Who will adopt electric vehicles? A segmentation approach of UK consumers

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Abstract

Climate change programmes around the globe are relying heavily on the electrification of transport, especially private battery electric vehicles and plug-in hybrids ('EVs'). These are novel technologies of which mainstream consumers have very little experience and knowledge, so they are psychologically distant from the category. This presents a methodological challenge. Yet, the weight afforded them in policy requires a better understanding of which consumers are most likely to adopt EVs and under what circumstances.

Jansson et al. (2009) concluded that potential consumers will have either a strong pro-environmental orientation or a strong inclination to own this new technology. As these are two distinct characteristics, consumers are likely to have different attitudes to car use, evaluate car attributes differently and attach different (symbolic) meanings to EVs. These, in turn, may translate into different patterns of adoption and use: strong inclinations towards new technology resulting in more car ownership and use (e.g. EV as additional car) and pro-environmental orientations leading to pro-environmental choices (e.g. replace current car with an EV, limit car use).

This paper presents the results of a field study conducted in 2010 in the UK (N=2,729) using a unique two-wave research design. In the first wave, general data was collected about car ownership, travel patterns and various individual characteristics (e.g. openness to technology, environmental attitudes). At the end of the first wave, information about EVs was provided to participants. Two days later, responses were collected on the perceived suitability and relative attractiveness of EVs. The two-wave design was aimed at reducing psychological distance, supporting information transfer into long-term memory, and facilitating non-conscious processing, thus better representing consumer choice processes. Applying cluster analysis to the various attitudinal measures, participants are segmented according to their pro-social and technology-oriented inclinations and some conclusions as to the characteristics of EV consumers are presented.

Introduction

In the context of urgent and complex challenges presented by carbon reduction targets, air quality goals and energy security ambitions, most developed and developing economies alike are placing huge hopes on the shoulders of electric vehicle propulsion, coupled with renewable energy supply. The enthusiasm has so far been largely channelled into passenger cars, with scenario studies, government projections and energy system models consistently proclaiming that the transport sector will heavily rely on the transformation of car technology to pull its weight toward policy objectives (Jozwicka & Pulles 2009; CCC 2008). However few of these studies make use of evidence based or theoretically grounded assumptions about consumer responses to this new technology. By and large, historic relationships between price/cost and uptake of internal combustion engines (ICEs) are used to project future penetrations of electric vehicles as though they represent an incremental technological transition and will diffuse through the market accordingly. In addition, future patterns of use and ownership of cars are assumed to stay broadly the same in the coming decades.

This paper starts from the premise that the uptake of fully battery electric vehicles (BEVs) and plug-in hybrid battery

electric vehicles (PHEVs) (hereafter referred to collectively as 'EVs' unless otherwise stated), is preceded by a complex decision task for consumers in terms of how they acquire and pay for their car-based mobility and whether or not an EV fits with their values and symbolic motivations as well as meeting their functional requirements. In order to examine this premise, we report the results of part of a large scale programme of work in the UK, sponsored by the Energy Technologies Institute, to model the consumer response to EVs. In this paper we concentrate on two closely related strands of this work: (i) the systematic review of theoretical and empirical studies in the area of car purchasing in general and EV adoption more specifically; (ii) the preliminary results from a field study conducted in 2010 using a unique two-wave research design in which 2,729 respondents completed both waves.

The aim of this paper is to promote discussion on how the challenges presented by this novel technology can be addressed by both academic research and commercial marketers of EVs, particularly given dynamic consumer preferences and attitudes. Secondly, the preliminary results suggest that symbolic motivations of consumers may be more important than instrumental or demographic factors in explaining EV adoption, especially among the early market. Evidence for this will be presented together with indications that there is more than one early group of adopters of electric vehicles as well as a variety of mainstream consumer segments, each with different motivations and propensity to adopt different types of technology.

Background

The literature review and empirical work upon which this paper is based is part of the Plug-in Vehicle Economics and Infrastructure [PiVEI] project commissioned and funded by the UK's Energy Technologies Institute[1] to develop and test pathways to a mass market adoption of electric vehicles in the UK. The programme of work involves a combination of consumer, infrastructure, economics and carbon modelling exercises. The 'Modelling the Consumer Response' work package has been designed to develop a model of attitudes to purchasing and behaviours when using plug-in vehicles as a function of the key factors affecting the consumer response. In relation to private consumers[2], this work package comprised a combination of:

- A systematic review of literature in the area of general car purchasing in general and EV adoption.
- Qualitative interviews of EV trial participants – 40 participants received familiarity training and the use of an electric vehicle (EV) for one week. In-depth, qualitative interviews were carried out pre- and post-exposure. This was the first UK electric vehicle trial to focus on mainstream consumers (rather than early adopters) and to study responses to both battery electric vehicles and plug-in hybrid electric vehicles.
- Questionnaire survey – a total of 2,729 respondents completed both waves of a two-part on-line questionnaire to elicit theoretically derived measures of instrumental, symbolic and affective attitudes relating to cars in general and EVs in particular as well as self-reported likelihood to adopt EVs.
- A choice experiment, carried out as part of the questionnaire survey, and used to develop a market simulation model of uptake.

This paper will firstly outline some of the key findings from the literature review before presenting the questionnaire development and survey results. The results of the qualitative phase are not reported in this paper, but it should be noted that the results were used to inform the questionnaire design. The choice experiment will also be reported separately. Also, due to the timing of the data collection, this paper concentrates on the literature review findings and only presents some preliminary quantitative results.

Literature review findings

Literature was sourced using systematic Boolean searches on electronic databases and 'snowballing' of published and grey literature using keywords related to (i) low emission/plug-in/hybrid or electric vehicles, combined with (ii) purchasing/recharging behaviour and motivations for car adoption. The literature fell into two broad categories:

1. Theoretical texts relating to individual models of decision making (including instrumental, symbolic and affective motives), technology diffusion or socio-technical transitions.
2. Empirical evidence based on (a) qualitative and conventional questionnaire surveys eliciting consumer attitudes and perceptions of (alternatively fuelled) vehicle attributes; (b) revealed and stated preference surveys of consumer behaviour regarding a variety of vehicle powertrains and (c) consumer responses to EVs before and after (small-scale) vehicle trials.

THEORETICAL FRAMEWORKS

The literature was examined in order to assess the theoretical models of individual and interpersonal decision making that could prove useful for further research into the uptake of EVs. In particular, the review set out to understand what these theories suggest may be the relative role of functional, affective and symbolic factors in EV choice and how the dynamics of consumption over space and time might be captured in empirical study.

The review discovered a very large body of material addressing consumer demand for the uptake of conventional vehicle technology and alternatively fuelled vehicles including EVs. Studies are largely dominated by economic modelling approaches using national data at the aggregate or individual levels or disaggregated data attempting to identify the factors that affect consumers' car buying behaviours in order to estimate market share (e.g. Axsen et al. 2009; Curtin et al. 2009; Element Energy 2009; Potoglou & Kanaroglou 2006; Dagsvik et al. 2002; Brownstone et al. 2000). However, sections of the literature expand or reject the notion of individual rational behaviour in favour of insights from theories originating in environmental or social psychology, behavioural economics, ecological economics, marketing or theories relating to the diffusion of innovations and social learning. The latter theories of

1. http://www.energytechnologies.co.uk/Home.aspx

2. Fleet consumers were also studied using qualitative methods, but these results are not discussed in this paper.

consumer choice and behaviour in social science tend to start (and remain focused) at the individual level by outlining such concepts as utility, preference, attitudes, morals and values. A key question is the degree to which preferences remain stable and how change in individual attitudes and social norms diffuse over time and space. Another issue is the extent to which social situations or collective behaviours are the result of individual actions alone with any role for larger institutions and 'other actors which configure the fabric and texture of daily life' (Shove 2010; see also Schwanen et al. 2011).

A (by no means exhaustive) categorisation of approaches used to study car purchasing behaviour, or which have potential to be used to examine the behavioural transition towards mass market uptake of EVs, are characterised in Figure 1. These theories are depicted here as falling within three interdependent levels.

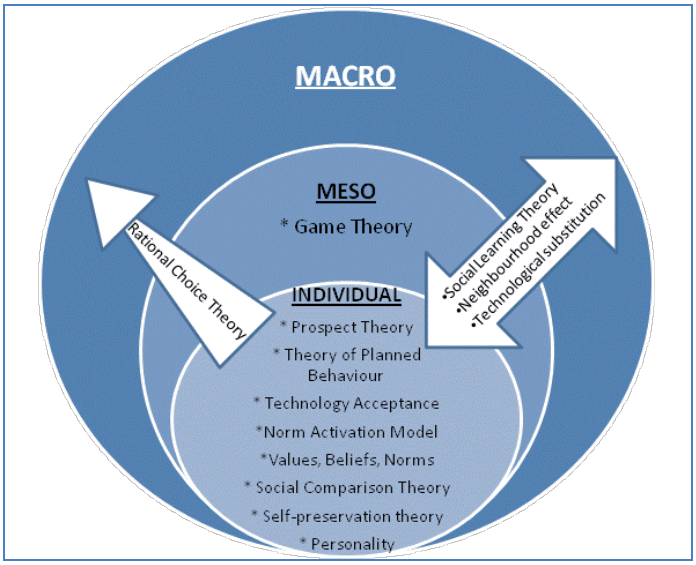

Figure 1: Levels and theories of behaviour change applied in the literature to EV adoption.

Individual level of behaviour change

In economics, Rational Choice (RC) Theory is the main theoretical paradigm used to understand the behaviour of individuals (or groups/organisations) and to explain collective (macro) outcomes. Hence the multi-level positioning of this theory in Figure 1. With respect to EVs, this theory assumes that individuals systematically consider car attributes and make rational cost-benefit analyses without reflecting on the worthiness of the goal, drawing upon the concept of procedural rationality where an outcome is reached by maximising personal advantage (Simon 1997). RCT provides a tool to conduct a wide variety of econometric modelling techniques whereby the application of discrete choice models derives coefficients to predict an implied monetary value per unit of change of a vehicle attribute.

This approach dominates the car purchasing literature including much of the recent literature on EV uptake. EV adoption is generally assumed to be more informed, take a longer time and involve more cognitive effort due to being a relatively infrequent act of significant financial and personal importance and is therefore often assumed to conform with the notion that people make a considered and rational evaluations of car makes, models and their attributes (Dagsvik et al. 2002; Brownstone et al. 2000).

In the context of EVs, understanding the role of rationality and conscious thought is key to designing appropriate research instruments and models that will, in turn, feed into private and public interventions designed to accelerate the transition towards this new technology. There are several variants of RC Theory which differ according to the degree to which the rationality criteria is 'bounded' (i.e due to financial constraints or limits of information processing) or subject to values and appeals to moral norms. The former definition lends itself to the study of positive economics whilst the latter tends to be linked with psychology. However, all variants of RC Theory assume individuals choose the best action according to unchanging and stable preferences and constraints. Consequently, there are elements of this theory that limit its application to car purchasing in general and EV adoption in particular.

Firstly, studies of car purchasing behaviour have discovered that only a small set of vehicle characteristics are used to make car choices so that consumers engage in limited economic rationality and employ rules of thumb or heuristics to make decisions (Anable et al. 2009; Turrentine & Kurani 2007; Simon 1997). These studies have also found that preferences are not stable and salient attributes often change considerably during the purchasing process. Secondly, individuals are likely to have asymmetrical information concerning cars, particularly in the early market for EVs, and are therefore unable to accurately assess their associated costs and benefits (Kurani et al. 2007). Linked to this is the idea that the majority of consumers do not have even the fundamental building blocks (such as knowing the mpg of their vehicle) to be able to make detailed payback calculations (Lane & Banks 2010; Anable et al. 2009; Heffner et al. 2007; Kurani et al. 2007; Turrentine & Kurani 2007). Thirdly, recent research has discovered that most consumers do have a general feel for how far they drive on a typical day, but nevertheless place a high premium on having the *option* to drive long distances (Element Energy 2009, Garling 2001; Golob & Gould 1998). Fourthly, EVs will have a number of unfamiliar attributes to consumers, including recharging and range, noise levels, safety and performance characteristics and a number of necessary unknowns concerning such factors as battery longevity, future electricity prices and government taxation policy. Finally, the results of the literature review suggest that models of car choice are likely to be inadequate without a proper consideration of impulsive or non-conscious processes including the role of affect (or emotion), identity, symbolism and personality – all constructs which are widely used in consumer research but are relatively absent from empirical studies of car purchasing. The assumption is that consumers attach an affective and symbolic meaning to certain objects such as cars, which is reflected in the identity of a person. Distinctions can be made between:

- the instrumental and functional use of objects (which themselves can take on symbolic meanings (e.g. fuel consumption)
- their emotional (affective) dimension, related to pleasure and the sensation of driving (Turrentine & Kurani 2007) and complexity and perceived risk (Thøgersen and Gärling 2001)

- their symbolic meaning, subdivided into two components: the person's position or social status and the expression of personal identity and values. Consumers can use an object as a means to express themselves or their social position (Dittmar 1992).

Symbolic motives have been studied in relation to vehicle choice, including electric vehicles, but not to the same extent as instrumental attributes. For example, households in California that have adopted non-plug-in hybrids (HEVs) as well as plug-in hybrid vehicles have been found to apply meaning such as independence from petroleum producers, advanced technology, financial responsibility, environmental and/or resource preservation and opposing war (Heffner et al. 2006; Kurani et al. 2007). In a study of state-wide vehicle sales data, Gallagher and Muehlegger (2007) estimate the effect of state and local incentives, rising gasoline prices, and environmental ideology on hybrid vehicle sales and find all three to be important. The appeal of (H)EVs for these early adopters is the belief that such a purchase would vividly demonstrate commitment to a cleaner environment and will act to offset some of the higher economic costs by conferring social benefits (Curtin et al. 2009). Similarly, using data on a community's share of green party voters as a proxy for community environmentalism, Kahn (2007) concludes that environmentalists are more likely to purchase HEV's than non-environmentalists.

However, somewhat in contrast to these findings, studies on vehicle purchasing behaviour in general tend to conclude that, in comparison with performance and capital cost, environmental benefits are relatively unimportant in the purchase decision (Anable et al. 2009; Lane & Banks 2010). Even where consumers are aware of a car's environmental performance, they are still unlikely to choose a car on this basis (Thatchenkery 2008). Nevertheless, in such cases, high fuel economy may be valued more for its symbolism than for its marginal financial value (Turrentine & Kurani 2007; Kurani et al. 2007). Therefore, it seems most likely that consumer interest in hybrid and EV technology, including the early adopters, is motivated jointly by concerns about the environment, increases in the price of fuel and a desire to be less dependent on petrol. Table 1 outlines a number of theories that attempt to extend or replace RC Theory.

Meso level of decision making

Since RC Theory is concerned with collective outcomes, a crucial question is how the micro and macro levels are linked. Often independent individual choices are simply aggregated. However, collective outcomes can arise from more complex transformation mechanisms. The meso level functions as a theoretical field where the structural mechanisms and interactions between macro and micro levels can be observed (Reid et. al. 2010).

One such mechanism based on RC Theory principles is Game Theory (GT), which analyses situations of strategic interdependence of rational actors (Von Neumann & Morgenstern 1944). In such situations, the outcome of an individual's behaviour also depends on the behaviour of others. In the case of EVs, a vehicle purchase is likely to be considered a household matter, which often implies an interpersonal decision making process (Davis 1976). Indeed, there are increasing calls for a better understanding of the household as a dynamic decision making unit, 'community of interest' and a 'reproducer of social structure' within the meso level (Reid et. al. 2010). In cases where household members do not initially agree about a purchase, perhaps due to a conflict in values or a disagreement on which option maximises their outcomes, a decision is likely to be preceded by a negotiation process. The underlining assumption is that each household member will attempt to maximise their position with each combination of game choice having an associated payoff. Although GT shares comparable limitations to RCT in that it assumes individuals are completely rational, the final decision is less likely to be regarded as optimising so much as 'satisficing' (i.e. adequate) (Simon 1997). This negotiation process is poorly understood in relation to car buying generally, but may be particularly crucial in predicting the likely uptake of EVs as the main or second family car and the subsequent negotiations that may take place about its usage patterns.

Macro level and dynamic processes

Consumer preferences cannot be considered to be static, particularly over the longer term. Increased market penetration will likely alter the way consumers value EVs and choose among them. In addition, consumers may use these vehicles differently to conventional vehicles. To capture this transition, sociological theories that stress the interpersonal environment offer key insights in to the attitude-behaviour link and account for the role of social factors, peer effects, social networks, imitative and learned behaviours not confined to the household sphere of connectivity. Consumers are also influenced in less direct ways by observing others in their social network and acquiring information and even attitudes and emotions which go on to determine perceptions and behaviour. Theories which capture this dimension of behaviour are outlined in Table 2.

EMPIRICAL EVIDENCE

Given that plug-in vehicles are novel technologies that mainstream consumers have no experience of, a surprising amount of relevant literature was discovered in the search. However, it is overwhelmingly dominated by the rational economic approach. This 'evidence' points by definition to the economic and instrumental barriers to EV uptake and is being directly translated into policy making in this area (e.g. the discussion on the need for publicly funded recharging infrastructure and economic incentives to consumers).

However, closer examination of the literature, particularly recently emerging vehicle trials, suggests that the barriers to uptake and the processes and speed of diffusion are likely to be more complex and slower than the econometric approaches suggest. For instance, more in-depth approaches reveal the lack of compromise around the option of being able to travel outside of daily normal range or use a car at short notice (Golob & Gould 1998; Gärling 2001; Element Energy 2009); the importance of complexity and perceived risk (Thøgersen & Gärling 2001); the degree to which fuel efficiency is systematically evaluated (Anable et al. 2009); the potential importance of public charging infrastructure to diffuse public awareness of EVs and instil confidence in the technology (Carroll & Walsh 2010; Tepco R&D Centre, cited in Element Energy 2009); the fact that many consumers are attracted to the idea of having their own

Table 1: Summary of the main theoretical 'backdrops' used to examine car choice behaviour – individual level theories.

Theory/ approach	Application to EV adoption
Prospect Theory(Kahneman & Tversky 1979)	
When consumers decide between alternatives that involve risk, they compare outcomes against certain reference points or 'rules of thumb' (see Anable et al. 2009) and attach extra value to attributes they are familiar with compared to similar items owned by others. Value is assigned to gains and losses relative to these benchmarks rather than to final outcomes. Losses tend to be given more weight (value) than gains.	Important for the early EV market as the theory proposes that people underweight outcomes deemed merely probable and overweight those deemed certain. Our review found a limited application of this theory to EVs (Axsen et al. 2009; Mueller & de Haan 2009), but it could offer a useful way of thinking about how consumers may trade perceived losses (e.g. range and practicality) against gains (e.g. fuel efficiency), particularly in an immature market when uncertainty is high.
Theory of Planned Behaviour (Ajzen, 1991)	
Behaviour is predicted by intentions, which in turn are predicted by three primary determinants (i) beliefs about consequences and their positive or negative evaluation (attitudes) (ii) perceptions influenced by others (normative beliefs) and what is believed to be approved by 'significant others' (subjective norms)) (iii) perceived ease or difficulty (control beliefs) and conviction that one can successfully execute the behaviour (perceived behavioural control).	Most common attempt to move away from purely economically rational approaches to incorporate socio-psychological factors. The TPB has been widely applied to consumer purchasing decisions in general and with direct reference to low carbon cars (Lane and Potter 2007).
Technology Acceptance Model (TAM) (Bagozzi et al. 1992; Davis 1989).	
This model adapts the TPB by replacing behavioural choice with usage of new technology and having two primary factors which determine intention to use: perceived usefulness and perceived ease of use of the technology	No references were found applying this model to EVs.
Norm Activation Model (NAM) (Schwartz 1977) and Values, Beliefs and Norms Theory (VBN) (Stern et al. 1999)	
Consumer behaviour is determined by values, personal norms, problem awareness and perceived responsibility. First, values can direct consumers' attention to products with similar meanings to the human values, and second, the effect of the human value could be transferred to the evaluation of the product meaning. E.g. An individual's preference for the value `prestige' would direct his or her attention to cars that have meanings similar to prestige and would contribute favourably to his or her positive evaluation of it.	Jansson (2009) applies VBN in the context of alternatively fuelled vehicles to examine the mediating effect that values, environmental beliefs, awareness of consequences and the ascription of responsibility have in activating personal moral norms *vis a vis* personal capabilities. He concludes that 'high involvement' green purchase decisions, such as alternatively fuelled vehicles, can be viewed as morally based. However, Allen & Ng (1999) also conclude that values affect choice by two routes through importance attached to individual attributes and through symbolic meaning
Personality McRae & Costa, 2003)	
The Five Factor Model of personality (openness, conscientiousness, agreeableness, extraversion, neuroticism) is often employed to understand how early an individual adopts an innovation ('innate innovativeness'). Miller (2009) has argued that the symbolic meanings of consumer products represent conscious or non-conscious signals to others about the user's personality traits	Garwood and Skippon (2010) found driving an EV signals high openness, high conscientiousness and high agreeableness. Choo & Mokhtarian (2006) investigated 'adventure seeker', organiser, loner and calm personalities and concluded that personalities spread somewhat more evenly across vehicle types than attitudes, but that adventure seeking tendencies can be predictive of car choice behaviour.
Social Comparison Theory (Festinger 1954)	
People continuously compare their opinions, behaviour and possessions with those of others and that people strive to be better off than others are.	No references were found applying this model to of EVs.
Self Preservation Theory (Schlenker 1980)	
People try to present themselves in a way that is congruent with their self-image, which implies that people may get a sense of personal identity from driving their car	No references were found applying this model to of EVs.

Table 2: Summary of the main theoretical 'backdrops' used to examine car choice behaviour – interpersonal or societal level dynamic processes.

Theory/ approach	Application to EV adoption
Social Learning Theory (Bandura 1977)	
The 'social' in SLT refers to the context within which learning occurs but, most importantly, SLT assumes people exist in a two-way relationship with their environments.	SLT was only found to be applied indirectly to car purchasing by being encapsulated in the Neighbourhood Effect:
Neighbourhood effect, 'Spillover', Threshold models (Granovetter 1978)	
The neighbourhood effect is the tendency for consumer preferences to change as technology becomes more prevalent in the market (also known as 'spillover'). Similarly, Threshold Models assume an individual's decision to participate depends on how many others have already decided to join in that behaviour. E.g., many buyers value diversity in the marketplace so that the more vehicles there are available, the more satisfied the consumer will be.	An EV consumer may want to have a critical mass of companion owners in order to guarantee reliability and widespread repair capability and may want a sufficient choice of makes and models available to them (Santini & Vyas 2005; Element Energy 2009). This captures the changes in social concerns, increased credibility and learning from others with more experience as well as marketing, education and shifts in social norms as the adoption rate increases. There have been a few attempts in the EV literature to explore these effects and model them. (Mau et al. 2008; Axzen et al. 2009; Heutel & Muehlegger 2009).
Technological Substitution Theory / Diffusion of Innovations (DOI) (Rogers 1962)	
This suggests the pattern of adoption of a new technology over time will follow a cumulative normal distribution as, faced with a new product, consumers can be classified into five categories: innovators, early adopters, early majority, late majority and laggards each influenced by 5 dimensions: (i) relative advantage (over the entity it supersedes), (ii) value compatibility (with the adopter's values, needs and experiences), (iii) complexity (how difficult it is to understand and use), (iv) trialability (can it be tested without or with limited costs) and (v) observability (influences the likelihood that *others* will adopt).	Many believe the classification by Rogers offers the most promising starting point for segmenting the potential EV market and that their early uptake will be characterised by the relatively small group of innovators and early adopters (Thøgersen & Gärling 2001). The former pursue new technology vigorously and will make EVs visible to the wider public, be opinion leaders to their peers whilst also providing feedback on improvements necessary for the second generation of EVs. However DOI theory is more descriptive than predictive.

source of fuel at home and to reduce the nuisance cost of refuelling at petrol stations etc (Kurani & Turrentine 2007) but that the majority of early adopters of EVs adopt a multi- car solution to optimise range and recharging time and have the option of a non-electric vehicle (Gärling 2001).

However, regardless of the approach used, the novelty of plug-in vehicle technology presents a significant challenge to the investigation of the consumer response to such vehicles and commands innovative survey techniques. Asking consumers to predict their interest in a radically new product that does not yet exist in the marketplace can result in notoriously inaccurate assessments. Since consumers have virtually no experience with EVs, it is unlikely that many can predict whether they will buy one until they become more familiar with the new technology and can imagine how they might integrate it in to their lifestyle and identity structure. The next section of this paper outlines the methodology and preliminary results of a large scale quantitative study which attempted to incorporate many of the theoretical constructs and consumer attitudes to EVs identified in the literature review.

Questionnaire survey findings

The aim of the questionnaire survey was to identify the characteristics of those consumers most likely to adopt a BEV or PHEV in the UK in the near term (next 5-10 years) but also to understand the characteristics and preferences of mainstream consumers as the market begins to mature. The survey was designed by incorporating findings from the literature review (i.e. the theoretical constructs that might be most useful to inform an understanding of the characteristics of EV adopters) and the specific attitudes expressed about EVs in the 22 interviews of those involved in the household trials (as outlined above). The data is used to identify the instrumental, affective, symbolic and contextual (i.e. demographic) factors most closely associated with a self-reported likelihood to adopt a BEV or PHEV, and to segment the market using statistical clustering techniques.

SURVEY METHODOLOGY

The two-wave survey design

Assessment of consumers' preferences for 'really new' product categories can be methodologically challenging (Hoeffler, 2003). Construal Level Theory (Liberman, Trope & Stephan, 2007; Trope & Liberman, 2003) proposes that 'psychological distance' affects the level of abstraction with which a product is construed. An object is psychologically distant when it is detached from a person's direct experience: the more psychologically distant an object, the more it is construed in high-level, abstract terms, rather than low-level, concrete terms. This suggests that research in which participants have not experienced EVs may be subject to large uncertainties. In relation to consumer choices, Unconscious Thought Theory (Dijksterhuis & Nordgren, 2006) suggests that consumers make 'better' decisions when information has been non-consciously processed than when they engage in conscious deliberation. 'Better' has

been operationalised as closeness to normative decisions (Dijksterhuis & Nordgren, 2006) and as post-choice satisfaction (Dijksterhuis, Bos, Nordegren & van Baaren, 2006).

In a study on this scale, it was not practical to provide direct experience of the vehicles to all participants. Instead, psychological distance was reduced by providing information about HEVs, PHEVs and BEVs to participants in Wave 1 and building in a two-day interval before Wave 2 of the survey. The interval provided an opportunity for non-conscious processing during which information could be integrated in long term memory with other semantic knowledge (about self, lifestyle, cars, driving, the environment, etc.). The delay also gave participants the opportunity to further explore publicly available information about plug-in electric vehicles, which mimics real life behaviour during the car purchase process. Whilst information alone cannot replace actual experience, it can allow the respondent to consider how the information may relate to them, their lifestyle and their travel requirements.

The material took approximately 5 minutes to read and was designed based on outputs from the qualitative thematic analysis and the literature review. The topics covered were those that emerged from the qualitative work (driving/power source, running costs, maintenance, noise level, range, refuelling and recharging, environmental impact). The aim was to provide respondents with key information that would be available to them in a more mature marketplace or after having had some experience of driving an EV or a PHEV.

Survey content

Wave 1 of the questionnaire consisted of sections on current car ownership, car use and general travel patterns, parking and charging capacity at home, attitudes towards owning and driving a car, attitudes towards new cars and technology including questions from the literature to test 'innovativeness' (Flynn et al 1996; Manning et al 1995; Roehrich 2004), personality characteristics (Nettle 2007), demographics and self-reported knowledge about EVs and likelihood to adopt a BEV or PHEV in the next five years as a main car and as a second car (i.e. four 'likelihood' questions were asked). This wave took about 20 minutes to complete, and was followed by the pre-read material. Wave 2 asked people whether they had spent time reading extra information about EVs, about their experience of using EVs, thoughts about plug-in cars in general, about PHEVs specifically and BEVs specifically. It then repeated the four 'likelihood questions' and how this might change in the light of various policy incentives, before finishing by asking about general attitudes towards environmental issues. This phase of the survey also included a choice experiment (not reported in this paper) and took about 20 minutes to complete on average.

Sample selection, survey administration and response rates

Before it was administered, the survey was tested by 18 participants selected to represent a spread of age, gender and socio-demographic bands. An on-line pilot survey was also undertaken with 101 completions of both waves of the survey. The survey was finally administered in October 2010 by an on-line market research company with access to a 750,000 strong panel of demographically diverse respondents throughout the UK. A screening question was used to allow only drivers who had purchased new or nearly-new cars (< 2 years old) within the last five years to complete the survey. This was to ensure that only those people who had recent experience of new car purchasing and associated decision making processes could respond. Participants were paid 50p (0.6 Euros) for completing the first wave of the survey and £3.00 (3.40 Euros) for completing the second wave. Invitations were sent to 49,501 individuals asking them to complete Wave 1. Of these, 4,240 completed it (8 %) and were sent an invitation two days later asking them to complete the second stage; 2,729 completed wave two, which gave a response rate of 65 % between the two surveys.

SURVEY RESULTS

This section will give a brief overview of the headline survey results as the analysis has not been finalised at the time of writing this paper. These results are split into four areas for discussion in order to assess both the methodology (the two-wave design and the inclusion on the survey of multiple theoretical constructs) and the early indications of the key antecedents of EV adoption for different consumer groups identified in this survey.

Likelihood of adoption and the impact of information and non-conscious processing

Before the 'pre-read' information was provided at the end of Wave 1, the majority of respondents felt uninformed about EVs, with less than 20 % feeling 'very' or 'quite' informed. Between the two waves of the questionnaires 25 % of the participants read additional information to that provided. A tiny majority claimed they had previous experience of a BEV or PHEV as a driver (<1 %) or passenger (3-6 %). Fourteen percent had some experience driving a standard hybrid electric vehicle (HEV), with 24 % having experience as a passenger.

In Wave 2,32 % of respondents said they are likely to choose a PHEV and 13 % a BEV as a main car in the next five years. The equivalent figures for a second car were 33 % and 17 % respectively. However, the results indicate that the processing of information between Waves 1 and 2 may have had an impact on attitudes to adoption. The results of a paired t-test[3] on the four likelihood questions completed by those respondents completing both waves demonstrates that the reported likelihood of adopting a PHEV as both a main and second car increased between wave one and wave two, as it did for BEV as a second car; however respondents reported likelihood *reduced slightly* for BEV as a main car (Table 3). For each car type, over 50 % of the sample changed their evaluation either up or down in each case. The proportions of people increasing or decreasing their likelihood score is shown in Figure 2.

These results are important for three reasons. Firstly the analysis indicates the difference in the likelihood to adopt two types of plug-in car technology. In Wave 2,32 % of respondents said they are likely to choose a PHEV and 13 % a BEV as a main car in the next five years. This result, combined with attitudinal and segmentation results from the study give a **strong indication that PHEVs and BEVs are perceived differently and are likely to be attractive to different people** (see segmentation results, below). This may tie in with experimental and qualita-

3. The paired t-test is used in before and after observations on the same participants (as in this study) to compare whether, in general, the effect of a particular intervention (in this case the information provision and time to assimilate) has led to a change on a particular measure (in this case the 'likelihood' scores).

Table 3: Comparison of likelihood of adoption between wave 1 and wave 2 (paired t-test).

	W1 mean* (sd~)	W2 mean* (sd~)	t#	Df^	p≤	Interpretation
PHEV main car	2.67 (1.11)	2.84 (1.14)	8.0	2728	.001	Higher intention in W2
PHEV second car	2.43 (1.18)	2.83 (1.15)	-18.0	2728	.001	Higher intention in W2
BEV main car	2.36 (1.07)	2.15 (1.10)	10.7	2728	.001	Lower intention in W2
BEV second car	2.24 (1.12)	2.31 (1.13)	-3.3	2728	.001	Higher intention in W2

* Likelihood to adopt was measured on a 5 point scale from 1 (very unlikely) to 5 (very likely); ~ sd = standard deviation (a measure of dispersion or spread around the mean). # t= test statistic (ratio of the difference between the sample means compared to the difference expected due to sample error); ^Df= degrees of freedom (tells you how much data is used to compute a statistic); p= probability that a statistic could occur due to sampling error and a result is gnerally said to be statistically signficant when the p-value is less than 0.05 or 0.01.

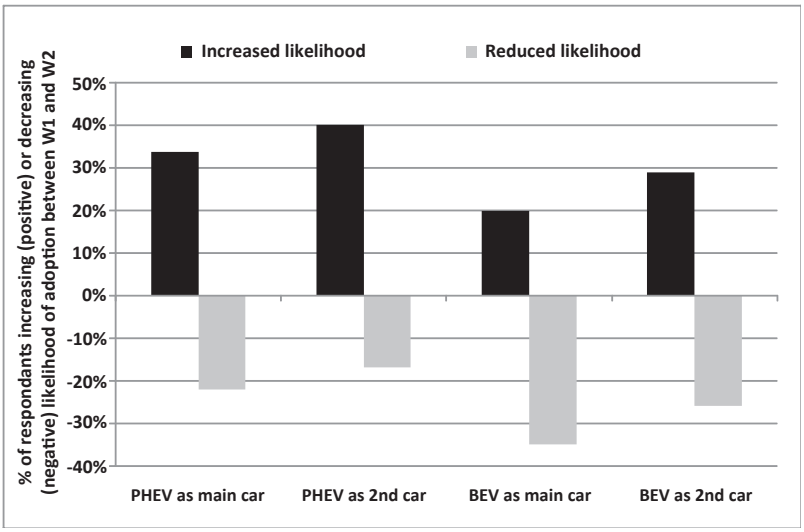

Figure 2: Percentage reducing or increasing their likelihood to buy between survey waves (n=2,729).

tive studies (mainly in the US) which have shown that consumers are likely to prefer PHEVs rather than BEVs as most are interested in high fuel economy and extended range provided by the hybrid operation (Kurani et al. 2007).

Secondly, it demonstrates the importance of differentiating between likelihood to adopt as a main car or additional car in the household. Whilst self-reported likelihood of adopting PHEVs was similar as a main and as a second car, **BEVs were more likely to be adopted as a second household car**. Even a quarter of those households who currently only have one car say they might adopt a PHEV as a second car (15 % for BEVs), thereby **indicating that EVs may be used in some cases to increase the number of cars per household**.

Thirdly, the change in self-reported likelihood between the waves is an indication of **how volatile opinions and preferences currently are in relation to EVs** and the challenge this poses for empirical work in this area. It is not possible to conclude definitively that the responses in Wave 2 are more valid than they would have been without the split design. However, theoretically this method allowed information about EVs to be integrated into long-term memory and facilitated non-conscious processing, so that it may better represent consumer choice processes in real world purchasing decisions. In addition, the fact that some respondents chose to supplement pre-read material with additional information is considered to reflect real market conditions where some people will choose to inform themselves more than others.

Underlying attitudinal constructs

In total, the questionnaire included 106 attitudinal questions which were derived from the qualitative work, and from the literature review. These statements covered six main issues reflecting broad conceptual dimensions around attitudes towards owning/driving a car, innovativeness, environmental values, beliefs about plug-in cars in general, beliefs about PHEVs and beliefs about BEVs. Exploratory factor analysis was used to uncover underlying psychologically meaningful constructs among these statements[4]. In factor analysis, variables that show similar patterns of variation across respondents are assumed to be associated with the same underlying construct. Table 4 shows how this resulted in 14 overarching factors capturing core issues around the practical concerns with EVs, general enthusiasm for the technology, a desire to own the latest technology in general and new car technology in particular and environmental values[5,6]. In addition, a few attitude statements

4. Principal components and Varimax rotation was used which is a method of finding uncorrelated sets of variables with the greatest variance. The threshold for factor loadings was set at 0.40 on the principal factor and a difference of at least 0.50 between subsequent loadings. Some items failed these loading criteria and were discarded before repeating the process.

5. Space is too limited here to include the full list of 106 attitude statements. The individual items and factor loadings are available from the corresponding author upon request.

6. A scale is internally consistent to the extent that items are correlated. Cronbach's Alpha provides a summary statistic to this effect. Alpha coefficients range from 0 to 1 and may be used to describe the reliability of each factor. Consistent with the literature, 0.7 was considered to be an acceptable reliability coefficient. In each

Table 4: Underlying attitudinal constructs discovered through factor analysis.

Factor Label	Interpretation	No. of Attitude statements	Cronbach's Alpha
Innovativeness	A desire to own and be seen with the latest technology	3	0.89
Environmental Identity	Concern for and identity with environmental issues	9	0.88
EV Openness	Desire for oil independence & excitement about EV technology	6	0.87
EV Positives	Belief in environmental and general benefits of BEVs/PHEVs	7	0.85
EV Instrumental	Belief in reliability and economy compared to 'normal' cars	5	0.84
EV Symbolic	Embarrassment/ pride in owning and driving an EV	4	0.82
Car Symbolism	Belief that cars are an expression of personality and status	3	0.82
EV WTP	Willingness to pay more for EVs and environmental benefits	3	0.82
BEV Anxieties	Concern about some of the practical aspects of BEVs	6	0.82
PHEV Anxieties	Concern about some of the practical aspects of PHEVs	6	0.80
Driving Affect	General enjoyment of driving and emotional aspects	4	0.75
EV Affect	Beliefs about performance and driving experience of EVs	7	0.70
EV Infrastructure	Desire to wait for rapid charging infrastructure	2	0.69
Car Authority	General car enthusiasm/ self proclaimed knowledge about cars	4	0.69
Single Item variables			
PHEV Identity	Association with other people who are likely to own PHEVs	1	n/a
BEV Identity	Association with other people who are likely to own BEVs	1	n/a
WTP for fuel economy	Willingness to pay more for a car with high fuel economy	1	n/a
MPG satisfaction	Satisfaction with mpg of current car	1	n/a
Parking concern	Perceived ease of finding somewhere to park/ charge at home	1	n/a
EV Safety	Perceptions of safety of EVs for driver and passengers	1	n/a
BEV Noise	Perceptions of safety of EVs for those outside the car	1	n/a

did not load on to any of the factors but stand alone as single item measures of specific issues such as the willingness to pay for low fuel costs, parking/charging availability at home, safety etc. The factors are a very valuable set of internally consistent constructs to be used in further analysis to understand consumer perceptions and motivations.

Predictors of 'likelihood' of adoption

Exploratory stepwise regression analyses[7] were used to identify sets of attitudinal and demographic variables which together provide useful estimates of the degree to which these factors are predictors of the self-reported likelihood to adopt a PHEV or BEV[8]. Table 5 summarises the results from the four regression analyses showing the most important factors in each case (in rank order according to their contribution to the variability in likelihood), with the demographic factors that remained significant highlighted in bold.

Overall, a common finding across each of these four scenarios is that **attitudinal factors are stronger predictors of likelihood to adopt than demographic factors** including income, total cars in the household and the availability of parking and charging at home. It is also noteworthy that the specific desire for rapid charging infrastructure comes far down the list or does not appear to be significant.

The attitudinal or demographic characteristics which explain the likelihood to adopt were found to be different depending on whether we look at PHEVs or BEVs and adoption as a first or second car. For adoption as a main car, **anxiety (e.g. about running out of charge) and identity (knowing others who would be attracted to PHEVs/BEVs) are the strongest predictors** (i.e. high anxiety leads to low likelihood to adopt), followed by a general openness and excitement about the technology, willingness to pay (for lower running costs for PHEVs or a general willingness to pay extra for the technology in the case of BEVs) and environmental values. The only demographic variable that appears as significant is gender where **men are more likely to be attracted to BEVs**.

For adoption as a second car, **identity and anxiety are still the strongest factors. However, some more practical factors also appear to be important, including capacity to charge at home and whether or not a household currently has a second car.** For PHEV as a second car, identity, capacity to charge at home, belief in the positives of EVs and EV affect (how good it would be to drive) are the main predictors. For BEVs as a second car, anxiety, and willingness to pay still dominate, followed by symbolism (how embarrassed one would feel to own) and general openness to the technology.

case, items which did not appear to be measuring the same construct thereby causing a lower alpha value were deleted.

7. In this case, the proportion of variance in the dependent variable (EV adoption) accounted for by each explanatory variable is assessed one by one in an iterative process. If each additional variable contributes to the model then it is retained, but all other variables are then re-tested to see if they are still contributing to the success of the model. This method provides a greater likelihood of ending up with the smallest possible set of explanatory variables being identified as relevant.

8. The choice of variables to include was based on extensive prior analysis to understand relationships/ correlations between independent variables and 'likelihood to adopt' and tests of linearity and multicollinearity. This had given some preliminary indication of which variables were potentially important predictors of EV adoption. Explanatory variables should be correlated with the dependent variable, but not strongly correlated with the other explanatory variables. This is the reason for the factor scores being used in the regression (which were derived in order to not be correlated with each other). By including all of the variables in one model, it helps overcome the risk that the effect of one variable (e.g. income) is confused with the effect of another (e.g. willingness to pay for fuel economy). Based on the prior analysis, there was no reason to assume that the relationships between the dependent variable and each explanatory variable were anything other than linear. The prior analysis had found some non-linear relationships between the income and age and some attitudinal variables. However, the failure of linearity in regression does not invalidate the analysis so much as weaken it.

Table 5: Ranking of significant predictors of 'likelihood' resulting from each of four stepwise regression analyses (demographic factors in bold).

PHEV (Main)	PHEV (Second)	BEV (Main)	BEV (Second)
1. PHEV Identity	1. PHEV Identity	1. BEV Anxiety	1. BEV Anxiety
2. PHEV Anxiety	2. Parking concern	2. BEV Identity	2. EV WTP
3. WTP fuel economy	3. PHEV/BEV Positives	3. EV WTP	3. EV Symbolism
4. EV Openness	4. EV Affect	4. EV Openness	4. EV Openness
5. EV Positives	5. EV Openness	5. EV Symbolism	5. EV Positives
6. Environmental identity	6. PHEV Anxieties	6. PHEV/BEV Positives	6. Car Authority
7. EV WTP	7. EV WTP	7. Environmental Identity	7. Environmental Identity
8. EV Symbolism	8. Car Authority	8. Car Authority	8. Parking concern
9. EV Affect	9. Environmental identity	9. Innovativeness	9. Innovativeness
10. EV Infrastructure	10. Innovativeness	10. EV Affect	10. EV Affect
11. Innovativeness	11. EV Symbolism	11. Driving Affect	11. EV Instrumental
12. Car Authority	12. EV Affect	**12. Gender**	12. Car Symbolism
13. Parking concern	**13. Total cars in household**	13. WTP fuel economy	**13. Total cars in household**
	14. EV Infrastructure		14. Current mpg satisfaction
	15. Car Symbolism		15. EV Infrastructure
	16. Employment status		

Potential consumer segments

More analysis is being undertaken to understand the relative importance of these factors. In particular, the combinations of factors which are important or salient for different groups of people and how this relates to likelihood to adopt EVs will be an outcome of the segmentation analysis for this study. Unfortunately this is not complete at the time of writing this paper. A combination of a-priori techniques (to separate company car drivers and a very small niche early adopter group) and post-hoc analysis applying cluster analysis to the majority of the variables outlined in Table 5 has discovered eight consumer segments. Each of these represent a unique combination of self-reported likelihood to adopt a BEV or PHEV and differ in terms of average perceptions, anxieties and the importance attached to symbolic, affective and instrumental factors in relation to car ownership and use.

The groups represent (i) a very early adopter group (Plug-in Pioneers) (ii) an early adopter of plug-in vehicles generally (Zealous Optimists) (iii) and of PHEVs specifically (Willing Pragmatists) (iv) a group enthusiastic about both types of EV but who have strong actual and perceived constraints to adoption (Anxious Aspirers) (v, vi, vii) three sceptical groups who differ on the degree to which they care about image and in terms of their demographic characteristics (Uninspired Followers, Conventional Sceptics; Image-conscious Rejecters) (viii) Company Car Drivers who show signs of openness towards EVs, particularly PHEVs and particularly as a second car.

The top five factors which distinguish the groups most strongly from one another include (i) 'Identity', which captures the degree to which people feel they associate with 'typical' EV owners (ii) 'Anxiety' which captures the perceived suitability of these vehicles particularly in relation to range and the 'hassle' factor (iii) 'parking difficulty' specifically relating to the perceived ease of being able to charge a vehicle at home (iv) 'willingness to pay' more for plug-in technology or environmental benefits (v) 'symbolic motives' which capture the perceived status, social acceptability and embarrassment or otherwise of owning an EV.

The most enthusiastic segments tend to be largely male, wealthier and more highly educated than the sample average. Age is a more complex predictor of segment membership with the Plug in Pioneers and the Company Car drivers being the youngest of all groups, but the Willing Pragmatists and the Zealous optimists being older. The four less enthusiastic segments are more diverse with a mixture of male and female and old and young profiles. However, they consistently tend to be less wealthy and educated than the more enthusiastic groups.

Whilst demographic factors such as income, education, gender and employment status are important variables on which to profile each group, overall the analysis has shown that demographic characteristics are insufficient for predicting and understanding the various EV adopter groups. Profiling the segments on variables such as identity, anxiety and symbolic motivations has enabled a deeper understanding of their underlying belief structures and motivations. The process has proven invaluable in understanding why people with the same or similar current behavioural patterns and demographic characteristics can behave in very different ways and respond to different stimuli in relation to EV adoption.

Discussion and conclusions

Plug-in electric vehicles are novel technologies of which mainstream consumers have very little experience and knowledge. This presents a methodological challenge in any attempt to predict their likely uptake and the policy incentives that would be most effective in transforming the car market. Equally, theories of behaviour change at the individual, meso and societal levels reviewed as part of a systematic literature review highlight that consumer preferences cannot be assumed to be static, particularly over the longer term. EVs are 'disruptive': they require a significant shift in behaviour by consumers. The literature suggests that the early adopters of EVs do not necessarily hold the key to understanding the early majority and thus it is important to understand the potentially unique characteristics of each group of EV consumers in order to more accurately inform those interested in the development of the EV market (e.g. the Government, vehicle manufacturers and energy suppliers).

The collection of a large scale, two-wave attitudinal survey measuring theoretically based antecedents to car and technology choice and based on prior qualitative work has confirmed the current volatility of attitudes towards EVs. Providing consumers with information about EVs and giving this time to be integrated in long term memory, and processed non-consciously, appeared to have a significant impact on consumer

preference, largely improving consumer outlook towards EVs, particularly PHEVs. This research has also confirmed the presence of a number of segments who are currently at the same stage on the 'adoption curve' but are motivated by different factors and are therefore likely to move towards adoption at different rates. In other words, the process has distinguished between people who may have relatively similar *current* behavioural patterns, demographic characteristics and even similar expressions of likelihood to adopt EVs, but seem likely to respond to different stimuli in relation to EV adoption and end up with very different *future* patterns. Further profiling the segments on these variables will enable a deeper understanding of the underlying belief structures and motivations of each group.

Different people appear to be attracted to PHEVs and BEVs, each for different reasons, the former more likely a product of a desire to be fuel efficient and the latter more a product of a willingness to pay for the technology for its own sake or for environmental reasons. This suggests that the optimal solution is likely to be a range of low carbon vehicle technologies with different configurations of all-electric range which offer various degrees of high fuel economy at a range of prices to appeal to a number of segments. What is clear is that in all cases attitudinal factors, particularly relating to symbolic motives, identity or specific attitudes about the technology are stronger predictors of the likelihood to adopt than demographic factors.

The results presented in this paper are preliminary and require further analysis. Nevertheless, clear indications are emerging, many of which confirm theoretical and empirical findings in the area of car purchase behaviour, about the inadequacy of approaches which focus on rational choice theory and instrumental and functional motives of car choice. The clearest conclusion is the need for innovative approaches to the study of EV uptake, particularly those that can investigate more than one plug-in vehicle technology, achieve large enough sample sizes to be able to segment the market and, ideally, can build in a temporal element to understand the dynamic processes of attitudinal and behavioural change in this area.

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