Electric mobility – a survey of different consumer groups in Germany with regard to adoption

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Abstract

Electric vehicles (EVs) are currently being discussed as a promising means to increase the energy-efficiency and sustainability of today's transport systems. To effectively promote and successfully diffuse EVs, it is crucial to identify the customer segments containing the most likely early adopters and to target development, marketing and policy measures towards these segments. This study aims to identify promising target groups for electric mobility and characterize them in detail with regard to relevant factors for adoption extracted from literature.

A large online survey has been conducted in Germany among actual users of EVs, consumers intending to adopt EVs in the future, consumers interested in EVs, but without concrete purchase intention and consumers who are not yet well informed about EVs. Amongst others, the survey includes items assessing (1) affinity towards EVs and likelihood of purchase and usage; (2) perceived advantages and characteristics of EVs; and (3) socio-demographic items.

The participants were divided into different consumer groups regarding their affinity towards EVs. Differences between these segments pertaining to their perceptions of EVs which – according to theory and empirical findings – might be relevant for the adoption are described. Finally, conclusions regarding promising marketing and policy measures to promote electric mobility are discussed.

Introduction

Currently, electric vehicles (EVs) are being intensively discussed as a sustainable and energy-efficient means of transport. They may offer advantages compared to traditional vehicles with regard to environmental impact and noise. However, there are still aspects that are critical for consumer acceptance and thus for a successful diffusion of electric mobility, e.g. high purchase costs and uncertainties with regard to range or reliability of the battery. Moreover, using and especially charging an EV implies a challenge to user habits. For a successful diffusion of EVs, it is important to target development and marketing as well as policy measures towards likely early adopters. However, due to the low commercial availability of EVs so far, valid scientific findings on and practical experience with consumer needs are rare.

Most industrialized countries and automobile manufacturers have launched huge research programmes 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 to study user acceptance as well as concepts and measures to promote adoption.

Consumer acceptance of EVs 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 EV, 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 EVs is only recent, and only a small number of EVs is available on the market. Thus, user experience with EVs of the current generation is rare. Previous surveys of users were conducted with users of the first generation of EVs 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 experiences and to arrive at a broad impression of the consumer perspective, a multi-methodological approach was applied in the project. In a qualitative approach, the aim was to explore factors promoting and inhibiting the diffusion of EVs as well as feasible and attractive vehicle and mobility concepts. In a first step, interviews with eight experts for individual mobility behaviour and acceptance of innovations were conducted, in order to identify relevant aspects for user acceptance of EVs. Additionally, a workshop with experts was organized to define promising target groups for electric mobility. Furthermore, experiences and test reports on using EVs which are published in the internet were systematically collected and analyzed. Finally, based on these results, a focus group design was developed and conducted with five groups of participants which represent likely target groups for electric mobility.

The studies within the qualitative approach indicate relevant dimensions and characteristics of EVs with regard to advantages and disadvantages compared to conventional vehicles, such as driving characteristics, costs of operation or environmental consequences. Moreover, they pointed out individual values with which EVs may be compatible, e.g. environmental protection. Thus, they ensure that the relevant aspects were covered within the operationalization of the theoretical relevant constructs.

Additionally, a quantitative approach was applied in order to identify promising target groups for electric mobility and characterize them in detail with regard to relevant factors based on Rogers' diffusion of innovation model (2003). Therefore, a broad online survey was conducted in Germany among different consumer groups. This paper presents methodology and results of the online survey and is structured as follows. First, a short overview on literature on acceptance and diffusion of technological innovation is given and the state of research with specific regard to consumer acceptance of EVs is presented. Subsequently, the methodology of the online survey is described before its results are reported. The last section discusses implications with regard to future development and policy recommendations.

User acceptance of EVS

This section gives a short overview of general theories to explain acceptance and diffusion of technological innovations by individual consumers. Next, research findings on consumer acceptance of EVs from the 1990s as well as available findings of current studies are briefly discussed.

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) the *relative advantages* (and disadvantages) of an innovation compared to conventional alternatives on the market; (ii) the *compatibility* with the adopter's values, experiences and needs; (iii) the *complexity*, i.e. difficulty to understand and use the innovation; (iv) the *trialability*, i.e. the possibility to test the innovation before the decision to adopt and (v) the *observability* or visibility of an innovation and its consequences.

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 (typically 2.5 % of the market); (ii) early adopters (13.5 %); (iii) early majority (34 %); (iv) late majority (34 %); and (v) laggards (16 %). Based on Rogers' DoI (2003), Gärling and Thøgersen (2001) conclude that the marketing of EVs should target potential adopters who already perceive advantages and disadvantages, compatibility with values and needs, and complexity of use and understanding of EVs in a favourable way, and further promote favourable perceptions of these and other potential adopters.

Other theories that have been applied to explain user acceptance of new technologies include the theory of reasoned action (TRA) by Fishbein and Ajzen (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 EV would be influenced by the personal attitude, e.g. personal expectations towards using EVs, as well as the more general societal perception of electric mobility, e.g. EVs as 'green' vehicles that should be used in order to contribute towards preventing climate change.

The Technology Acceptance Model (TAM) by Davis (1993) has also been applied in various studies to explain adoption of innovation. It regards 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 the social norm, thereby adding an inter-individual factor.

Comparing the three approaches to technology acceptance, it turns out that they include similar variables that are supposed to explain acceptance at 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, plus the complexity or ease of

use. The most comprehensive model is the DoI of Rogers (2003). Exclusive to Rogers' (2003) model are the variables trialability and observability. However, the social norm towards the innovation is not covered explicitly and sufficiently by this model, although Rogers (2003) himself points out that, for consumers adopting the innovation in a later phase of the diffusion process, the expectation of others becomes a relevant reason for adoption. Thus, we regard the DoI extended by the social norm as influencing variable as useful model for this study (Figure 1).

CONSUMER ACCEPTANCE OF EVS IN THE 1990S

In the 1990s, when EVs 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 EVs of the 1990s were homogeneous with regard to their socio-demographic characteristics and were typically male, middle-aged, well educated, had a family and an above average income.

With regard to psychological variables, based on Swiss data, Knie et al. (1999) could identify four types of users who differed significantly in their attitudes and their mobility behaviour: (i) users who are characterized by their concern for ecological issues and who consider the EV as an ecological alternative to conventional vehicles; (ii) users who regard the EV as a technologically challenging product which plays an important part in their lifestyle; (iii) users who are often travelling in the city and who regard the EV as a good means 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 EVs are likely to be bought by households which are motorized above average. Often, the EVs 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) found a high satisfaction with electric mobility, despite 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 EVs in the 1990s, which were used both in urban and rural areas, indicate that use patterns of EVs often change with actual use. Even if the vehicle was not bought as a 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 EV are not sufficient. Modal split hardly changed with the purchase of an EV. 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 a 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 EVs 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.

CONSUMER ACCEPTANCE OF EVS OF THE CURRENT GENERATION

As outlined in the introduction, user experience with EVs of the current generation is rare. In the starting field trials, consumer acceptance and experience of actual users is examined; in most cases, results are not yet available. Qualitative studies have been conducted with potential consumers to explore relevant aspects for user acceptance of the current generation of EVs and identify potential target groups, as well as vehicle and mobility concepts which seem attractive from the user perspective (e.g. ABF 2010; Peters & Dütschke 2010; Peters & Hoffmann 2011). Also, quantitative surveys with potential consumers have been conducted recently, often by some kind of consulting agencies or other associations (e.g. Fraunhofer IAO & PwC 2010; Roland Berger 2010; TÜV SÜD & Technomar 2009). These surveys mostly assess if and when consumers would purchase or use an EV, their general attitude towards electric mobility, expectations with regard to characteristics such as range or loading time, and willingness to pay for EVs. However, to our knowledge, they have not been based on scientific theories on consumer acceptance or diffusion of innovation which define relevant psychological factors influencing adoption of an innovation. Moreover, they face the problem that it is difficult for consumers to express valid attitudes, preferences and intentions regarding new, rather unfamiliar vehicle types. Thus, even when large samples have been surveyed, the validity, reliability and generalizability of their results is a critical point, these results might change when consumers acquire more experience.

RESEARCH QUESTIONS

The presented outline points out the need for quantitative surveys based on relevant theory which compare consumers with experience of EVs with other consumers who are less informed. Based on this, target groups of potential early adopters can be identified and characterized in detail, with regard to factors relevant for acceptance. As Gärling and Thøgersen (2001) pointed out, in the first market phase of EVs, marketing should be targeted to these target groups in order to influence their perceptions in a more favourable direction.

According to the presented outline, Rogers' (2003) model extended by social norm (Figure 1) represents a useful model to study the perceptions of different target groups.

Based on this model, we focus on the following research questions:

1. How do the predictors of the model, i.e. the perceptions of EVs influence the intention to purchase and use an EV in the whole sample as well as within the respective consumer groups?
2. What are the differences between various consumer groups with different experience of and interest in EVs with regard to these factors?

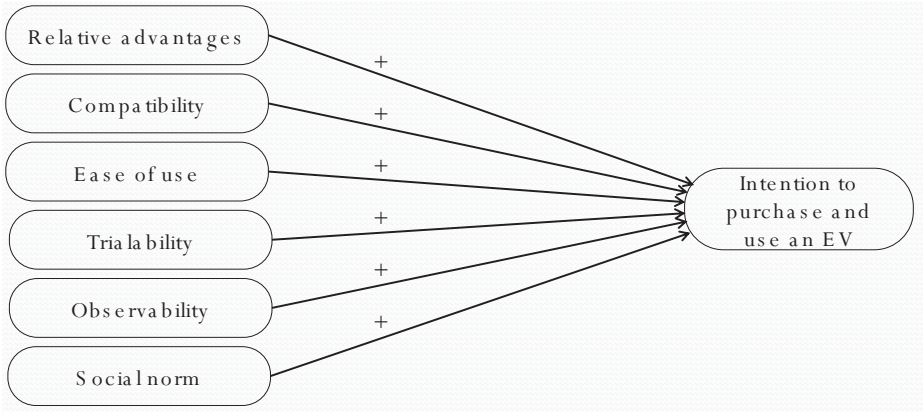

Figure 1. Theoretical model to explain intention to purchase and use an EV, adapted from Rogers (2003), enriched with social norm. The variable complexity of Rogers' DoI (2003) is substituted by the variable ease of use which represents the positive specification of this construct.

Method

An online survey (N = 969) was conducted in Germany among actual users of EVs, consumers intending to adopt EVs in the future, consumers interested in EVs, but without concrete purchase intention and consumers who are not yet well informed about EVs. Before the sample and the different consumer groups are described, we shortly outline the relevant modules and items of the questionnaire in the following section.

QUESTIONNAIRE

Consumer groups. Several indicators were included in order to divide the respondents into groups according to their use of an EV as well as their affinity to and interest in EVs. The following four groups were differentiated (1) *users*, (2) consumers with *purchase intention*, (3) people *interested* in EVs, but without concrete purchase intention, and (4) consumers less or *not interested* in EVs. First, the person was asked if she owns or drives an EV. People who confirm this question are selected as "users". Two items assessed whether the participant has already made the decision to buy an EV within five years and if she is generally interested in EVs. If both questions were answered yes, the participant was assigned to the purchase intention group. If only the interest item was affirmed, participants were classified as belonging to the group of interested consumers without purchase intention. Participants affirming none of the above were classified as not interested. The decision whether participants fell into the group of interested or not interested consumers was based on the basis of one single item, which is very easy to confirm. Thus, two additional indicators were assessed to provide further validation of the grouping: (a) a behavioural indicator includes five items assessing participants' search for information about EVs with a binomial response scale including yes vs. no (e.g. "I have collected information from manufacturers or car dealers."); (b) a knowledge indicator checks the knowledge of respondents on EVs by means of twelve items (e.g. "EVs can usually be charged by means of a conventional electrical outlet." with response scale: "right"/"wrong"). Both indicators should correlate with interest in EVs.

Psychological variables. Each of the psychological constructs included in the theoretical model was measured by several items which were formulated specifically to the topic of purchase of EVs and their use, respectively. The items were based on Rogers' (2003) definitions and recommendations and on previous studies of acceptance of innovations, in particular on a study of Artho (2008) which applied the DoI to the case of adopting innovative heating systems. Respondents usually rated their agreement on a 7-point response scale ranging from 1 (= not at all the case) to 7 (= very much the case). 16 items were used to assess the *perceived relative advantages* of EVs[1]. The items were collected, based on a literature review and represent advantages and disadvantages which are often associated with EVs. Each characteristic is assessed both for an EV and for a conventional vehicle with combustion engine. This procedure ensures that both powertrains are evaluated independently and response tendencies in favour of one of the powertrains are avoided (Artho 2008). In order to ensure that the evaluation only refers to differences due to the respective powertrain, the car size class which the respondent associated most with EVs was included in the items regarding both powertrains. This car size class was assessed by presenting pictures of three classes, *small vehicles (e.g. subcompact, micro, ultra-light/trike)*, *mid-sized vehicles (e.g. station wagon, sedan, compact)* and *large vehicles (e.g. sport utility vehicle/SUV, family van, sports car)*. *Compatibility* with own values, experience and need was assessed by four items which refer both to aspects of personality and to daily habits and needs. A set of six items served to measure *complexity and ease of use respectively*[2] and two items to measure *trialability*. *Observability* and *social norm* were each assessed by four items.

Intention to purchase and use an EV. The DoI aims to explain the diffusion of an innovation, i.e. the adoption by individuals. As a measure for the (prospective) adoption of EVs, this study measures the variable intention to purchase and use an EV (within the next five years) by assessing the following indicators: attitude towards a purchase within the next five years; likelihood, to purchase an EV within the next five years; inten-

1. For the items assessing relative advantages, the meaning of the response scale values differed: 1=very low/not sufficient and 7=very high/absolutely sufficient.

2. In the analyses, we use – analogue to the other model variables – the positive term *ease of use* instead of *complexity* and code items so that higher values on this variable indicate an easier use of EVs and are assumed to correlate with the target variable.

tion to use an EV in case of purchase; and likelihood to substitute a vehicle with combustion engine by an EV. From these indicators of the target variables, only the attitude towards a purchase was measured by several items using semantic differentials slightly modified from rating scales developed by Davis (1993).

The wording of the items assessing the model variables included in the final analyses are presented in Tables 1, 2 and 3 which depict the results of the factor analyses for the various variables.

Socio-demographic characteristics and individual mobility behaviour. Finally, questions about socio-demographic characteristics of the respondent and his or her household were included, as well as questions on individual mobility behaviour (e.g., sex, age, household size, place of residence, kilometres travelled per day).

PROCEDURE AND SAMPLE

After pre-testing the questionnaire, the survey was conducted from 15.8.2010 till 12.9.2010 by means of the software EFS-Survey (www.unipark.info). The survey was publicly available and not limited by a code.

The recruitment of participants for the survey was conducted by means of the internet and was designed to be both neutral and specific to the topic (automobiles and EVs). Precisely, online media such as blogs, newspapers and journals were asked to publish calls for participation. Associations, vehicle manufacturers and dealers were asked to disseminate to customers and members respectively. Additionally, own calls for participation were published in various online forums, and friends and colleagues were asked to disseminate the call.

On the whole, 3,497 accesses to the starting website of the survey were counted during the data collection period. 2,301 people dropped out before finishing the survey. As the majority dropped out at the starting side, i.e. before the actual start of the survey, the completion rate of 34.2 % is regarded as satisfactory. From the sample of participants who completed the survey, the following records were excluded: (1) records of participants not living in Germany; (2) records of participants who are younger than 18 years old.

The resulting sample of N = 969 respondents contains 81.4 % men. The mean age was 40.9 years (min. = 18, max. = 90, *S.D.* = 13.14), the modus of monthly household income was €2001-3000 on a categorical scale, the average household size was 2.48 persons (*S.D.* = 1.55; adults: *M* = 2.04, *S.D.* = 1.27; children: *M* = .45, *S.D.* = 0.82), and the average number of cars owned by a household was 1.43 (*S.D.* = 0.93). 43 % of respondents live in cities of more than 100,000 inhabitants. The other participants are distributed almost evenly in villages of less than 5,000 inhabitants (20 %), in small towns (19 %) or in medium-sized cities (18 %). The survey sample contains 51 % respondents with a university degree and 42 % respondents working in technical jobs.

With regard to the consumer groups which were distinguished, users represent the smallest group with *N* = 92. As consumers with concrete purchase intention, *N* = 244 respondents could be identified. The group of interested consumers without purchase intention includes *N* = 352 data sets and the group of consumers who are not interested in EVs includes *N* = 281 respondents.

With regard to socio-demographic differences, the users represent the eldest group (*M* = 45.0 years). They have the lowest rate of women (5.4 %), live in bigger households (*M* = 2.8 persons) with more children (*M* = 0.7) and have more cars (*M* = 2.2) than any of the other groups.

The group of consumers with purchase intention is younger than the user group (*M* = 42.9 years), includes more women (9.4 %), live in households with *M* = 2.7 persons and with less children than the users (*M* = 0.4). This group owns 1.4 cars on average.

The interested group has an average age of *M* = 39.7 years, 17.9 % women and a household size of *M* = 2.4 persons with *M* = 0.5 children. In this group, a bigger percentage (49.7 %) lives in a major city (with a population above 100,000) than in any of the other groups. This group owns 1.3 cars on average.

The group of consumers who are not interested in EVs is quite similar to the above group in terms of age (*M* = 39.5 years) and household size (*M* = 2.4 People), but has less children (*M* = 0.4), owns more cars (*M* = 1.4) and includes more women (31.7 %).

The whole sample should ideally be representative for the population of potential new car buyers in Germany. However, valid data for this population were not available to us. Compared to the population of new car buyers, the survey sample might contain more men as well as more participants with above average education and higher interest in technology. It is to be expected – and is also intended due to statistical reasons[3] – that users and consumers with purchase intention are overrepresented within the sample, as they might be especially motivated to participate in the survey. Regarding characteristics relevant for adoption behaviour, we assume that each group itself can be viewed as representative for the corresponding group in the population. Thus, as we did not aim to estimate the proportion of the various groups, but only study differences between the perceptions of these groups, the validity of our results should be ensured.

Results

In this section, the results of the conducted analyses are described before they are interpreted and discussed in the last section.

DESCRIPTIVE ANALYSES

Psychological variables

Statistical principal components analysis (PCA) seeks to describe the similarities within a set of psychological variables by creating a limited number of underlying dimensions (factors). In this study, PCA is used to confirm the factors of the research model, to find possible sub-dimensions of these factors and to test one-dimensionality of the target variable.

The analysis of the ratings on the relative advantage items indicated four relevant dimensions which summarize the perceived advantages (or disadvantages) of EVs in comparison to conventional vehicles (Table 1). Based on the content of the

3. For sufficient statistical power, it is necessary that a significant number of the consumers with more experience of and interest in EVs is represented within the dataset.

Table 1. Factor loadings, internal consistencies and explained variances resulting from a PCA on items assessing relative advantage.

Items assessing relative advantages	Factor 1 (RA driving)	Factor 2 (RA operation)	Factor 3 (RA infra-structure)	Factor 4 (RA basic)
Driving pleasure	.826			
Acceleration performance	.666			.444
Attainable maximum speed	.648			.556
Ability to simplify my life	.642	.401		
Costs per 100 km		.811		
Emissions generated when driving		.787		
Follow-up costs for repairs and spare parts		.706	.428	
Dependency on fossil fuels		.704		
Breakdown frequency		.600		
Supply network for service and refueling			.740	
Choice of various models			.650	
Range till refueling			.604	
Purchase price			.593	
Safety standard				.823
Comfort				.814
Loading capacity				.720
Explained variance of factors	28.47	15.45	9.50	6.41
Cronbach's alpha	.73	.78	.64	.71

Note 1. The numbers represent factor loadings above .4, which indicates that the respective dimension is sufficiently assessed by an item.

Note 2. The wording of the introduction to the items was: “How would you personally rate the following aspects for [car class] with an internal combustion engine (gasoline/diesel) in general?” and “How would you personally rate the following aspects for [car class] with an electric motor?” respectively; response scale: 1 = “very low/not sufficient”, 7 = “very high/absolutely sufficient”.

Table 2. Factor loadings, internal consistencies and explained variances resulting from a PCA on items assessing the variables compatibility, ease of use (complexity), trialability, and social norm.

Items	Factor 1 (social norm)	Factor 2 (ease of use)	Factor 3 (trialability)	Factor 4 (compatibility)
People react positively when they see an electric car on the road.	.874			- .429
Other road users are pleased to see an electric car on the road.	.855			- .406
Electric cars have a positive image in society.	.771			
The people who are important to me find electric cars good.	.734			- .612
An electric car is simple to drive.		.786		- .428
An electric car is easy to operate.	.420	.745		- .413
Operating an electric car is easy to understand.		.713		
In order to use an electric car, I must know about some technical matters. (-)		.514		
I have the opportunity to test an electric car as long as possible to form an opinion about it.			.864	
I have the opportunity to try an electric car within my circle of friends.			.859	
Driving an electric car is easily compatible with my habits.	.498			- .869
An electric car is well suited to carry out my daily tasks.	.520			- .821
It is difficult for me to schedule re-charging the battery with my planning. (-)				- .714
An electric car suits my personality.	.680			- .697
I am confident that I can use an electric car efficiently.	.514			- .692
An electric car shows what is important to me.	.554			- .636
Explained variance of factors	38.51	9.55	8.46	6.91
Cronbach's alpha	.85	.60	.67	.86

Note 1. The numbers represent the loadings above .4, which indicates that the respective dimension is sufficiently assessed by an item.

Note 2. (-) = Items were reversed in coding for the analyses so that higher values correspond to higher values on perceived ease of use.

Table 3. Factor loadings, internal consistencies and explained variances resulting from a PCA on items assessing intention to purchase and use an EV.

Items	Factor (intention to purchase and buy)
Assuming you had an electric car available, how often would you use it instead of a car with an internal combustion engine? (response scale: 1 = never, 7 = always)	.835
If you were to buy a car within the next 5 years (independently of whether you really intend to or not), how likely is it that you would buy an electric car? (response scale: 1 = very unlikely, 7 = very likely)	.817
Attitude towards purchase (aggregating 5 items: All in all, buying an electric car within the next 5 years I personally find … with 5-point response scales: a) good - bad, b) wise - unwise, c) advantageous - disadvantageous, d) useful - useless, e) positive - negative)	.814
Assuming you had an electric car available. How likely is it that you would do without an additional car with an internal combustion engine? (response scale: 1 = very unlikely, 7 = very likely)	.733
Explained variance	64.11
Cronbach's alpha	.788

Table 4. Significant standardized regression coefficients b and explained variance R^2 of the target variable resulting from regression analyses for variables predicting intention to purchase and use an EV within the different consumer groups.

Predictor variables	Users ($N > 85$)	Purchase intention ($N > 210$)	Interested ($N > 269$)	Not interested ($N > 200$)	Total ($N > 764$)
Compatibility	.349**	.274***	.451***	.588***	.549***
RA operation	.278**		.193**		.146***
RA driving				.133*	.132***
Social norm			.125*	.165*	.095**
RA basic		.150*			
Ease of use					-.056*
R^2 (adjusted R^2)	.261 (.242)	.113 (.103)	.380 (.372)	.614 (.606)	.584 (.581)

Note 1. Meaning of predictor variables: compatibility = compatibility with own values, experiences and needs; RA operation = relative advantages in costs of operation and maintenance and in environmental consequences; RA driving = relative advantages in driving characteristics; social norm = perceived expectations of relevant others with regard to purchase and use of an EV; RA basic = relative advantages in basic features such as safety, comfort, loading capacity; ease of use = ease of understanding and using EVs.

Note 2. Step-wise method. Significance level: *$p < .05$; **$p < .01$; ***$p < .001$. Missing data were excluded pair-wise.

items, the factors were named as: (1) relative advantages in driving characteristics (RA driving); (2) relative advantages in costs of operation and maintenance and in environmental consequences (RA operation); (3) relative advantages in market and infrastructural characteristics (RA infrastructure); and (4) relative advantages in basic features such as safety, comfort, loading capacity (RA basic).

The analysis of the other model variables could confirm the model factors (1) social norm, (2) ease of use, (3) trialability, and (4) compatibility. However, the variable observability could not be confirmed by means of the respective items[4], which were therefore, excluded from the further analyses. The factors and items included in the further analyses are presented in Table 2.

From the target variables, only the attitude towards the purchase of an EV was measured by several items. A PCA of these items indicated one factor[5]. Therefore, the items were included by an average score in a PCA of all items measuring the target variable *intention to purchase and use an EV*. This PCA suggested again a one-factor solution (Table 3). That means that a one-dimensional target variable assessing intention to purchase and use an EV could be computed out of a set of items assessing various aspects such as likelihood of and attitude towards buying an EV as well as likelihood of its usage and of substitution of a conventional vehicle.

Thus, the factors which were found by the analyses correspond very well to the theoretically expected variables, except the variable observability, which could not be confirmed by the analyses. The final variables were constructed by computing the individual average scores across the associated items. Means and standard deviations of the variables included in the analy-

4. The items of the variable observability loaded on three factors and showed a low internal reliability of α = .39.

5. The factor summarizing the items assessing attitude towards the purchase of an EV explains 81% of the variance and shows an internal reliability (Cronbach's alpha) of α = .94

Table 5. Means (and standard deviations) of perceived characteristics of EVs and of intention to purchase and use an EV, rated by different consumer groups.

Consumer group	RA driving	RA operation	RA infrastructure	RA basic	Social norm	Ease of use	Trialability	Compatibility	Intention to purchase and use an EV
Users ($N > 84$)	0.56 (1.29) [I, N]	2.54 (1.77) [I, N]	-2.74 (1.37) [I, N]	-0.81 (1.49) [N]	5.40 (1.20) [I, N]	5.66 (1.09) [N]	4.57 (2.12) [P, I, N]	6.00 (0.95) [I, N]	5.21 (1.15) [I, N]
Purchase intention ($N > 209$)	0.10 (1.19) [I, N]	2.53 (1.73) [I, N]	-3.14 (1.29) [I, N]	-0.86 (1.25) [N]	5.12 (1.16) [I, N]	5.84 (0.84) [I, N]	1.9 (1.54) [U]	5.72 (0.92) [I, N]	5.47 (.81) [I, N]
Interested ($N > 268$)	-0.54 (1.24) [U, P, N]	1.54 (1.53) [U, P, N]	-3.68 (1.20) [U, P]	-0.88 (1.26) [N]	4.63 (1.29) [U, P, N]	5.61 (1.03) [P, N]	1.64 (1.25) [U]	4.70 (1.25) [U, P, N]	4.32 (1.13) [U, P, N]
Not interested ($N > 199$)	-1.50 (1.69) [U, P, I]	0.72 (1.80) [U, P, I]	-3.61 (1.45) [U, P]	-1.42 (1.51) [U, P, I]	3.60 (1.58) [U, P, I]	5.08 (1.23) [U, P, I]	1.65 (1.21) [U]	3.57 (1.60) [U, P, I]	3.35 (1.50) [U, P, I]
Total ($N > 763$)	-0.53 (1.54)	1.67 (1.83)	-3.42 (1.35)	-1.01 (1.38)	4.58 (1.47)	5.55 (1.08)	2.02 (1.68)	4.77 (1.54)	4.41 (1.44)
F-value (Sig.)	F (24.170) = 20.603 ($p < 0.001$)								F (2.966) = 143.603 ($p < 0.001$)

Note 1. Meaning of variables: RA driving = relative advantages in driving characteristics; social norm = perceived expectations of relevant others; RA operation = relative advantages in costs of operation and maintenance and in environmental consequences; RA infrastructure = relative advantages in market and infrastructural characteristics; RA basic = relative advantages in basic features such as safety, comfort, loading capacity; social norm = perceived expectations of relevant others with regard to purchase and use of an EV; ease of use = ease of understanding and using EVs; trialability = possibility to test EVs before the decision to adopt; compatibility = compatibility with own values, experiences and needs.

Note 2. For the variables RA driving, RA operation, RA infrastructure and RA basic, negative values correspond to perceived disadvantages of EVs compared to conventional vehicles, positive values correspond to perceived advantages. For the other variables, the values correspond to the response scale 1 = "not at all the case" to 7 = "very much the case". The letters in brackets indicate from which consumer group the respective mean is significantly different, where U stands for "users", P for consumers with "purchase intention", I for "interested" consumers and N for consumers "not interested" in EVs.

ses are depicted in Table 5 for the whole sample, as well as for the various consumer groups.

MULTIVARIATE ANALYSES

Predicting intention to purchase and use an EV

In order to analyze the contribution of the included variables (four factors of relative advantages RA driving, RA operation, RA infrastructure, RA basic, as well as compatibility, trialability, social norm and complexity) to the target variable (intention to purchase and use an EV), regression analyses were conducted. Analyses were conducted separately for each consumer group as well as for the whole sample. The regression models for the whole sample as well as for the various consumer groups are presented in Table 4.

The regression analyses for the whole sample of this study show, first of all, a significant contribution of compatibility of own values, experience and needs to the intention to purchase and use an EV. Additionally, significant effects are observed for relative advantages with regard to operational costs of EVs and driving characteristics. Moreover, social norm (i.e. perceived expectations of relevant others) and ease of use both play a minor, but still significant role for the purchase and use intention. The relevance of the social norm in the global model is low, as the perceived social norm plays a significant role only in some of the consumer groups. In line with Rogers' (2003) theory, social norm shows an increasing importance for participants who may belong to late-adopting groups (i.e. generally interested as well as not-interested participants). However, contrary to the hypothesized positive influence in the model, a negative, but very low influence of ease of use is indicated by the analyses. This means that respondents' intention to purchase and use an EV would be higher, if they perceive the use of EVs as more complex, i.e. less easy. As indicated by the minor beta coefficient, this relationship is not strong and might not apply to the whole sample. However, it seems reasonable that in samples with a high level of education and affinity towards new technology, a certain technological complexity could also represent a positive characteristic, if it is still manageable for the individual consumer. Overall, 58 % of variance of the participants' intention to purchase and use an EV can be explained by these variables.

The important role of compatibility also becomes apparent in its significant contribution within each consumer group, while differences can be observed between consumer groups for the other predictors. A significant effect was also observed for relative advantages with regard to operational costs of EVs in the groups of users and of generally interested people. Relative advantages or disadvantages with regard to driving characteristics of EVs are indicated to be relevant for the (low) in-

tention of consumers who are not interested in EVs. For both consumers who are not interested in EVs and those who are interested but without concrete purchase intention, answers on intention to use and purchase EVs also vary, depending on the perceived social norm with regard to the use of EVs. Within the group of consumers with concrete intention to purchase an EV, besides compatibility, relative advantages relating to basic features of EVs explain part of the variance. With regard to these results within groups, it is important to consider that variance of intention to use and purchase is rather restricted in the groups of consumers with purchase intention (*S.D.* = .81; cf. Table 5), thus, there is less variance to be explained by the predictor variables than within the other groups, i.e. less chance for predictors to show significant effects. Moreover, it should be noted that the exclusion of missing values leads to reduced group sizes, which affect the predictive power of the regression analysis, in particular in the already smaller groups. This means that possible effects of the influencing variables on the target variable have less chance to be identified within small samples as smaller regression coefficients will not become significant.

Analyzing differences in the model variables between consumer groups

Table 5 shows the means of the model variables for the whole sample and for the various consumer groups. The absolute values for the whole group, as well as for the specific consumer groups, allow conclusions on the general acceptance of EVs. The evaluation of relative advantages show that EVs generally and on average are perceived as nearly equal to conventional vehicles in terms of driving characteristics, and slightly inferior in terms of basic characteristics, like security or storage capacity. The perception of costs and environmental consequences and ease of use is widely positive, but there are big differences between the consumer groups in their perception of the social norm, trialability and compatibility. Infrastructure, not surprisingly, is perceived as highly superior for conventional vehicles.

In order to study whether the variables differ significantly between the consumer groups, analyses of variance were conducted (cf. Table 5). In general, the results indicate significant differences between the four consumer groups with regard to the various variables. As post-hoc analysis, pair-wise separate comparisons were conducted to analyze in detail between which groups and in which variables significant differences can be observed.

The analyses generally show that the more interested respondents are in EVs, and the more experience they have, the more they evaluate the various dimensions in favour of EVs, though the groups do not differ significantly from each other in all variables. The differences between neighbouring groups representing neighbouring phases in the adoption process might be most interesting, as they indicate starting points for a shift of consumers to another phase of adoption by changing the relevant perceptions in a more favourable direction. Therefore we focus on these comparisons in the following.

Consumers with concrete purchase intentions and users hardly differ significantly from each other in the assessed perceptions of EVs. Only, trialability is rated clearly inferior by the first group, as well as by all other non-users. The other variables are assessed similarly by users and consumers with purchase intention.

Comparing consumers with purchase intentions with those who are interested but have not (yet) decided to adopt an EV, compatibility, driving characteristics, operational costs and social norm are evaluated significantly more positively by the consumers with purchase intentions. With regard to the perception of basic features and trialability, no significant differences were found.

When comparing the respondents who are not interested in EVs and the respondents interested but without concrete purchase intention, driving characteristics, operational costs, basic features, ease of use and compatibility of electrical vehicles, as well as social norm towards their use are evaluated significantly more positively by the interested consumers, while assessment of infrastructure and trialability was not significantly different between these groups.

With regard to the intention to purchase and use an EV, the results indicate significant differences between the four consumer groups. By means of a post-hoc analysis, significant differences regarding the intention to use and purchase an EV could be observed between all groups, except between users and consumers with concrete purchase intentions.

Discussion and conclusions

SUMMARY AND DISCUSSION OF THE RESULTS

This paper aims to identify promising target groups for electric mobility and characterize them in detail with regard to relevant factors for adoption. Drawing from psychological research on the adoption of innovations and technology acceptance, this model integrates the predictors of Rogers' DoI model (2003) and, additionally, includes the variable social norm which is indicated by Fishbein and Ajzen's TRA (1975) and extensions of Davis' TAM (1993).

The absolute values of different dimensions assessing evaluation of EVs show that EVs generally are perceived as nearly equal to conventional vehicles in terms of driving characteristics, and slightly inferior in terms of basic characteristics like security or storage capacity. While infrastructure is perceived as highly superior for conventional vehicles, the perception of costs and environmental consequences and ease of use is widely in favour of EVs. With regard to the perceived social norm, trialability and compatibility with own values and needs, there are large differences between the consumer groups.

The results of the regression analyses point out that perceived compatibility of EVs with own values and needs plays the most important role for the intention to purchase and use an EV, both in the whole sample and in each consumer group. Further, perceived advantages regarding costs and environmental aspects, as well as driving characteristics show a relevant influence on the intention to adopt EVs.

A significant influence of the perceived market and infrastructural requirements on the purchase and use intention was not observed for any of the groups. Further development and need for infrastructure and service might be very difficult to assess at such an early stage of market diffusion, when different forecasts and estimations are still being controversially discussed. It might be assumed that this discussion leads to a

vague opinion on these aspects. This could be an explanation as to why no significant effects could be observed.

As well, ease of use and trialability do not have a significant effect in any of the groups. While ease of use does not seem to be regarded as major problem, as the respective means indicate, the very low means of trialability in all non-user groups indicate that opportunities for testing EVs are rarely available, or rarely perceived by non-users. Though perceived trialability does not show a direct influence on the purchase and use intention, opportunities to test might be decisive in influencing other relevant variables. By testing EVs in daily life, consumers can experience, e.g., if EVs are compatible with their needs or if they are comfortable to drive.

Results concerning differences between the various consumer groups generally indicate a clear relation between a more positive perception of the respective characteristics of EVs with more experience and interest in EVs. Users and consumers with concrete purchase intentions only differ significantly in their perception of trialability of EVs. People who already use EVs evaluate trialability as significantly higher than any other group. As they have already adopted an EV, they may already have collected a significant amount of information and thus have a higher level of information also on possibilities and opportunities to test EVs.

The other model predictors as well as the intention to purchase and use an EV fail to differentiate between users and people with purchase intentions. This could be interpreted as a sign that the consumers with purchase intentions have come to almost the same conclusions regarding the properties of EVs as the user group, but they have not yet implemented their intention into real action, i.e. so far they have not purchased an EV. Thus, the question is what causes the delay in purchasing an EV. Our results suggest that, in fact, perceived or objective lack of possibilities to try out and evaluate EVs in use and to compare different models in real life could be one significant barrier to actual adoption. Testing an EV would allow validation of the own perceptions and to check if EVs really are compatible with own habits and needs. Thus, opportunities to test might effectively help to encourage the actual implementation of the purchase or use decision.

Such a pronounced decision-making and evaluation behaviour is typical of the group of early adopters, according to Rogers (2003). At their time of adoption, the purchase of an EV still holds more risks than at later times of adoption. Moreover, the currently still limited availability of EVs and the expectation of future price reductions could inhibit the final purchase decision. Consumers with intention to purchase could still wait for a bigger variety of models to enter the market at a lower price, which is a reasonable forecast of market development. These factors were not covered in this study. However, the low value of explained variance in this group supports the assumption that other factors, which are not included in the model, exert an influence. In general, a delayed and carefully considered purchase decision seems indicative for the early majority adopter category which may 'wait and see' for a while, according to the motto "not [to be] the first by which the new is tried, nor the last to lay the old aside" (Rogers 2003, p. 284).

In contrast to the theoretical assumptions, ease of use is rated significantly higher by respondents with purchase intention than by users. One possible explanation is that users' perceptions of ease of use rely partly on first-generation EVs, while people considering buying an EV evaluate upcoming second-generation models. Another explanation would be that potential buyers overestimate the ease of use of EVs, not knowing exactly the real-life hassles that can occur with new and unfamiliar technologies. However, regarding this result together with the minor, but still significant positive influence of ease of use on purchase and use intention indicated by the regression analyses, we assume that current users of EVs, who represent the very special group of innovators according to Rogers (2003), often perceive a certain technological complexity as a welcome challenge and positive characteristic which allows them to set themselves apart from other consumers. Accordingly, they could expect difficulties in use for other consumers though they themselves get well along with their EVs.

Generally interested people evaluate EVs differently from users and consumers with purchase intentions in many dimensions, but not in their perceptions of basic characteristics of EVs, such as security or storage capacity. They evaluate the driving characteristics of EVs, the operational costs and environmental consequences of driving an EV, and the existing infrastructure significantly more negatively, or less positively, than people with purchase intentions and users. In terms of driving characteristics, the interested people prefer conventional vehicles while users and consumers with purchase intention prefer EVs. Interested people without concrete purchase intention perceive a lower social norm towards EVs and a lower compatibility with their lifestyle and daily habits. The relevance of compatibility and the social norm, besides perceived operational costs and consequences, is also shown by the results of the regression analysis for the intention to purchase and use EVs within the group of affine respondents. In particular, the predictive significance of the perceived social norm for the intention to purchase and use an innovation is described by Rogers (2003) as typical for the late majority adopter category to which the group of interested consumers without concrete purchase intention might correspond. According to Rogers (2003) this group is generally sceptical towards innovations, but considers adoption due to peer pressure and economic necessity (e.g. when EVs will have lower overall costs than conventional powertrain vehicles in the future). In contrast to the group with purchase intentions, but in line with actual users, the generally interested respondents perceive EVs as more difficult and complicated to use. However, in contrast to users, they might perceive complexity less as a positive but rather as a negative characteristic. According to the hypothesized causal relations within the theoretical model of this study (Figure 1), the differences in the perception of EVs by affine people result in a significantly lower intention to purchase and use EVs.

Finally, people who are not interested in EVs have a significantly inferior image of EVs than all other groups, with regard to almost all dimensions which were assessed. Their lack of interest might have different reasons: on the one hand, lack of knowledge or lack of contact to EVs might be the cause that an innovation is not even taken into consideration. On the other hand, at least some of the non-interested respondents could have considered EVs in detail, but could have decided against this new technology. Also, financial restrictions might inhibit

a consideration of such technological innovations (cf. Rogers 2003).

When interpreting the results, it is important to keep in mind that the survey was conducted during an early stage of the market introduction of EVs. Thus, these variables and their relations may be changing with the further development of the market and with higher observability of EVs in the streets and within peer groups. Moreover, the results might be influenced by the specific situation and policy measures within Germany and might be different for other countries. In Germany, research and development as well as pilot studies are promoted with a large budget and the topic of electric mobility attracts much attention from the media. However, neither monetary nor non-monetary purchase incentives (e.g. usage of bus lanes or parking space restricted to EVs) currently exist – except a waiver of the motor vehicle tax –, nor are any incentives planned to be introduced in the next years. In countries which provide more financial as well as non-financial incentives for the purchase and usage of EVs, the perceptions might be more in favour of such vehicles.

With regard to theory, our study contributes to the development of theoretical frameworks for explaining people's acceptance of innovations by applying the DoI to the case of EVs. The prospective design studying acceptance during an early market phase enriches the often retrospective studies of innovation diffusion and technology acceptance. However, as we used correlational data, the causal interpretations of our study should be handled with care. Moreover, as mentioned before, conclusions about the size of the different consumer groups or about their socio-demographic characteristics are not possible. With regard to (online) surveys in general, and the topic of this study in particular, deviations from the general population of car buyers with regard to socio-demographic characteristics such as age, sex, education and income have to be expected. However, regarding characteristics relevant for adoption behaviour, we assume that each group itself can be viewed as representative for the corresponding group in the population.

CONCLUSIONS

Finally, we want to emphasize the practical implications of this study and draw conclusions for marketing and policy measures to promote electric mobility. Our results indicate starting points in different phases of the adoption process. As recommended by Gärling and Thøgersen (2001), marketing should be targeted first to consumer groups who represent the most likely next adopters. But as well, perceptions of other target groups could be shifted carefully in a more positive direction. However, attention has to be paid to shifting consumers' perceptions of electrical vehicles in a positive, but realistic direction and that consumers are supported in making a decision which they will not regret afterwards. Disappointed consumers of EVs might be less useful for a successful diffusion of EVs.

In general, the most promising approach is to focus on variables which could be confirmed as relevant predictors for the purchase and use intention, as well as on variables in which the respective groups significantly differ from the neighbouring group with a higher affinity to EVs. These variables should be influenced in a more positive direction, either by guiding perceptions or by improving underlying circumstances, such as tailoring products, services and infrastructure more to the needs and expectations of the respective target group.

According to the results, measures which enhance the perceived compatibility of EVs with own values and needs should be most effective. Information, demonstration and opportunities to test EVs in daily life, in particular for a longer time period, could help consumers to decide and ideally assure them that EVs are really compatible with their daily needs and with their habits. Routines in which EVs differ from conventional vehicles, such as charging processes or routing under consideration of remaining range, should be designed, communicated and supported by means of appropriate technical devices so that they are easy to manage in daily life. Moreover, the range of models of EVs should be oriented towards various user groups, so that the different user groups will be able to select the model which is most appropriate for them.

Another focus should be placed on basic characteristics, financial and environmental costs as well as driving characteristics of EVs. Especially with regard to consumers with purchase intention, information on or minor improvements to basic characteristics such as safety and comfort could remove the last barriers, by removing the perception that EVs have slightly inferior basic equipment. Perceived costs of EVs could be improved by information on low operational costs, as well as appropriate business models which reduce or reallocate high purchase costs. Moreover, it seems important to ensure that environmental assessment is in favour of EVs by respective regulations (e.g. charging with "green energy") as well as information on these environmental aspects. Perceptions of driving characteristics of EVs which are often perceived as very positive when consumers actually experience driving an EV (cf. Peters & Dütschke 2010), could be enhanced by low-threshold opportunities to test EVs, e.g. in urban traffic. In general, our study emphasizes the relevance of improved trialability of EVs which should be used actively in marketing campaigns and promotional measures, and seems an effective measure to reduce barriers and correct or validate consumers' perceptions. Last but not least, with regard to consumers with concrete purchase intentions who are, however, still hanging back, appropriate business models could help to reduce financial and technological risks and encourage actual adoption.

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