster have the lowest annual and daily mileage with cars and they live closest to their workplace. They have fewest cars in their household and their average net household income is with 3,500 € the lowest in the whole sample.

Respondents of the cluster with rather **young respondents** (n_3=10) who are undecided in their purchase intention of a BEV within the next 10 years are predominantly living in villages and little towns with less than 20,000 inhabitants (7 of 10). They state that public charging stations within the scope of their homes are rather not important to them. They are not willing to pay more for energy coming from renewable resources and the electricity mix is less important to them than to respondents in all other clusters what indicates that respondents in this cluster are less environmental conscious than respondents of other clusters. They frequently do car sharing or carpooling. They use cars at 20 days a month and have a high annual mileage. Respondents of this cluster have mainly participated in the French questionnaires (60%).

It should be considered that these results refer to the CROME users in the French-German border region, so they are neither representative for the German nor for the French population.

IMPLICATIONS AND DEDUCTIONS FOR STAKEHOLDERS AND POLICY DEVELOPMENT

The analyses of the German Mobility Panel (cf. Figure 6) show that people living in smaller communities tend to have better possibilities to park their cars, more cars in their households and a higher annual car mileage. This makes BEV favourable in rural areas. In cities on the other hand more alternative means of transport are available and average commuting distances are lower. Furthermore, the BEV specific findings of the first CROME survey correspond with the analyses of the German Mobility Panel. This allows deriving different recommendations in order to make BEV more attractive for many households in bigger communities:

As most of the households in bigger communities are only equipped with one car, this car is used for multiple different purposes (cf. Chlond et al. 2013) (e.g. to commute, to make long distance holiday trips, to go shopping and to take other people for a ride). Mobility guarantees could be provided to households which are only having one car, but are thinking about purchasing a BEV, like e.g. the possibility to rent an ICEV when longer distance travels are necessary. Potential BEV customers need to be certain about the fact, that the range problem of BEV does not have any bad impact on their mobility behaviour. People who have only one car at home are more likely to decide not to buy a BEV, because they might need a car for long distance travels sometimes during a year and are afraid that they cannot use their only car for these special, occasional trips. Providing mobility guarantees could be a solution to the perceived range problem (range anxiety) of BEV.

As people living in bigger communities are used to multimodal mobility a recommendation is to develop car sharing concepts with BEV and public accessible charging infrastructure accordingly. During the last decade the number of conventional car sharing users has been increasing by about 200% (Loose 2012) in Germany. New car sharing offers have been introduced in Berlin, Munich, Hamburg and Hannover in 2011 and have been tested in the years before in Ulm/Neu-Ulm (Loose 2012). The new offers are characterized by the lack of fixed parking spaces for the cars and the possibility to return the cars at different places from where the cars have been picked up. This could be further developed and adapted to the special necessities for BEV, what would be especially interesting for bigger cities, since people there are less likely to buy BEV due to the facts mentioned before: the restrictive parking situation, the availability of other means of transport, the lower number of cars available in households as well as the lower average car mileage.

The challenges for diffusion of BEV in commercial fleets differ in some points from the diffusion process of BEV in private households. This is mainly due to two advantages in the fleet: (1) The vehicle could be used more often (several times a day), which increases the annual mileage, and (2) the limited range could be compensated by other ICEV in the fleet. According to Wietschel et al. (2012) the most important part of total cost of ownership (TCO) of an ICEV running 14,000 kilometres a year is the vehicle depreciation and the fuel costs. Since purchase prices of BEV are significantly higher compared to ICEVs', TCO of BEV is higher for short observation periods and low mileages. Under good conditions (long lifetime of the battery and low battery prices), the lower operating costs of BEV can compensate for the higher investment, when the BEV has a high annual mileage.

In the CROME questionnaires respondents have been classified in users and decision makers/fleet managers. The latter group consists of 28 respondents. First results indicate that over 65% of them state, that the purchase price for BEV is too high or much too high. This is for the current prices perspicuous. Only 17% state that the price is adequate. On the other hand 66% of them state that they think operating costs for BEV are lower than for ICEV. Only 10% state that they think they would be higher – which is not perspicuous. 24% state that they do not know. 25% of CROME's fleet managers and decision makers stated that the average mileage of cars is higher than 20,000 kilometres per year. Since these fleets' car mileage is sufficiently high, BEV might already be a profitable option today. However, for businesses the TCO might not be the only influencing factor. Compared to the users of the BEV the percentage of decision makers and fleet managers indicating that prestige is one of the three major reasons for buying a BEV is significantly higher (27.5% compared to 3.4%).

Out of a pure TCO perspective it is not yet profitable to substitute ICEV with BEV in business fleets in most cases. Profitability could be achieved by increasing the annual mileage through a more intensive car use. Innovative cooperations between companies purchasing or leasing BEV together and sharing it could be established. These kinds of business models in order to increase the mileage of BEV imply new challenges concerning reservation possibilities, authentication and billing services. Integrated information systems with software solutions managing multi user and inter-company usage of BEV could be supportive in order to further establish innovative business models like car sharing with BEV in practice.

CONCLUSION

Within the framework of a fleet test including more than 100 BEV which are predominantly company fleet vehicles and used by several persons a user acceptance study is accomplished in the French-German border region. Analyses indicate that there are two major different developments that need to be considered in order to further develop user acceptance of BEV. On the one hand there are potential BEV customers who live in smaller communities. For the majority of them private parking places are sufficiently available what allows a smooth charging of BEV. Households in rural areas are more likely to have a second car and the cars located there tend to have a higher annual mileage. This is supported by findings within the CROME project, which indicate that user acceptance of BEV is higher in households with more passenger cars.

According to these preliminary results, allocating BEV in the French CROME project area could currently be more promising than allocating them in the German CROME region. TCO for BEV are lower in France due to lower operating costs (i.e. electricity price) and the 7,000 Euro bonus that is provided by the French public authorities if a BEV is purchased[11]. Additionally the population density is lower in France and a higher percentage of the population lives in communities with less than 5,000 inhabitants (40.5% of the French population compared to 13.4% of the German population).

Our cluster analysis with CROME data seems to confirm this hypothesis as it shows that acceptance for BEV is highest for the user group that predominantly lives in French communities with less than 5,000 inhabitants, with two or more cars in the household, a higher average annual mileage and a higher average commuting distance (*frequent drivers*). The range problem is negligible, as the range suffices for commuting and a second car is likely to be available in the household. Profitability aspects are less relevant compared to other user groups, since household incomes as well as annual car mileage is higher, so the BEV is more likely to get competitive to ICEV.

Furthermore, a gap between real usage of public charging stations and stated importance of public charging stations can be observed: Public charging infrastructure is desired, but is only likely to be used occasionally by some users as vehicles are predominantly charged at the premises or at home and public accessible charging infrastructure was not installed in the whole CROME project region during the time of the survey. Analyses of CROME results indicate that stated importance of public charging stations is statistically related to community size (cf. Ensslen et al. 2012) and can be explained by the existing restrictive parking situation in bigger communities.

Barriers to accept BEV are higher for other groups of BEV users according to findings of the cluster analysis. These groups of potential future BEV customers need additional services or technologies that lower individual barriers like e.g. the availability of parking places with a power socket at home or at the workplace. If BEVs' range is a problem due to occasional longer distance travels of a potential BEV customer, mobility guarantees could be provided in order to compensate for this BEV specific disadvantage.

According to the respondents to the first online questionnaire within the CROME project one of the most important barriers against purchasing a BEV is the subjective disadvantageous price-performance-ratio. Especially users in bigger communities indicate disadvantageous TCO values for the BEV due to their lower annual average car mileage *(Urban occasional car drivers)*. There, the higher barriers for BEV acceptance deliver the basis for new business models, like car sharing with BEV. In order to make car sharing with BEV possible, there is a need of a system backbone that manages communication between users and service providers. Standardized communication between different market participants should be set up in order to integrate different service providers' systems to offer interoperable solutions. Within CROME, the Bosch (e)Mobility Brokering Services have been set up and tested in order to demonstrate that interoperable solutions for BEV specific charging services are possible, even in the cross-border context.

[11] http://www.developpement-durable.gouv.fr/Bonus-Malus-2012,2041.html

OUTLOOK

Further research is necessary concerning appropriate services for individuals' different mobility needs in order to increase user acceptance of BEV (e.g. car sharing with BEV, fast charging, reservation of charging stations, mobility guarantees as well as parking and charging guarantees for people buying or leasing BEV). Questions about potential BEV users' willingness to pay for these services as well as their capacity to bridge the gap to ICEV (regarding BEVs' range, profitability and availability of parking places) need to be further analysed.

ANNEXURE

Table 5 – Attributes and their corresponding original and transformed characteristics for cluster analysis data preparation

Attributes \ Characteristics	Original values	Values after transformation
Have you already experienced BEV as driver or passenger?	Yes, during several rides	3
	Yes, during one or two rides	1.5
	No, never	0
How important are public charging points within the scope of your home to you?	Completely unimportant	1
	Unimportant	2
	Moderately important	3
	Important	4
	Very important	5
	No answer	3.2 (arithmetic mean)
How important are public charging points within the scope of your workplace to you?	Completely unimportant	1
	Unimportant	2
	Moderately important	3
	Important	4
	Very important	5
	No answer	3.8 (arithmetic mean)
How important is the current electricity mix (coal, nuclear, renewable,…) the BEV is charged with to you?	Completely unimportant	1
	Unimportant	2
	Moderately important	3
	Important	4
	Very important	5
	No answer	3.8 (arithmetic mean)
How frequently do you think the BEV will be charged at the following different places? (At home / at the premises / at public charging points in your home country and abroad)	No possibility to charge	1
	Never	2
	Sometimes	3
	Frequently	4
	Always	5
	Don't know / No answer provided	2.3 / 4.8 / 2.9 / 2.3 (arithmetic means)
Can you imagine privately purchasing an BEV within the next ten years?	Yes	3
	Maybe	2
	No	1
In which context do you personally use the BEV? (For private trips / For business trips)	Yes	2
	No	1
	No answer provided	1.1 / 2 (arithmetic means)
How much do you think is it to drive 100 km with an BEV?	< 0.30 €	0.25
	0.30 € - 0.99 €	0.6
	1.00 € - 2.99 €	2
	3.00 € - 4.99 €	4
	5.00 € - 6.99 €	6
	7.00 € - 10.00 €	8.5
	> 10.00 €	11.5
	No answer provided	2.5 (arithmetic mean)
How frequently will you presumably use the BEV?	Almost never	0.25
	Infrequently	0.75
	At 1 to 3 days per month	2
	At 1 to 3 days per week	8
	Only at workdays	21
	Every day	30
	Don't know / No answer provided	10.2
Distance between your parking place at home and the next power socket?	< 2 m	1
	2 – 5 m	3.5
	5 – 10 m	7.5
	> 10 m	12.5
	Don't know / No answer provided	4.3
How frequently do you use the following modes of transport? (Car / Bicycle / Trains for long distance travels / Regional means of public transportation / Car sharing or carpooling)	(Almost) daily	21.5
	At 1-3 days per week	8
	At 1-3 days per month	2
	Infrequently	0.75
	Never or almost never	0.25
	Don't know / No answer provided	18.9 / 5 / 1.6 / 2.9 / 1.8 (arithmetic means)
How many vehicles do you have in your household? (Cars / Scooters, mopeds or motorbikes / Bycicles)	0	0
	1	1
	2	2
	3	3
	4	4
	> 4	5
	No answer provided	1.9 / 0.5 / 2.4
How many kilometers do you on average travel by car at workdays?	< 5 km	2.5
	5-10 km	7.5
	11-25 km	18
	26-50 km	38
	51-100 km	76
	> 100 km	125
	Don't know / No answer provided	39.7
How many kilometers do you travel by car annually?	< 5,000 km	2,500
	5,001-10,000 km	7,500
	10,001-15,000 km	12,500
	15,001-20,000 km	17,500
	> 20,000 km	22,500
	Don't know / No answer provided	14,690.5 (arithmetic mean)
Where is your private parking place at home located at?	In a garage	4
	Outside and covered	2
	Outside and uncovered	1
	No private parking place available	0
	No answer provided	3 (arithmetic mean)
Respondents' age	[Age in years]	[Age in years]
	No answer provided	43.8 (arithmetic mean)
How many persons live in your household?	0	0
	1	1
	2	2
	3	3
	4	4
	> 4	5
	No answer provided	2.8 (arithmetic mean)
What is the monthly net income of your household?	1,000 – 1,999 €	1,500 €
	2,000 – 2,999 €	2,500 €
	3,000 – 3,999 €	3,500 €
	4,000 – 4,999 €	4,500 €
	5,000 – 5,999 €	5,500 €
	6,000 – 6,999 €	6,500 €
	> 7,000 €	7,500 €
	No answer provided	3,697 €
Community size	[Number of inhabitants]	[Number of inhabitants]
	No answer provided	41,865 (arithmetic mean)

Table 6 –Outliers identified with the single linkage fusion algorithm during cluster analysis

Respondent / Attributes	1[12]	2[13]	3[14]	4[15]	5[16]	6[17]	7[18]	8[19]	9[20]	10[21]	11[22]	12[23]
Monthly net income of household	n/a	4,000–4,999€	n/a	n/a	3,000–3,999€	n/a	3,000-3,999€	2,000-2,999€	2,000-2,999€	1,000-1,999€	1,000-1,999€	1,000-1,999€
Community size - Village (less than 5,000 inhabitants) - Small town (between 5,000 and 20,000 inhabitants) - Medium-sized city (between 20,000 and 100,000 inhabitants) - City (over 100,000 inhabitants)	Medium-sized city	Small town	City	Medium-sized city	Medium-sized city	Medium-sized city	Medium-sized city	Medium-sized city	Medium-sized city	Medium-sized city	City	Medium-sized city
Questionnaires completed by survey language	German	German	German	German	German	German	German	French	French	French	French	French
Can you imagine privately purchasing an BEV within the next 10 years?	No	Maybe	Yes	No	Maybe	Maybe	Maybe	Maybe	Maybe	Yes	Maybe	Yes
How important to you are public charging stations within the range of your home / your workplace? (1 = not important at all, … , 5 = very important)	n/a	4	4	1	4	1	4	3	4	1	5	4
Would you be willing to pay more for charging your BEV with energy from renewable sources only?	Don't know	No	Yes	No	Maybe	Maybe	Yes	Yes	Don't know	No	No	Yes
How many days per month do you use a car as means of transport?	Infrequently	(Almost) daily	(Almost) daily	At 1-3 days per week	At 1-3 days per week	At 1-3 days per month	(Almost) daily	(Almost) daily	(Almost) daily	(Almost) daily	At 1-3 days per week	(Almost) daily
How many days per month do you use a bicycle as means of transport?	(Almost) daily	At 1-3 days per month	At 1-3 days per month	(Almost) daily	Infrequently	(Almost) daily	At 1-3 days per week	Infrequently	Infrequently	Infrequently	Never or almost never	Infrequently
How many days per month do you use regional means of public transportation?	(Almost) daily	(Almost) daily	Infrequently	Never or almost never	Infrequently	At 1-3 days per month	Infrequently	Never or almost never	Never or almost never	Never or almost never	Infrequently	Never or almost never
How many days per month do you use car sharing offers or you do carpooling?	At 1-3 days per month	Never or almost never	Never or almost never	Never or almost never	Never or almost never	At 1-3 days per month	Never or almost never	At 1-3 days per month	Never or almost never	Never or almost never	Don't know	Never or almost never
How many kilometers do you on average travel by car on workdays?	< 5 km	5 - 10 km	11 - 25 km	11 - 25 km	< 5 km	< 5 km	11 - 25 km	> 100 km	51 - 100 km	51 - 100 km	< 5 km	< 5 km
How many kilometers do you on average travel by car annually?	< 5,000 km	5,001 - 10,000 km	> 20,000 km	10,001 - 15,000 km	10,001 - 15,000 km	< 5,000 km	5,001 - 10,000 km	> 20,000 km	15,001 - 20,000 km	15,001 - 20,000 km	15,001 - 20,000 km	10,001 - 15,000 km
How far away is your workplace from home?	10 - 20 km	10 - 20 km	5 - 10 km	10 - 20 km	1 - 5 km	20 - 40 km	5 - 10 km	> 60 km	1 - 5 km	40 - 60 km	< 1 km	1 - 5 km
How many cars do you have in your household?	0	2	2	2	2	0	2	1	1	2	1	4
Where is your private parking place at home located at?	No private parking place available	Outside and uncovered	In a garage	In a garage	In a garage	No private parking place available	Outside and covered	In a garage	In a garage	In a garage	No private parking place available	Outside and uncovered
How far away is your parking space from the next power socket?	n/a	> 10 m	5 - 10 m	< 2 m	< 2 m	n/a	< 2 m	5 - 10 m	2 - 5 m	n/a	n/a	> 10 m

[12] This person could also be considered as an *urban occasional car driver*. But as this person does not have a car, sometimes does car sharing and has a low annual mileage, she did not fit to any of the clusters.
[13] This person living in a small town and having a high household income does not fit in the group of the *frequent car drivers*, because she has a low annual mileage.
[14] This person lives in a city and states that public charging stations close to his home are important. On the other hand she has two cars and a garage as well as a high annual mileage.
[15] This person lives in a medium-sized city and has a garage with a short distance to the next power socket making him conclude that public charging infrastructure nearby his home is not important to him. Additionally he would not be willing to pay more for energy coming from renewables and consequently does not fit to the group of *urban occasional car drivers.*
[16] This person lives in a medium-sized city but has a garage for his two cars with a short distance to the next power socket and only uses the cars at 1 to 3 days per week and thus neither can be considered being a *frequent car driver* or to fit into the *cluster where a major part of the respondents has been grouped*.
[17] Cf. footnote 12.
[18] This person would perfectly fit to the *urban occasional car drivers*, but he uses his car on a daily basis with a comparably high daily distance.
[19] This person has a very high annual mileage. Additionally she has a garage and so could be considered being one of the *frequent car drivers*. But she lives in a medium-sized city, only has one car in the household and a comparably low income.
[20] Cf. footnote 19.
[21] Cf. footnote 19, but two cars in the household.
[22] This person could also be considered as an *urban occasional car driver*. But this French person almost never uses a bicycle and would not be willing to pay more for electricity with renewable origin.
[23] This person would perfectly fit to the characteristics of the *urban occasional car drivers*, but she has 4 cars in the household and uses a bike only infrequently. Furthermore, net household income is comparably low.

ACKNOWLEDGEMENTS

This research was made possible by the CROME project [ref. no. 01ME12002], funded by the Federal Ministry of Economics and Technology and the Federal Ministry of Transport, Building and Urban Affairs in Germany and the French programme "Investissements d'avenir programme véhicule de futur". Furthermore we would like to thank Magali Pierre (EDF – R&D), Anne-Sophie Fulda (EIFER) for their comprehensive help during the development phases of the online questionnaires and the helpful comments for this paper. Furthermore, we would like to thank Florian Soldner for his contribution to this publication.

REFERENCES

ACEA (European Automobile Manufacturers' Association) (2010): ACEA position and recommendations for the standardization of the charging of electrically chargeable vehicles, Brussels.

ACEA (European Automobile Manufacturers' Association) (2011): ACEA position and recommendations for the standardization of the charging of electrically chargeable vehicles, Brussels.

Achtnicht, Martin; Bühler, Georg; Hermeling, Claudia (2012): The impact of fuel availability on demand for alternative-fuel vehicles. Transportation Research Part D: Transport and Environment, Volume 17, Issue 3, 262-269.

Backhaus, Klaus; Erichson, Bernd; Plinke, Wulff; Weiber, Rolf (2008): Multivariate Analysemethoden: Eine anwendungsorientierte Einführung. 12. Auflage, Springer, Berlin.

Bergs, Sigfried (1981): Optimalität bei Cluster-Analysen, Münster.

Biere, David; Dallinger, David; Wietschel, Martin (2009): Ökonomische Analyse der Erstnutzer von Elektrofahrzeugen. In Zeitschrift für Energiewirtschaft 33 (2), pp. 173–181. Available online at http://www.springerlink.com/content/37h812k4m862181n/fulltext.pdf.

Chlond, Bastian (2013): Mobilitätsverhalten und Mobilitätsbedürfnisse versus neue Antriebskonzepte: Wie passt das zusammen?, in: Jochem, P., Poganietz, W., Grunwald, A., Fichtner, W. (Eds.), Alternative Antriebskonzepte bei sich wandelnden Mobilitätsstilen, KIT Scientific Publishing, Karlsruhe, 185–208.

Deffner, Jutta; Birzle-Harder, Barbara; Hefter, Tomas; Götz, Konrad (2012): Elektrofahrzeuge in betrieblichen Fahrzeugflotten - Akzeptanz, Attraktivität und Nutzungsverhalten. Available online at http://www.isoe.de/fileadmin/redaktion/Downloads/Mobilitaet/st-17-isoe-2012.pdf, updated on 3/02/2012, checked on 8/06/2012.

Dütschke, Elisabeth; Schneider, Uta; Peters, Anja; Paetz, Alexandra-Gwyn; Jochem, Patrick (2011): Moving towards more efficient car use - what can be learnt about consumer acceptance from analysing the cases of LPG and CNG, in: ECEEE 2011 Summer Study Proceedings, updated on 24/05/2011, checked on 21/09/2012.

Ensslen, Axel; Babrowski, Sonja; Jochem, Patrick; Fichtner, Wolf (2012): Existe-il des différences d'acceptation des véhicules électriques entre la France et l'Allemagne? - Premiers résultats de l'analyse scientifique du test de flotte Cross Border Mobility for Electric Vehicles. 11ème séminaire francophone est-ouest de socio-économie des transports. Karlsruhe.

European Commission (2013a): Proposal for a directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure. Brussels. Available online at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0018:FIN:EN:PDF, checked on 08/04/2013.

European Commission (2013b): EU launches clean fuel strategy. Brussels. Available online at http://europa.eu/rapid/press-release_IP-13-40_en.htm, checked on 10/04/2013.

Eurostat (2010): Bevölkerungsdichte nach NUTS-3-Regionen. Available online at http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_r_d3dens&lang=de, checked on 27/09/2012.

French-German Working Group (2010): Status Report: German-French Working Group "Electro Mobility", Paris/Berlin.

German Mobility Panel (2009): Primary data. Karlsruhe. Available online at http://daten.clearingstelle-verkehr.de/order-form.html.

Götz, Konrad; Sunderer, Georg; Birzle-Harder, Barbara; Deffner, Jutta (2012): Attraktivität und Akzeptanz von Elektroautos, ISOE-Studientexte 18, Frankfurt.

Gomez-Vilchez, Jonathan J.; Jochem, Patrick; Fichtner, Wolf (2013), THE IMPACT OF ELECTRIC VEHICLES ON THE GLOBAL OIL DEMAND AND CO2 EMISSIONS, submitted to WCTR 2013, Rio de Janeiro, Brazil.

IEC (International Electrotechnical Commission) (2010): Re: Low voltage plugs, socket-outlets and couplers for Electric Vehicles (EV), Plug-in Hybrid Electric Vehicle (PHEV), and National Installation Rules Result on Document for Comments 23H/233/DC, Technical Committee 23: Electrical Accessories, Subcommittee 23H: Plugs, socket-outlets and couplers for industrial purposes, Geneva.

IEC (International Electrotechnical Commission (2010): IEC 61851-1 Ed. 2.0: Electric vehicle conductive charging system – Part 1: General requirements, Belgium.

Infas (Institute for Applied Social Sciences) & DLR (German Aerospace Centre) (2008). MiD – Mobilität in Deutschland 2008. Berlin.

Jochem, Patrick; Kaschub, Thomas; Fichtner, Wolf (2012): How to Integrate Electric Vehicles in the Future Energy System?, in: Hülsmann, Michael; Fornahl, Dirk (Eds.): Evolutionary Paths Towards the Mobility Patterns of the Future, Springer, Heidelberg, Germany (forthcoming).

LeGoy, Philip R.; Buckley, Gerald J.M. (2012): Low Voltage Grid Connections for Electric Vehicle Infrastructure in Europe, IEEE Power Engineering Society General Meeting, San Diego, CA.

Loose, Willi (2012): Bundesverband CarSharing e.V. - Jahresbericht 2011. Der CarSharing-Markt in Deutschland differenziert sich weiter aus. Available online at http://www.carsharing.de/images/stories/pdf_dateien/jahresbericht_2011_2012_druckversion.pdf, updated on 30/07/2012, checked on 4/10/2012.

Mennekes (2012): www.mennekes.de/en.

Nationale Plattform Elektromobilität (2012): Die deutsche Normungs-Roadmap Elektromobilität – Version 2, Berlin.

Pierre, Magali; Jemelin, Christophe; Louvet, Nicolas (2011): Driving an electric vehicle. A sociological analysis on pioneer users. Energy Efficiency, Volume 4, Issue 4, 511-522.

Rogers, Everett M. (2003): Diffusion of Innovations. 5th edition, New York.

Theisen, Thomas; Marques, Rui Filipe (2012): Facilitating e-mobility: EURELECTRIC views on charging infrastructure. Brussels.

Van den Bossche, Peter; Noshin, Omar; van Mierlo, Joeri (Eds.) (2012): A tale of three plugs: Infrastructure Standardization in Europe. EVS26, 06.05.2012 - 09.05.2012. Los Angeles.

Wietschel, Martin; Dütschke, Elisabeth; Funke, Simon; Peters, Anja; Plötz, Patrick; Schneider, Uta et al. (2012): Kaufpotenzial für Elektrofahrzeuge bei sogenannten "Early Adoptern". Available online at http://isi.fraunhofer.de/isi-media/docs/e/de/publikationen/Schlussbericht_Early_Adopter.pdf, updated on 16/05/2012, checked on 29/05/2012.

Windisch, Elisabeth (2012): The impact of public policies on the adoption of privately owned electric vehicles - A socio-economic analysis. 11ème séminaire francophone est-ouest de socio-économie des transports. Karlsruhe.