CONSUMER AND USER PREFERENCES TOWARDS ELECTRIC MOBILITY

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ABSTRACT

Electric vehicles offer advantages compared to traditional vehicles with regard to environmental impact and noise. Aspects which are still critical for a successful diffusion include the maximum range, purchase price and charging duration of electrical vehicles as well as feasible concepts of providing the necessary infrastructure. On the one hand, technological breakthroughs are necessary; on the other hand, knowledge about consumer and user behaviour is crucial to direct development of technology and of general requirements and to enable effective promotion of electric vehicles. Due to the low commercial availability of electric vehicles so far, scientific findings and practical experience on consumer behaviour and needs are rare. In order to explore factors promoting and inhibiting diffusion of electric vehicles as well as feasible and attractive vehicle and mobility concepts, interviews with experts were conducted. Together with conclusions from research on acceptance of technological innovation and from findings on characteristics and behaviour of electric vehicle users from the 1990s, the interview results suggest first answers on questions about user preferences towards electric mobility and provide implications for further research and development.

Keywords: transport, electric vehicles, consumer behaviour, user behaviour

INTRODUCTION

Electric vehicles, their future development and integration into the transport sector are currently intensively discussed. Electric mobility offers significant environmental potentials: reduction of CO_2 emissions and of local emissions such as particulate matter or noise, increase of energy efficiency, and the possibility to better integrate fluctuating renewable energy sources. However, the success of electric vehicles depends on several critical aspects, including their maximum range, purchase price and charging duration as well as feasible concepts of providing the necessary infrastructure. On the one hand, technological breakthroughs are necessary; on the other hand, consumer acceptance will decide about actual diffusion and about specific patterns of electric vehicle use and thus, about the actual advantages that can be realized. Knowledge about consumer and user preferences is therefore crucial to direct technical development and to enable effective promotion of electric vehicles.

Most industrialised countries and automobile manufacturers have launched huge research programs for battery and vehicle development and are starting field trials to test technology and to explore consumer acceptance as well as successful mobility solutions and business models. In 2009, the German government, amongst others, launched a large research project running until July 2011 which is conducted by a network of Fraunhofer Institutes to promote the marketability of electric mobility. The research reported here is part of this project and aims at exploring promoting and inhibiting factors to consumer acceptance of electric vehicles as well as promising target groups together with feasible and attractive vehicle and mobility concepts.

Consumer acceptance of electric vehicles and critical aspects for their diffusion can be studied using various methods. Surveys with potential consumers, if and when they would purchase or use an electric vehicle, face the problem that for consumers it is difficult to express valid attitudes, preferences and intentions regarding new, rather unfamiliar vehicle types. Usually, such statements are based on comparisons with conventional vehicles and on corresponding use patterns. Surveys of actual consumers or users allow statements based on real experience. However, the current trend towards electric vehicles is only recent, and only a low number of electric vehicles is available on the market. Thus, user experience with electric vehicles of the current generation is rare. Previous surveys of users were conducted with users of the first generation of electric vehicles in the 1990s. However, these experiences refer to vehicles and charging infrastructures which were less developed than those currently or soon available on the market. Thus, the results can be transferred to the current situation to some extent, but need to be considered with care.

In order to consider the current state of technology, current societal conditions and new experience, a first step of our research was to explore relevant aspects of consumer acceptance of electric vehicles by means of interviews with experts on individual transport behaviour, car use and purchase behaviour, and acceptance of new technology. Based on the results from the interviews, in summer 2010, extensive workshops will be carried out with potential private consumers. The aim of this step is to recheck on factors of consumer

acceptance and feasibility and attractiveness of the concepts identified in the interviews and to promote their further development.
This paper presents methodology and results of the expert interviews and is structured as follows. First, as a starting point for the design of the interviews the various aspects of electric mobility are presented with regard to their prospects for development. Next, a short overview on literature on acceptance and diffusion of innovation is given and the state of research with specific regard to consumer acceptance of electric vehicles is presented. Subsequently, the methodology of the interviews is described, before their results are reported. The last section discusses first implications with regard to future development and policy recommendations and questions to be studied in more detail.

ELECTRIC MOBILITY: CHALLENGES AND REQUIREMENTS

From the current point of view, various paths of development and integration of electric mobility into our transport system are conceivable. In the following a brief overview of the current state of technology and concepts for the use of electric vehicles is given. Technical aspects of vehicle configuration are described, but also aspects of infrastructure, mobility concepts and business models.
The term electric mobility usually relates to individual motorized passenger transport and includes vehicles which use one or more electric motors or batteries with electric energy for propulsion (cf. Wietschel & Dallinger, 2008). Current concepts are (i) hybrid electric vehicles (HEV) which combine a conventional (internal combustion) engine with some form of electric propulsion; (ii) plug-in hybrid electric vehicles (PHEV), i.e. hybrid electric vehicles whose batteries can be recharged by connecting to an external electric power source; (iii) all-electric or battery electric vehicles (BEV) which use energy stored in rechargeable batteries; and (iv) hydrogen vehicles with fuel cells (FCV), which create electricity to power an electric motor using hydrogen. In this study, we focus the term electric vehicles on PHEV and BEV, i.e. on vehicles which can or must be recharged regularly by connecting to the grid for vehicle operation.
Battery powered vehicles are by far no phenomenon of the recent decades. Even before Carl Benz and Gottlieb Daimler presented their prototypes of petrol powered coaches in 1884 and 1885, electric vehicles had been on the roads in Paris for five years. Around 1900 gasoline cars had been the exception in the USA with a market share of 22%, while 38% of road vehicles were electricity powered. Because of the high weight of batteries related to their energy content and the appearance of cheap oil on the markets gasoline and diesel engines crowded out electric power trains in cars. In the 1990s, electric cars experienced a first revival with several commercially available models and field trials. But again, very cheap oil which was around 20 US$ per barrel and little progress in battery technology cooled down the interest in electric cars worldwide. The last companies to quit their production programs of battery powered cars were the French auto manufacturers in 2005. Since then, mainly manual conversions of standard gasoline cars are available on the market.

Battery technology

A major advantage compared to the first generation of electric vehicles in the 1990s might pertain the management of the batteries which increases their life time (de Haan, 2009). Even though a technological breakthrough has yet to come, current batteries have higher energy densities, shorter charging times and lower costs (de Haan, 2009).

Energy content and driving range: According to Hacker et al. (2009) the energy demand of solely battery powered cars is between 40 and 48 kWh with power requirements between 80 and 100 kW, allowing driving ranges between 150 and 200 km. Lithium-ion batteries are among the candidates meeting these demands best with projected energy densities of up to 200 Wh/kg.

However, problems with temperature control and safety still make the use of high energy variants in automobiles difficult. Alternative concepts currently explored include air as cathode material (lithium-air, lithium manganese or nickel, manganese titanium) (Batteries International, 2010). Together with improvements in the battery pack control system, an overall increase of energy density, and thus of the driving range of electric cars, of up to 100% in the coming decade may be assumed. Even in case these expectations are not met, ranges of 200 to 300 km for medium sized EVs can be expected.

Regarding the driving range which is currently possible with electric batteries (150 and 200 km), an evaluation of mobility panel data for Germany (KIT, 2010) shows that with this range and only charging over night roughly 60% of weekly travel profiles could be covered.

Charging duration and charging cycles: Current battery electric vehicles require a charging period of eight to ten hours in the standard or slow charging mode. This battery preserving charging time will not significantly change with new technologies. However, new battery concepts will allow for rapid loading within one hour or less. But this fast loading is expected to decrease the battery life expectancy considerably, also with new materials or control technologies. Thus, fast loading is an option, but will most likely remain an exception also with future battery concepts. According to de Haan (2009) the number of possible charging cycles will not only be increased by battery cell materials and control systems, but also by using sufficiently big batteries allowing their operation in an optimal charging range. Experience with the first generation Toyota Prius, which is successfully operated in taxi fleets since more than 10 years, supports this hypothesis.

Costs: High investments are necessary for the batteries. Biere et al. (2009) assume 600$/kWh in 2010 and expect a decline to $ 350 to 300 within the next ten years. This means that today a battery of 40kW costs $ 24,000 and that this sum may be reduced to $ 12,000 – which still implies a substantial investment. In general, estimates on the future costs of battery power are diffuse. Optimistic prognoses arrive at a reduction factor around three to four between 2010 and 2015. But still, the costs of an electric car would be above the costs of a conventional car. Only in the long term, when cost reductions per energy unit are down by a factor 10, electric cars could compete in price.

Vehicle concepts

Nearly all big car manufacturers have announced the mass production of battery powered vehicles in the coming years. Ranges vary around 160 km with charging times between 7

and 8 hours. In most cases rapid charging is offered. Up to now, most manufacturers only run prototypes of their vehicles and the production has already been delayed in several cases. The vehicles promised by the manufacturers are not available in many cases, and models for final customers will not be available before 2011. Smaller manufacturers like the Norwegian company Think! or other SMEs are offering small series of electric vehicles which may enter the market on a broader scale.

These delays are inevitable as being mobile with battery powered vehicles does not just mean to exchange the internal combustion engine (ICE) by an electric motor, the tank by a battery and the drive train by cables and electronics. Additionally, the possible range, the necessary charging time and the battery costs are interdependent and cannot be optimized in isolation. Thus, it seems promising to adapt electric vehicles to different specific purposes and not to provide vehicles which fulfil as many mobility requirements as possible. Basically, various combinations of speed, range and vehicle size are conceivable including options from small vehicles, larger passenger cars, sports vehicles to local delivery vehicles. For longer ranges or bigger vehicles sole electric propulsion is difficult with contemporary batter technology. Hybrid concepts either in the form of conventional hybrids (HEV) or plug-in hybrid vehicles (PHEV) are an option to extend the shortcomings of purely battery powered vehicles (BEV) and to prevent problems of range and charging infrastructure. However, hybrid concepts come at the cost of implying two power trains and thereby including the disadvantages of both systems, at least to some degree. Finally, the current trend towards e-bikes, e-scooters and the development of three-wheelers illustrate the possible variety of electric mobility.

Infrastructure

It was mentioned above that private loading stations at the drivers' homes would theoretically enable 60% of respondents in the German mobility panel to fulfil their daily mobility requirements. For these stations, intelligent electricity grids will be needed allowing to postpone the loading to a certain degree to prevent from overloads of the electricity grids and to make best use of fluctuating renewable energy sources. In the most advanced case these intelligent facilities would allow for unloading the battery to a certain degree if required by the electricity provider. But since this "vehicle-to-grid" (V2G) concept has implication on the life expectancy of the battery, the question of suitable incentives and business models arises. Although V2G appears being a very interesting market for the power supply industry, it can be considered as a topic dealt with in a more advanced state of the market, when the number of electric vehicles on the road will be sufficiently high.

Up to now, no intelligent and detailed concepts have been developed how to realize load management. Challenges include incentives for owners' of vehicles, the design and development of the necessary information and communication technology as well as legislative issues.

Charging infrastructures in public locations which is safe against vandalism and accidents may be rather expensive. Moreover, they need to be equipped with intelligent software for recognizing the customer and managing a payment system. The revenues for funding their installation, however, are limited as the monetary value of a full loading, which blocks the station for several hours, is in the range of several Euros, not to mention the question if users

really charge at such public stations. The operator's profit margin is thus very limited, if existing at all. Economically more viable are charging stations in protected semi-public spaces, such as car parks, at shopping centres or at working places (Wietschel & Kley, 2009).

Mobility concepts and business models

Since electric vehicles will hardly be able to compete with conventional cars in terms of range, price, capacity and flexibility, integrating electric vehicles into more general mobility concepts or new business models are widely discussed issues. Driven by the concern of high costs and limited life times of car batteries, also new business models for car batteries are discussed. Possible models include the leasing on the basis of charging cycles or battery swap systems, such as the concept proposed and tested by the Better Place initiative in Israel and Denmark.

Because of range and capacity limits, electric vehicles could perhaps replace a conventional vehicle in a household which owns more than one car; thus, for long distances, the conventional vehicle could be used. The same idea lies behind concepts that discuss the integration of electric vehicles into company fleets.

The core idea of mobility concepts, however, goes beyond the simple mix of propulsion technologies. For example, electric vehicles could serve as commonly accessible city vehicles extending service supplied by public transport (cf. Canzler & Knie, 2009). In principal, various providers of such mobility services are possible such as public transport companies, car sharing or energy providers. On the one hand, investigations on the technical and economical feasibility of such mobility concepts as well as suitable corresponding business models are necessary. On the other hand, pro-activism and acceptance of such concepts by the various stakeholders will also determine which concepts will be developed by whom.

Electric vehicles and sustainability

Another important issue beyond technical, infrastructural and conceptual challenges relates to the more broader impact of electric vehicles. Battery powered cars reduce local air pollution and noise drastically, and thus, are a perfect means of improving quality of urban life. Across their entire life cycle, including vehicle and battery production as well as disposal, the environmental sustainability of electric cars, however, depends on a number of factors. In first instance, the primary energy mix of the electricity for charging the batteries plays a decisive role. Only if this energy is generated to a large extent by renewable sources, life cycle emissions of greenhouse gases get below those achievable with modern small-sized gasoline or diesel cars. Another relevant factor is the life expectancy of the battery. Due to the energy needed for its production life spans of 7 to 10 years are required to compete with the CO_2 balance of traditional cars. Recent investigations of life cycle emissions with other air pollutants even indicate that for specific pollutants, such as SO2, battery powered vehicles perform far worse than traditional cars.

Another issue is the effect of electrified transport on peoples' health. The increasing number of e-bikes and e-scooters include the risk of replacing CO_2-free muscle-powered transportation. The same holds for the impacts of silent electric cars which reduce noise but might also imply the risk of accidents.
Finally, rebound effects which can be induced by any increase in energy efficiency of technologies and related behaviour could occur also when promoting electric mobility.

USER ACCEPTANCE OF ELECTRIC VEHICLES

This section gives a short overview on general theories to explain acceptance of technological innovations by individual consumers. These theories will be used in the discussion section in order to structure the findings from the interviews. Next, research findings on consumer acceptance of electric vehicles of the 90ies are shortly presented which will also be used to provide a framework for the interpretation of results.

Acceptance of new technologies

Theories of acceptance of new technology and diffusion of innovation aim to explain how and when individuals adopt innovations (i.e. ideas, applications or objects that are perceived as new), and thus, why some innovations successfully enter the market, while others do not.
The model which is most applied to diffusion of innovation and empirically well proven is the Diffusion of Innovation-model (DoI) by Rogers (2003). According to Rogers (2003), besides socio-economic characteristics, the general or specific innovativeness and communication behaviour of an individual, the decision process to adopt or reject an innovation is influenced by the individually perceived attributes of the innovation: (i) relative advantage, (ii) compatibility with the adopter's values, experiences and needs, (iii) complexity, i.e. difficulty to understand and use the innovation, (iv) trialability and (v) observability. According to the innovativeness of a consumer, i.e. the degree to which a person is relatively earlier in adopting an innovation compared to other consumers, Rogers (2003) divides the (potential) consumers of an innovation into (i) innovators (typical 2,5% of the market), (ii) early adopters (13,5%), (iii) early majority (34%), (iv) late majority (34%), (v) laggards (16%).
Based on Rogers` DoI (2003), Gärling and Thøgersen (2001) conclude that marketing of electric vehicles should target potential adopters who already perceive advantages and disadvantages, compatibility with values and needs, and complexity of use and understanding of electric vehicles in a favourable way, and further promote favourable perceptions of these and other potential adopters. Promising target segments for the first phase of marketing might be (i) the public sector, (ii) 'green' companies and (iii) multi-car households whose values, lifestyle and transportation need regarding the second car is compatible with electric vehicles of the current state of technology. In a second phase, the single-car-household market can be targeted again based on identification of the most likely first adopters.
Other theories that have been applied to exlain user acceptance of new technologies include the theory of reasoned action by Fishbein and Aijzen (1975). This theory describes the intention to use or apply a technology as predicted (i) by the attitude towards the relevant

behaviour, i.e. the expectation and evaluation of consequences of this behaviour, as well as (ii) by the perceived social norm, i.e. an individual's expectation that this kind of behaviour is expected by others. Applied to the context of electric mobility, this implies that the probability to use an electric vehicle would be influenced by the personal attitude, e.g. personal feelings about electric vehicles as complex technological systems, as well as the more general societal perception of electric mobility, e.g. electric vehicles as 'green' vehicles that should be used in order to contribute to prevent climate change.
The Technology Acceptance Model (TAM) by Davies (1989) explains technology acceptance as influenced by two variables, the perceived ease of use and the perceived usefulness of a technology. The TAM-model has been extended to include social norm, thereby adding as well an interindividual factor.
Comparing the three approaches to technology acceptance, it turns out, that they include similar variables that are supposed to explain acceptance on an individual level: The usefulness of the product and its relative advantage compared to alternatives, the compatibility to personal as well as social norms, values and attitudes, the complexity or ease of use. Exclusive to Rogers` (2003) model are the variables trialability and observability. These two, however, refer to a more basic level and refer to characteristics of a technology which can be used actively in the marketing process.

Consumer acceptance of electric vehicles in the 1990s

In the 1990s, when electric vehicles had their first boom, pilot studies were conducted in various countries. The most comprehensive analysis of consumer data with regard to their characteristics, use patterns and experience was undertaken by Knie et al. (1997, 1999) who conducted a secondary analysis of pilot studies from Austria, France, Germany, Norway and Switzerland.
According to their findings, the users of electric vehicles of the 1990s were homogenous with regard to their socio-demographic characteristics and were typically male, middle-aged, well educated, had a family and an income above average.
With regard to psychological variables, based on Swiss data, Knie et al. (1999) could identify four types of users which differed significantly in their attitudes and their mobility behaviour: (i) users who are characterised by their concern for ecological issues and who consider the electric vehicle as an ecological alternative to conventional vehicles, (ii) users who regard the electric vehicle as technological challenging product which plays an important part of their lifestyle, (iii) users who are often travelling in the city and who regard the electric vehicle as a good mean to be mobile either in combination with public transport or as a substitute, and (iv) affluent users who are curious and have enough money to afford an additional, somewhat exclusive and latest car model.
With regard to vehicle use, the data suggests that electric vehicles are likely to be bought by households which are motorized above average. Often, the electric vehicles substituted a second car which had to be replaced or they were bought due to increased mobility needs. In all countries which were included in the study, Knie et al. (1999) could find a high satisfaction with electric mobility, despite of partly still significant flaws of the vehicles. Generally, driving behaviour, handling, transport capacity, energy consumption and operation costs were positively evaluated. Satisfaction with security and driving range, however, depended very

much on the vehicle type. Criticism related to capacity, life time and management of the batteries, the high purchase price and insufficient service.
Experience with electric vehicles in the 1990s, which were used both in urban and rural areas, indicate that use patterns of electric vehicles often change with actual use: Even if the vehicle was not bought as first or main vehicle, for many users it becomes the vehicle for everyday use and for short distances, while the conventional vehicle is only used if range or transport capacity of the electric vehicle are not sufficient. Modal split hardly changed with the purchase of an electric vehicle. In general, the use of such a vehicle often led to learning effects, which again affected user behaviour and attitudes. Technical constraints were not necessarily perceived as disadvantage if other advantages existed, e.g. environmental advantages combined with fun of driving. Type and amount of daily travel were consciously considered again and behaviour was adapted to the technical capacities. Based on their research, Knie et al. (1999) regard electric vehicles as supporting a flexible and pragmatic choice of transport mode and thus as possible contribution to a feasible multimodal mobility without conveying the experience of being constrained.

Research Questions

The presented outline on the current state of development of electric mobility identified five major challenges: high purchase costs, limited range, unclear state of reliability, a little developed public infrastructure and the steady improvement of conventional vehicles (cf. also de Haan, 2009). Research from the field of technology acceptance point out that on an individual level, the usefulness of the product and its relative advantage matter as well as its compatibility to personal as well as social norms, values and attitudes; furthermore the complexity or ease of use, the trialability and observability of the technology are important. Research analyzing data on characteristics, use patterns and experience of electric vehicle users of the 1990s indicate target groups, use patterns and needs regarding electric vehicles. These results provide hints and first hypotheses on target groups and attractive vehicle and mobility concepts for the new generation of electric vehicles which have to be studied in more detail.
However, prior or current research has just begun to analyze which of the more technological advantages need to be solved first and in what direction technological concepts as well as infrastructural and conceptual solutions should be further developed in order to enable a significant market diffusion of electric vehicles. It is the aim of our study to contribute to filling this gap in the literature. We therefore focus on the following three questions and analyze possible answers in the light of the theories outlined as well as the findings from the 1990ies.

1. Which factors will significantly influence user acceptance of electric vehicles?

2. Which concepts and requirements regarding vehicle concepts, infrastructure, and business models are necessary and attractive for consumers?

3. What are likely consumer groups which will adopt electric vehicles in a first market phase?

In order to develop valid answers to the outlined questions our research project includes a two-step methodology for gathering empirical data. As a first step, expert interviews were conducted covering the full range of critical topics and open questions outlined above. These expert interviews were then used as a basis to develop a research design for conducting focus groups with potential consumers. These focus-groups will be carried out in summer 2010.

This two-step approach was used for the following reason: As electric vehicles are still rare on the streets, it is difficult for potential consumers to form and express valid attitudes, preferences and intentions regarding this new and therefore rather unfamiliar product. Thus, spontaneous statements by potential consumers are usually biased by comparing electric vehicles to conventional vehicles and corresponding use patterns. To overcome this problem we used the expert interviews to identify relevant aspects for consumer acceptance as well as promising concepts for electric vehicles. This material is then used to develop focus groups which allow discussing these aspects and concepts in detail with potential consumers and thus, to overcome the tendency to take – due to lack of experience - the conventional vehicle as benchmark.

METHODOLOGY FOR EXPERT INTERVIEWS

In this section the methodology for the expert interviews is now described in more detail.

Interview-partners: The main focus of this study lies on promoting and inhibiting factors as well as feasible and attractive vehicle and mobility concepts for electric mobility. To be able to identify experts that have relevant knowledge on this topic we concentrated on individuals that either have been working or researching in the area of individual mobility for several years and that have gathered experience with new concepts for individual mobility in this time, preferably with electric mobility. Based on these requirements we compiled a list of experts that were then contacted and asked to take part in this study. Interviews were conducted with the eight experts presented in Table I who jointly cover a broad range of expertise on the topics of interest.

Table I – List of experts on individual transport behaviour which were interviewed.

Interview partner	Affiliation
Till Ackermann	Association of German Transport Companies (VDV) in Cologne, Germany
Weert Canzler	Social Science Center Berlin (WZB), project group on mobility / Innovation Centre for Mobility and Societal Change (InnoZ) in Berlin, Germany
Peter de Haan	Ernst Basler & Partner (EBP) in Zollikon, Switzerland
Sylvia Harms	Helmholtz Centre for Environmental Research (UFZ) in Leipzig, Germany
Doris Kortus-Schultes	Niederrhein University of Applied Sciences, Competence Centre “Frau und Auto” (Women and Cars) in Mönchengladbach, Germany
Markus Mehlin	German Aerospace Center (DLR), Institute of Transport Research, in Berlin, Germany

Marco Piffaretti	Protoscar SA in Rovio, Switzerland
Jens Schade	Dresden University of Technology, Traffic and Transportation Psychology in Dresden, Germany

Procedure: During the interviews a structured interview-guideline developed in advance was used in order to ensure that all topics of interest were covered during the interview itself. This guideline was developed based on a literature review aiming at identifying topics that might be of relevance to user acceptance, i.e. it aimed at covering all aspects of electric mobility that might be of relevance to the user.
The interviews were conducted by one or two individuals from the authors of this paper. In the first interviews two of the authors took part in order to be able to jointly review the interview guideline if necessary and to enhance standardization. The guideline was used in a flexible way and mainly served as a check list; thus, the order of topics varied between the interviews.
The scope of the interviews included hybrid vehicles as well as full electric vehicles, cars as well as bikes and scooters. However, it turned out, that the interviewees were mainly referring to BEVs; thus, if not noted otherwise, the results presented below are valid for full electric cars. Generally, the interviews focused on the situation on the German market.
The guideline started using a scenario approach: Interview partners were asked to imagine individual mobility in Germany in ten years from now. If the interviewees did not include or refer to electric mobility in their scenario, we explicitly asked which role they assume for electric mobility. Then a list of topics that are possibly relevant for consumer acceptance was discussed with the interview-partners. This list included factors promoting and inhibiting electric mobility, infrastructural aspects, target groups for electric mobility, business models, energy demand management (both load levelling and vehicles re-delivering energy into the grid) as well as recommendations and possible measures to promote electric mobility.
The interviews were recorded and transcribed afterwards. In a next step, they were coded using Atlas.ti. A list of codes was produced based on the topics from the interview guideline. These topics were supplemented with additional codes if this turned out to be necessary during coding. Additional topics that were repeatedly mentioned during the interviews and therefore warranted coding were decision making processes, general aspects of individual mobility as well as possible rebound effects. The coding process itself followed a two-step procedure: First, quotations were identified within the interview-transcripts that referred to one of the codes. In a next step, all referenced quotations for one code were summarized identifying arguments and details provided on this topic. In this paper we will concentrate on presenting the results on promoting and inhibiting factors, infrastructure, target groups and business models.

RESULTS FROM THE INTERVIEWS

Promoting and inhibiting factors

The experts interviewed for this study identified a range of factors that might contribute to a market diffusion of electric vehicles. To structure these factors, we grouped along the

following four dimensions: (i) technological development and vehicle attributes, (ii) market situation, (iii) user-related factors, (iv) macro factors and (v) market development.
The first dimension summarizes statements on rapid technological development regarding battery technology in connection with decreasing prices for the battery and the vehicle as a whole. Moreover, possible triggers from a technological point of view were seen in technological innovations like machine-to-machine interfaces that enable multifunctional usages, e.g. connecting to smart-home devices as well as the easy way of driving.
The second dimension includes the idea that attractive business models will be available on the market, e.g. combining mobility services which offer electric vehicles as public means of transport as well as attractive vehicle concepts, e.g. small vehicles for transport that are financially attractive for some companies due to the need of driving a lot on short distances.
From a potential user's point of view (third dimension) the experts identified the ease and comfort of driving as well as the fun conveyed by quiet, however quickly accelerating electric cars that also easily and powerfully drive backwards and break efficiently due to recuperation. Parking is also supposed to be relatively easy as electric cars will probably be relatively small. Thus, the driving experience is seen as a major driver towards electric mobility. The mentioned promoting factors from a user perspective also include the possibility for congruence of environmental-friendly attitudes and car-usage as well as – at least during the early years of market diffusion – of expressing these views openly and explicitly through using such a vehicle.
On a macro level (fourth dimension), experts identified a long list of possible or actual trends and conditions that might contribute to promote electric vehicles. Reaching peak oil or at least increasing prices for oil is one of these factors as well as increasing awareness of climate change and political action on mitigation. Related to this, renewable energy is expected to be extended in the years to come and electric vehicles might offer the possibility of including fluctuating renewables more effectively. Additionally, Asia is seen as promising market for electric vehicles which will feed back into the European / German market. Regarding trends in the area of transport and mobility, experts expected an increasing trend to combine various means of transport, e.g. public transport with bike or car, to be advantageous for electric vehicles which could easily be integrated into such 'transport chains'. Especially organisations who have already gathered experience in public transport or car-sharing could forward this trend towards more electric mobility. This option to use electric vehicles to extend public transport also fits with a trend towards smaller (still attractive) cars. On top of this, electric mobility is in congruence with the desire for a reduction of noise from traffic and it has a very positive image as being innovative and ecological.
On a more concrete level, experts expected that the trend towards electric mobility might profit from the expectations raised through a broad discussion in the media as well by the steps already taken by the government and the relevant companies.
Experts also reflected on possible lines of development (fifth dimension). Electric vehicles might first become attractive in the sector of small vehicles like bikes and scooters. Another way that electric mobility may take is seen in a gradual 'electrification', i.e. a move from plug-in hybrids to full electric cars. Fleet operators, e.g. with company or car-sharing fleets, are seen as first significant customers. These segments will make electric vehicles more visible in neighbourhoods and on the streets and provide the possibility to try electric vehicles via

car-sharing etc. Together with the feasibility demonstrated by these customers, reservations of other potential adopters may be reduced.

However, experts did not only identify promoting factors, but also a long and broad list of factors that might hinder or slow down the market diffusion of electric vehicles. These could be structured along the same dimensions used for the promoting factors except the last dimension, market development: (i) technological development and vehicle attributes, (ii) market situation, (iii) user-related factors and (iv) macro factors.

With regard to the first dimension, the high price of electric vehicles due to the costs of the battery was mentioned by all of the interview partners to hinder the market diffusion of electric vehicles. The prices for the battery are currently far too high for potential users and on the short run a significant price reduction is not to be expected. Regarding the battery the experts also pointed out that sufficient levels of reliability as well as warranty concepts will be needed before broad market diffusion is possible. The time necessary for loading the battery was also mentioned as a problem, however, not as often and as significant as the other battery-related factors. Moreover with regard to the battery, experts stated that its capacity will probably raise fears from the potential users' point of view. More specifically, interviewees expected that potential user would want intelligent systems for monitoring the state of the battery and be afraid of complex handling requirements, e.g. handling of the cable. Furthermore, vehicles will need to have at least some capacity to transport people and goods beneath the driver.

Regarding the vehicles currently or shortly on the market, the interviewees expected that the low rate of availability, especially of carefully designed and tested high-quality vehicles, as well as the low driving range of the first vehicles on the market will be a significant barrier to market diffusion.

In relation to the second dimension, the market situation, several aspects were already mentioned, e.g. warranty concepts for the battery and low availability of thoroughly designed vehicles. In addition to those, experts assumed that more infrastructure will be needed – this point will be elaborated in more detail below. Moreover, it was stated that intelligent and detailed concepts how to advertise electric vehicles on the market are missing, e.g. for renting e-bikes, and that those currently discussed are not attractive for many, e.g. leasing batteries.

From the perspective of potential users (third dimension), experts could imagine strong barriers to the diffusion of electric vehicles. First of all, it seems not likely that many users now or in the near future will be motivated or interested to look for this kind of vehicles as most users are perfectly happy with conventional cars and the range of products available on the market. Conventional cars fulfil a wide variety of needs and will probably act as a strong frame of reference. With this reference frame, electric cars might be perceived as less attractive on many dimensions. Thus, interviewees expect that potential users will regard electric vehicles as second class and disadvantageous. In addition to this, to penetrate the market, electric vehicles have to overcome buying habits that have developed over a long period of time and consumers' generally tendency to avoid risks.

Furthermore, the use of electric vehicles could be perceived by consumers as causing high cognitive load, i.e. more planning of daily mobility due to low battery capacity and charging time. Users will have to get used to new kinds of technical data and acquire additional knowledge. Several experts also expect that potential users will have doubts on safety

aspects, e.g. categorizing small electric cars to be less safe due to their small size. Finally, with regard to consumers that adopt electric vehicles because of environmental reasons, experts pointed out the risk of doubts on the environmental advantages of electric vehicles which could strongly discourage this consumer group.
On a macro-level (fourth dimension), increasing efficiency of conventional cars as well as alternative technologies are seen as competing against electric vehicles. As well, lower oil prices due to a weak economy might inhibit the diffusion of electric mobility. Especially for Germany, doubts were raised whether the relevant actors, i.e. the government, power generators, automotive industry, public transport, are willing and able – due to various reasons – to support a development towards electric mobility on the long run.

Infrastructure

Regarding infrastructural aspects, the experts interviewed in this study expect individuals to load their vehicles mostly at home and at their workplace and only incidentally in public places. Thus, the provision of infrastructure at the place of living and working is seen as most important with regard to charging requirements. However, a publicly accessible infrastructure is seen as crucial for promoting electric cars, as it will increase observability of electric mobility and reduce reservations which might prevent people from buying. It is expected that people will want to know that there is an infrastructure they could use if necessary before they will feel safe enough to invest into electric vehicles.
From a user perspective, charging infrastructure should fulfil the following requirements mentioned by the interviewees: Compatibility with all kinds of electric vehicles; an easy and transparent system for usage and billing; prevention of vandalism; intelligent and simple interfaces monitoring battery capacity as well as possibility for loading the battery.
The exchange of batteries is seen as critical – also from a user perspective: Users might be reluctant to exchange such a vital and expensive part of their vehicle.

Target groups and business models

The identification of possible target groups was another important element of the interviews. It turned out that this discussion was often closely connected to business models, thus, these two aspects are presented concurrently in this section. The ideas provided by the interview partners can be categorized by either starting from specific functions and characteristics of trips for which the electric vehicles is used or from certain attributes of individuals. These two categories will now be elaborated in more detail sequentially.
With regard to specific functions and trips, electric vehicles were seen as being especially appropriate for use in urban areas where travel distance is usually within a limited range. First of all, they could be used in company fleets, especially by the segment of various service providers such as mobile care services, which often have frequent and regular short trips in urban areas. Next, electric vehicles were expected by experts to be adopted by multi-vehicle households to replace one of these vehicles. In the same way the electric vehicle could become useful for consumers who are already combining various means of transport flexibly and pragmatically. Here, various concepts are conceivable for electric vehicles:

vehicles in the ownership of the user, car-sharing vehicles or vehicles to complement public transport. Electric vehicles are expected by experts to cut off market shares of all travel modes: driving by conventional cars, travelling by public transport as well as cycling and walking.
Regarding user attributes, electric vehicles were discussed as being convenient and attractive for those who are wealthy and have little time (and would therefore be interested in innovative and pragmatically usable transport offers), those who are interested in new and innovative technology, want to express attitudes via their vehicle, are environmentally aware or interested in recent trends.

DISCUSSION

The current state of development of electric mobility points out that the successful diffusion of electric vehicles faces several major challenges which are high purchase costs, limited range, unclear state of reliability, a little developed public infrastructure and the steady improvement of conventional vehicles. Knowledge about potential target groups of electric vehicles, i.e. about their needs and preferences is crucial to direct further development of technology, infrastructure as well as attractive vehicle concepts and mobility concepts. As practical experience with the upcoming generation of electric vehicles and thus, on actual users is rare, interviews with experts were conducted in order to explore factors and concepts which might be relevant for consumer acceptance of electric mobility.
Together with prior research on acceptance of technological innovation and a review of findings on characteristics and behaviour of electric vehicle users of the 1990s, the interview results offer a broad view on the topic by illustrating promoting and inhibiting factors which might be decisive for a successful diffusion of electric mobility, opening the range of potential developments of market diffusion, as well as approaches to develop feasible concepts for vehicles and their integration in the transport sector.
With regard to the further development of the market, many concerns and reservations are mentioned in the interviews. However, experts perceive also promising circumstances and trends which – if persistent – could promote electric mobility effectively. Relating the results to the theory outline provided above, it turns out that progress regarding the battery technology is needed as well as further development of attractive concepts for vehicles types that meet consumer needs. However, these vehicles need to be adapted to and to be carefully integrated into broader mobility concepts. Infrastructural development is important as well, however, a basic infrastructure is expected to be sufficient during the early stages of market diffusion.
From the point of view of theories on technology acceptance, five factors were identified in the relevant literature that are widely discussed and analyzed in the research on technology innovation: the usefulness of the product and its relative advantage; compatibility to personal as well as social norms, values and attitudes; the ease of use; trialability; observability. For electric vehicles, the last two are low up to now: as vehicles are hardly available on the market they can neither be tried nor observed. In line with this research, interview-partners identified increasing presence of electric vehicles on the streets and in neighbourhoods as a promising way to further electric mobility. Perceived ease of use will strongly depend on the

design of the models that will first enter the market; the experts interviewed repeatedly mentioned the importance of carefully designed interfaces, especially those who are new to users, e.g. systems monitoring the state of the battery. Looking back at the mega-trends identified by the experts as well as the target groups discussed, it seems very likely that electric mobility is in congruence with social norms and relevant attitudes. Regarding the usefulness and the relative advantage of electric vehicles, again the issue of vehicle and mobility concepts comes to the fore. Intelligent concepts and realizations are needed – and will strongly influence, if not determine the future of electric mobility.

With regard to the consumers, the first types of users from the 1990s seem to be promising as well for the new generation of electric vehicles. Moreover, new possible or broader user groups were described and seem to be promising due to the chances offered by improved technology and better or new vehicle and mobility concepts. However, for different user groups different products, i.e. different vehicle and mobility concepts, might be attractive. The development and evaluation of such concepts together with potential consumers will be crucial to ensure success of market development.

Finally, experts point out that consistent and extensive measures to promote electric mobility are important, also in the long run, when the current hype might cool down again. However, they have to be carefully designed and targeted. If, for example, financial incentives are implemented too early or too broadly, negative consumer experience with vehicles of low quality or rebound effects could be the consequence. The interviewees emphasized that measures should also include non-financial advantages for users. Together with attractive vehicle concepts, mobility solutions and business models and a positive image, such measures can help to integrate electric mobility successfully into the transport sector.

Limitations and further questions

This paper is mainly based on expert interviews. Interview studies are always selective as the results to be obtained depend on the knowledge and experience of the interview-partners. Although we carefully tried to assemble a broad spectrum of views on the topic under study, it may well be that some aspects are missing. Moreover, although the experts surveyed do have a long history of research and practice in their respective fields, they also answered to our questions from a theoretical point of view as current practical experience with electric mobility is hardly available.

Thus, it is necessary to complement this kind of analyses with potential as well as actual users in order to come to generalizable results on user acceptance. Further analyses will be made possible in the coming months, in our research through conducting extensive workshops with potential users as well as in the numerous field trials that are currently prepared. However, in this paper, we were able to identify relevant issues that should be studied in detail in the future. Questions that are of special interest to future research relate to detailed attractive mobility concepts for transportation including electric vehicles as well as specifying the interfaces which are of special interest to potential users. It is therefore the aim in our research project to further develop these ideas and to discuss them with potential consumers in order to identify promising ideas at an early stage.

Conclusion and outlook

In this paper, we provided first explorative answers on questions about user preferences towards electric mobility. Our data leads to the conclusion that electric vehicles face a broad list of challenges for successful implementation into the transport sector; most important are issues around necessary technological progress regarding the battery. However, electric mobility also fits with significant current mega-trends, e.g. increasing awareness of climate change, rising prices for fossil fuels and an openness for new concepts for mobility. Thus, after failing market entry in the 1990ies, electric vehicles do have another significant chance to enter the market.

REFERENCES

Batteries International (2010). Chasing the lithium dream. Cover Story: all things Lithium. Batteries International, Vol. 75.

Biere D., D. Dallinger and M. Wietschel (2009). Ökonomische Analyse der Erstnutzer von Elektrofahrzeugen. Zeitschrift für Energiewirtschaft, 2, 173-181.

Canzler, W. and A. Knie (2009). Die Stadt der kurzen Wege ist stets unter Strom. Der Tagesspiegel, Edition 17.2.2009. Berlin.

de Haan, P. (2009). Die zweite Generation der Elektromobile. Swiss Engineering – STZ, 12, 40-41.

Fishbein, M. and I. Ajzen (1975). Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research. Addison-Wesley, Reading, MA.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly, 13, 319-339.

Gärling, A. and J. Thøgersen (2001). Marketing of electric vehicles. Business Strategy and the Environment, 10, 53-65.

Hacker F., R. Hartman, F. Matthes, and W. Zimmer (2009): Environmental Impacts and Impact on the Electricity Market of a Large Scale Introduction of Electric Cars – critical review of literature. ETC/ACC technical paper 2009/4, European Topic Centre on Air and Climate Change.

Hacker, F., W. Zimmer, J. Deffner and K. Götz (2010). Optimierung der Umweltentlastungspotenziale von Elektrofahrzeugen – Integrierte Betrachtung von Fahrzeugnutzung und Energiewirtschaft. Arbeitspapier zum Thema: Dimensionen von Elektromobilität – Diskussion von Konzepten und Geschäftsmodellen als Grundlage für die empirische Akzeptanzanalyse. Research funded by the Federal Ministry for Environment, Nature Preservation and Nuclear Safety (BMU), Berlin. Öko-Institut, Institut für Sozialökologische Forschung (ISOE). Berlin.

KIT (2010). Das deutsche Mobilitätspanel. Karlsruhe Institute of Technology (KIT), Institut für Verkehrswesen (IfV), tms infratest.

Knie, A., O. Berthold, M. Hård, T. Buland, H. Gjøen, B. Truffer and S. Harms (1997). Consumer user patterns of electric vehicles. Discussion Paper. Wissenschafts-zentrum Berlin für Sozialforschung, Berlin.

Knie, A., O. Berthold, S. Harms and B. Truffer (1999). Die Neuerfindung urbaner Automobilität. Elektroautos und ihr Gebrauch in den U.S.A. und Europa. Ed. Sigma, Berlin.

Rogers, E. M. (2003). Diffusion of innovations (5th edn). Free Press, New York.

Wietschel, M. and D. Dallinger (2008). Quo vadis Elektromobilität? Energiewirtschaftliche Tagesfragen, 58, 8-15.

Wietschel, M. and F. Kley (2009). Eine Bewertung der Ladeinfrastruktur für Elektrofahrzeuge. Zeitschrift für Automobilwirtschaft (ZfAW), 3.