Consumer responses to Electric Vehicles Literature Review

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List of acronyms and abbreviations used

BEV	Battery electric vehicle
CNG	Compressed Natural Gas
EHC	English House Conditions Survey
EV	Electric vehicle (used as a generic term to refer to BEVs, PHEVs & REEVs)
HEV	Hybrid Electric Vehicle
GHG	Greenhouse gas
ICE	Internal combustion engine
LEV	Low emission vehicle
NTS	National Travel Survey
PHEV	Plug-in hybrid electric vehicle
REEV	Range Extended Electric vehicle
RP	Revealed Preference
SP	Stated Preference
VED	Vehicle Excise Duty
V2G	Vehicle to Grid

In the following report, the term “Electric Vehicle (EV)” is used generically and captures both BEVs and PHEVs, if making a distinction is not necessary. Non plug-in (HEVs) are labelled as such. Descriptions of studies which specifically refer to BEVs or PHEVs use these acronyms.

Executive summary

The scope of the systematic literature review was not restricted to literature relating only to plug-in vehicles, since such literature is limited as a result of the limited commercial availability of electric vehicles. Studies focusing on other vehicle technologies can provide valuable insight into consumer preferences.

The search strategy involved identifying relevant search terms through reading key papers and consulting among the wider project team. A number of search key words were identified and used to search five databases for qualitative, quantitative, theoretical or review articles.

The search for evidence regarding the consumer response to electric vehicles generated approximately 160 pieces of literature of which 88 were taken forward for review after a three-stage selection process. Four broad categories of literature were found:

- revealed and stated preference surveys of consumer behaviour
- qualitative and conventional questionnaire surveys eliciting consumer attitudes and perceptions
- evidence of consumer responses to EVs before and after small-scale vehicle trials
- theoretical texts relating to socio-technical transitions, symbolic behaviour and consumer segmentation.

The greatest proportion of literature was in the form of stated and revealed preference surveys. The state of the evidence on consumer adoption of electric vehicles revealed some key observations, including:

- There is mixed evidence on the role that purchase price plays in the acquisition of (H)EVs and the premium which certain segments may be prepared to pay to own an electric vehicle. Consumer responses to the greater price premiums of plug-in vehicles in terms of purchase probabilities is generally greater than can be justified based on purely economic rationale.
- There is likely to be a more useful, finer grained segmentation than the most commonly used ‘early adopter/ early majority’ groupings.
- There is clear evidence to suggest that most consumers do not even have the fundamental building blocks to be able to make detailed payback calculations.
- Rising oil prices may lead to more economically rational considerations, but the speed of price increases and the relative cost of different fuels have greater influence.
- Fiscal incentives need to be designed so that they are conceived separately from the purchase price but purchase and tax incentives are likely to be less important than the relative costs of fuel.
- Other incentives, such as parking, congestion charge and HOV (for explanations of all abbreviations used in this report, please refer to the list of abbreviations preceding this Executive Summary) benefits are likely to be less important than purchase price incentives and highly context dependent.

- Studies have generally found the lack of recharging infrastructure to be less of a concern to consumers than range per se. Experience and knowledge does not change desired vehicle range.
- Trial data consistently shows users are over cautious when planning journeys, using a fraction of available range and charging frequently.
- Public charging infrastructure is not the biggest barrier to uptake and public 'slow' charging facilities will be of limited functional value. However, charging infrastructure will have an important function to diffuse public awareness of EVs and instil confidence in the technology.
- Uncontrolled patterns of recharging are likely to be highly varied at the disaggregate level and there is very little evidence to illuminate the potential impact of tailored electricity charging tariffs and smart (controlled) charging.
- Many consumers are attracted to the idea of having their own source of fuel at home and to reduce the nuisance cost of refuelling at petrol stations.
- Evidence from the USA and limited evidence from the UK suggests that PHEVs may be more popular than BEVs given the attractiveness of high fuel economy and extended range provided by blended operation.
- Consumers tend to have negative perceptions regarding EV's performance but these are often greatly improved even after a very short exposure to a vehicle. However, it is possible that longer exposure to a vehicle exacerbates negative perceptions of issues such as range and reliability.
- Models of car choice are likely to be inadequate without a proper consideration of symbolism and identity. EVs have been found to be associated with meanings such as lower resource consumption, independence from petroleum producers, advanced technology, financial responsibility, saving money, opposing war as well as environmental and/or resource preservation.
- Environmental benefits are only one of many symbolic meanings attached to EVs and may play an important role for only a small minority of consumers.
- Various personality traits such as innovativeness, narcissism and openness may also be associated with early EV adoption.
- No conclusions can be drawn as to whether the early adopter groups of EVs are likely to have similar traits to current hybrid and EV owners.
- One of the strongest influences on uptake will be the 'neighbour effect' as EVs become more widespread and consumers become influenced by others and more confident in the technology.
- It is likely that households will adopt a multi-car solution to optimise range and recharging time and the choice of which vehicle to use and it is possible that consumers may use and drive EVs differently to conventional vehicles.
- There is very little evidence regarding the decision making processes of public and private fleet purchasers.
- There is very little evidence on: (mis)perceptions of the various powertrains (HEVs, PHEVs, BEVs, REEVs); various safety concerns such as safety ratings, the volatility of the battery upon impact in an accident and perceived safety of charging arrangements; concerns around the availability of maintenance expertise and breakdown cover in emergency

situations; feelings in relation to battery disposal and lifecycle costs; consumer perception of other costs such as such as battery replacement and resale value; expectations around electricity prices vis-à-vis oil prices and the potential response to different charging tariffs; acceptability of controlled/ smart charging and V2G technology; different models of car and battery ownership and finance; emotional reactions such as how a car feels to drive and the pleasure gained from the experience; issues around identity and who is expected to own and use EVs; potential geographical 'hotspots' from which a shift in consumer behaviour towards EVs will diffuse. This would relate to the settlement types and neighbourhoods most conducive to uptake.

Some of these issues and omissions have already been picked up in the qualitative interviews undertaken with 'long exposure' participants and may also arise during the subsequent qualitative work.

1 Summary of the main findings

Plug-in vehicles are novel technologies of which mainstream consumers have no experience. This presents a significant challenge to the investigation of the consumer response to such vehicles. This systematic review of the international evidence provides a solid understanding of consumer behaviour relating to the uptake of cars in general and EVs (including fully electric, plug-in hybrid and range extended electric vehicles) in particular. This will underpin future primary data collection being undertaken as part of the Consumers and Vehicles sub-project of the ETI Plug-in Vehicle Economics and Infrastructure programme.

1.1 The state of the evidence

The search for evidence generated approximately 160 pieces of literature of which 88 were taken forward for review. The literature falls into four broad categories. These include: (i) revealed and stated preference surveys of consumer behaviour regarding a variety of vehicle powertrains; (ii) qualitative and conventional questionnaire surveys eliciting consumer attitudes and perceptions of vehicle attributes, alternatively fuelled vehicles and policy incentives; (iii) evidence of consumer responses to EVs before and after small-scale vehicle trials; and (iv) theoretical texts relating to socio-technical transitions, symbolic behaviour and consumer segmentation.

The evidence is largely dominated by rational, economic modelling approaches using national data at the aggregate level or individual, disggregate level which attempts to identify the factors that affect consumers' car buying behaviours, in order to estimate market share. However, sections of the literature reject such approaches or at least supplement them with insights from theories utilising environmental or social psychology, marketing, or models of transitions or social learning.

1.2 The UK car market

In 2009, non-private registrations (business and fleet) accounted for 49% of all new cars registered in the UK. A significant proportion of the non-private sector comprises individuals with a large degree of autonomy over their choice of company car ('user choosers'). Only 5% of households acquire a new car in any given year. Those in managerial and professional jobs are most important to the retail car market as they account for just over 40% of new cars currently owned and for 40% of new car purchases.

1.3 The relative importance of functional, affective and symbolic motives

There are a number of different types of factors, economic and non-economic, that influence how and why cars are purchased. Many of these are common to all powertrains, but some, such as availability of charging infrastructure, are specific to EVs.

In recent surveys examining general car purchasing behaviour which, ask people to rank the vehicle attributes most important to them, respondents tend to assign approximately equal importance to a number of attributes of the vehicle. These include size, style, reliability and comfort in addition to fixed and variable cost attributes, such as purchase price, fuel consumption/running cost. According to these studies, of less importance are attributes such as impact on the environment and resale value. Used car purchasers pay more attention to price, reliability and fuel consumption and new car buyers place more emphasis on safety, style, design, comfort and quality.

There is mixed evidence on the role that purchase price plays and the premium which certain segments may be prepared to pay to own a fuel efficient or an electric vehicle. Overall, studies have found a good deal of interest among consumers for EVs, particularly PHEVs, as well as a good deal of resistance based on the estimated cost of this new technology. The high price of EVs has been noted as a main barrier to uptake in a few surveys and modelling evidence based on stated preference experiments suggest that purchase price has the greatest influence on car choice. However, consumer responses to increasing price premiums of plug-in vehicles in terms of purchase probabilities is generally greater than can be justified based on purely economic rationales. This means that consumer acceptance is not solely determined by costs as emotional and other non-economic and functional factors influence the likelihood of future purchases.

It is likely that early adopters of EVs will be willing to pay more for their purchase and many may not even compare the price difference with conventional vehicles. However, there is also likely to be more than one early adopter segment, most of which are driven by economic considerations in their own way. These include being less dependent on volatile oil prices, cash flow analyses rather than detailed payback calculations, and the high value placed on saving time refuelling and possibly parking or driving in High Occupancy Vehicle (HOV) and bus lanes.

Clear evidence exists to suggest that most consumers do not even have the fundamental building blocks to be able to make detailed payback calculations. This is set to be exacerbated when fuel costs are subsumed in to electricity bills. Studies in the US show that drivers of PHEVs omitted their grid-based electricity use when discussing fuel economy even though many in-vehicle displays indicated the consumption of both sources of energy. In terms of consumer perception of other costs such as such as battery replacement costs and resale value, there is nothing to be gained from the literature on these factors.

However, rising oil prices may lead to more economically rational considerations, particularly if these prices rise rapidly. In particular, consumers are likely to pay attention to the *relative* costs of different fuels. In summary, the evidence review suggests that whilst there is no question that widening the gap between electricity prices and fuel prices will make EVs more attractive, policy makers and modellers may have a tendency to over-emphasise the importance of rational deliberation of longer term running costs and payback periods.

1.4 The importance of range and recharging infrastructure

Similar conclusions apply to recharging behaviour where patterns may not be driven by cost savings but more by convenience. The most comprehensive evidence to explore the issue of range and refuelling behaviour has emerged from before and after studies of vehicle trial participants or existing owners of BEVs or PHEVs.

Studies have generally found the lack of recharging infrastructure to be less of a concern to consumers than range *per se*. Indeed, the clear consensus in the evidence so far is that consumers will mainly recharge their EVs at home and in workplace car parks and frequent recharging will be the norm at least at first. Reliance on proxy aggregate variables such as housing types and parking availability can lead to underestimates of the potential to recharge given the greater propensity than the average for car owners to have parking facilities and other options for recharging, such as at workplaces. Many consumers are attracted to the idea of having their own source of fuel at home and to reduce the nuisance cost of refuelling at petrol stations.

Public recharging infrastructure is likely, however, to play a key role in the diffusion of this technology by signalling its success and changing social norms.

Nevertheless, on an individual basis, range seems to be more important than recharging per se and few are willing to devote resources to reducing recharging time. Despite acknowledgement by consumers that their travel patterns do not necessarily require ranges longer than around 50 miles for most journeys, there remains a high premium placed on the option to drive longer distances. Trial data consistently shows users are over cautious when planning journeys, using a fraction of available range. EVs with a range of around 100 miles may start to be attractive as second cars but there is a wide variation in willingness to pay for extra range. Experimental and qualitative studies have shown that consumers are likely to prefer PHEVs rather than BEVs and that the optimal solution is likely to be a range of PHEVs which offer various degrees of high fuel economy at a range of prices to appeal to a number of segments.

1.5 Perceptions of EV performance

In general, preferences for greater fuel efficiency are often found to be overshadowed by stronger affinities for power, acceleration and size. Consumers have been found to have generally negative perceptions with regards to alternative vehicles' attributes especially with regards to performance factors such as acceleration and top speed. Importantly, however, in the findings of the few EV vehicle trials that have been conducted, ratings of EV performance tends to increase once consumers have gained some experience of the vehicles.

Size and practicality are important purchase factors and are a common starting point for vehicle selection. Perceptions of size in relation to EVs have not been widely studied, however.

In comparison with performance, size and capital cost attributes, environmental benefits are of relatively little importance in the purchase decision. There is debate over the extent to which adopters of EVs have or will have above average environmental awareness. It seems that some consumer would be prepared to pay more to drive cleaner or zero emission vehicles, but this often relies on the idea that the alternative vehicles can match conventional types in performance. It seems most likely that there will be an early adopter and an early majority consumer segment who have stronger than average environmental motivations, but that these will not be the determinant factor in whether this technology is mainstreamed.

1.6 The influence of government incentives

Despite the proliferation of incentive programs, particularly in the US with respect to HEVs, their efficacy is unclear. Particularly uncertain is the point in the decision making process that fiscal or other incentives are likely to have the most influence on purchasing patterns and the ways in which instruments can be packaged together to have the optimum effect.

Studies of existing car purchase subsidies on conventional and HEV technology suggest that these have been effective in stimulating demand. However, there are two clear findings from the evidence. The first is that fiscal incentives need to be designed so that they are conceived separately from the purchase price. It seems that consumers are more sensitive to sales tax incentives than income tax incentives. The second is that purchase and tax incentives are likely to be less important that fuel price which is the main determinant.

With regard to other types of incentive such as preferential treatment for EVs with respect to HOV lanes and bus lanes, congestion and parking charges, there

is only substantive evidence in relation the first of these. Evidence from the US suggests that HOV lanes could be important, but less important than other incentives and fuel prices, and very dependent on the specific local context including the level of congestion. The higher than average uptake of EVs in London and the location of people owning these vehicles does suggest that parking incentives and the congestion charge can influence the level of adoption.

1.7 Symbolic and emotional considerations

Models of car choice are likely to be inadequate without a proper consideration of impulsive or non-conscious regulatory processes including the role of affect (or emotion), identity/symbolism (the wider meaning of goods) and personality and values in car preference. There is overlap between the more functional and the psychological considerations as choices depend on how attribute levels are perceived and the emotional reactions they provoke.

Emotional reactions such as how a car feels to drive and the pleasure gained from the experience or the complexity involved in maintenance or refuelling is virtually unstudied. More attention has been paid to symbolic motives. For instance, we are beginning to understand that EVs may be associated with meanings such as lower resource consumption, independence from petroleum producers, advanced technology, financial responsibility, saving money, opposing war as well as environmental and/or resource preservation. These symbolic evaluations can relate to the whole vehicle or to more specific functional or financial attributes such as fuel economy. Consumers then infer connotations to these meanings such as ‘behaving ethically’, ‘concern for others’, ‘being intelligent’ or ‘unique’ and if these relate to self identities and values, they will be expressed through adoption of EVs.

Various personality traits may also be associated with EV adoption. Innovativeness reflects the degree to which an individual makes innovative decisions independently of the communicated experience of others and, when combined with product knowledge, are powerful individual attributes on which to segment consumers. Narcissism (individuals who see themselves, and who want others to see themselves, as special or superior) is also hypothesised to be associated with greater interest in the symbolic rather than the functional value of products in the context of EVs. Driving an EV has also been found to be associated with high openness, high conscientiousness and high agreeableness.

1.8 Consumer segments

Segmentation of current and potential future EV adopters has been largely based on the idea from technological diffusion theory that consumers can be classified into five categories: innovators, early adopters, early majority, late majority and laggards. The early adopters of EVs are generally thought to have higher income, car ownership and higher mileages than the average and tend to live in multi-car households. But in terms of motivation, there is unlikely to be one early adopter segment as some will be driven by altruism and philosophical reasons for wanting to reduce fuel consumption, and others will be driven by the technology or have a financial motivation not necessarily backed up by detailed payback calculations.

Other segmentations have combined the technology diffusion segments with attitudinal and other data. For instance, survey data and parking data has been combined with Mosaic geodemographic information to identify potential ‘hotspots’ in cities in which to target investment in public charging infrastructure.

1.9 Diffusion effects

Consumer preferences cannot be considered to be static, particularly over the longer term. It is likely that increased market penetration will alter the way in which consumers value EVs and choose among them. There is a tendency for consumer preferences to change as technology becomes more prevalent in the market due to the changes in social concerns, increased credibility and learning from others with more experience as well as marketing, education and shifts in social norms. A study of market data in the US found that different models of HEV had different patterns of diffusion and this was attributed to different signals of quality across different models fuelled by media stories and word of mouth. Market share ratios can be added to surveys to try and elicit consumer preference and spillover effects, although these techniques are highly speculative.

In addition, it is possible that consumers may use these vehicles differently to conventional vehicles and this could lead to rebound effects such as increased car ownership, more driving or 'upsizing' which could counteract efficiency gains. There may also be positive benefits to driving style given the imperative to preserve all electric driving range. There is very little evidence on any of these possible behaviour changes. EVs are likely to be adopted as second vehicles, but it is possible that this will mainly be in households which already own multiple vehicles. Figures on HEV adoption in Switzerland do not show additional car ownership, but in the US they do.

2 Introduction

2.1 Context

The Consumers and Vehicles sub-project of the ETI Plug-in Vehicle Economics and Infrastructure project aims to identify and quantify the key factors which influence consumer behaviour in the uptake and use of future plug-in vehicle technologies. Primarily this will be achieved by the collection of qualitative data collected from a small household electric vehicle (EV) 'trial' combined with quantitative data from a large-scale survey of households (WP 1.3). These data will, in turn, form inputs to a quantitative model of vehicle uptake rates and usage patterns (WP 1.4).

This report precedes the primary data collection and modelling by reviewing existing literature. This will inform the conceptual foundation for the empirical research and contribute to the design of survey instruments best placed to identify the unique factors that are likely to impact the consumer response to plug-in vehicle technology.

2.2 Scope and objectives of the review

Plug-in vehicles are novel technologies of which mainstream consumers have no experience. This presents a significant challenge to the investigation of the consumer response to such vehicles. It also means that existing literature can essentially only contribute theoretical or experimental evidence given the lack of revealed preference data and empirical studies relating to these vehicles.

Nevertheless, the need to develop innovative survey techniques to overcome this challenge means that it is necessary to inform the survey design with a solid understanding of consumer behaviour relating to cars including economic, functional, emotional and symbolic adoption factors at the individual level and peer effects and interactions at the interpersonal or societal level. As such, the empirical research will benefit from grounding in broader concepts in the fields of consumer choice and decision making as well as any recent literature on consumer perceptions of or experience with hybrid or plug-in vehicle technology.

In this light, examples of some of the questions we are seeking to answer in the literature review are as follows:

- What is the relative role of functional, affective and symbolic factors in car choice?
- What are people's expectations about the performance of these vehicles and how does this compare to their experience? How do attitudes and preferences change after adoption?
- What are the expectations surrounding the availability of recharging facilities? What are the likely patterns of recharging behaviour?
- Do people's values and attitudes change as the number of people who adopt these vehicles increases? Can the diffusion impact be captured in a research design?
- To what extent are different people motivated by different factors? What can this tell us about those likely to be the earliest adopters and mainstream consumers of plug-in electric vehicles?
- Are people likely to use plug-in vehicles differently compared to their current travel patterns?

- Are there likely to be certain geographical hotspots from which a shift in consumer behaviour towards EVs will diffuse?
- How can government incentives be used to encourage uptake and use of these vehicles?

In light of these research questions, two issues regarding scope need to be highlighted. Firstly, the review has not been restricted to literature relating to plug-in electric cars only. This is primarily because studies on consumer preferences for such technology are still limited in line with its limited commercial availability and because there is insight to be gained from studies on other vehicle technologies. Secondly, as section 3.1 will reveal, at least half of all new cars in the UK are first registered by fleet or business consumers. As will be discussed, a large proportion of these vehicles are likely to be adopted as the result of private individuals exerting a great deal of influence over the decision process. The literature on fleet car adoption is much smaller than for private consumers and this review has concentrated on private car choices.

2.3 Structure of this report

This section of the report is divided into three remaining sections. Section 0 outlines the approach used to search, select and synthesise the literature used in this review. Section 3 presents the evidence review, divided into subsections with emphasis on what we know about the importance that consumers attach to the functional and psychological attributes of cars. The final section reflects on the evidence in order to inform the design of the empirical work on private consumers being undertaken in the remainder of the Consumer and Vehicles project.

2.4 Method

The review used a search strategy designed to capture aspects of consumer demand for electric vehicles relating to the following issues, also used to screen the literature:

1. the current UK car market and what is known about new car adopters
2. theories applicable to car choice
3. the car purchasing process including the relative importance of functional, symbolic and individual factors
4. policy incentives likely to impact on the adoption of electric vehicles
5. specific issues impacting on consumer acceptance of plug-in vehicle technology
6. segmentation of car owners/adopters
7. the likely impact of plug-in electric vehicle use on attitudes, recharging behaviour and travel patterns
8. potential dynamic effects which may impact on the rate of uptake of plug-in electric vehicle technology.

The methodology adopted for this review aimed to meet, as closely as time and resources allowed, the standards of a systematic review[1]. These standards include focusing on answering specific questions, using protocols to guide the review process, seeking to identify as much of the relevant research as possible, appraising the quality of the research, synthesising the research findings and updating in order to remain relevant. The latter stage was particularly important

[1] Petticrew, M.A. and Roberts, H. (2006). *Systematic Reviews in the Social Sciences,* Oxford, Blackwell.

in this review as much of the literature on electric vehicles is very recent and could not be found using traditional literature searches.

2.5 Search strategy

The search for relevant literature started with identifying relevant search terms. The success of this review was to a large degree dependent on the ability of the project team to identify every possible terminology variant of the concepts in question. Deriving the search terms involved reading key papers and consulting among the wider project team.

Whilst it was necessary to use a range of terms that were as specific as possible, the keywords were not restricted to specific technical terms. **Table 1 shows the search keywords that were identified.** First order search terms were related to energy efficient cars using as many specific terms relating to plug-in electric technology as was feasible. In all cases, terms related to cars were combined with terms related to purchasing/motivation/refuelling behaviour. In order to construct a logical relationship among these research terms and to avoid running searches unnecessarily with overlapping search terms, Boolean search terms ('and', 'or', 'not') were used.

Table 1: Main keywords used in the literature searches

STEP 1: terms related to energy efficient / plug-in electric cars:		
• low emission *and* car *or* vehicle *or* automobile		
• low carbon *and* car *or* vehicle *or* automobile		
• energy efficient *and* car *or* vehicle *or* automobile		
• electric *and* car *or* vehicle *or* automobile		
• battery *and* car *or* vehicle *or* automobile		
• plug-in *and* car *or* vehicle *or* automobile		
• hybrid *and* car *or* vehicle *or* automobile		
• limited range *and* car *or* vehicle *or* automobile		
• alternative *and* car *or* vehicle *or* automobile		
• **STEP 2: terms related to purchasing / recharging behaviour and motivations:**		
• purchase	• choice	• refuel*
• buying	• preference	• recharg*
• adoption	• perception	• range anxiety
• uptake	• attitud*	• early adopters
• consum*	• motivation	• segment*

These keywords were used to search five databases, namely, ScienceDirect, Scopus, Google Scholar, PsychInfo and the Transport Research Laboratory Knowledge Base[2]. Studies could be qualitative, quantitative, theoretical, or review articles. They could also be peer reviewed academic sources as well as published or unpublished reports. To find 'grey' literature, members of the team were also asked to nominate additional studies (particularly unpublished or recently published studies) and reference lists were also consulted ('snowballing').

[2] The TRL Knowledge Base comprises a number of databases, including the Transport Research Abstracting and Cataloguing System (TRACS). This is the main catalogue of transport research publications held both in the TRL library and elsewhere. It contains bibliographic references and abstracts of English and foreign language articles from journals, books and research reports. It is the English language version of the worldwide ITRD (International Transport Research Documentation database) and contains abstracts from publications in the USA, Australia, Scandinavia, the Netherlands and Canada, in addition to UK material. The database has been updated daily since 1972 and comprises over 260,000 items.

2.6 Study selection and inclusion criteria

The search process generated approximately 160 pieces of literature. In order to prioritise this list for review, a three-stage process was undertaken.

1. The first of these noted the basic information about each document, e.g. title, where it was published, authors and context, and assessed the document against the eight screening issues (listed above) to determine its relevance for the study.
2. If it was considered to be relevant, it was then assessed further in a second stage. For each piece of literature reviewed, its relevance to the issues was documented in an Excel spreadsheet, reproduced here as Table 2. Where a piece of literature did not offer relevant material in any of the categories, it was rejected for further review. Where it did offer relevant material it was read in detail and notes were taken under each relevant issue.
3. As the review got underway, gaps in certain topic areas became evident. These included, for example, literature on the symbolic motives applicable to car preference. In order to fill the gap, titles and abstracts of accumulated literature were scanned in order to prioritise these references.

It became evident early on that the search strategy had resulted in more references than could be included given the resources available. Consequently, a decision was made to reject publications if any of the following were true:

- where the main focus was an assessment of the merits of different methods and techniques applied to car choice modelling
- where the main focus was the knowledge and information sources (such as advertising, ecolabelling) relevant to car choice, these were deemed as not immediately relevant to the core project aims and out of scope
- studies undertaken since 2000 were prioritised
- studies undertaken in the UK context were prioritised.

This process was led by one member of the study team and cross-checked by the second reviewer, particularly all undecided cases. It led to 88 references being taken forward for detailed review.

2.7 State of the evidence

The literature falls into four broad categories:

i. revealed and stated preference surveys of consumer behaviour regarding a variety of vehicle powertrains

ii. qualitative and conventional questionnaire surveys eliciting consumer attitudes and perceptions of vehicle attributes, alternatively fuelled vehicles and policy incentives

iii. evidence of consumer responses to EVs before and after small-scale vehicle trials

iv. theoretical texts relating to socio-technical transitions, symbolic behaviour and consumer segmentation.

By far the greatest proportion of literature is in the form of (i) stated and revealed preference surveys. The following key observations can be made about the state of the evidence on consumer adoption of EVs:

- The dominance of stated preference surveys is due to the attempt, since the early 1980s, to overcome the challenge of asking consumers to predict their interest in a radically new product that does not yet exist in the marketplace. However, much of this literature is US dominated and often based on a limited number of attributes and powertrains. Consequently, apart from offering insight into vehicle attribute measurement, the specific modelling results provide little useful prediction of likely UK consumer response to EV products and incentives.
- Many relevant attributes such as size, performance, range and refuelling/recharging time have been poorly measured in both stated preference and more standard qualitative and quantitative survey techniques. Consequently we have a very poor understanding of the role that these instrumental factors may play in EV uptake.
- Private consumers have difficulty in providing answers to willingness to pay questions in surveys as very few currently know their fuel consumption and calculate their vehicle running costs.
- Value placed on fuel economy and different vehicle technologies is influenced by symbolic, affective and instrumental factors. These include anticipated driving affect (i.e. the emotional pleasure derived from driving), expression of the person's position or social status, and the expression of personal identity and values, including environmental values. We have some understanding of the importance of these factors, but there is little indication that symbolic and instrumental factors have been considered in parallel or that attempts have been made to incorporate this understanding into predictive modelling of EV uptake.
- Evidence on the role of policy incentives is fragmented and largely US focused.
- Recent work originating from EV vehicle trials in the UK and elsewhere has provided invaluable evidence on recharging patterns and expectations, driving behaviour and some attitudinal data. However the evidence base does not help us to predict the likely impact of EV uptake on travel patterns or car ownership.
- Attempts to segment consumers with respect to EV uptake have largely been restricted to the crude early adopter/early majority model rather than a finer grained classification based on an understanding of motivations and preferences.
- There is a lack of application of social and behavioural psychology to understand impulsive individual processes and social dynamic effects. The lack of evidence is most apparent in relation to the processes thought to take place at the interpersonal, community or societal level as opposed to the individual level. Sociological theories that stress the interpersonal environment offer key insights of the attitude-behaviour link and account for the role of social factors, peer effects, social networks, imitative and learned behaviours.
- Likewise, there is an almost complete absence of qualitative data to gain insight into the psychological processes guiding the formation of beliefs and preferences with regard to EVs.
- There is very little evidence relating to the decision making processes underpinning the adoption of EVs into public and private sector vehicle fleets.

2.8 Summary table

Table 2 provides a conceptual 'map' of the literature included in this review. It uses headings which approximate to the sections of this report to indicate main areas of focus for each study included. This resource is a main point of reference throughout the remainder of this report as findings are synthesised under each of these sections.

Table 2: Overview of the reviewed literature

(please note, light grey ticks denote a lower level of attention to this area in the relevant publication)
DC = discrete choice; MNL = Multi-nomial logit; RP = Revealed preference; SP = Stated preference; SEM = Structural Equation Modelling

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Adler, T., Wargelin, L., Kostyniuk, L., Kavelac, C. & Occhuizzo (2003).					✓				✓	✓								Telephone, mailback and www, SP, 2002, California, N=2200, nested MNL	✓	
Ahn, J., Jeong, G., & Kim, Y. (2008).				✓														SP, Face to face, N=280, Age 20-59 with a car. Seoul, July 2005. Discrete Choice model	✓	
Allen, M. W. & Ng, S. H. (1999).			✓			✓												Mail survey, N=270, New Zealand. Tested value and attitude scales. Factor analysis, ANOVA		
Alvarez-Daziono, R. & Bolduc, D. (2009).							✓		✓									Hybrid choice model/ SP, N=866, Canada. Bayesian method and classical estimation method	✓	
Anable, J., Lane, B. & Banks, N. (2009).				✓		✓		✓										Semi structured interviews		
Angle, H. et al. (2007).				✓		✓				✓		✓	✓					Survey, N=1151, UK, 2007, drivers aged 17+		

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Axsen & Kurani (2008)		✓			✓						✓							On-line SP + RP survey, N+535, Canada; Hybrid Choice model; 3 penetration scenarios; hypothetical information about the technology from 3 different sources (newspaper, brochure and personal testimonial)	✓	
Axsen, J. & Kurani, K. S. (2010).					✓						✓		✓					Three part on-line survey collected from new vehicle buyers, N=877, California, 1 day travel diary, design games		
Axsen, J., Kurani, K. & Burke, A. (2010).					✓													Design games		
Axsen, J., Mountain, D. C., & Jaccard, M. (2009).									✓					✓				On-line SP+RP, N=943, Canada and California, owners of new vehicles, March 2006, aged 19+, drove 3+ times per week, lived in an urban area; HEV owners purposively sampled	✓	
Batley, R.P., Toner, J.P (2003).																		SP, UK, summer 2002, N=331, MNLM	✓	
Beggs, S., Cardell, S., & Hausman, J. (1981).					✓													Ordered logit model, N=~200, 9 cities in USA, principal drivers of a compact or sub-compact car, all commuters with daily round trips <50 miles		

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Beresteanu, A. & Li, S. (2009).									✓									Data set of vehicle registrations in 22 Metropolitan areas 1999-2006, market equilibrium model		
Bollinger, B. & Gillingham, K. (2010).			✓			✓												Diffusion of PV panels using data on installations in California		
Brownstone, D, Bunch, D.S. & Train, K. (2000).					✓				✓									SP + RP, multi-wave panel survey, N=2857California, June 1993, Mixed logit	✓	
CABLED (2010).											✓	✓						GIS data loggers on 22 Mitsubishi iMievs		✓
Cambridge Econometrics (2008).				✓						✓			✓					Telephone survey, N=900, recently purchased a new or nearly new vehicle; Some SP (to changes in different costs of motoring); RP analysis to estimate own and cross elasticities of past behaviour of households; WTP for fuel efficiency; Discrete choice (mix	✓	
Cao, X. & Mokhtarian, P. (2003).					✓													Literature review		
Carroll, S. & Walsh, C. (2010).		✓			✓					✓	✓	✓		✓			✓	Trials and before and after questionnaires		✓

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Chéron, E. & Zins, M. (1997).							✓				✓							Short SP of focus group participants (N=37) using linear regression		
Choo, S. & Mokhtarian, P. (2006).				✓		✓				✓			✓					Mail survey, N=1904, San Francisco, 1998,many attitudinal variables (ANOVA, Chi sq) + MNL	✓	
Choo, S., & Mohktarian, P.L. (2004).				✓		✓				✓			✓					Mail survey, N=1904, San Francisco, 1998,many attitudinal variables (ANOVA, Chi sq) + MNL	✓	
Coad, A., de Haan, P., & Woersdorfer, J. S. (2009).			✓					✓						✓				Secondary analysis of Swiss household data to understand link between policy support and behaviour		
Competition Commission (2000).	✓																	Analysis of UK car market		
Curtin, R.; Shrago, Y. & Mikkelson, J. (2009).		✓																Interviews with 2523 adults		
Dagsvik, J.K., Wennemo, T., Wetterwald, D.G. & Aaberge, R. (2002).					✓													SP, random sample, Norway, N=662	✓	

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
De Haan, P., Mueller, M. G., & Peters, A. (2006).						✓							✓		✓			Survey of Hybrid owners, N=367, Switzerland		
De Haan, P., Peters, A. & Mueller, M.G. (2006).																		Survey of Hybrid owners, N=367, Switzerland		
De Haan, P., Peters, A., & Scholz, R. W. (2007).								✓							✓			Survey of Hybrid owners, N=367 Switzerland		
Dft (2009a).	✓																	UK National Travel statistics		
DfT (2009b).	✓																	UK National vehicle registrations		
Diamond, D. (2008).									✓									Secondary data analysis of impact of HOV lanes in Virginia		
Diamond, D. (2009).									✓									Cross sectional analysis of Hybrid registration data to investigate impact of incentives		
Eftec (2008).	✓			✓														Aggregate discrete choice modelling using RP	✓	
Element Energy (2009).	✓				✓				✓	✓	✓	✓					✓	Review of literature; analysis of NTS and EHC survey; Survey of Private + Fleet EV owners (N=36 + 11) and EV considers (N=215+16)		

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
EST (2007).	✓			✓				✓					✓					MNL based on historic data and detailed consumer survey	✓	
Ewing, G.O. & Sarigöllü, E. (1998).					✓				✓									Montreal, N=881, post-war suburbs, drivers to work or school,	✓	
Experian (2009).	✓																	UK Market Research Data		
Gallagher, K.S. & Muehlegger, E.J. (2007).									✓									Consumer data 2000-2006 on sales of hybrids coupled with data on US Government incentives		
Garcia, R. (undated).														✓				Agent based modelling		
Gärling, A. & Johansson, J. (1999).		✓			✓				✓		✓							3 month EV trials+ before/ after in depth interviews		✓
Gärling, A. & Thøgersen, J. (2001).			✓										✓					Review		
Gärling, A. (2001).		✓	✓		✓		✓											Questionnaires (N=1349+569); Internet marketing tool (N=30); showroom visits and test-drives (N=30); Free 3 month trials (N=42 families)		✓
Garwood, M. & Skippon, S. (2010).		✓	✓		✓		✓			✓	✓							EV trials (N=92), post experience questionnaire		✓

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
GfK Automotive (2006).				✓														Web based research using GfK's NOPs e-panel; 1468 respondents, April - July 2006 new car owners		
GfK Automotive (2009).				✓		✓												Web based research using GfK's NOPs e-panel; 2000 respondents, April - May 2009 new and used car buyers; private motorists and company car drivers		
Girard (undated)													✓			✓		Analysis of Hybrid owners in London + Mosaic data to identify 'Hotspots'		
GLA (2009)					✓													Web based research using GfK's NOPs e-panel, N=1468, April - July 2006 new car owners	✓	
Golob, T. F. & Gould, J. (1998).		✓			✓						✓	✓						Two week trials, travel diary, California 1995-96, N=69, pre & post surveys		✓
Golob et al. (1993)					✓												✓	Three phase SP survey, MNL, N~900, California, 1991	✓	
Greene, D.L., Duleep, K.G., & McManus, W. (2004).		✓			✓													Nested MNL calibrated to 2002 model year sales, 8 scenarios tested	✓	
Heffner, R. (2007).		✓					✓											Household interviews		

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Heffner, R. R., Kurani, K. S., & Turrentine, T. S. (2007).							✓											Ethnographic interviews with hybrid vehicle owners, California + semiotic theory		
Heffner, R., Kurani, K. & Turrentine, T. (2006).							✓											Review of semiotics		
Heutel, G. and Muehlegger, E. (2009).									✓					✓				Reanalysis of dataset in Gallagher and Muehlegger based on consumer purchases of new vehicles		
Hodson, N. & Newman, J. (2009).												✓						Analysis of US car driving patterns		
Huetink, F.J., Van der Vooren, A. & Alkemade, F. (2005).			✓						✓					✓				Agent based simulation model in Dutch context for hydrogen		
Jahnsson,J. (2009).			✓							✓				✓				Two postal surveys N=1904 + N=1691,Sweden, car owners with a boost of AFV owners, 2006 and 2008		
Kahn, M.E. (2006).							✓							✓				Uses Census track panel data for Los Angeles County over 3 years to track diffusion of Hybrid Vehicles		
Klein, J. (2007).					✓		✓		✓				✓					Online + telephone survey (N=118)		

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Kurani, K. & Turrentine, T. (2004)		✓	✓		✓		✓											57 households who purchased new or used (8 HEVs), semi structured interviews		
Kurani, K. S., Turrentine, T., & Sperling, D. (1996).			✓		✓		✓					✓		✓				Experiment-oriented interviews + four stage mail survey (N=454) with some SP		
Kurani, K., Heffner, R. & Turrentine, T. (2007).		✓			✓		✓				✓		✓	✓				Semi structured interviews + 23 converted Prius's		✓
Lane, B. & Albery, T. (2009).							✓											Focus groups and telephone surveys, Camden UK, May-July 2009		
Lane, B. (2005).	✓	✓	✓	✓		✓		✓		✓			✓				✓	Desk based review		
Lane, N. & Banks, N. (2010).	✓			✓		✓		✓		✓								Focus groups + web based survey (N=~1000) of new and nearly new (up to two years old) UK car buyers		
Larrick, R.P. & Soll, J.B. (2008).				✓														Short questionnaires to elicit knowledge about fuel consumption		
Martin, E. et al. (2009).		✓																Ride and drive clinics' with pre and post surveys (N=182)		✓
Mau, P. et al. (2008).														✓				Two SP surveys (N=916 + 1019), Canada, www, survey for different technology and treatment groups with different market shares, DC model	✓	

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
																		(capital vintage model)		
Mintel (2009).	✓																	1000 Internet users aged 16+ who own a car		
Mueller, M. G. & De Haan, P. (2009).			✓				✓		✓				✓					Agent based microsimulation using Swiss Data		
Peters, A., de Haan, P., Scholz, R.W (unpublished).				✓			✓											Two wave survey, June 2005, N=1150		
Peters, A., Scholz, R.W. & Gutscher, H. (unpublished).				✓			✓											Survey of 302 Swiss new car purchasers, SEM		
PLANYC (2010).		✓			✓		✓		✓		✓		✓					Semi structured interviews, focus groups + full length survey (N=1384)		
Potoglou, D. & Kanaroglou, P. S. (2007).									✓	✓						✓		Internet, Canada (urban Hamilton), 2005, N=482, NMNL	✓	
Roche, M.Y. et al. (2010).		✓	✓			✓											✓	Literature review		
Sangkapichai, M. & Saphores, J.D. (2009).					✓				✓									Telephone survey, California, July 2004, ordered choice model, N=2505, perceptions of environmental policies		

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Santini, D.J. & Vyas, A.D. (2005).			✓				✓		✓				✓	✓				SP + RP; logit model but develops coefficients for early group and majority buyers	✓	
Skerlos, S. J. & Winebrake, J. J. (2010).									✓									Review article		
Skinner, I. et al. (2006).	✓			✓		✓		✓		✓						✓	✓	Review article		
SMMT (2010a).	✓																	Market data		
SMMT (2010b).									✓									Market data		
Sovacool, B. K. & Hirsh, R. F. (2009).		✓	✓											✓				Review article/ Thinkpiece		
Thatchenkery, S.M. (2008).																		Crosssectional data on vehicle registrations (2006) + other datasets + MNL modelling		
Thøgersen, J. & Gärling, A. (2001).			✓					✓					✓					Current car owners in Gothenburg, Sweden. Mail back questionnaires, Sept 1998, N=165+782; SEM		
Turrentine, T. S. & Kurani, K. S. (2007).			✓		✓	✓												Semi structured interviews		
Whelan, G. (2007).	✓									✓								RP (data from FES and NTS, discrete choice (binary dogit)	✓	

Author(s)	Current UK car market	Public perceptions of AFVs	Theories/ Approaches	Functional + cost Attributes		Emotional/ psychological factors		Policy attributes/ incentives		Socio-economic characteristics	Recharging behaviour	Travel behaviour	Segmentation	Dynamic effects	Rebound	Land use planning	Fleet	Approach		
				ICE	(H)EV	ICE	(H)EV	ICE	(H)EV									Method	SP/ RP	Trials
Ziegler, A. (2010).					✓		✓			✓								SP CAPI Survey in car dealerships (N=598, Germany 2007-2008; those intending to buy a vehicle in near future); multinomial probit	✓	

3 Review synthesis

3.1 The current UK car market

In order to set the Consumers and Vehicles study in context and assist with survey design, this literature review sought to collate information on the broad composition of the UK car market including the main consumer segments, demographics of new and used car 'adopters' and recent trends in the uptake of low emission, hybrid and electric vehicles. The intention was to inform the sampling frame to be applied in the main quantitative survey.

Disaggregated information on the consumer-side of the UK automotive market is not easily available. Statistical data on new registrations are taken from a number of sources including the Society of Motor Manufacturers and Traders (SMMT) and the Driving Standards Agency (DSA) (SMMT 2010a; DfT 2009b). In addition, the UK National Travel Survey (DfT 2009a) offers an insight into the proportion of households with cars and some insight into the broad geographic distribution of ownership. However, information on the demographic composition of consumers in terms of who tends to purchase brand-new or used vehicles is contained in a limited number of available consumer insight reports (Mintel 2009; Experian 2009).

3.1.1 Level of car ownership

At the end of 2008, there were just over 27 million cars licensed in the UK (DfT 2009a). Over the past two decades, the proportion of households with more than one vehicle has almost doubled with 44% of households in the UK having one car and 32% more than one car in 2008. Over the same period, the proportion with no car at all has fallen by 15 percentage points (to 24%). The number of cars per household has risen steadily over the 20 years, as has the number of vehicles per adult, which now exceeds six cars for every ten people aged 17 and above compared with four in 1985/86.

Factors behind this growth include higher levels of affluence leading to ownership of second cars, increased numbers of women in the workforce, and an increased tendency for older age groups to drive (Whelan 2007; Mintel 2009).

3.1.2 UK car sales

Figures for car sales in the UK show that, in 2009, about 2 million cars were registered as new and 7 million were sold. Thus, used car sales accounted for 77% of all cars sold (SMMT 2010a).

New car sales can be divided into a number of possible customer categories, although only three tend to be used. These are private, business and fleet.

Table 3 shows that in 2009, non-private registrations (business and fleet) accounted for 49% of all new cars registered.

Table 3: New and use cars sales in the UK (2005–2009)

	2005	2006	2007	2008	2009
Total New	**2,439,717**	**2,344,864**	**2,404,007**	**2,131,795**	**1,994,999**
% Fleet	49%	49%	50%	52%	44%
% Business	7%	7%	7%	6%	5%
% Private	44%	44%	44%	42%	51%
Total Used	**7,576,724**	**7,584,466**	**7,487,544**	**7,186,286**	**6,798,864**
Total All	**10,016,441**	**9,929,330**	**9,891,551**	**9,318,081**	**8,793,863**
% New	24%	24%	24%	23%	23%
% Used	76%	76%	76%	77%	77%

Source: SMMT 2010a

From these figures it is clear that any investigation of consumers' car purchasing preferences needs to consider both the private and non-private customer segments. However, with respect to understanding the decision making processes which impact on the adoption of new cars, it is important to understand the degree of autonomy which private individuals within the non-private sector are likely to be able to exert over their choice of car.

There exists a wide variety of fleet customers including companies that buy thousands of new cars each year and companies that buy only a small number. Some fleet customers buy large numbers of similar cars for their employees' use on the company's business; others allow their employees to choose their own model variants, normally subject to some restrictions. **Table 4 attempts to define each of the three categories and offers a picture of the degree of autonomy over vehicle choice that may exist.**

It is important to note that a high proportion of cars registered as 'non-private' will not be used and taxed as a 'company car.' This is clearly the case for rental cars, and many dealer/manufacturer cars have simply been pre-registered but will be used and taxed as private vehicles. This may be why Lane (2005) categorised the market into business fleets, individual consumers, and contract hire/leasing companies. In addition, there are some doubts expressed over the accuracy of the allocation of registration data. These data are derived from information recorded by the dealer when the car is sold, the accuracy of which is not checked and can be influenced by other factors (e.g. sales targets to a particular type of customer) (Skinner et al. 2006).

Evidence suggests that 'non-private' cars generally have more than twice the annual mileage of private cars, have larger engines, are more likely to be diesel, and are heavier than private cars (DfT 2009; Skinner et al. 2006). It is also worth noting that households with a company car are more likely to own a second car than comparable households whose first car is privately purchased (Whelan 2007).

Table 4: Definition of the main car customer segments in the UK

Segment	%	Definition	Degree of private individual autonomy
Fleet	44%	A vehicle that is registered to a fleet of 25 or more cars, or a fleet of 25 or more commercial vehicles. Also included: • cars pre-registered by supplier or dealers • daily rental car companies • Motability* cars • leased vehicles	On average, fleets are made up of about 8–10 cars in companies with no written policy about which cars should be adopted. The car adopters can be classified as follows: 1. Zero choice: e.g. all sales engineers are given a specific make/model but they are free to be used privately 2. Restricted choice: companies which source from certain car manufacturers only and, depending on the grade of the employee, can choose the appropriate sized car 3. User-chooser: employees get to choose any car within a price band and, increasingly, below a certain level of emissions (e.g. 160 g CO2/km)
Business	5%	These cars are part of fleets of less than 25 cars, with a very high proportion in single 'fleets'.	Assume high proportion of 'user choosers'.
Private	51%	Cars for the personal use of a private individual.	Total autonomy

Source: compiled from SMMT (2010a), Competition Commission (2000) and personal communication with Nigel Underdown (Energy Savings Trust)

* Motability is a government-run charitable scheme to provide cars at low prices to people receiving the higher rate of mobility allowance and is the biggest single source of fleet cars in Europe. Using the SMMT data for 1998, the Motability scheme accounted for 7 per cent of all new cars registered and 15 per cent of all fleet registrations (Competition Commission 2000). This is potentially a very interesting 'segment' as individuals get an allowance to purchase a car but have many characteristics which would otherwise suit EVs: they are car dependent and 'home centric', tending to make short car journeys with dedicated parking spaces. In addition, EV vehicles do not have gears which are important for certain types of disability.

3.1.3 Recent trends in UK car sales

As Table 3 indicates, there has been a drop in both new and used car sales in the UK. Prior to the collapse in sales in 2008 and 2009 as the recession took hold, sales of new cars had been falling in the UK since 2004. Indeed, consumer insight research from Mintel concludes that the UK car market suffers from a 'significant underlying structural weakness' in that it is largely a 'mature replacement market' and the frequency with which car owners replace cars is falling (Mintel 2009). Mintel claim this is partly because cars have become more reliable and durable and there is less risk of higher repair costs if cars are owned for longer. Also, high rates of depreciation on cars results in a large funding gap between the resale value of a currently owned car and its new or younger used replacement.

This trend has been exacerbated by the recession but has been temporarily relieved by the introduction of a car scrappage scheme in mid 2009 which gave owners of older cars a £2,000 discount off a new small car. The incentive stemmed the collapse in new car sales (funding 300,000 new car purchases) but had the opposite effect on used car sales which fell sharply in 2009. The scrappage scheme has therefore been successful in bringing a different type of

buyer into the new car market by converting formerly used car buyers into buying brand new cars.

In contrast to the overall drop in car sales, sales of alternatively fuelled cars (AFVs) including hybrid and fully electric cars have risen during all but the most recent year since 2005. Sales of AFVs still only account for less than 1% of new sales, with around 15,000 units sold in 2009 in the UK, 98% of which were petrol/electric hybrid vehicles. Only 55 all-electric units were sold in that year (SMMT 2010a). More generally, the average engine size of licensed cars is stabilising, with an established market shift towards smaller vehicles, particularly minis and superminis.

3.1.4 How are cars financed?

Mintel suggests that nearly three-quarters of new cars are likely to be bought for more than £10,000. In a recent survey in the UK of purchasers of new and nearly new cars (N=1000, Feb-April 2010), one study found a slightly smaller proportion (around 60%) had paid more than £10,000 (Lane & Banks 2010). The modal car price paid by participants who had recently bought a new or nearly-new car was £11–15k.

Lane & Banks also found that the majority of participants had acquired their current car through an outright purchase (61%), with hire purchase (11%) and personal loans (12%) also proving popular, corroborating evidence from Mintel which suggests 38% of (new and used) car sales were on finance in 2008.

Interestingly, Mintel believes it has identified a general societal trend in the UK of people becoming less motivated by 'owning stuff' and "are more concerned with expressing fashion and glorifying transience by renting" (Mintel 2009). As a consequence it believes there may be a greater trend away from outright ownership of cars towards renting or leasing programmes, particularly if the car industry develops a new form of revolving credit where the car 'buyer' pays an initial deposit and then a fixed monthly fee which carries on indefinitely.

3.1.5 Who buys new and used cars?

A new car is purchased by around 5% of households a year according to the Target Group Index (TGI), a syndicated survey of 25,000 households representative of the population of Great Britain, conducted annually by BMRB (Cambridge Econometrics, 2008).

It is, however, difficult to find detailed information on who buys new cars. Mintel market intelligence informs us that the AB (Managerial and Professional) segment[3] is fundamental to the retail car market as it accounts for just over 40% of new cars currently owned and for 40% of new car purchases (Mintel 2009). However, it also suggests that C1s (Supervisory and Clerical) are a potential growth market for new cars during periods of economic growth.

Data on the car purchasing intentions of current car owners show that almost a third of those stating they intend to buy a brand new car over the following 12 months are existing owners of a car bought second-hand. Linked to this, it is also clear from the data that older people tend to own a greater proportion of cars owned from new.

From this information, there are four important issues which impact on the design of a survey of potential adopters of EVs:

[3] AB Managerial and Professional; C1 Supervisory and Clerical, C2 Skilled Manual, DE Unskilled Manual and Unemployed

- given that only 5% of households per annum acquire a new car, it would be very difficult to conduct a survey of new car users using a random probability method (Cambridge Econometrics 2008)
- given that a third of people who currently own a second-hand car say they intend to buy a new car next time around, it may not be necessary to only concentrate on people who have only purchased a brand new car in the past
- new car purchases are more frequent in the older age groups. However, given that the younger people of today are likely to be the new car purchasers of tomorrow, it might also be worth surveying some younger, potential new car purchasers. However, this is difficult as their preferences and attitudes are likely to change as they get older and their needs change.
- For the purposes of researching car consumers, it would also be worth knowing the proportion of people who purchase 'nearly new' vehicles. However, this information was not found.

A discussion of the recent evidence on who has tended to adopt hybrid and EV cars in the UK and elsewhere is included in 3.7.

3.2 Approaches to the study of vehicle adoption

As the search results for this review demonstrated, there is a very large body of literature addressing consumer demand for cars, albeit dominated by studies of conventional vehicle technology as opposed to attempts to predict the uptake of alternatively fuelled and, more specifically, plug-in electric vehicles. Studies are largely dominated by rational, economic modelling approaches using national data at the aggregate level or individual level, disaggregate data attempting to identify the factors that affect consumers' car buying behaviours in order to estimate market share. However, sections of the literature reject such approaches or at least supplement them with insights from theories from environmental or social psychology, marketing or models of transitions or social learning.

It is beyond the scope of this review to document comprehensively the large body of research that has been applied to understanding the factors at play in the vehicle market and consumer attitudes and preferences for vehicle technology. Here we describe briefly the main theoretical backdrops revealed in this literature review. In subsequent sections we develop insights from these theoretical approaches by examining in more detail the factors that have been found to influence consumer choice with respect to conventional, hybrid and electric vehicles.

Table 5 offers a categorisation and brief overview of the dominant theoretical backdrops found. The categorisation follows a trajectory from (i) individual conscious and rational processes which shape decisions and actions, to (ii) emotional, impulsive and non-rational individual processes, to (iii) interpersonal or societal level dynamic processes of change.

Table 5: Summary of main theoretical 'backdrops' to the literature

(i) Individual conscious and rational approaches			
Approach / methodology	**Underlying assumptions [original references]**	**Application to vehicle choice**	**References (applied to vehicle choice)**
Rational decision making	Automobiles are thought of as bundles of attributes desired by consumers, such as fuel economy, durability, style, performance, safety, and brand. Different makes and models are distinguished by the various attributes they offer. Consumers (i) make rational cost-benefit analyses and (ii) choose the option that maximises their benefits and minimises their costs subject to their preferences, knowledge, alternatives and budget.	Preferences for environmental goods and services which are not usually traded within the market mechanism can be inferred by revealed preference and stated preference techniques: • Revealed preference: is a method that assumes that consumer behaviour can be predicted on the basis of their current (revealed) behaviour. • Stated preference: the assumption is that consumers have well defined preferences, and is used to analyse the trade-off that individuals would be willing to make between the good in question and some other good (usually money). Some studies combine revealed and stated preference data. The application of discrete choice models or energy-economy models derives coefficients to predict an implied monetary value per unit of change of a vehicle attribute. These estimated parameters can be used for the derivation of potential policy incentives.	Alvarez-Daziono & Bolduc (2009); Dagsvik et al. (2002); Ewing & Sarigöllü (1998); Golob & Gould (1998); Greene et al. (2004); Mau et al. (2008); Potoglou & Kanagoglou (2007); Ziegler (2010) Brownstone et al. (2000); Axsen & Kurani (2008); Axsen et al., (2009); Cambridge Econometrics (2008); Santini & Vyas (2005)
Theory of Planned Behaviour	Behaviour is determined by behavioural intention and that intention is determined by (i) attitudes to the behaviour (ii) social norms about the behaviour and (iii) perceived behavioural control (i.e., the extent to which people think it is easy or difficult to engage in that specific behaviour). [Ajzen (1991)]	In this context, an individual's acceptance of a technology, although not strictly a psycho-sociological term, can be regarded as an intention to adopt or use the technology, or to consent or actively support its development.	Roche et al. (in press); Lane & Potter (2007)

(ii) Individual unconscious and emotional approaches			
Approach / methodology	**Underlying assumptions [original references]**	**Application to vehicle choice**	**References (applied to vehicle choice)**
Norm Activation Model / Value Beliefs Norm Theory	Consumer behaviour is determined by values, personal norms, problem awareness and perceived responsibility [Schwartz (1977); Dietz & Stern (1994); Stern (2000)]	At the general level, these models suggest that human values influence general constructs such as attitudes, attributes, consequences, or consumption values that in turn influence product choice. At the specific level, these models represent how certain human values influence certain product choice through particular association networks. 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. For instance, an individual's preference for the human value `prestige' would direct his or her attention to products that have meanings similar to prestige, such as a Mercedes-Benz, and would contribute favourably to his or her positive evaluation of the automobile.	Roche et al. (in press); Allan & Ng (1999); Jansson et al. (2009)
Symbolism	Consumers base their behaviour on the symbolic meaning that they attach to a product. [Dittmar (1992)]	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 (1) the instrumental and functional use of objects, (2) their emotional dimension, related to pleasure and relaxation, and (3) their symbolic meaning, as a symbol of identity. The symbolic function can, in turn, be subdivided into two components: the person's position or social status and the expression of personal identity and values. Therefore, consumers can use an object as a means to express themselves or their social position.	Heffner, Kurani & Turrentine (2006, 2007)
Risk perception	Consumers base their behaviour on the extent to which they believe that engaging in this behaviour is a risk to them personally, to society or financially. [Slovic (1987); Sjoberg (1998)]	The premise of this approach is that whilst experts rely on complex risk assessments for their decisions, the general public make judgements based on individual characteristics, such as risk awareness, perceived control over a situation and experience with risks.	Roche et al. (in press); Coad et al. (2009)

Heuristics	Consumers engage in limited economic rationality as they have limited cognitive capacity and therefore rely on 'short cuts' to make decisions. [Kahneman, Tversky & Slovic (1982); Berretty, Todd & Martignon (1999)]	People have limited cognitive capacity and therefore rely on simplifying assumptions and quick decision tools. Hence, it may be that such heuristics are used when distilling information on new car attributes so that only a limited set of characteristics are used to make a decision. Likewise, when eliciting information through surveys such as 'how much would you pay for better fuel economy', respondents may answer with an accessible rather than an accurate number. This simplifying effect can be exacerbated with the absence of direct experience when consumers attempt to answer preference questions.	Turrentine & Kurani (2007); Mueller & de Haan (2009); Garwood & Skippon (2010)
Prospect theory	This tries to model real life choices rather than optimal decisions. When consumers decide between alternatives that involve risk, they evaluate potential losses and gains. People decide which outcomes they see as identical and they set a reference point and consider lower outcomes as losses and higher as gains. [Kahneman & Tversky 1979]	Financial incentives for EVs should be designed so that consumers perceive them separately from the purchase price. Consumers can be expected to be more sensitive to fees than to rebates of the same magnitude.	Mueller & de Haan (2009); Axsen et al. (2009)
Personality and self identity	Five factor model of personality (openness, conscientiousness, agreeableness, extraversion, neuroticism). [Goldberg, (1992), (1993)] Narcissistic Personality Inventory (authority, entitlement, exhibitionism, exploitation, self-sufficiency, superiority and vanity). [Raskin and Hall (1981)]	This approach is based on the theory that the symbolic meanings of consumer products represent conscious or non-conscious signals to others about the user's personality traits. A number of studies have striven to uncover personality traits associated with how early an individual adopts an innovation ('innate innovativeness'). Narcissism is hypothesised to be associated with greater interest in the symbolic rather than the functional value of products Choo & Mokhtarian investigated 'adventure seeker', organiser, loner and calm personalities with respect to vehicle choice modelling and concluded that personalities spread somewhat more evenly across vehicle types than do attitudes, but that adventure seeking tendencies can be predictive of car choice behaviour.	Choo & Mokhtarian (2006) Garwood & Skippon (2010);Gärling & Thøgersen (2001)

(iii) Interpersonal or societal level dynamic processes

Approach / methodology	Underlying assumptions [original references]	Application to vehicle choice	References (applied to vehicle choice)
Diffusion of innovations / Innovation theory	Innovations can be classified along five dimensions; the likelihood and rate of adoption of an innovation is determined by consumers' perception of the innovation on these dimensions. [Rogers (1962)] Although innovativeness is conceptualised as a personality trait measureable in, for instance, individual favourable attitude, perceived benefits, willingness to sacrifice and latent need, this relative-time-of adoption definition focuses more on the dynamics of the diffusion process at the interpersonal or societal level than on (more static) individual predispositions.	Five dimensions to classify innovations: (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). Five types of adopters can be distinguished: Innovators: first individuals to adopt an innovation; willing to take risks, youngest in age, highest social class, great financial lucidity, very social and have closest contact to scientific sources and interaction with other innovators; Early adopters: second fastest category of individuals who adopt an innovation; typically younger in age, have a higher social status, have more financial lucidity, advanced education, and are more socially forward than late adopters; Early majority: tend to be slower in the adoption process, above average social status, contact with early adopters; Late majority: adopt an innovation after the average member of society; typically sceptical about an innovation, below average social status, very little financial lucidity, in contact with others in late majority and early majority; Laggards: last to adopt an innovation; typically focused on "traditions", lowest social status, lowest financial fluidity, oldest of all other adopters, in contact with only family and close friends. Many believe the classification by Rogers (1962) offers the most promising starting point for segmenting the potential EV market.	Gärling & Thøgersen (2001); Gärling 2001; Lane (2005); GfK Automotive (2006); Huetenik (2005); Heutel & Muehlegger (2009).

Social learning theory	Consumers acquire new information, attitudes and behaviour by observing others in their social network. [Bandura, (1977); Hirshman, (1973)]	Social interaction determines consumers' behaviour to some extent. It is assumed that particularly early adopters seek new information and experiences through social interaction and advertising. Moreover, early adopters are likely to have more contact with other early adopters who can serve as a role model and sparring partners.	Bollinger & Gillingham (2010); Huetenik (2005)

Whilst Table 5 demonstrates the potential breadth of approaches that could be applied to an investigation of consumers and vehicles, it belies the imbalance within the literature and the overwhelming domination of the rational economic approach. Moreover, even where environmental psychology is applied to the study of the relationship between attitudes and intended car purchase behaviour, it still tends to be a utility maximising approach. The most commonly applied theory is the Theory of Planned Behaviour which suggests that behaviour is the outcome of a reasoned set of planned decisions.

Yet, models of car choice are likely to be inadequate without a proper consideration of impulsive or non-conscious regulatory processes including the role of affect (or emotion), identity/symbolism and personality in car preference. A fundamentally different approach to understanding behaviour towards the environment is that of symbolism, widely used in consumer research. Heffner et al. (2006, 2007) have recently taken up the seminal literature and lessons of recent studies exploring the symbolic meanings of cars, and have produced empirical results regarding the purchase of hybrid cars (see Section 3.4). These studies are based on the assumption that vehicles symbolise ideas related to self-identity and that the choice of a vehicle is used to communicate interests, beliefs, values, and social status. Studies of symbols rely usually on ethnographic interviews. A possible caveat in the use of this approach for the study of new technologies such as plug-in vehicles is that new symbolic meanings take time to appear and be communicated among consumers.

Alternative models in heuristics have also been used in the environmental psychology field and have been more accurate in explaining how people make complex decisions, especially when lacking complete information. However, they have only been mentioned effectively 'in passing' in the literature on car consumers. A consistent finding is that pre-purchase research activity is limited, even though the car purchase is a major durable good (Mueller & de Haan 2009).

Even where the consumer decision-making process may be a result of conscious choices among an array of alternatives these choices are systematically related to psychological processes (i.e., perception, attitudes, beliefs formation) and any models need to make salient the role that human values play in consumer behaviour. Allen & Ng (1999) suggested that basic human values have a direct influence on consumer choice when individuals evaluate the symbolic meaning of a product and thus make an affective judgment about it. For instance, strong symbolic motives to express one's personality and social status with one's own car may inhibit the activation of a personal ecological norm to purchase a more fuel economical vehicle (Peters et al. (in press)).

The Norm Activation Model (NAM) gives prominence to values, but in reality all of the approaches in Table 5 are linked in some way. For instance, the potential of values-based measures to explain behaviour is enhanced when personality traits are included to capture awareness of consequences of behaviour and denial of responsibility (Choo & Mokhtarian 2006). Likewise, a number of studies have found that potential adopters' perceptions of an innovation on the dimensions outlined by Rogers are better predictors of vehicle adoption than personality and demographic characteristics (Gärling & Thøgersen, 2001). Still, personality, values and socio-demographics may offer valuable supplementary segmentation criteria.

The greatest dearth of evidence exists in relation to the dynamic processes thought to take place at the interpersonal, community or societal level. Sociological theories that stress the interpersonal environment offer key insights of the attitude-behaviour link and account for the role of social factors, peer effects, social networks, imitative and learned behaviours.

We will return to the individual and interpersonal level concepts including segmentation and the characterisation of early adopter segments in sections 3.6 and 3.7 by reviewing their specific application to the adoption of electric vehicles.

3.3 Cost and functional vehicle attributes

There are a number of different types of factors, economic-and non-economic, that influence how and why cars are purchased. Many of these are common to all powertrains, but some, such as availability of charging infrastructure, are specific to electric vehicles. This section summarises the literature on functional attributes. Functional attributes are the instrumental-reasoned motives which relate to the economic or general practical attributes of a vehicle. Whilst the term 'functional' implies objectivity, there is still the potential for these to be conceptualised differently by different consumers and, where the evidence sheds light on this, these differences are discussed.

3.3.1 Attributes measured in revealed and stated preference studies

Modern welfare economics assumes consumers are rational decision makers with well defined preferences. Associated models stipulate that individuals will choose options that maximize utility (i.e. satisfaction or pleasure) subject to their preferences, knowledge of alternatives and budget.

Models used to capture these preferences can be classified as aggregate or disaggregate. Aggregate models are used to forecast regional or national demand or car ownership levels (e.g. Eftec 2008), whereas disaggregate models[4] generally consider the household as the unit of analysis and apply random utility theory to predict household vehicle choice. A "coefficient," through a set of equations and specified relationships, predicts an implied (or buyer-perceived) monetary value per unit of change of a vehicle or policy attribute.

These models tend to concentrate on:

- cost and physical attributes associated with cars, household and driver characteristics and brand loyalty
- more recently, models used to predict the uptake of alternatively fuelled vehicles also include some variables which are not applicable to conventional vehicle technology but which are likely to greatly affect uptake such as availability of fuel stations/charging points, refuelling/recharging time and maintenance cost (Alvarez-Daziono & Bolduc 2009; Dagsvik et al. 2002; Element Energy 2009; EST 2007; Ewing & Sarigöllü 1998; Golob & Gould 1998; Greene et al. 2004; Mau et al. 2008; Santini & Vyas 2005; Ziegler 2010)
- some models include policy attributes such as subsidies, excise duties, preferential parking and high occupancy vehicle lanes which may influence consumer preferences for new technology (Adler et al. 2003; Alvarez-Daziono & Bolduc 2009; Cambridge Econometrics 2008; Ewing & Sarigöllü 1998; Potoglou & Kanagoglou 2007; Santini & Vyas 2005)
- vehicle and household characteristics are mainly considered as explanatory variables in the models
- the models do not usually consider consumers' travel attitudes, personality, lifestyle, and mobility as factors that may affect the vehicle type choice (Choo & Mokhtarian 2006) (See section 3.4 for further discussion).

[4] These can be further divided into (i) vehicle purchasing models (ii) vehicle-holding models depending on whether the model looks at the most recently purchased or to any owned vehicles respectively (Choo & Mokhtarian 2006).

We reviewed 21 studies spanning at least two decades involving conventional choice models. All but one of these studies use disaggregate discrete choice models for the vehicle type choice. Most are based on data from stated preference (SP) surveys that look at intended behaviour in hypothetical or constructed markets since alternative energy sources and plug-in electric vehicles are still in limited supply or do not exist in the market place (e.g. Ewing & Sarigöllü 1998; Dagsvik et al. 2002; Potoglou & Kanaroglou 2006; Ahn et al. 2008). Other studies (e.g. Brownstone et al. 2000; Axsen et al. 2009) combine SP and revealed preference (RP) data. These techniques analyse the trade-off that individuals would be willing to make between the good in question and some other good (usually money). The inferred economic preferences can be used for estimating the monetary values of environmental goods and examining the response of the model to different policy scenarios can provide insight to the future market viability of lower carbon vehicle technologies (EST 2007).

Again, it is beyond the scope of this review to detail the modelling and analysis approaches and the resulting attribute coefficients. In any case, most published studies are US or Canadian based and therefore are likely to have been calibrated to these markets. Exceptions to this include EST (2007), Cambridge Econometrics (2008) and Batley & Toner (2003) in the UK, Ziegler (2010) in Germany and Dagsvik et al. (2002) in Denmark. In addition, it can be difficult to make general conclusions on the dominant factors influencing vehicle choice from these models as different vehicle categories were chosen, and different attribute measures and trade-offs were examined.

Nevertheless, the overview suggests that first, higher purchase price tends to be negatively associated with the probability of choosing a vehicle, as does operating cost. Brand loyalty is often significant, as is the number of seats, luggage space, engine size and horsepower. Similar to conventional vehicles, purchase price or operating cost are also significant in most models which include alternatively fuelled vehicles. However, specific to AFVs, various performance variables, especially driving range, fuel availability and fuel flexibility appear as a significant factor (Dagsvik et al. 2002, Brownstone et al. 2000; Ewing & Sarigöllü 1998). In their own review of this literature, Cao and Moktarian (2003) point out that a lower emissions rate also increases an individual's probability of choosing AFVs "*suggesting that the innovative attribute of AFVs is well accepted by at least a niche market [of] environmentalists*" (p17).

Of direct interest to the wider ETI study is an understanding of *which* vehicle attributes have been measured in previous studies. Within stated preference surveys, the most important attributes apart from cost of vehicle purchase and operation that distinguish EVs from conventional vehicles have been found to be: range between refuelling, availability of fuel, multiple fuel capacity, incentives and, less importantly, reduction in emissions. Other attributes such as vehicle size, performance (mainly maximum speed), dual fuel capacity and market penetration, have also been explored. **Table 6 itemises the studies included in this review and documents the main vehicle attributes modelled.** These attributes will be discussed in more detail in the remainder of this section.

Table 6: Summary of the attributes measured in SP/RP surveys

AUTHOR(S)	METHOD	Powertrains	Purchase price		Fuel cost		Other costs			Fuel availability / Recharging				Performance / Driveability				Safety	Size	Emissions	Incentives/ Priviledges	Penetration	mileage	Make/ model/ style	OTHER
			Purchase price	Purchase subsidy	Fuel efficiency/ consumption	Fuel cost	Service and maintenance (including battery replacement)	Depreciation	Other	Fuel availability	multi-fuel capability	Range	Time to refuel/ recharge	Horsepower/ performance	Acceleration	Comfort/ ride quality	Top Speed								
Adler et al.(2003)	Telephone, mailback and www SP, 2002, California, N=2200, nested MNL	petrol, diesel, HEV	✓	no vehicle sales tax on purchase		£/yr	✓							✓	0-60				subcompact, mini etc		free parking at public meter, use of HOV			✓	
Ahn et al. (2008)	SP, Face to face, N=280, Age 20-59 with a car , Seoul, July 2005. DC model	petrol diesel, CNG, LPG, HEV	(all cars considered to have same pp)		km/litre	£/litre	tax and maintenance per 6 months							✓										general passenger vs. RV or SUV	
Alvarez-Daziono & Bolduc (2009)	Hybrid choice model/ SP, N=866, Canada. Bayesian method and classical estimation method	petrol, natural gas, HEV, HFC	✓			✓				% of stations selling the fuel				power relative to user						relative to a standard gasoline vehicle	HOV lane access				
Axsen. & Kurani (2008)	On-line SP + RP survey (N+535, Canada); Hybrid Choice model; 3 penetration scenarios; hypothetical information about the technology from 3 different sources (newspaper, brochure and personal testimonial)		% of user	tax rebate (% HEV capital cost)		£/week (based on mpg and ave. expenditure)								% change relative to user						relative to current vehicle		market share ratios			
Axsen et al. (2009)	On-line SP+RP, N=943, Canda and California, owners of new vehicles, March 2006, aged 19+, drove 3+ times per week, lived in an urban area; HEV owners purposively sampled	HEV, petrol	% of user	tax rebate (% HEV capital cost)		£/week								HP relative to user						relative to current vehicle		3 penetration scenarios			
Batley & Toner (2003)	SP, UK, summer 2002, N=331, MNLM	petrol/diesel; near term AFV, compromise option	on the road price or credit price			running costs (incl.depreciation and maintenance)	✓	retained value after 3 yrs or 36000 miles				range on full recharge or refuel	time for a full refuel or recharge		0-60		✓		% of a yr2000 petrol car					
Beggs et al. (1981)	Ordered logit model, N=~200, 9 cities in USA, principal drivers of a compact or sub-compact car, all commuters with daily round trips <50 miles	petrol, BEV	✓			£/10 000 miles						range before refuelling/recharge			✓		✓		seating capacity						warranty, air conditioning

AUTHOR(S)	METHOD	Powertrains	Purchase price		Fuel cost		Other costs			Fuel availability / Recharging				Performance / Driveability				Safety	Size	Emissions	Incentives/ Privileges	Penetration	mileage	Make/ model/ style	OTHER
			Purchase price	Purchase subsidy	Fuel efficiency/ consumption	Fuel cost	Service and maintenance (including battery replacement)	Depreciation	Other	Fuel availability	multi-fuel capability	Range	Time to refuel/ recharge	Horsepower/ performance	Acceleration	Comfort/ ride quality	Top Speed								
Brownstone et al. (2000)	SP + RP, nulti-wavepanel survey, California, June 1993, N=2857m Mixed logit	BEV, natural gas, methanol	price divided by natural log of household income			home and service station £/mile				Availability per 10 gas stations		miles between recharging/refuelling	at home and at a service station		0-30		✓		size relative to a compact car + luggage space	relative to 1995 new gasoline vehicle				luxury vs import/ car, truck or van	
Cambridge Econometrics (2008).	Telephone survey, N=900, recently purchased a new or nearly new vehicle; Some SP (to changes in different costs of motoring); RP analysis to estimate own and cross elasticities of past behaviour of households; WTP for fuel efficiency; Discrete choice	diesel or petrol, or 'anything else'	base price		l/100km	£/100km			insurance, VED					engine size, maximum HP, power to weight ratio	✓	✓	✓	breaking distance, No. of airbags	seating capacity, length, width, wheelbase, weight, boot volume, number of doors	CO2 g/km			household ave mileage	manufacturer + make and model	mechanical reliability, taste, warranty, security, transmission, amenities
Cambridge Econometrics (2008).	Short SP of focus group participants (N=37) using linar regression	BEVs										✓	✓				✓								cost and delay of a dead battery
Dagsvik et al. , D.G. & Aaberge, R. (2002)	SP, random sample, Norway, N=662	LPG, BEV, Dual fuel	✓		l/10km						✓	✓					✓								
Element Energy (2009)	Review of literature; analysis of NTS and EHC survey; Survey of Private + Fleet EV owners (N=36 + 11) and EV considers (N=215+16)	BEV, PHEV	✓							✓		✓	✓	✓								✓	✓		unfamilarity with the technology
Eftec (2008)	Aggregate discrete choice modelling using RP	6 categories of fuel type	✓			£/100km		resale price	fixed annual costs inc VED and insurance premiums					engine size	secs to 100km/hr; no. of gears			no. of airbags; anti lock braking system	length x width; no. of doors	CO2 g/km				13 body types	transmission, air conditionng, alloy wheels
EST (2007).	MNLI based on historic data and detailed consumer survey	12 vehicle technologies	✓			£/yr or 16000km	✓	✓	Insurance, VED	availability of infrastructure		distance on full tank			✓	smoothness (torque curve/ gear shift); refinement (NVH and Ride/Handling)	✓	perceived safety	load capacity; no. of passengers	CO2 g/km		availability to purchase			reliability

AUTHOR(S)	METHOD	Powertrains	Purchase price		Fuel cost		Other costs			Fuel availability / Recharging				Performance / Driveability				Safety	Size	Emissions	Incentives/ Priviledges	Penetration	mileage	Make/ model/ style	OTHER
			Purchase price	Purchase subsidy	Fuel efficiency/ consumption	Fuel cost	Service and maintenance (including battery replacement)	Depreciation	Other	Fuel availability	multi-fuel capability	Range	Time to refuel/ recharge	Horsepower/ performance	Acceleration	Comfort/ ride quality	Top Speed								
Ewing & Sarigöllü (1998)	Montreal, N=881, postwar suburbs, drivers to work or school,	petrol/diesel, fuel efficient, BEV	✓				✓					✓	time spent refuelling		0-60 compared to user					✓	time and cost of commuting (weekly cost for fuel and parking)				
Golob et al. (1993)	Three phase SP survey, multinomial logit (N~900) California 1991	petrol, LPG, CNG (dual fuel), BEV (high performance and low performance)	✓			✓				% of stations selling the fuel; home and work recharge	✓	✓		✓						perceived % of gasoline cars					
Greene et al. (2004)	NMNL calibraed to 2002 model year sales, 8 scenarios tested	diesel, HEV	✓	x	mpg (+ real world penalty)	£/mile				% of stations selling the fuel		✓	value of time saved not refuelling	HP, torque									decreasing with age of vehicle		
Mau et al. (2008)	Two SP surveys (N=916 + 1019), Canada, www, survey for different technology and treatment groups with different market shares, DC model (capital vitage model)	petrol/diesel HEV(gas-electric), HFC	% of user	% of capital cost		% current car				% of stations selling the fuel		distance between refuelling										market share ratios			warranty
Potoglou & Kanaroglou (2007)	Internet, Canada (urban Hamilton), 2005, N=482, NMNL	petrol/diesel, HEV, and AFV	relative to base	purchase tax		£/year (% of gasoline car)	annual cost relative to base			% of stations selling the fuel					0-60				class/ size	% of a present day average car	HOV lanes, parking fees				urban form
Santini & Vyas (2005)	SP + RP; logit model but develops coefficients for early group and majority buyers	petrol/diesel, HEV				£/mile						range			0-60				luggage space % of base trunk		HOV lane access				potential to provide back-up power to a house
Ziegler (2010)	SP CAPI Survey in car dealerships (N=598, Germany 2007-2008; those intending to buy a vehicle in near future); multinomial probit	petrol/diesel, HEV, gas, biofuel, HFC, BEV	% of user			euro/100km				% of stations selling the fuel		km per tank capacity		✓					small vs large	CO2 g/km			km per year		company car

3.3.2 The relative ranking of cost and functional attributes

Designing a discrete choice experiment entails three initial decisions: identifying relevant attributes to include, deciding the number and values of the discrete levels of each attribute and how many alternatives to include in a choice set. This process itself is reliant on previous studies and prior empirical work to elicit the attributes and attribute levels.

The majority of SP studies conclude that purchase price is the most influential factor. However, this is not necessarily borne out by other types of study which have elicited attitudes using a more simple ranking exercise (see Table 7). These studies often have the advantage of including a number of variables which cannot be easily measured in discrete choice models such as attributes relating to quality, comfort and perceptions of reliability and image/status.

Table 7 shows the results of five recent studies undertaken in the UK which have measured the importance attached to various attributes by those involved in the car purchasing process. These have been ordered in the table according to the importance attached to purchase factors found in the most recent UK study (Lane & Banks 2010). This study also has the advantage of having elicited these ranked attributes using open-ended questions so as not to pre-empt attribute choice[5].

[5] Participants were allowed to offer up to 10 responses, which they then scored on a four-point Likert scale ranging from 'Not important' (0) to 'Overwhelmingly important' (3). Responses were allocated to key categories by the survey team and the rankings reflect the weighting given to each factor.

Table 7: Comparison of ranks of importance given to attributes that influence the car purchase decision from five recent UK studies.

(NB Top five attributes in red/orange)

Car attribute	Lane & Banks 2010 ~	GFK 2009 ^	Mintel 2009 #	Cambridge Econometrics 2008 *	Angle et al. 2007 +
Fuel consumption/ running cost	1	4	3	4	3
Size/Practicality	2	1			
Purchase price	3	2	1	5	2
Style/Appearance	4	6	5	8	8
Reliability	5	3	2	1	1
Comfort	6	5	6	2	5
Safety	7		4	3	7
Brand/ image/reputation	8	10	9	12	4
Emissions	9		10	11	10
Performance/Power	10	8	11		
Fuel type	11				
Personal experience	12			9	9
Engine Size	13			14	6
Road tax	14	7			
Features/Gadgets	15				
Maintenance	16		13	10	9
Transmission	17				
Quality	18		7		
Insurance cost	19	9	8	13	9
Recommendation					12
Dealer				15	
Warranty period			12	6	
Security				7	11
Resale value			14	16	
Credit facilities			15	17	
Company car tax		11			

Sources:

~ Lane & Banks 2010: Internet survey, Feb-March 2010, N=1000 people who had either recently bought a brand new or nearly new car or were planning to make a purchase in the next 12 months (unprompted)

^ GfK 2009: Internet survey, April/May 2009, N=2000, new and used car purchasers/intenders (rankings for new cars used here) (prompted)

Mintel 2009: Internet survey, Dec 2008, N=1000 aged 16+ who own a car, (rankings for new cars used here) (prompted)

* Cambridge Econometrics 2008: Face to face (CAPI), May 2007, N= 900 those who had bought a brand new car, or a car that was less than 12 months old, in the past 12 months (prompted)

+ Angle et al. 2007: N=1020 all drivers involved in the car purchase decision, new and used cars (prompted)

From this it is clear that respondents assign approximately equal importance to a number of non-cost attributes of the vehicle such as size, style, reliability and comfort in addition to fixed and variable cost attributes, such as purchase price, fuel consumption/running cost. According to these studies, of less importance are attributes such as impact on the environment, warranty periods and resale value. Moreover, to the extent that comparisons can legitimately be made between these studies, consumer focus does not seem to have

shifted in favour of environmental issues over time, although there is some suggestion from these results that fuel consumption has recently become a higher priority.

It should also be noted that studies have found differences between new and used car buyers. Used car purchasers pay more attention to price, reliability and fuel consumption and new car buyers place more emphasis on safety, style, design, comfort and quality (Mintel 2009). This is also reflected in the table in the study by Angle et al. (2007) whereby both new and used car purchasers were studied.

It is also important to note that none of these studies specifically set out to examine vehicle attributes in the context of alternatively fuelled vehicles. The question is whether attributes that on the face of it are independent of the electric vehicle option (e.g. size) are in fact treated differently due to a new set of values and scrutiny employed by purchasers in a diversifying market. This question will be addressed in the following sections.

3.3.3 Purchase Price

Two issues are important in the consideration of the role of purchase price/capital cost[6]. First is the extent to which it is a determining factor in the choice of a vehicle and second is the premium consumers are willing to pay for a variety of vehicle attributes.

Modelling evidence based on stated preference surveys suggest that purchase price has the greatest influence on car choice. However, in the five ranking exercises considered above, purchase price ranked between first and fifth in importance among other cost and non-cost attributes. Any discrepancy is likely to be explained by the 'funnelling' process employed during purchasing in which people work within certain budgetary constraints (Lane 2005, Skinner et al. 2006). This places purchasing cost as one of the most important adoption factors but it can mean that 'lesser' factors may end up having a greater than expected role in the latter stages of purchase in influencing competing makes/models within the same price bracket. This can have implications for research on this topic as consumers often downgrade the importance attached to purchase price as they assume it is a given. In a recent focus group exercise, Lane and Banks noted that purchase price was hardly mentioned as a factor by people as the 'downstream' factors were freshest in their mind (Lane & Banks, 2010).

Many of these studies have not had an explicit focus on EVs. Element Energy, on the other hand, undertook a web based survey of private and commercial current EV owners and 'EV considerers' and asked people to rate the relative disutilities of EV ownership (Element Energy 2009). They found that both private EV owners and EV considerers consistently state that high price is the greatest challenge to ownership. It is also an important challenge for fleet users, but other factors (such as range, time to charge) were equally as important in their case.

Many studies have attempted to calculate the premium car buyers would be prepared to pay for a PHEV or BEV. The findings are related to the trade offs which are found to take place between purchase price and other attributes such as fuel economy, image and performance (examined below). It is difficult to summarise these studies as they have each used such diverse methods of elicitation. Nevertheless, there appear to be some common conclusions:

- studies have found a good deal of interest among consumers for EVs, particularly PHEVs, as well as a good deal of resistance based on the estimated cost of this new technology (Curtin et al. 2009; Element Energy 2009)

[6] Used interchangeably from this point onwards.

- however, consumer responses to increasing price premiums of plug-in vehicles in terms of purchase probabilities is generally greater than can be justified based on purely economic rationales. This means that consumer acceptance is not solely determined by costs as environmental and other non-economic factors influence the likelihood of future purchases (Curtin et al. 2009)
- the role of purchase price is discussed in all of the literature attempting to define the early adopter market for LEVs and (P)HEVs and BEVs. The possible characteristics of the early adopter segment will be discussed further in section 3.6. Suffice to say here, it is likely that early adopters of EVs will be willing to pay more for their purchase and many may not even compare the price difference with conventional vehicles (Element Energy 2010; Kurani et al. 2007; Heffner et al. 2007; PlanNYC 2010).

On the latter point Kurani, Heffner, and Turrentine (2007) suggest that if PHEV buyers behave in the same way as the early market for HEVs, *"data on consumers' willingness-to-pay for PHEV technology derived from the assumption that people are simply comparing powertrains in otherwise identical vehicles may not be useful in predicting demand"*' (p5). However, this does not assist our understanding of the likely behavioural response to price by the 'early majority' segment.

3.3.4 Fuel economy

A review of the vehicle choice literature highlights inconsistency observed within and between studies on the importance of fuel efficiency as a factor in the purchasing behaviours of consumers. Some studies found that consumers are not primarily concerned about fuel efficiency (Kurani et al. 2007; Turrentine & Kurani 2007; Santini & Vyas 2005; Sovocool & Hirsh 2009) whereas other studies found a positive correlation between fuel efficiency and purchase decisions (Cambridge Econometrics 2008; Popp et al. 2008). Others highlight the 'mpg paradox': that although 'mpg' is reported by car buyers as a key decision factor, little effort is actually made to compare fuel consumption data during the decision-making process (Lane, 2005; Anable & Lane, 2008; Sovocool & Hirsh 2009; Skinner et al. 2006).

The ranking exercises outlined in Table 7 suggest that fuel efficiency is indeed the cost factor that respondents often consider most important. It is possible that the importance attached to this has risen recently given high oil prices and recessionary pressures (Banks & Lane 2010; Anable & Lane 2008; Sovocool & Hirsh 2009). This has been reflected in recent car purchase trends in the UK towards smaller vehicles (SMMT 2010a). However, despite recent trends, there is debate as to the degree to which the stated importance attached to fuel economy translates into vehicle preference at the individual level.

A common assumption is that consumers will pay more for technologies that increase fuel economy only if the initial cost of these technologies is offset by the cost savings during a specified period of time, known as the 'payback period'. Consumers are assumed to consider the cost of fuel and fuel economy both in their travel and vehicle choices, and to consider such costs over time.

Many stated choice experiments are designed with this assumption in mind and set out to understand the fundamental trade-off between vehicle price and fuel cost (Beggs et al. 1981; Cambridge Econometrics 2008; Curtin et al. 2009; Eftec 2008; EST 2007; Garwood & Skippon 2010; Santini & Vyas 2005). Discount rates are used widely when assessing a consumer's awareness of lifetime cost savings and therefore predicting market uptake of new energy saving products ranging between 0 and 41% (EST 2007; Sovocool & Hirsh

2009; Beggs et al. 1981).The higher the discount rate, the less consumers take account of lifetime costs.

Based on consumers' actual expenditure on fuel with their current vehicles, in the US context Curtin et al. (2009) found the average payback period for the added premium to be offset by fuel savings ranged from 2.0 to 8.5 years at an inflation-adjusted discount rate of 3%. In the UK, Cambridge Econometrics (2008) found that households are willing to pay £510 in extra purchase price to reduce fuel costs by £1 per 100 km, implying a discount rate of 6-19%, a rate comparable to the findings of other studies. Garwood and Skippon (2010) conclude that consumers will be willing to pay purchase premiums of up to 4 times the perceived annual running cost savings.

EST questioned the relatively high valuation their UK-wide consumer survey inferred for fuel consumption. The valuations implied the average consumer would capitalise up to 20 years of fuel costs at the point of purchase (at 2007 fuel price). EST make the observation that, in addition to the effect of *''expectation bias' whereby survey respondents tend to overestimate the factors the survey is supposed to be investigating"'* (p35), the discrepancy may reflect consumers' difficulty in converting from fuel consumption (expressed in l/100km and miles per gallon (MPG)) into an effective yearly cost.

This concurs with several studies showing that the majority of consumers do not have even the fundamental building blocks to be able to make detailed payback calculations. Three separate studies in California with conventional vehicles, HEVs and PHEVs found that few consumers of any vehicle type actually perform payback computations when purchasing any type of vehicle (Heffner et al. 2007; Kurani et al. 2007; Turrentine & Kurani 2007). The latter study included eight hybrid owners and the authors emphasise "*no hybrid owner we interviewed was solely or even importantly interested in saving money on gasoline. They did know a lot more about the vehicle and the environmental issues it addresses than they did about their own gasoline cost"* (Turrentine & Kurani 2007, p1221).

These studies found that many did not know the mpg of their vehicles, much less what they spent cumulatively on fuel in a month or a year. Therefore, the authors suggest such consumers will have no way of knowing how much they might save in a 'fuel economic' vehicle.

Similarly, two recent studies in the UK (Anable et al. 2009; Lane & Banks 2010) investigated recent purchasers of brand new or nearly new vehicles and found the 'mpg' metric is rarely used by motorists to calculate future costs or to systematically compare vehicles. Instead, simplistic rules are used to decide on what is 'good' or 'bad' such as simple comparisons with the previously owned vehicle, or assuming all cars in a certain vehicle class will have approximately the same fuel economy. Once the initial 'ball park' criteria has been satisfied, no further comparisons or calculations are made. These are the simplifying heuristics highlighted in Table 5.

In both studies, around half the sample were able to quote their car's fuel economy in terms of miles-per-gallon and around 35% of the 2010 web-survey sample were able to volunteer a value for annual fuel cost. Consumers are most likely to offer a value for the most recent expenditure to fill up the tank, or an average weekly or monthly fuel cost. In the Cambridge Econometrics study (2008) only 17% were able to state the fuel efficiency band of the car they had purchased.

Other studies have set explicit exercises to test people's understanding of mpg. Larrick and Soll (2008) found the mpg metric is frequently misunderstood and can lead to inaccurate judgements. For instance, the idea that upgrading a car from 18mpg to 28mpg saves twice as much fuel for the same distance of driving as upgrading from 34mpg to 50mpg generally

tends to catch people out. This reflects the fact that mpg does not capture the way people generally conceptualise fuel economy.

The inability of consumers to balance longer term running costs with upfront investment is otherwise known as consumer 'myopia' (Skinner et al. 2006). Lane (2005) identified a number of reasons why 'mpg' is reported by car buyers as a key decision factor, but in reality, little effort is made to compare fuel consumption data during the car-purchase process:

- car buyers assume a similar 'mpg' for all cars within a class
- car buyers have little confidence in published fuel economy data
- car buyers believe that improving 'mpg' compromises performance and safety
- fuel costs are too complex for consumers to compute (combining 'mpg' and pence per litre to give pence per mile).

There are three factors which may serve to strengthen the role that fuel economy plays in the choice of vehicles.

Firstly, rising oil/petrol prices may lead to more economically rational consideration by consumers. There is evidence of this in the UK market where UK motorists are now taking account of fuel economy and choosing more fuel-efficient cars as evidenced by the significant shift to smaller cars in recent years (SMMT 2010a). However, the research by Anable et al. in the aftermath of the rising oil prices in the UK in 2008 showed that it is not the fuel economy metric itself which is conceptually driving behaviour (Anable et al. 2009). Although car buyers still refer to fuel economy (in terms of 'miles-per-gallon' or equivalent) it was more simply the cost to fill up the tank that instigated the change in behaviour towards more efficient vehicles.

Secondly, a related factor is the rate at which fuel prices may increase and the specific impact this has on behaviour. Smaller gains in fuel economy seem to be evaluated with a higher discount rate than the larger ones (Santini & Vyas 2005). Santini and Vyas argue that consumers are likely to pay more careful attention to fuel savings when the amounts are large. The differential can be due to technical efficiency, but can also be due to the rate with which oil prices rise. Anable et al. (2009) concluded that the rapidity with which prices had risen during 2008 had led to a threshold effect in which fuel costs had penetrated sufficiently into consumers' consciousness so as to stimulate new behaviours. Sovacool and Hirsh (2009) similarly concluded that the fuel price rises in the UK during 2008 had convinced some consumers to switch permanently from gas-guzzling to more energy-efficient automobiles. But it also appears that the motivations for this switch were not detailed economic analyses, but simple reactions to sharp increases in the price of fuel. Moreover, Kurani et al. (2007) observed that respondents appeared to assume that electricity would remain either constant in price, or would increase in price more slowly than gasoline.

Thirdly, the diversification of fuel choices and prices could have an impact on consumer decision making processes, particularly in conjunction with volatile oil prices, awareness of oil dependence and security as well as new fuel economy instrumentation and CO2 awareness (Kurani et al. 2007). Studies based on real consumer experience so far suggest that these new energy sources do not result in more attention being paid to fuel costs. For instance, Kurani (1992 cited in Kurani et al. 2007) studied Compressed Natural Gas (CNG) buyers in New Zealand and found that instead of calculating fuel costs, *relative* natural gas and gasoline prices were used to gauge satisfaction with their vehicle conversions. More recently, the same authors observed that drivers of PHEVs omitted their grid-based electricity use when discussing fuel economy even though many in-vehicle displays

indicated the consumption of both sources of energy. Whilst different behaviours may be observed in BEVs, it seems plausible that consumers are accustomed to measuring vehicle fuel economy in a certain way and there is little indication of how electricity use will be conceptualised and evaluated.

Once again, the early adopter segment is often hypothesised as being atypical of how the market will develop (see Section 3.7). It could be, for example, that early adopters of EVs may not undertake any meaningful calculation of fuel consumption and cost as they are less motivated by financial savings. On the other hand, a finer segmentation of HEV early adopters between 2003 and 2007 in the US found four of the five segments they identified as clearly financially motivated in their own way (Klein 2007). **These motivations are outlined in Box 1**.

BOX 1: Five Segments of Prius Car Buyers in the US (2003–2007)

The Prius costs less than the alternative

- consumers are able to purchase and operate the Prius for less, sometimes far less, than they would have spent on a car if they had not purchased a hybrid
- it cannot be assumed that the consumer is choosing between two otherwise identical cars and elects to purchase the hybrid car instead of the one with the conventional gas engine
- even those who would have spent an identical amount on a conventional car had a financial motivation—they believed that the Prius would save them money on gas

Buyer calculated return on investment differently than the experts

- 16% of Prius buyers stated that the primary reason for buying the Prius was to save money on gas and given the various analyses that show hybrids do not save enough on gas to pay for their higher purchase price, there might be a tendency to view these people as making an uninformed choice
- however, all analyses regarding the costs and benefits of a hybrid purchase are based on assumptions—whether or not hybrids make financial sense is very much in the eye of the beholder and a cash flow analysis of hybrid ownership costs coupled with intended length of ownership can lead to a conclusion that hybrids make economic sense

Buyer bought the Prius to drive in the carpool lane

- For 12% of buyers, getting to drive in the carpool lane even when they were driving alone was their primary motivation for buying a Prius and far exceeds the incremental cost of the car
- At the time of the study six states (Arizona, California, Florida, New Jersey, Utah, and Virginia) allow some hybrid drivers to drive in the carpool lane regardless of the number of passengers in the car

Buyer bought the Prius as an inexpensive fun car

- 5% of the respondents purchased their Prius because they liked its image as a fun car
- the Prius' distinct image was an important factor and all of these people would have bought a less expensive car if they had not purchased the Prius

Early adopters

- 27% of the study sample comprised of people willing to pay a premium to help the environment or to be among the first to own a hybrid

Source: Klein 2007

The segmentation outlined by Klein has a parallel with Santini and Vyas' solution to the problem posed by the fact that consumers do not undertake any considered calculation of future running costs. They offer the hypothesis that "*once the pragmatic majority buyer decides that a technology is interesting, that buyer seeks out other scarce, but important, expert pragmatists to acquire the information needed to make an intelligent decision on whether to make a purchase. Thus … the fact that buyers do not know how to use Net Present Value*[7] *(NPV) analysis is not important — what is important is that they know where to find information from someone who does do NPV analysis"* (Santini & Vyas 2005, p98).

Fuel economy can be a symbolic factor as well as a functional one. Lane and Banks (2010) believe the high importance that new UK car buyers attribute to fuel economy can be seen not only as one of the most important car purchase factors, but also as a way of conceptualising a car's environmental impact. Kurani et al. (2007) found fuel economy to be an important symbol among drivers who view resource conservation or thrift as important. They also noted that consumers also assign non-monetary meaning to fuel prices, for example seeing rising prices as evidence of conspiracy.

In addition to highlighting the limitations inherent in rational choice modelling of consumer behaviour, the findings on fuel economy have implications for incentivisation of EVs and recharge tariff structures discussed in Section 3.6. In summary, the evidence review suggests that whilst there is no question that widening the gap between electricity prices and fuel prices will make EVs more attractive, policy makers and modellers may have a tendency to over-emphasise the importance of rational deliberation of longer term running costs and payback periods. Similar conclusions apply to recharging behaviour where patterns may not be driven by cost savings but more by convenience (Section 3.3.9).

3.3.5 Other running costs

Consumer myopia also applies to other relevant cost factors such as **tax, maintenance, insurance, depreciation, disposal costs** and, in the case of EVs, **costs of battery replacement**. These costs could be important in the uptake of EVs because of possible trade-offs between the higher capital cost and frequency of battery replacement, and the lower tax and maintenance costs (Ewing & Sarigöllü 1998; Cao & Mokhtarian 2003). Gärling and Johansson (1999) found that low **maintenance costs** were one of the reasons offered most frequently in interviews of families who had used an EV for three months.

Table 7 showed that in simple ranking exercises these attributes are given less weight in the decision making process. **Service and maintenance costs** have been examined in a variety of stated preference surveys (Table 6), often combined in a category covering all vehicle running costs. As expected, discrete modelling exercises conclude that these costs have a negative impact on preference and the effect is usually weaker than other measured attributes.

Perhaps as a consequence of this, they are rarely considered in any detail in studies of car purchasing behaviour. One exception is Ewing & Sarigöllü (1998) who estimate how much lower weekly commuting costs would have to be to compensate people for each $100 annual increment of **maintenance** costs for an EV. The conclusion was that to have competitive running costs, savings from the EV's lower operating costs should be triple any higher maintenance costs it may incur. This suggests that policies such as electronic road pricing or carbon taxes for non-EVs might be needed to help improve the image of the EV's relative operating costs.

[7] defined as the sum of the present values (PVs) of the individual cash flows/ costs

Similarly, Potoglou and Kanaroglou (2007) estimated willingness to-pay for acquiring benefits such as reduced maintenance and fuel costs, tax exemptions, and improved vehicle performance. They concluded that households would pay between $500 and $1200 to save $100 in annual maintenance cost.

Resale value is thought to be an important consideration in car purchasing and yet is rarely examined as a discrete adoption factor. In-depth interviews with recent purchasers of new cars found a fifth of the sample spontaneously mentioned resale value as a cost issue that had played a role in car choice (Anable et al. 2009). However, a similar unprompted questioning technique on a larger sample did not find people mentioning depreciation as an important factor (Lane & Banks 2010). Using historic data in a nested logit model, EST (2008) found resale price to be an important determinant of household choice of new car.

The impact of **battery replacement cost** on consumer willingness to adopt electric vehicles is virtually unexplored in the literature reviewed for this study. Santini and Vyas (2005) recommend including the lease cost of the battery pack as a proxy variable, but do not discuss the potential impact on preference.

Another cost factor specific to EVs is the possibility of generating revenue by selling electricity back to the grid. **Vehicle-to-grid (V2G),** combined with smart charging, have been proposed as one method to offset the additional costs of PHEVs. This concept has not been explored with UK consumers in any of the literature reviewed. However, Kurani et al. (2007) found that the drivers that did mention this technology were either employees of the electric utilities or were excited about the possibility of providing electricity to their home during electricity outages. Scovacool & Hirsh (2009) are pessimistic about this technology as they feel that even with technical problems resolved, the V2G concept may not gain widespread acceptance if the experience of the first-cost hurdle experienced in other technologies (e.g. home insulation, water heaters) are anything to go by. Nevertheless, the ideas of EVs providing extra revenue or emergency power may be valued by some consumers and is likely to be worth further evaluation in the UK context.

3.3.6 Performance

For electric vehicles to gain mass market acceptance the performance and drive aspects are thought to need to be similar or superior to conventional vehicle technology. Preferences for greater fuel efficiency are often found to be overshadowed by stronger affinities for **power, acceleration and size** (Thatchenkery 2008; Axsen et al. 2009; Lane & Banks 2010).

Yet assigning a standard measure of utility to a vehicle's performance or other attributes is difficult as the level of utility depends on the individual's perception (Alvarez-Daziona & Bolduc, 2009; Skinner 2006). This is especially important with respect to vehicle performance as consumers have been found to have generally negative perceptions with regards to alternative vehicles' attributes especially with regards to performance.

For instance, in recent focus group discussions in London, electric vehicles were the most widely known type of alternatively fuelled vehicle (Lane & Albery 2009). This may be because of the London setting of the research and the rapid uptake in recent years of G-Wiz electric quadricycles in the city due to their exemption from the Congestion Charge. There are also several electric charging points in Camden where the research took place. Yet, the researchers note that very few people are able to explain confidently how electric vehicles work but nevertheless hold a general perception that electric vehicles have a lower level of performance than conventional vehicles, with inferior **acceleration, lower top speed and low range** being common issues mentioned. It is interesting to note, however, that this lower performance is not always viewed as a disadvantage given the driving conditions in London. A second point worthy of note is that unlike similar surveys conducted a decade or

so ago, Lane and Albery remark that 'milk-floats' are not mentioned by participants in any of the discussions suggesting that evaluations of these vehicles have improved in recent years.

With respect to hybrid vehicles, a minority are often also confused about whether hybrid vehicles need to be recharged as well as refuelled (Lane & Albery 2009; Axsen & Kurani 2008). However, in the recent UK study, participants who had an opinion about this technology were generally positive about the level of **performance** and usability offered by hybrid vehicles. By contrast, in the USA, Greene et al. (2004) found that consumers think of **fuel economy** and **low pollution**, but not high **performance** in relation to hybrid vehicles.

Importantly, in the findings of the few EV vehicle trials that have been conducted (see Table 3.6), ratings of EV performance increases once consumers have gained some experience of the vehicles. Garwood and Skippon (2010) found that EVs were perceived by consumers as having better 0–30mph **acceleration**, better **smoothness** and lower **noise** than conventional vehicles after short drive-trials with four-seater Mitsubishi iMiEV vehicles.

Recent trials in the North East of England found that although the overall performance of the (two-seater Mercedes Smart) vehicles were rated as 'good' as compared with a similar classed fossil fuelled vehicle, users rated the **noise** level and the **environmental feel good factor** of the EV more positively than other performance criteria (Caroll & Walsh 2010).

In a study of drivers of converted Toyota Prius', Kurani et al. (2007) note that the most common request was for higher **top speed** and the ability for all-electric drive on highways, but that few commented on other related performance metrics such as **acceleration** times or **passing power**. This supports Santini and Vyas' (2005) argument for inclusion of at least one **top-speed** variable in SP surveys.

3.3.7 Size and carrying capacity

Size / practicality was ranked top in a 2009 internet survey in the UK (GfK 2009) and second in the recent unprompted survey undertaken by Lane and Banks of over 1000 purchasers of new vehicles in the UK (Lane & Banks 2010) (Table 7). In parallel focus groups, vehicle size ranked as the most important purchase issue as measured by the number of Post-Its generated during group discussions, and was one of the top three factors in five of the six groups (*ibid.*). It is a vehicle attribute often traded off with fuel economy. As the reason most often given for the importance of vehicle size was the need to carry children, the choice of car was seen to be heavily influenced by life stage. The exception to this was when choosing a second car enabling respondents to choose a model more to their own liking rather than serving family requirements.

The authors note that for many participants, **size** was a common starting point for vehicle selection, and a factor which had priority over other purchase issues. Terms repeatedly mentioned are '**number of seats or doors'**, '**headroom'**, '**legroom'**, '**boot space'**, '**seat height'** and 'physical size' of the vehicle. Similarly, Skinner et al. (2006) suggest that where size ranks lower in surveys this could be accounted for by the 'two stage' decision process wherein an initial filter is applied to select vehicles of the desired size and body type, after which other attributes are more consciously considered.

Traditional functional vehicle characteristics such as performance and vehicle size are still of considerable symbolic value alongside fuel economy and low CO2 emissions. Symbolic values are discussed in Section 3.4.

3.3.8 Range / battery life

What proportion of UK car mileage could be carried out using EVs?

Several authors have compared current travel patterns with the likely range and charging infrastructure that may be available.

In the UK context, Element Energy has offered the most comprehensive analysis of travel patterns of existing EV owners and 'considerers' in addition to analysis of the UK National Travel Survey. Their findings are summarised in Box 2.

Box 2: What proportion of UK car mileage could be carried out using EVs?

Analysis of EV owners and 'considerers'

- For those with EVs already, the vehicles are most commonly used for travelling 10–20 miles a day, with some using them for up to 40 miles a day. They observe that the daily mileage of 'EV considerers' is generally greater than 40 miles and their journeys for commuting, visiting friends and family and school runs tend to be longer.
- EV owners typically have lower mileages than the population overall.

Results from the NTS Analysis

- The driving patterns of a significant proportion of the UK population are dominated by relatively low daily distances. For example, half the people in the sample analysed did not exceed 40km (25 miles) on any day of the travel diary week. This implies that the majority of trips for many drivers could be done by today's EVs.
- Commuting is the dominant trip purpose and around two-thirds of commuting trips are less than 16km (10 miles). This suggests that there is a significant number of commuters with round-trip commutes of less than 20 miles.
- An important distinction must be made between trips and distance. For example, a vehicle with a utilised range of 100km, would account for over 90% of trips, but only 60% of overall UK car-km.
- Assuming a utilised range of 80km (i.e. the capable range is much higher, between 120km and 240km), 50% of all UK vehicle-km can be undertaken by EVs. The remaining distance is undertaken by a relatively small number of high mileage individuals.
- A combination of increased EV range and suitable range extension facilities (i.e. charging infrastructure and/or battery exchange networks) will be needed to achieve high EV car-kilometres and deep cuts in CO2 emissions
- To achieve an 80% reduction in CO2, assuming that renewable electricity was used to charge EVs, would require a vehicle with a utilised range of circa 200km (and therefore a capable range between 300km-600km, assuming current behaviour patterns). Battery technology is unlikely to deliver this very high, single charge range in an affordable vehicle.
- If all drivers switched to PHEVs with electric range of 30km, up to 48% of all car-km could be done in electric mode. This percentage rises to 63% and 72% for PHEVs with electric range of 50km and 70km respectively.

Source: Element Energy 2009

Range anxiety

Limited range and long refuelling times are significant barriers to the acceptance of EVs. The potentially lower operating costs of EVs compared to conventionally powered vehicles are not valued highly enough to overcome both the purchase price and this major disutility,

especially for BEVs (Beggs et al. 1981; Chéron & Zins 1997; Element Energy 2009; Garwood & Skippon 2010; Golob & Gould 1998; Santini & Vyas 2005).

The most comprehensive evidence to explore the issue of range has emerged from before and after studies of vehicle trial participants or existing owners of BEVs or PHEVs. **.**

Table 8 summarises the seven studies reviewed in which trials had formed a major part of the investigation.

Table 8: Summary of before/ after studies of vehicle 'trials'

Author	Which cars	Method	Who	Where	When	Data collection
CABLED (2010)	25 Mitsubishi iMievs (range 60–80 miles on full charge)	Vehicles loaned for 12 months	Members of public part of TSB/ CABLED trial		13/12/09 – 12/3/10	Usage data (not charging) collected from demonstrator vehicles
Carroll & Walsh (2010)	4 BEVs (two seater: smart Mercedes, 60mph top speed)	1–4 vehicles loaned up to a month to fleet users/ managers + public 'test drives'	10 fleets, 195 drivers (7 local council, 2 private company, 1 university) + 69 members of public at 3 events	NE England	~2009	Fleet user (N=113), fleet manager (N=8) and public drive events before and after questionnaires
Gärling (2001)	BEVs (Renault Clio Electrique, 4 seater, 60–70km range, 10 hr charging time)	Loaned to families for three months chosen from a random survey	42 families with at least one child + 32 Renault Clio owners	Goteborg (Sweden)	1998–00	Before/after interviews; travel diaries in weeks with own car (before and after) and with the EV in alternate weeks during the trial (N=74)
Garwood & Skippon (2010)	BEVs (Mitsubishi iMiEV; 4 seats, 100 mile range, recharging time 6–7 hours)	10 mile drive: pairs of participants each driving for half the round-trip OR commute home, recharge at home, return next day	92 employees of E.ON	UK (unspecified)	2009–10	Post experience questionnaire (N=58)
Golob & Gould (1998)	BEVs (Manufacturer prototypes; two-seaters, range = 100m)	Loaned to families for two weeks	69 private individuals selected from survey sample	California	1995–96	Travel diary (N=63) + pre & post surveys (N=69)
Kurani et al. (2007)	15 PHEV conversions	Had all been operated for less than 12 months	23 individuals whose (private or company) HEVs had been converted	Mainly California but USA-wide	2006–07	Semi structured interviews
Martin et al. (2009)	Hydrogen FCVs (Mercedes A-Class F-Cell)	Ride and drive clinics: 3 mile drives + visit to refuelling station in pairs	182 Employees of public departments and the University	California	2007	Pre and post surveys (N=182)

A recent study of participants of a short-drive BEV trial in the UK found BEVs with a range of 100 miles will start to be attractive as second cars; with a range of 150 miles they will start to be attractive as main cars (though not to high income consumers) (Garwood & Skippon 2010). One study in Europe found that interest in owning EVs actually *decreased* after a few

months of use due to concerns over range and that the range per charge should be at least 130km (compared to the 60–70km range of the Renault Clio Electrique trial vehicles) (Gärling 2001). Golob and Gould also found that experience with BEVs did not change perceptions about desired vehicle range. Even though keeping a travel diary gave users direct feedback that they were usually travelling less than 50 miles per day, there remained an expectation that vehicles should have a range of 100 miles or more (Golob & Gould 1998).

Thus, a high premium is placed on the ability to have the *option* to drive long distances, despite the fact that most consumers acknowledge that longer trips can be relatively rare (Element Energy 2009) The majority of participants in the Swedish study felt the range should be longer even though their experience in the trials was that the EV had fulfilled their travel needs and expectations (Gärling 2001). Golob and Gould suggest it may be to do with a "*psychological association between vehicle ownership and the freedom to travel with wider boundaries*" (Golob & Gould 1998, p447).

Under-utilised range

In BEV/PHEV trials, drive data shows that users are over cautious when planning journeys. In recent BEV trials with public and private fleets in the North East of England, the maximum journey length was 18km, representing only 46% of the minimum range (Caroll & Walsh 2010). The authors of this study suggest that range anxiety effects were significant throughout the trial with 93% of journeys commencing with over 50% battery state of charge and only 7% of journeys were undertaken when the battery was showing less than 50% state of charge. Moreover, users began modifying their driving style when the state of charge approached 50%.

The first data to be released from one of the UK's Technology Strategy Board (TSB) trials, shows data for 25 Mitsubishi iMievs during the first three months of usage (using GIS data loggers) (CABLED 2010). Approximately two-thirds of all journeys made were shorter than 5 miles in length (mean=6 miles), with quite high frequency throughout the day, suggesting people use their cars for short journeys at lunch time or to collect children from school. The mean number of miles driven each day was approximately 22 miles.

Analysis of existing BEV users in the US suggested that between one-third to one-half of the technical range is actually used (Golob & Gould 1998). In Swedish trials, around 50% of total driving range tended to be used and only two out of 74 participants said they had started to recharge after the warning light came on (Gärling 2001). In Tokyo, battery utilisation rates were examined before and after a fast charger was installed in the city (Tepco R&D Centre, cited in Element Energy 2009). Beforehand, around one-third of the potential range was utilised, but this increased to two thirds following installation. This suggests that fast charging, not number of charging points, is a key factor in optimising EV range.

The BEV trial study in Sweden examined which trips were undertaken in the EV (Gärling 2001). Trips with the BEV were shorter than those with the participants' own cars and most commonly used for work, chauffeuring and shopping. Indeed, the latter two journey purposes increased when the subjects got the BEV. Interestingly, more than half of the participants reported a change in their travel behaviour and their way of driving to match the specific attributes of the BEV. About 15% of the participants stated that they had had to give up car trips, 30% that they had had problems with the limited driving range, 5% that they had had problems with the relatively long recharging time, and 25% stated that they had had problems with the limited cargo space.

Element Energy conclude that "[i]n the early stages of EV adoption, concerns over infrastructure may limit exploitation of range to circa one third of technical capacity. Longer term this utilisation ratio should increase as users become more familiar with the technology and fast charging infrastructure becomes more widespread" (Element Energy 2009, p13).

Willingness to pay for extended range

In two choice experiments of both existing UK EV owners and 'considerers', participants were asked how much they would pay for additional range or how much range they would expect for a given cost (Element Energy 2009). Whilst EV owners had a slight tendency to be willing to pay more than considerers and there was a wide range in values, the median willingness to pay can be summarised as in the range of £45–£111 per mile.

Will consumers prefer BEVs or PHEVs?

PHEVs do not suffer the same restrictions as BEVs given the range extension provided by the liquid fuel operation. Several studies have concluded that consumers are likely to prefer PHEVs (Axsen & Kurani 2010; Axsen et al. 2010; Element Energy 2009; Garwood & Skippon 2010; Kurani et al. 2007).

In an experiment using a one-day diary, a tutorial on PHEVs and design games in which participants could create their own vehicles and set their own goals, there was a strong interest in increasing vehicle range, but not through all-electric range (AER). The strongest motivation was for higher fuel economy achieved through blended operation. All-electric operation was incorporated into the designs by only 2.7% and 3.9% of respondents in the higher and lower cost conditions respectively (Axsen & Kurani 2008; Axsen et al. 2010). With respect to PHEVs, Kurani et al. (2007) found that most owners run their cars on electricity as much as possible when driving conditions permit.

These studies concluded that most of those who are interested in a PHEV are interested in less technologically advanced PHEVs than assumed by experts. Another study concluded that 20 miles of all-electric range seemed to be the minimal acceptable amount (Kurani et al. 2007). This study concluded that the solution is likely to be to offer PHEVs in a variety of configurations with some PHEVs which offer no AER but instead attain very high fuel economy with a lower purchase price, and others with higher AERs appealing to different segments of car buyers. This would include those who are strongly motivated by the symbolic meanings of PHEVs.

Element Energy found that EV owners are willing to pay slightly more for PHEVs than considerers of EVs, although even among these early adopters of EVs, the amount they are prepared to pay is lower than battery supply costs. Nevertheless, Element Energy conclude "that PHEVs with a range of 40 miles in electric mode could achieve significant market uptake while delivering electrification of the overwhelming majority of vehicle trips" (Element Energy 2009, p1).

Another possible solution is that households will adopt a multi-car solution to optimise range and recharging time and the choice of which vehicle to use (Chéron & Zins 1997; Gärling, 2001; Golob & Gould 1998). Indeed, Element Energy comment that nearly all the EV owners in their study also had access to a non-electric vehicle (Element Energy 2009) and Golob and Gould (1998) found that whilst participants in the vehicle trial were able to use the EV vehicle for much of their daily travel, they switched to gasoline vehicles on days with longer trips. Kurani et al. (1996) developed the concept of 'hybrid households' to refer to households that own various vehicles to satisfy different travel needs.

3.3.9 Availability of Charging Points

Range anxiety is likely to be exacerbated in the current situation where public charging infrastructure is minimal (Element Energy 2009; Carroll & Walsh 2010). However, studies have generally found the lack of recharging infrastructure to be less of a concern to consumers than range *per se*. Indeed, the clear consensus in the evidence so far is that consumers will mainly recharge their EVs at home and in workplace car parks and frequent recharging will be the norm at least at first (Garwood & Skippon 2010; Gärling 2001; Element Energy; Kurani et al. 2007).

Nevertheless, qualitative and quantitative research consistently reveals a concern from consumers about how and where they will be able to 'fuel' their vehicles (Plan NYC 2010, Element Energy 2010; Golob & Gould 1998). A key issue in predicting the environmental benefits and fuel savings from PHEVs is the frequency and timing of recharging, especially when many studies assessing the impact of EVs on the electricity grid generally assume these vehicles will charge only during periods of off-peak power demand.

What patterns of charging behaviour might consumers adopt?

In the vehicle trial studies outlined in Table 8 and other studies of EV owners, recharging patterns have been documented.

A survey of 36 existing EV owners (unspecified types) in the UK found they primarily recharge their EVs at home and commercial owners at company premises (Element Energy 2009). Similarly, in three month trials of EVs with 74 families in Sweden, the EVs were most often charged at home (66–82% of recharges) and there was no change in recharging behaviour over time (Gärling 2001).

In the trial of fleet users in the North East of England, a mix of indoor and outdoor charging was used (Carroll & Marsh 2010). Half of the public sector fleets had some access to dedicated recharging infrastructure and consequently rated charging facility availability and safety 20% and 13% higher than private fleets respectively. Overall there was a positive attitude towards charging which the authors believe shows that the users accepted the electric vehicle charging requirements, and did not draw comparison to refilling a conventional vehicle with fuel.

Table 9 summarises the different charging regimes used. Some users may have experienced all the charging regimes whilst others only a few.

Table 9: Recharging method, equipment and frequency in the Cenex EV trial

Recharging regime description	No of recharging regime experiences
Recharged at work	86
Recharged indoors	45
Recharged using dedicated recharging facilities	38
Recharged outdoors	39
Recharged using a normal indoor plug socket	39
Recharged using an extension lead	18
Recharged using a normal outdoor plug socket	9
Recharged at home	7
Total	**281**

Source: Carroll and Marsh 2010

Usage data after three months of use of 22 Mitsubishi iMievs in the UK showed that each car is parked on average 97% of the time (Aston University 2010). Usage data shows two main periods when a vehicle is parked (and thus can be charged): 8pm–7am when most cars will be at home locations provides the main opportunity for charging and 9am–3pm also provides a period when EVs are used less and thus could be charged. However, the authors suggest that because this trough is not too pronounced, if people do need to charge in this period, fast charging would be more appropriate. People tended to leave their EV plugged in over night or even for several days if they were not using it. There was an initial peak between 6pm and 8pm and between 10pm and 2pm when people set the timer on their charger so as to benefit from off-peak power. Other statistics associated with the charging data show that people charge their EV every 0.57 days, that is, approximately twice a day. Also the EV was plugged for the equivalent of 22% of the time.

In observations of 15 PHEV conversions in the USA, nearly all vehicles were regularly charged during daytime business hours. When drivers had the capability to refuel from the electricity grid (which was often as all could recharge from a common household outlet) and, as for many of these people, did not personally face the different costs of doing so, they recharged whenever possible. This included 'opportunity' charging at hotels, friends' houses and offices visited during the day. The vehicles that were plugged in most often were those that made short trips (less than 40 miles) and regularly returned to a single location where recharging was available. Many participants explained that since they were driving a PHEV, they wanted take advantage of recharging (Kurani et al. 2007). However, in a study of driving patterns, parking and charging availability, home was identified as by far the most frequent location of recharge opportunities within respondents' existing travel and recharge potential. Neither work nor other non-home locations had recharge potential that was available for more than 9% of respondents for any 15 minute interval during the day (Axsen & Kurani 2010).

Availability of parking

Parking affects recharging and the patterns observed in private households and to some extent fleet vehicles will be dictated to a large degree by parking availability.

The English Household Condition Survey[8] offers an indication of the proportion of households with access to various types of parking facilities. Analysis of this dataset indicates that fewer than 50% of city centre households have access to adequate parking facilities, while around 95% of rural households do have parking (Element Energy 2009). However, Element Energy note that both household car ownership and parking availability increase as rurality increases, which suggests that most car-owning households do have access to parking. In addition, their analysis of the ONS Omnibus survey also suggests that around 80% of car owning households use a garage or other off-street parking facility. They conclude "*[t]his suggests that in a world with mass uptake of EVs, a large proportion of EV owners would be expected to recharge at home and would not require additional infrastructure to keep their vehicles charged at home"* (Element Energy 2009, p30).

Studies in California also agree that reliance on proxy aggregate variables such as housing types and parking availability can lead to underestimates of the potential to recharge, Estimates of parking availability could be overly pessimistic as households who buy new cars may be more likely to live in houses with dedicated parking facilities (Axsen & Kurani 2008; Axsen & Kurani 2010, Axsen et al. 2010). They suggest it is worth considering the

[8] CLG (2007) English House Condition Survey 2007. London:Communities and Local Government.

opportunities for additional charging outlets that people may have. In addition to a web based survey and the use of PHEV design games, they produced a travel diary which also asked people to record their proximity to the nearest charging plug every time they parked. A parking spot was considered to be viable for recharging if located within 25 feet of an electrical outlet. They believe this identified more home-charging opportunities than aggregated Census or other data identified. From these studies they conclude:

- at least half of the survey population (N=877) are already equipped for at-home vehicle recharging
- people currently have little opportunity to recharge at their workplace or other locations: only 4.4% of respondents found outlets at work, and 9.1% found outlets at all other non-home locations (e.g. friend's home, school, or commercial site)
- recharge potential (i.e. the spatial-temporal correspondence between a parked vehicle and a 110-volt electrical outlet) peaks between 12am and 6am when most vehicles are parked at home and reaches a broad minimum from 10am to 4pm when most vehicles are parked at work or other locations or are being driven
- given the access to recharging and the distribution of PHEV designs from the games, the authors estimate that about one third of U.S. new vehicle buying households have both the required infrastructure and interest to purchase a vehicle with plug-in capabilities.

Survey research in New York noted that, of those who do own a car, many park their cars on the street or in commercial garages (Plan NYC 2010). Nevertheless, they believe a large group of early adopters will be willing to change behaviour to accommodate EVs by paying more to obtain an assigned parking spot. These early adopters did not express a strong need for public charging infrastructure to be available through the city.

Average time parked at a destination

In the study of 36 EV owners (unspecified type) in the UK, many considered that additional recharging facilities on street, at petrol stations, public car parks, supermarkets, and in the driveways/garages of friends and family offer moderate or high benefits (Element Energy 2009). However, an estimation of the utility of publicly available slow charging facilities using the trip diary data in the UK National Travel Survey shows that when away from the home or office, the average resting time of a vehicle at its destination is around one hour (Element Energy 2009). This suggests public slow charging facilities would be of limited value. Slow charging facilities at workplaces, on the other hand, could be of high value to commuters given that cars spend around seven hours on average parked at the workplace and around three-quarters of commuter cars are parked in private car parks.

This analysis, combined with the evidence cited above (i) from Tokyo that fast charging points are likely to promote increased utilisation of EVs and (ii) that public recharging infrastructure is not the primary barrier to uptake, suggests that any prioritisation of investment in slow charging facilitates could be misguided (Element Energy 2009; PlanNYC 2010). However, public charging infrastructure could play an important role in the diffusion of this technology by signalling its success and changing social norms.

3.3.10 Time spent recharging

Linked to the issues of range and charging infrastructure discussed above is the issue of the value of time spent refuelling or recharging vehicles. This falls in to two issues: (i) the

willingness to pay for faster recharging times in order to extend the flexibility and range of a vehicle and (ii) the value of time saved not having to visit petrol stations.

On the first issue, the evidence suggests that people do not seem willing to devote extra resources to reduce recharging time. In a simple choice exercise between cars with a range of either 50 or 100 miles and recharge time of 3, 6 or 12 hours, range was found to be more important than recharging time unless the difference in recharging time for short and long range vehicles is large (Garwood & Skippon 2010). Similarly, in a U.S. study, few respondents were willing to devote resources to reduce recharging time (Axsen & Kurani 2010). In a study of PHEV drivers in the US, rapid charging was not a priority for most drivers in this study; most were satisfied with 110V recharging. However, this example illustrates that for some PHEV drivers, rapid charging is important (Kurani et al. 2007).

On the second issue, there is little evidence on the nuisance value associated with refuelling events. Qualitative research has found some people would value not having to go to a petrol station (Kurani & Turrentine 2007). Another study looked at both diesel and hybrid powertrains and concluded that models must consider not only the value of time saved refuelling but also the nuisance cost of refuelling in order to correctly estimate the value of greater range (and presumably the lower physical effort and time spent personally refuelling with an EV) to consumers (Greene et al. 2004).

3.3.11 Emissions/ environmental performance

Findings from studies on vehicle purchasing behaviour in general conclude that, in comparison with performance and capital cost attributes, environmental benefits are of relatively little importance in the purchase decision (Skinner et al. 2006; Lane 2005; Lane & Banks 2010; Anable et al. 2009; Angle et al. 2007; Roche et al. 2009). Even where consumers are aware of a car's environmental performance, the consumer is still unlikely to choose a car on this basis as other attributes are generally more important (Thatchenkery 2008).

Despite recent changes in the UK to link Vehicle Excise Duty (VED) to CO2 emissions rather than engine size, engine size still plays an important role in people's minds with respect to a vehicle's environmental impact and many believe that style and performance need to be compromised to 'be environmentally friendly' (Anable et al. 2009; Banks & Lane 2010; Angle et al. 2007). Moreover, the concept of 'emissions' is much less familiar than the concept of fuel economy. In particular, car buyers are consistently more able to benchmark a figure quoted in 'miles-per-gallon' than they are a value of CO_2 emissions. Fuel economy is primarily perceived by car buyers as a running cost rather than as an environmental proxy—'cost effective' or 'cheap to run' are phrases often associated with 'fuel economy' and 'miles-per-gallon' or 'mpg'. Lower emissions are often seen as a 'bonus' once the primary objective of lower running costs has been secured (Lane & Banks 2010).

However, a web survey of 1000 recent car purchasers in the UK discovered that environmental attitudes did influence the rankings of the most important purchase factors so that those who claim to be most concerned ranked fuel economy higher and price lower than the average (Table 7) (Lane & Banks 2010).

There is, however, much debate over the extent to which adopters of (H)EVs have or will have above average environmental awareness and/or preference for greater fuel efficiency. Studies on current (H)EV owners or participants of vehicle trials identify high rankings or ratings of environmental performance which would appear to differentiate them from the mass market (Element Energy 2009; Carroll & Walsh 2010). Other authors have concluded that some consumers would be prepared to pay more to drive a cleaner fuelled or zero-emissions vehicle that is similar to their own, but these studies tend to rely on the

proposition that the alternative vehicles can match conventional types in performance (Martin et al. 2009; Ewing & Sarigöllü 1998). Another study constructed a hybrid choice model of vehicle choice including perceptions and attitudes and defined an environment-related latent variable which enters directly into the choice process (Alvarez-Daziona & Bolduc 2009). They concluded that the environmental concern variable has a significant impact on the vehicle purchase decision, but mainly among those who currently use public transport and among women, older people and more educated people.

Two studies in the US which analysed state-wide vehicle sales data found a correlation between environmental preference and the rate of uptake of HEVs (Kahn 2007; Gallagher and Muehlegger 2007). Using data on a community's share of green party voters as a proxy for community environmentalism, Kahn concludes that environmentalists are more likely to purchase HEVs than non-environmentalists. Gallagher and Muehlegger 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.

It is possible that early adopters will place a value on emissions reduction but that any model coefficient should drop to zero for majority buyers (Santini & Vyas 2005). 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). 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).

However, Ziegler found that 'environmental concern' did not have any significant effect on the choice of hybrid vehicles, but did have a significant impact on the (stated) choice for an EV (Ziegler 2010). An earlier study concluded that positive attitudes towards the environmental benefits of EVs are not generally accompanied by higher purchase intentions, and especially so in the presence of increased information about and experience of EVs where these benefits became a lower priority for buying EVs relative to other attributes in the stated preference survey after exposure (Golob & Gould 1998).

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. Klein's five segments of hybrid purchasers (Box 1) illustrates the various dominant attitudes that seem to have led to the purchase of hybrid vehicles in the US between 2003–2007, only one of which was clearly environmentally motivated. This illustrates the necessity for market segmentation to capture the fact that some segments will be prepared to pay higher premiums than others to capture the symbolic and altruistic motives that may be important for some consumers.

3.4 Psychological factors (affective and symbolic)

As section 3.2 argued, models of car choice are likely to be inadequate without consideration of impulsive or non-conscious regulatory processes. Even where consumer decision-making may be the result of conscious choices among an array of alternatives, these choices are systematically related to psychological processes (i.e., perception, attitudes, beliefs formation) and any models of vehicle choice need to make salient the role that non-instrumental factors play in consumer behaviour. Even when vehicles are equivalent in every way from an economic point of view, different makes, models, and styles connote different social messages about the owner (Curtin et al. 2009).

'Attitude' is a term which is used very loosely, in various contexts and may be used to describe any of the following personal attributes: awareness, concern, knowledge, understanding, opinion, personality, beliefs and cultural values (Lane, 2005). In this

respect, a useful classification of decision factors relevant to understanding vehicle choice is the following:

- *Instrumental factors* refer to general practical or functional attributes of a vehicle; for example costs, driving range and maximum speed of a vehicle.
- *Affective factors* refer to the feelings evoked by owning or travelling in the vehicle, such as anticipated driving affect, satisfaction, excitement, pleasure or control.
- *Symbolic factors* relate to how consumer goods can serve as symbols or have wider meanings and how these can be used to express social status or personal identity and values; for example, being seen as 'green' or as someone who owns the latest technologies.

There is overlap between these three classes of decision making factor. The functional and economic attributes discussed in the previous section can be clearly classed as instrumental motives. However, perceptions are relevant here because the choice process depends on how attribute levels are perceived by the individual beliefs of a consumer. In addition, emotional reactions to functional attributes such as speed can be classed as affective motives, and functional attributes can also take on symbolic meanings, as discussed below.

3.4.1 Affective factors

The literature on the non-instrumental attributes of vehicle choice is much less developed than the discussion on cost and functional attributes. Indeed, there is very little evidence on the role of affective as distinct from instrumental or symbolic factors. Only one text in the review (Gärling 2001) specifically addresses the '**pleasure of driving'** by asking EV trial participants to rate their experience on a 5 point scale compared to their conventional vehicle. The results showed that more than 80% of the subjects thought that driving the EV gave the same or more pleasure than their conventional vehicle. In the qualitative study, the subjects' definition of the concept 'Pleasure of driving' most often included words like **reliable**, **ease of use**, **ease of maintenance**, **comfort**, **noiselessness**, and **speed**, and so the cross-over with functional attributes is clear. In the UK Cenex trial, users rated the overall '**performance'** of the vehicles compared to a similar classed fossil fuelled vehicle as 'good' as well as rating an environmental '**feel good factor**' which can evoke emotional responses (Carroll & Walsh 2010). Another study found that 'quiet', '**smooth'** and 'silent' were offered to describe the sensation of driving an HEV in all-electric mode (Turrentine & Kurani 2007). However, both of these latter studies comprise very crude measures of affect which are more akin to instrumental evaluations. Overall, the emotional response to driving an EV and the role it plays in vehicle choice is poorly understood.

Thøgersen and Gärling (2001) also measured '**complexity** and **perceived risk'**. These items referred to perceived ease of maintenance, ease of driving, noise, safety and risk when recharging. Again, these are akin to evaluations of functional attributes, but tend to provoke emotional responses and together reflect the perceived complexity, or cognitive effort, of using an EV. They also measured he 'feeling of luxury' gained from driving an EV compared to a conventional vehicle of the same brand.

3.4.2 Symbolic factors

[Note, extra references in footnotes in this section are papers not reviewed as part of this study but relate to particular theories underpinning the concepts cited.]

Symbolic motives, although potentially more elusive, have been studied in relation to vehicle choice, including electric vehicles, albeit still not to the same extent as instrumental

attributes. The majority of research in this area has originated from researchers at UC Davis who have examined HEVs and PHEVs in relation to the meanings afforded them and the identity constructed by buyers (see all references by Kurani, Heffner & Turrentine). Symbolic meanings associated with (P)HEVs are found to be multiple and multi-layered. For example, households in California that adopted these vehicles have been found to apply meanings such as:

- lower resource consumption/living lighter
- independence from petroleum producers
- advanced technology
- financial responsibility
- saving money
- environmental and/or resource preservation
- opposing war
- rising fuel prices as evidence of conspiracy

These authors also propose that future research could concentrate on the ability of alternatively fuelled vehicles to symbolise the idea of 'extended personal territory', as EVs could potentially be able to provide (or store) electricity independently. These symbolic evaluations can relate to the whole vehicle or to more specific functional or financial attributes such as fuel economy to which meanings such as 'lower resource consumption' can be applied even though fuel savings are likely to have never been calculated:

> *"High fuel economy, particularly numbers over 100 MPG may be valued more for their symbolism than for their marginal financial value. Episodes of 100+ MPG, even if brief, signal to drivers that the vehicle has valued qualities: that it is technologically exceptional, environmentally friendly, or financially sensible. Seeing 100+ MPG on the fuel economy display, even if briefly, may signal to drivers that the vehicle has important qualities: it is unique, environmentally-friendly, and financially-sensible."*
>
> (Kurani et al. 2007, p13)

Important symbolic meanings are also attached to the technology itself. Kurani et al. found that the further their participants could drive their PHEVs on all electric range, the more they associated their cars with high technology, environmental preservation, economic sensibility and the freedom from petroleum fuels.

In addition, consumers infer connotations to these meanings such as 'behaving ethically', 'concern for others', 'being intelligent' or 'unique':

> *"Lowering their resource consumption becomes an important subplot in a narrative self identity, first symbolized then made real by the availability, purchase and use of a high fuel economy HEV."*
>
> (Kurani et al. 2006, p218)

These meanings relate, in turn, to self-identities which are expressed through buying, owing and using the vehicle. Utility is derived from presenting these identities or self images.

The importance of **identity**, **self image** and **status** is difficult to elicit in a research setting, but car advertisers are well aware of its importance and often play to the individual's sense of **control**, **power**, social status and **self-esteem** (Steg, 2004 cited in Skinner et al. 2006). In quantitative instruments, status or identity has likely been captured by measuring the importance of 'style/appearance' which, in a recent UK study, ranked as the second

most important purchase issue after fuel economy (see Table 7 and Lane & Banks 2010). Graham (2001), on the other hand, asked respondents to indicate the importance of 'attention/pioneer' as a reason to buy a HEV, which was selected by 33% of respondents (cited in Santini & Vyas, 2005).

Garwood and Skippon (2010) measured symbolic meanings through 10 questionnaire items based on the domains of the five factor model of **personality** (openness, conscientiousness, agreeableness, extraversion and neuroticism)[9]. The approach is based on the theory that the symbolic meanings of consumer products represent conscious or non-conscious signals to others about the user's personality traits. They found that driving an EV signals high openness, high conscientiousness and high agreeableness.

Another general personality trait that has been examined in the context of EVs has been '**innovativeness'** reflecting 'the degree to which an individual makes innovative decisions independently of the communicated experience of others' or, more precisely, 'domain specific innovativeness' which refers to a trait reflecting 'the tendency to learn about and adopt innovations (new products) within a specific domain of interest' (Thøgersen & Gärling 2001). The authors find that innovativeness, combined with product knowledge, is a powerful combination of individual attributes to use to segment the population and understand perceptions of EVs and intention to purchase. High innovativeness is a precursor to early adoption but is not a prerequisite for more mainstream consumers of EVs once the technical and infrastructural concerns are mitigated.

Narcissism (individuals who see themselves, and who want others to see themselves, as special or superior) is hypothesised to be associated with greater interest in the symbolic rather than the functional value of products (Gärling & Thøgersen 2001). Similarly, Allan and Ng (1999) concluded that the symbolic and affective meaning of car purchasing behaviour was greater when **values** were indirectly linked to purchase behaviour. Values can direct consumers' attention to products with similar meanings to the human values and the effect of the human value can be transferred to the evaluation of the product meaning. For instance, an individual's preference for the human value `prestige' would direct his or her attention to products that have meanings similar to prestige, such as a Mercedes-Benz, and would contribute favourably to his or her positive evaluation of the automobile. Similarly, strong personal norms or values in favour of the environment could offset some of the higher economic cost of owning an EV by conferring social benefits onto any perceived superior environmental performance of these vehicles (Curtin et al. 2009; Jansson et al. 2009).

It may be that the symbolic meanings attached to EVs will take some time to become established and widely held as the market matures. However, symbolism is important to understand at an early stage as consumers attempt to differentiate them from other types of vehicles (Heffner et al. 2006).

3.5 Socio-demographic factors

Most studies of vehicle type choice reviewed for this report generally use disaggregate discrete choice models (multinomial logit and nested logit) for the vehicle type choice, and vehicle, **individual and household characteristics** are mainly considered as explanatory variables in the models. From these studies and other quantitative and qualitative evidence

[9] Digman, J. M. (1990). Personality structure: Emergence of the five-factor model. *Annual Review of Psychology, 41,* 417-440; Saucier, G., & Goldberg, L. R. (1996). The language of personality: Lexical perspectives on the five-factor model. In J. S. Wiggins (Ed.), *The five-factor model of personality: Theoretical perspectives* (pp. 21-50). New York: Guilford.

(sometimes relating to general levels of car ownership) we can make broad conclusions about the relationship between socio-demographic indicators and vehicle preference. These relationships are summarised in **Table 10**.

Table 10: The link between socio-demographic characteristics and vehicle choice

Factor	Evidence
Income	In general, car ownership propensity increases with income, although the elasticity varies by household and area type. Income elasticities fall as incomes increase, are higher in London and where the head of the household is retired (Whelan 2007). In Switzerland, hybrid car buyers had a significantly higher household income and education level than owners of similar sized conventional vehicles (de Haan et al. 2006) but a study in the UK found the higher people's income, the more likely they are to adopt an EV as a second car but not as a main car (Garwood & Skippon 2010). Buyers' sensitivity to purchase price and maintenance costs are inversely affected by income. An example of variation by household income is that engine size in the UK increases from an average of 1.4 litres for households with mean income less than £9,000 to 1.8 litres for those with mean household income greater than £45,000 (Cambridge Econometrics 2008). However, the coefficients are likely to be different across different income thresholds as higher-income consumers use a lower discount rate (Adler 2003; Santini & Vyas 2005; Potoglou & Kanaroglou 2007). Lower income consumers are less able to afford the higher up-front premium for a hybrid and more likely to discount future fuel cost savings from a hybrid purchase (Diamond 2009). The early adopters are likely to have higher incomes than the early majority who are themselves likely to have higher incomes than the average new car buyer (Santini & Vyas 2005).
Gender	Women have a stronger preference for environmentally friendly cars which is consistent with the empirical studies which show that women have a stronger preference towards the environment and a stronger willingness to contribute (e.g. Torgler et al., 2008 cited in Ziegler 2010; Gärling 2001). As regards EVs, it seems that (on average) men are more reserved towards this technology than women (Carroll & Walsh 2010; Dagsvik et al. 2002). Men have a significantly higher stated preference for hydrogen and somewhat less high for other alternatively fuelled vehicles than women. (Potoglou & Kanaroglou 2007; Ziegler 2010). Overall, it seems that woman focus more on instrumental attributes (e.g. safety, reliability, price) and men more on symbolic attributes (e.g. size, power, brand image) (Mintel 2009; Angle et al. 2007). Results from interviews show that females to a higher degree than males experienced EVs as safe, attractive, and useful for work and visiting trips (Gärling & Johansson 1999). Female respondents are found to consider that a highly-priced car has a greater utility as a result of its perceived superior performance, but for men, the higher price is associated more with the ability to impress (Moutinho 1996 cited by Skinner et al. 2006). In contradiction to this evidence, Element Energy (2009) found that nearly all EV owners and EV considerers in its survey in the UK were male. They suggest this may present a challenge if EVs are targeted at two car households where the lower mileage vehicle driver is female.

Education	Potoglou and Kanaroglou (2007) report a significantly positive effect of higher education on the choice of HEVs. This may be consistent with Skinner et al. (2006) who report that, in households with only one car, and where the head of the household is educated to college level, operating costs of the vehicle seem to be of more significance, which at least implies a greater awareness of lifetime running costs (Skinner et al. 2006).
Age	Ziegler (2010), Potoglou and Kanaroglou (2007) and Ewing and Sarigöllü (1998) all report a significantly negative effect of age on the stated choice for alternative fuel vehicles and report a significantly negative impact of age on the choice for fuel-efficient and electric vehicles. Older respondents consider reliability; younger respondents mention style. Impact on the environmental was more likely to be mentioned by older respondents (Angle et al. 2007).
Presence of children	Households with children are more likely to choose larger vehicles, vans/people-carriers or diesel-engined vehicles (Whelan, 2007, Angle et al., 2003).
Employment status	The number of adults in employment has a strongly significant effect on ownership levels over and above that generated by any additional household income. Take the example of a three adult household in a metropolitan area with two workers and a joint income of £25,000. Increasing the number of workers from two to three increases the probability of owning one or more cars from 84% to 85%, two or more cars from 54% to 59% and three or more cars from 22% to 29%. The net result is an increase in the forecast number of cars for that household from 1.42 to 1.53. Whilst this does not seem like a large change, it is significant when grossing up to the mass market. (Whelan 2007)
Existence of a company car/ other cars	The provision of a company vehicle significantly increases the probability that a household will acquire additional vehicles. For example, for a three adult household living in a metropolitan area with two workers and a joint annual income of £25,000, the provision of a company car increases the conditional probability that the household will own a second vehicle from 54% to 77% and increases the conditional probability that a household will acquire three or more vehicles from 22% to 28%. Were the household to acquire two company vehicles, the probability that they will own three or more cars is increased from 22% to 40% (Whelan 2007). Element Energy (2009) found that the majority of EV users (internationally and in the UK) are multi-car families. They point out that this is at odds with the idea of EVs being ‘urban city cars’ as car ownership (and parking availability) is lower in urban areas. However, they point out that in the UK, around 90% of all households are in the ‘other urban centre', ‘suburban residential', or ‘rural residential’ categories. They also acknowledge that multi car households have higher disposable income and fit the idea that EVs may be adopted as a second car as a ‘hedge’ against the limitations of this new technology.
Car mileage	In a Dutch study, the authors make the observation that high mileage drivers are more likely to be attracted to lower fuel costs (Rouwendal & de Vries 1999, cited in Lane 2005). Diamond (2009) uses state registration data to evaluate the determinants of hybrid vehicle adoption. He finds average miles travelled per year in the state all significantly influence hybrid vehicle adoption. Average vehicle

	miles travelled (VMT) per capita was significant with coefficients between 0.8 and 1.5, meaning that a 10% increase in average per-capita miles travelled would result in an 8–15% increase in state hybrid market share, depending on the hybrid model. Gallaher and Mueller (2007) analysed US HEV sales data and other state wide data and found the relationship between fuel prices and high-economy hybrid sales is significantly more pronounced in states where the average per capita annual mileage is greatest. This is consistent with their prediction that high mileage individuals have the greatest incentive to adopt high-fuel economy hybrids in response to an increase in fuel prices. Santini and Vyas (2005) assume that the early buyers will be individuals who drive far more miles per year than the typical vehicle owner (or far more hours per year), but could not cite any evidence to back up this assumption.
Residential location	Even where there are high income levels in densely populated areas, the level of car ownership is not as high as might be expected, as public transport is often a more effective form of transport in these areas (Dargay & Gately 1999 cited in Skinner et al. 2006). Car size has been found to be a function of population density, with a negative correlation between larger cars and population density (Whelan 2007). Potoglou and Kanaroglou (2007) examined the relationship between vehicle choice and neighbourhood characteristics in Canada. Estimates from discrete choice models of households' latest vehicle-type choice suggest that preferences for less fuel-efficient vehicles are marginally affected by the diversity of land-uses at the place of residence (fewer SUVs are owned where land uses are heterogeneous), after controlling for travel to work attitudes and socio-demographic characteristics of individuals and households.

In conclusion, these findings suggest that the use of a single set of coefficients for a presumed single population may not be a sensible way to model consumer preference for EVs (Santini & Vyas 2005). However, recent attempts to model vehicle choice in the UK have concluded that not enough work has been done to investigate the socioeconomic drivers of car purchase behaviour and understand 'taste heterogeneity' and the estimation of confidence intervals around predicted elasticities (Cambridge Econometrics 2008; Eftec 2008).

3.6 Policy influences and incentives

Identifying the most relevant attributes and characteristics of early adopter and mainstream EV consumer segments is important for the design of effective incentives to promote uptake. However, despite the proliferation of incentive programs, particularly in the US with respect to HEVs, their efficacy is unclear. Particularly uncertain is the point in the decision making process that fiscal or other incentives are likely to have the most influence on purchasing patterns and the ways in which instruments can be packaged together to have the optimum effect.

The literature review has not enabled clear answers to these questions to be presented here. Some empirical work has been carried out on revealed preference market data to attempt to identify the independent impact of government incentives or fuel price rises or more practical measures such as High Occupancy Vehicle (HOV) lanes. Others have included

questions on incentives in stated preference surveys and have inferred an impact from discrete choice modelling. The remainder of this section reviews the evidence on different categories of incentive and draws some general conclusions on the nature of policy interventions in this area.

A range of forms of fiscal incentives could be applied to the EV market and are indeed already being used in many forms in many countries. These include subsidies for EV buyers (UK), subsidies for certain parts of the fleet (e.g. taxis, public agencies) (China), subsidies or feebates for 'green' vehicles (various European countries), tax credits or rebates (US), car tax exemptions (Germany, UK), reduction of sales tax for EVs (Denmark)[10].

Some authors have drawn some strong conclusions from stated preference and modelling consumer preferences that fiscal incentives are required to compensate for both the higher capital costs and for barriers to uptake such as battery range (Element Energy 2009; Ewing & Sarigöllü; de Haan et al. 2007).

The UK Climate Change Committee included in its second reporting period some analysis of the level of upfront support required to incentivise consumers to buy EVs and PHEVs over the period to 2020. In this case, the total subsidy is equivalent to the Net Present Value of the lifetime costs of cars and based on varying assumptions about battery costs and discount rates. The latter is based on varying assumptions about consumer myopia and the degree to which they place weight on future fuel savings and is acknowledged as a critical uncertainty and risk to the efficacy of any upfront price support scheme. In any case, some have warned that even incentives which make the investment in an EV 'NPV neutral' to offset the higher capital costs with lower running costs would not be sufficient to overcome market barriers, particularly beyond the early adopters (Element Energy 2009). They suggest "*Even a significant intervention such as a grant to cover the additional capital cost of an EV (relative to the incumbent) would not of itself be enough to ensure significant uptake. There would remain the significant disutility associated with limited range of EVs.*" (p11). In a UK survey which elicited 'willingness to pay', the authors found that a purchase incentive of approximately £2000 would be sufficient for the early adopter group but larger incentives would be required for more mainstream consumers.

This chimes with rather less quantitative assessments based on recent consumer behaviour in New York. PlanNYC noted that the early adopters in New York City appear willing to pay a premium for the experience of owning an electric vehicle and are flexible about adjusting their driving behaviors to rely mostly on home charging. In the light of this, they suggest that actions such as investment in a high-density public infrastructure or *additional* financial incentives do not appear to stimulate significant incremental demand among the early adopters. But the federal tax credit for EVs amounts to up to $7,500 already and consumers beyond the early adopter segment are likely to need a higher incentive than this.

Moreover, there are running costs other than the fuel to consider. In an analysis of a range of instruments to alter the cost of both vehicles and travel (including time penalties/ incentives such as HOV lanes), Ewing and Sarigöllü (1998) concluded that price subsidies for cleaner vehicles were the only type of instrument that is likely to achieve environmental objectives, albeit only realistic if commensurate taxes were applied to more polluting vehicles. They conclude that in order to have competitive running costs, savings from the EV's lower operating costs should be *triple* any higher maintenance costs it may have. This suggests that policies such as electronic road pricing or carbon taxes for non-EVs might be needed to help improve the image of the EV's relative operating costs.

[10] Caution should be taken as this is neither a fully up to date or exhaustive list as the information is based purely on the literature which materialised for this study which did not specifically set out to look at incentives.

In a European based study which examined vehicle ownership and whether or not the person had benefited from a Canton based tax rebate (which vary from 10% - 100% of the car ownership tax) de Haan et al. (2007) concluded that rebates on car ownership taxes seemed to be effective and had increased sales of Prius cars by 25%.

In the UK, there is recent experience of a purchase subsidy, albeit not related to environmental objectives or EVs, that had high consumer reaction to it and accelerated market change to a greater extent than other fiscal instruments (such as a change to the first year circulation tax) have made. The scheme was designed to deliver a boost to the car industry at a time when it needed it most, offering a £2,000 grant to scrap an old car in exchange for a new one. The figures show that the scheme contributed to approximately one fifth (20%) of all new car registrations whilst in operation. Of those, 54% had never bought a new car before. Although never intended as an environmental incentive, the scrappage scheme also had the effect of amplifying the shift to smaller cars and HEVs which was already happening in response to the economic slowdown (Mintel 2009). While the mini and super-mini segments normally account for around 40% of the new car market, they represent over 70% of cars registered through the scheme. Figures from SMMT show that cars registered under the incentive had an average CO2 value of just over 133g/km, 10% below the new car average, and almost 50 g/km below the average emissions of the vehicles scrapped (SMMT 2010a). This could be taken as an indicator that such instruments are effective and the next step would be to design one with explicit objectives to accelerate the uptake of EVs.

However, in reality there is little consensus in the literature on either the potential efficacy of fiscal instruments to incentivise the uptake of EVs, or their most effective design. For example, at least three authors have analysed data on the registration of hybrid vehicles and correlated uptake with policy incentives and fuel prices, albeit all in the context of the US, and all three have conclude that other factors, particularly fuel price, may have more of an impact than subsidies themselves (Diamond 2009; Beresteanu et al 2007).

Diamond compared HEV adoption patterns between 2001 and 2006 to the US average for specific states that have changed incentive policies with a view to understanding whether the way in which the incentive was implemented had an impact. Averaging over the six years, he found that, overall, incentives had no significant impact on market share. For instance, he found that States who exceeded or lagged behind the US national average in terms of sales before the policy change also did so afterwards. In other words, any impact that individual policy changes may have had were less important than the other key determinants which he found were fuel prices, driving patterns and environmentalism (measured using an index reflecting each State's environmental management framework and commitment to green measures). Fuel prices were found to be the most significant, with a 10% increase in average prices resulting in, on average, a 72–93% increase in state HEV market share, depending on the vehicle.

Diamond (2009) notes that this finding may be consistent with other survey and interview findings that we noted in Section 3.3.4 that consumers buy hybrids based on general notions of perceived savings rather than a detailed benefit-cost or lifecycle cost analysis. He believes that fuel prices serve as the most visible signal for consumers to think about fuel savings and fuel economy, so that relatively minor variations can lead to significant changes in adoption patterns, particularly for people in the market for a new car at the time of rising prices. He noted the 'symbolic' $4.00 dollar a gallon marker that was reached in the summer of 2008 and suggests this prompted a significant change in driving habits and preference for fuel efficient vehicles. Moreover, he suggests that "*even if consumers did try to explicitly calculate the lifecycle costs of hybrid ownership, recent volatility and uncertainty in future gas prices over time would make this calculation difficult. Fuel prices*

are largely beyond consumers' control, which might make a hybrid attractive simply as an insurance policy or hedge against future volatility and price spikes" (p982).

In a similar exercise, but simulating the effect of different fuel prices on HEV sales, Beresteanu (2009) found the effect of income tax deductions on HEV sales in the US in 2005 to be less than 5%, but this increased to 20% of sales when they were changed to be more favourable income tax credits of up to $3400 (varied according to model) from 2006. However, he found that changes in fuel prices had a larger impact than these incentives. Had fuel prices stayed at the 1999 levels, HEV sales in 2006 would have been 37% lower, while the effect of the federal income tax credit program was estimated at only 20% in 2006. In the light of the considerable actual increase in fuel prices in the US he concludes that, in the absence of these increases, the sales of hybrid vehicle would have been significantly less.

Gallagher and Muehlegger (2007) also studied the relative effect of tax incentives, gasoline prices, social preferences and other non-monetary incentives (for example, preferential access to high occupancy lanes and parking etc.) on hybrid sales in the US. They found that tax incentives explain a 6% increase in hybrid vehicle sales, but that fuel prices explain 27% of the increase. They also found that changing travel intensity (per capita vehicle miles and average commuting time) or social preferences for environmental quality and energy security (based in state level per capita membership of the a grassroots environmental organisation (the Sierra Club)) are responsible for 33% of the increase from 2000-2006.

There is consensus that fiscal incentives need to be designed so that they are conceived separately from the purchase price. It seems that consumers are more sensitive to sales tax incentives than income tax incentives. Gallagher and Muehlegger (2007) for instance, found that a sales tax waiver of mean value ($1,037) was associated with more than twice as large a demand effect as a tax credit of mean value ($2,011). This is because the sales tax is more transparent at the time of purchase, rather than income incentives which must be known about and understood and so their impact is delayed.

This chimes with 'prospect theory' (see Table 5) which shows that consumers set a reference point and consider lower outcomes as losses and higher ones as gains (Mueller & de Haan 2009). This has implications for survey measurement and modelling as subsidies are perhaps best explained as a reduction in upfront cost and measured as a coefficient (Axsen et al. 2009).

Overall, Diamond (2009) concluded that the overall dampening of the effect of monetary incentives on vehicle sales may be because dealers factor in these incentives into their pricing structure and charge consumers more for the vehicles. In this case, the subsidies effectively act a subsidies to car dealers without increasing adoption rates.

Indeed, there are broader questions raised about the social distribution of the benefits of fiscal incentivisation of EVs. The fact that EVs are likely to be adopted by higher income groups means that incentives are likely to disproportionately benefit higher income consumers who are more likely to purchase hybrids in the first place. On the basis of his analysis of HEVs in the US, Diamond (2009) concludes that, given the apparent weak or negligible effect of monetary incentives, this could result in incentive payments effectively creating a subsidy for the highest income consumers without significantly affecting their purchase decisions. Along the same lines, Curtin et al. (2009) note that tax credits are bound to make EV purchases more likely, but they believe that the fact that most buyers would have to finance the total price of the vehicle, including the premium, before they could claim the tax credit would limit their impact to the already narrow group of new vehicle buyers who were more likely to pay cash rather than finance the vehicle. The authors believe that if the tax credit could be converted into a reduction of the purchase

price its impact on sales would be much greater and more equitable to those who purchased on credit. Skerlos and Winebrake (2010) believe that greater benefits could be achieved for the same government investment if subsidies for EVs were targeted to where the social benefits are largest. They suggest subsidies would more effectively encourage new entrants to the EV market if they were offered to lower income individuals in a higher amount relative to individuals with affluent incomes and that different geographical areas would yield greater environmental, health, and energy security benefits.

This evidence is clearly superficial in breadth and depth and is clearly limited by its main focus on HEVs rather than EVs. Nevertheless, overall, it seems to suggest a combination of economic and social incentives may be the most effective for the successful introduction of EVs. Some of these other incentives are discussed in Table 11.

Table 11

Table 11: Summary of available incentives

Factor	Evidence
HOV Lanes	The majority of the commentary is in relation to HOV lanes in the US. HOV lanes are not common everywhere, but tend to be in areas with most congested traffic and air quality problems. States, such as Virginia, California, New York, New Jersey, Florida, and Utah, allow hybrid owners waivers from high occupancy vehicle (HOV) lane restrictions on one or more highways in the state. Overall the evidence suggests that, whilst the presence of the HOV incentive does seem to have made a difference to sales, the impact of this as an incentive is very dependent on the circumstances in the wider locality. Both Diamond (2008) and Gallagher and Muehlegger (2007) found that Virginia's HOV lane seemed to have had an impact on market share in that state, but not elsewhere. Another study found the impact was only significant among those who are long distance commuters (Sangkapichai & Saphores 2009). The value of HOV lanes to consumers have been assessed in SP studies alongside other incentives. In trying to work out the best measure to use, Santini and Vyas (2005) suggest a metric based on the value of time saving and the actual time saving to calculate the dollar equivalent savings per annum. However, they suggest that the value of time may be higher for high income earners and that the privilege of using HOV lanes for some drivers could, at least in principle, outweigh the value of the fuel savings. Also, the real value may be in the reduction in stress to some people. Nevertheless, in actual SP studies, HOVs are often not significant. For instance, an SP study in Canada including the elimination of vehicle sales tax, permission to drive in HOVs and free parking found the latter two incentives were not significant when purchasing and AFV or HEV (Potoglou & Kanaroglou 2007). Similarly, in a study in California of diesel and HEVs, the provision of access to HOV lanes was generally a much lower-valued incentive compared to purchase taxes and providing free parking, likely because only a fraction of California vehicle owners travel in corridors where they can take advantage of these lanes (Adler et al. 2003).
Bus lanes	No evidence
Low emission zones	No evidence

Discounted parking	With respect to parking, in addition to the two SP studies cited above (Potoglou & Kanaroglou 2007; Adler et al. 2003) – one of which did and the other did not find free parking to be a significant factor – the only other evidence was found in relation to actual EV ownership in London. Here the GLA plotted the geographical locations of current ownership of EVs and found that there is a band across London, from the north to the south west, where electric vehicles are more popular (GLA 2009). They claim that this can at least be explained in part by the policies of free and discounted parking in Camden and Westminster and the installation of charging points in these areas. However, no quantitative analysis has been carried out of the relative importance of various factors.
Congestion charging	In relation to the London congestion charge, HEVs and BEVs have been exempt from the charge (worth up to £2000 per year). In 2009 there were over 1,700 electric vehicles and 15,000 hybrids are registered for the Congestion Charge discount relating to 0.06% and 0.5% of the total number of vehicles registered (GLA 2009). This represents many times the proportion of (H)EV vehicles in the UK vehicle fleet as a whole and is some demonstration of the influence that this exemption has had on the local market for EVs. Element Energy (2009) remark that this type of incentive might be in keeping with the promotion of EVs as 'City cars' but is at odds with other necessary ingredients for their adoption, namely high car ownership and access to dedicated parking.
Electricity tariffs/ time of use charging with peak/off peak pricing	This was only mentioned by Kurani et al. (2007) who acknowledge that various methods have been proposed including time of use rate schedules, smart timers and smart meters to discourage vehicle recharging during peak hours but also to potentially make EVs more attractive overall to consumers. Already they claim that unconstrained access to under-priced electricity could be an incentive, but time of day 'constraints' could also be repositioned to consumers as ways in which benefits could be further maximised.
Information	Lane and Albery (2009) observed in qualitative research in Camden (where EVs are more popular than many areas of the country), that many individual participants were aware of some measures that are designed to encourage the use/purchase of AFVs, but most are imprecise about the details. Incentives of which individuals are aware include: lower parking costs, preferential road tax rates and the Congestion Charge discount for AFVs. PlanNYC (2010) concluded that, given the likely strong demand among early adopters and the limited short-term supply of vehicles, initial actions would be most effective if they focused on helping early adopters enter the EV market. For example, likely early adopters may not fully understand the benefits and challenges of using an EV, so providing clear information could significantly boost early adoption. Survey respondents also voiced a desire to have a convenient and easy-to-understand process to install necessary charging equipment, at home or in a commercial garage.
Green electricity services	No evidence reviewed
Vehicle procurement	No evidence reviewed

3.7 Segmentation

[Note, extra references in footnotes in this section are papers not reviewed as part of this study but relate to particular theories underpinning the concepts cited.]

The antecedents of EV adoption may be different across different sub-groups in the population. We have already discussed some of the different adoption behaviour and motivations that may exist between different socio-economic groups and between different markets such as fleet and private consumers. However, groups may also be defined by whether they are early or late entrants into the market, or by their diverse characteristics, motivations for uptake and receptivity towards the marketing of the innovation at a single point in time. In the former case, it is important for studies assessing the large scale adoption of EVs not only to identify the likely preferences of those individuals who can allow the technology to get its first significant foothold in the market, but to avoid basing model coefficients and predictions on the early adopters which are likely to have different requirements to the mainstream consumers (Element Energy 2009; Santini & Vyas 2005). In the latter case, it will also be necessary to capture the diversity in consumer preference at any one point in time and consider the option that many different configurations of EVs may have to be offered to appeal to different segments of car buyers.

3.7.1 Theory of technological substitution and 'early adopters'

The application of technological substitution theory can be appropriately applied to EVs given their new arrival in the marketplace compared to conventional vehicles. This theory suggests that the pattern of adoption of a new technology over time will follow a normal distribution as, faced with a new product, consumers can be classified into five categories: innovators, early adopters, early majority, late majority and laggards (Rogers 1962[11]; Santini & Vyas 2006; GLA 2009; Cao & Mokhtarian 2003). The uptake of new products tends to be characterised by the relatively small group of innovators and early adopters. The former pursue new technology vigorously and their endorsement is important for early adopters through demonstration, word-of-mouth and imitation (Thøgersen & Gärling 2001). The early adopters, on the other hand, do not necessarily hold the key to understanding the early majority and thus it is important to understand the potentially unique characteristics of these 'early' and 'mainstream' groups of EV consumers (Moore 2002 cited in Santini & Vyas 2006).

Figure 1 shows that the cumulative adoption of a new technology follows a sigmoid curve, with adoption growing slowly in its initial year, growing steeply as it reaches its half-way point, and growing flatly as it is close to its saturation level (maximum penetration). However, the specific shape of the curve is dependent on the rate of substitution, saturation level and adoption delay (Cao & Mokhtarian 2003). For disruptive technologies which require a significant shift in behaviour by consumers, Moore (2002)[12] believes there is a 'chasm' between the early adopters (the enthusiasts and visionaries) and the early majority (the pragmatists) who have very different expectations which requires different targeting and positioning of the product using different marketing, pricing and distribution channels.

[11] Rogers, E.M. (1962) *Diffusion of Innovations*. New York: Free Press.

[12] Moore, G. (1991, revised 1999) *Crossing the Chasm: Marketing and Selling High-tech Products to Mainstream Customers*

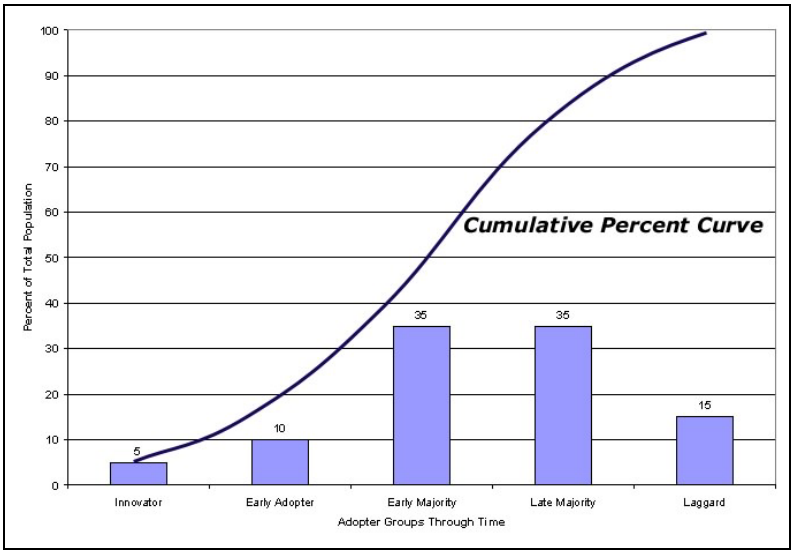


Figure 1: Distribution of Theory of Diffusion adopter groups

3.7.2 Who are likely to be the early adopters of EVs?

It has been hypothesised that the innovator/early adopter groups of EVs are likely to have similar traits to current hybrid and EV owners (GLA 2009). However, there is little information on the profile of the low carbon car market in the UK, presumably on account of its relatively small size and commercial confidentiality of the data. Slightly more data exists in relation to HEV owners in the USA.

Table 12 summarises the potential characteristics of private early adopter and early majority adopters of EVs according to the literature, based on theoretical/SP studies and analysis of existing HEV/EV owners. From this, it can be seen that there is much speculation about the early adopter segment and currently very little discussion about who the 'early majority' EV consumer might be. There is also some disagreement over the extent to which the early adopter segment will be sensitive to the potential size of the premiums on EVs and the nature of their financial motivation *vis a vis* other symbolic motives such as innovativeness, the environment or the desire to be less dependent on oil.

Table 12: Potential characteristics of early EV adopter groups

	Innovators + Early adopter	Early majority
General	Early HEV owners in Switzerland had significantly higher household income and education than owners of similar sized conventional vehicles (de Haan et al. 2006). Early petrol-hybrid owners were more likely to be female, older than average, very highly educated, from very high income households, driver lower than average mileage and keep their vehicle longer than average before resale (JD Power 2004 cited in Lane 2005). Tend to be wealthier than average, are new car purchasers and urban dwellers (Shell 2004 cited in Lane 2005). Tend to live in multi-car households (Element Energy 2009; Gärling 2001; Kurani et al. 1996).	
Common needs	Purchase for a combination of altruism and 'bragging	The next generation

and wants	rights', fascinated with the technology of the car and may have philosophical reasons for wanting to reduce fuel (Santini & Vysa 2005). More likely to buy high fuel efficient models than the majority. Malesh noted that 86% of Honda Insight buyers said fuel economy "was extremely important" versus 44% among all new vehicle buyers. Hermance (2003) gave an equivalent figure for Toyota Prius buyers of 80% (cited in Santini & Vyas 2005). Currently own vehicles with higher than average fuel efficiency ratings (Curtin et al. 2009). Early HEV owners in Switzerland rated fuel consumption and technology higher at the expense of other criteria such as brand preferences and design (de Haan et al. 2006). Individuals differing in innovativeness will evaluate the attributes of the vehicles differently (Thøgersen & Gärling 2001).	of larger, more mainstream hybrids will emphasize luxury and power rather than environmental benefits (Lane 2005).
Price	Willingness to buy at a higher price premium (PlanNYC 2010). Sensitivity to on-going costs, particularly the price of fuel (Lane 2005). Less sensitive to higher capital costs and more likely to account for lower running costs (Element Energy 2010). They need a fuel efficient car: higher average income but higher annual driving characteristics thus place higher value on fuel cost. Therefore use NPV type considerations. However, the early adopters of the Honda Insight were not buying just to save fuel. Potential early adopters and/or early buyers indicated, through the national and California surveys, their willingness to "ignore" a high vehicle price if they liked other attributes (Santini & Vyas 2005). More likely to believe fuel prices will remain high in the future (JD Power 2004 cited in Lane 2005). Although a first time PHEV buyer is likely to have relatively high income, these consumers were as sensitive as moderate or lower income consumers to the potential size of the premiums on PHEVs (Curtin et al. 2009). Klein (2007) believes the attitude towards price is more complex than the premium versus fuel cost model and offers a finer segmentation whereby four segments were clearly financially motivated, but *in their own way* (see Box 1). Some early adopter groups are more price sensitive than others (see Table 15) (Shell 2004 cited in Lane 2005).	Capital cost is the primary factor (Element Energy 2010). Will not support high price margins + less need to control fuel cost. Use NPV considerations (Santini & Vyas).
Incentives	Do not need high density public charging network. Large tax incentives may be unnecessary. Need information about benefits of owning an EV and 'recognition' for being early adopter (PlanNYC 2010).	
Charging, Range and other attributes	Likely to place a higher value on such attributes as acceleration, luggage space, range, and top speed because they spend more time in the vehicle than the majority buyer. Similarly, since they also have higher income, early buyers value time more highly, so driver ability to accelerate quickly, drive fast, bypass refuelling stations, and spend less time in maintenance facilities are argued to be more valuable to this group	As confidence in electric batteries grows and publicly accessible infrastructure becomes more visible on London's streets, it is

	(Santini & Vyas 2005). Very positive about EVs and this may include switching from an on-street parking space to one in a local parking garage (PlanNYC 2010). Will want ability to charge off-street overnight (GLA 2009). First time PHEV buyers are likely to own their own home, have convenient access to an electric outlet, and relish the opportunity to avoid gas stations and recharge their vehicles overnight at off-peak pricing (Curtin et al. 2009).	expected that households without off-street parking will consider purchasing EVs as well. (GLA 2009).
Environmental attitude	High value on Green Motoring (Element Energy 2010). A tendency to value environmental issues (Lane 2005). Have expressed a desire to espouse an environmentally friendly lifestyle and already challenge themselves to reduce their fuel usage (PlanNYC 2010). The first time buyer will be highly educated and think it is important to signal his or her commitment to a cleaner environment to others (Curtin et al. 2009). Environmental concern is not necessarily a characteristic of potential early buyers (Kurani et al. 1996).	'Green motoring' benefits less relevant (Element Energy 2010).
Innovativeness	Current adopters of EVs and HEVs have been prepared to pay a premium for new technology which in some circumstances has functionality limitations (GLA 2009). Propensity for new vehicle technology (Lane 2010). Will pay to support new technology (Element Energy 2010). Already possess vehicles with latest technology (PlanNYC). Will assign more 'points' (dollar value) to technological improvements than would the average consumer evaluating ICE technology (Santini & Vyas 2005).	Early adopters will recommend technology to early majority but need continual improvement in the technology for this to happen (Santini & Vyas 2005).

3.7.3 What other subgroups of EV consumers might there be?

The Greater London Authority has undertaken analysis of current EV and hybrid vehicle owners in London (GLA 2009). Using postcode data on these owners, they have used the MOSAIC geodemographic segmentation[13] to develop a picture of the likely dominant socio-economic characteristics of EV early adopters. The analysis found that most current EV owners and 60% of hybrid owners fall in to 5 of the 61 Mosaic household types. These groups are as follows:

Table 13: Mosaic types who own electric or hybrid cars in London in 2009

Mosaic Type	Description	%		
		EV Owners	Hybrid Owners	All Londoners
Global connections	Affluent middle-aged singles living in central London	28	21	5
Cultural leadership	Professionals living in middle ring suburbs and working in	14	13	4

[13] This tools draws on 400 nationwide data variables to characterise every UK postcode as one of 61 household types. See www.Experian.co.uk

	Central London			
New urban colonist	Ambitious singles or couples living in high density suburbs	14	10	10
City adventurers	Young and single skilled workers living in inner suburbs	9	9	7
Corporate chieftains	Business managers living in detached houses in outer suburbs	7	6	2
Other	(various)	28	41	72

Source: GLA 2010

The Mosaic segmentation has been fused with a segmentation based on Anable (2005)[14] to present a richer, attitudinal typology (**Table 14Error! Reference source not found.**). Using key characteristics of Mosaic segments including car trip making, lifestage, income and use of other travel modes, the Driver Type segmentation was tied to each postcode in London. Using the same data as above on the distribution of EV and HEV vehicles in London, the following segmentation of early adopters in London emerged:

Table 14: Driver types (based on Mosaic) who own EVs or HEVs in London in 2009

Driver	Description	%		
		EV Owners	Hybrid Owners	All London
Car Free Lifestyle	Have chosen to live without relying on car and, even if they own a car, use it relatively infrequently preferring to travel by public transport, foot and cycle. They are the most likely to agree that *"I would be willing to pay higher taxes on car use if I knew the revenue would be used to support public transport"*	33	34	13
Environmentally Aware	Well educated and hence aware of environmental issues like climate change. This has not always fed through to their behaviour but nevertheless, they are above average users of rail and cycle modes, and they are the most likely to agree that *"Being environmentally responsible is important to me".*	32	29	14
Aspire to drive	Low current car ownership, but largely because they can't afford to run a car or owing a car is too much hassle.	16	10	37
Committed to car	A typical viewpoint is *"People should be allowed to use their cars as much as they like, even if it causes*	4	6	15

14 Anable, J. (2005) Complacent Car Addicts or Aspiring Environmentalists? Identifying Travel Behaviour Segments Using Attitude Theory. Transport Policy. 12 (1), pp.65-78. Steer Davis Gleave used data from the London Lifestyle survey (N=2,350) to create a Driver Typology and 'mapped' these on to the Mosaic segments.

	damage to the environment" Least likely to want to reduce their car use or to support environmental taxes.			
Dissatisfied Drivers	Use their cars a lot but don't enjoy doing so - the statement which typifies their viewpoint is: "*I drive because it's convenient and not because I enjoy it".*	3	8	13
Care Free Car	Greatest car usage and lowest bus usage. Still somewhat in denial about environmental issues and many of them believe that *"Environmental threats such as global warming have been exaggerated".*	2	11	8
Can't be categorised		10	12	1

Source: compiled from (i) Steer Davis Gleave (undated) Introduction to Mosaic Driver: a geodemographic segmentation based on driver types. (ii) Girard, M (2009) Promoting Electric Vehicles in London. TfL delivery Unit. Presentation to Brimsdown Freight Quality Partnership Conference.

What is apparent from this segmentation is the fact that just under 50% of current EV owners are potentially associated with attitudinal segments who otherwise would not own a car (the Car Free Lifestyle and the Aspire to Drive segments).

Another study cited in Lane (2005) also indicates that the profile of early adopters of alternatively fuelled vehicles is likely to be more complex than the characteristics offered in Table 12 suggested. The study had focused on consumer acceptance during the early growth phase of market development of new car fuels and technologies (liquefied petroleum gas (LPG), compressed natural gas (CNG), hydrogen, ethanol (E85), bio-fuels and gas-to-liquid (GtL) fuels; and also hybrid-electric and fuel cell technologies). The report identified 7 early adopter segments in the UK (

Table 15).

Table 15: New fuel and vehicle technology early adopter segment definitions

Stars	Green papas	Ms Fast-tracker	Mr Fast-tracker	Individualists	Long hauler	Fleet buyers
Extremely fashionable High social status Low mileage / high frequency use Private use Emotional view of vehicles Urban dweller Not motivated by environmental concerns Interested in technology Cost insensitive Performance driven	Extremely sensitive to cost Middle class - "nest builder" Medium mileage and frequent use Private/professional use Functional view of vehicles Urban dweller Environmentally conscious Less interested in technology Insensitive to performance	Concerned with safety Medium mileage and frequent city user Private use Functional view of vehicles Urban dweller Less sensitive to environment No interest in technology Insensitive to performance	Fashionable middle class Medium mileage and frequent user Private use / commuting Emotional view of vehicles Urban dweller Not environment driven Interested in technology Insensitive to cost Performance driven	Medium mileage / usage frequency Private use Emotional view of vehicles Urban dweller Highly environmental sensitivity Interested in technology Demand similar refuelling experience Style driven	Extremely sensitive to cost and technology reliability High mileage and frequent use Commuting Functional view of vehicles Urban/rural dweller Less sensitive to environment Interested in technology Sensitive to availability and performance	Motivated by total cost of ownership Highly sensitive to financial incentives High mileage and frequent use Technology reliability paramount Centrally/ depot based Business/professional use Less interested in fashion Environmental issues not a priority

Source: Shell (2004) *Consumer acceptance of new fuels and vehicle technologies*. Cambridge MBA students' study conducted on behalf of Shell). Presentation to the LowCVP, 2004 cited in Lane 2005.

Whilst all seven segments share common characteristics such as the fact that they are all new car purchasers, have higher than average wealth, are urban dwellers and are interested in technology and innovation, they are also different in terms of the fact that some segments are more price sensitive than others and engage with the market at slightly different times. HEV owners are likely to be mainly Stars, Individualists, Mr Fast Tracker, Ms Fast Tracker, Long Haulers and Fleet buyers. Being the largest segment, Fleets play a key role in the early stages of market development and are seen as the key drivers of infrastructure and vehicle development. They therefore play an important role in raising awareness of new fuel/vehicle technologies.

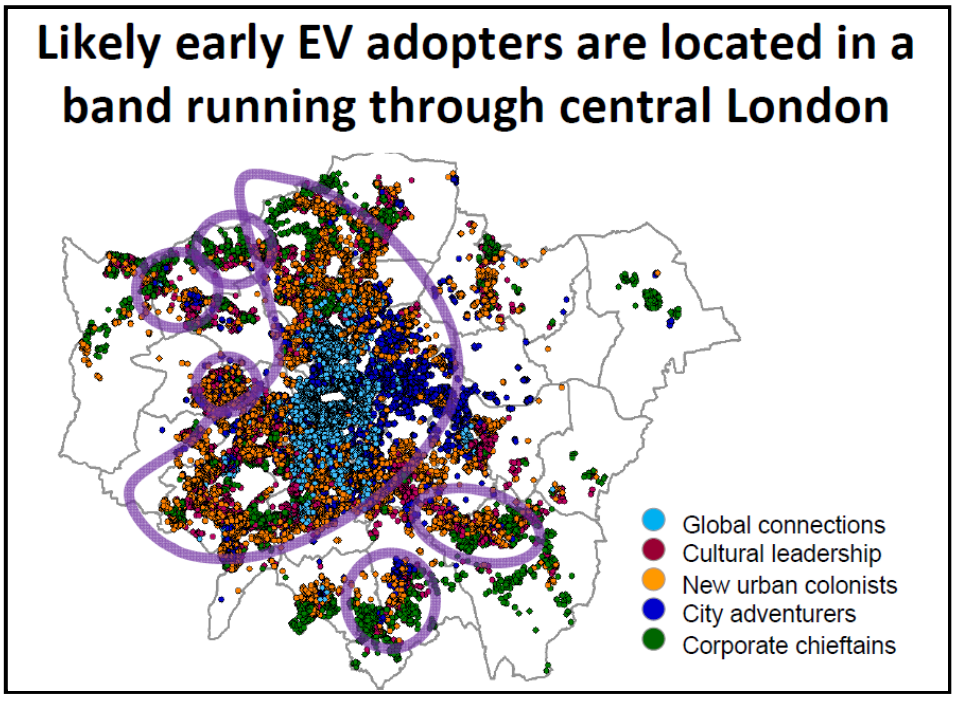
Finally, Thøgersen and Gärling (2001) offer a segmentation based on the segmentation of potential adopters of EVs according to differences in attribute importance weights. They use structural equation modelling and confirmatory cluster analysis based on perceptions, knowledge about and attitudes towards EVs, innovativeness, environmental concern, demographic and background variables. The study identifies the importance of measuring 'objective' knowledge towards EVs as this is a stronger predictor of intention to buy an EV than other variables. They find that a combination of measures of innovativeness and product knowledge produces a useful segmentation with groups that vary in terms of the value placed on certain attributes (such as the compatibility of an EV with certain types of journey). Four groups based on a combination of high/low innovativeness and high/low product knowledge were discovered. People with high innovativeness and high knowledge who also hold positive attitudes towards EVs are likely to be the early adopters, but the segment with high innovativeness and high knowledge but with unfavourable attitudes may also be a sensible target. Those in the high knowledge/ low innovativeness segment are likely to be the most difficult targets as they hold the least favourable attitudes towards EVs on average.

3.7.4 What might segmentation mean in terms of targeting and accelerating the uptake of EVs?

With respect to current ownership of EVs and HEVs in London, they are primarily located in a band across London from the north to the south west. As mentioned in Section 3.6, this can be at least partially explained by incentives such as free and discounted parking and the installation of a large number of charging points already (GLA 2009). The GLA have used their Mosaic segmentation to inform their strategy to invest in the installation of supplementary charging points at locations where utilisation is likely to be highest, i.e. at 'hotspots' (GLA 2009). The Mosaic analysis was put together with the following location specific factors:

- availability of off-street parking
- locations where vehicle owners drive substantial distances (as this helps maximise the environmental benefit of EV usage)
- multi-car ownership households where the likelihood of switching second cars to EVs is high.

Overlaying this information gives rise to a map (Figure 2) of the likely EV hotspots throughout London.



Source: GLA 2009

Figure 2: GLA analysis of the location of likely early EV adopters in central London

3.8 Dynamic effects

Consumer preferences cannot be considered to be static, particularly over the longer term. It is likely that increased market penetration will alter the way in which consumers value EVs and choose among them. In addition, it is possible that consumers may use these vehicles differently to conventional vehicles. This section reviews the evidence on how

values, attitudes and norms might change with direct or indirect exposure to EVs, and whether car ownership and travel patterns may change as a result of owning one.

3.9 Diffusion effects

The tendency for consumer preferences to change as technology becomes more prevalent in the market is known as the 'neighbour effect' or 'spillover' (Mau et al. 2008; Axzen et al. 2009; Heutel & Muehlegger 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 that will take place as the adoption rate increases (Axzen et al. 2009; Heutel & Muehlegger 2009). This, in turn, feeds into the technological learning that refers to the increasing progress that is realised with increased diffusion (Heutink et al. 2009).

Many buyers value diversity in the marketplace so that the more vehicles that are available to the consumer, the more satisfied the consumer will be. For instance, a consumer may want to have a critical mass of companion owners in order to guarantee reliability and repair capability at many locations and may want to have a sufficient choice of makes and models available to them (EST 2007; Santini & Vyas 2005; Element Energy 2009).

Stronger marketing and direct word of mouth are assumed to favour diffusion, providing feedback is favourable. No studies have estimated the potential impact of marketing, direct social exposure, and indirect word of mouth on the consumer uptake of EVs. Drivers of EVs, at work or in private, will promote EVs in their social networks, provided they are satisfied with the product, and the technology is demonstrated just by being in public streets and car parks (Gärling & Thøgersen 2001). However, in mature car markets such as in the US, Europe, and Japan, the impact of direct word of mouth is likely to be small when EVs are introduced because of the long lifetime of vehicles causes a lag in new vehicle sales (Struben & Sterman 2008).

Mau et al. (2008) investigated these effects by eliciting consumer preferences for HEVs and hydrogen fuel-cell vehicles while triggering changes in their preferences by giving different groups different market penetration scenarios. The hypothetical market share ratios selected were: less than 1% (0.03%), 5%, 10% and 20%. The results suggested that changes in market share affect consumer behaviour and increase consumers' propensity to choose HEVs given equal monetary costs as compared to conventional vehicles. Interestingly, the importance consumers placed on the non-monetary attributes generally declined as market share increased. In a similar study, the importance that consumers placed on certain attributes of a new technology changed as the new technology gained market share (Leiby & Rubin 2003 cited in Mau et al. 2008). Axsen et al. (2009) attempted to model these changes in intangible costs with increased market share but acknowledged that "*current preferences are difficult to disaggregate and future preference scenarios are highly speculative*" (p237). In a UK discrete choice modelling exercise, it was assumed consumers apply a penalty to each new technology until a given penetration into the vehicle parc is reached (2.5% of the fleet akin to the proportion of consumers in the 'innovator' segment) (EST 2007).

This review found one attempt to model the diffusion effect using revealed preference data. Heutel & Muehlegger (2009) wanted to understand how learning caused by exposure to hybrids affected their diffusion in the US. They found that different models of HEV (Toyota Prius, Honda Insight) had different patterns of diffusion. They found that higher penetration rates of the Toyota Prius are associated with higher per-capita sales of all hybrid models, but especially for Toyota models compared to Honda models. Penetration rates of the Honda Insight have a negative effect on sales of new hybrids, and this effect is more negative for

other Honda models. They attribute this to the fact that the Prius signalled a higher quality effect which is consistent with the anecdotal evidence from model sales and from stories in the media about these two models. They also attribute it to the theoretical models of learning and uncertainty described in this section. However, they also acknowledge that there may be other network effects such as the fact that higher HEV penetration in a state may lead to more mechanics able to serve them which would lower their costs in that state and increase adoption.

Although based on the diffusion of hydrogen vehicles, one study attempts an agent based modelling simulation to understand the importance that social networking might play in influencing the resulting pattern of uptake in the Netherlands (Heutink et al. 2009). The results indicate that when social network effects are taken into account, diffusion is slower than is found in many 'roadmapping' exercises. Moreover, it showed that quite a few more refuelling stations are necessary to reach the benchmark diffusion rates. In particular, it showed that an initial strategy to place infrastructure nationwide rather than in urban areas would be preferable, particularly if these are coupled with learning strategies.

3.9.1 Changing attitudes through direct experience with EVs

Exposure through media and information can change perceptions and preferences, but experience with vehicle trials to date shows that a direct experience with the technology can also have a powerful impact.

The results from recent trials generally show that drivers' expectations on various performance criteria were exceeded as a result of test-driving the vehicles. In a UK trial, 58% of private users felt more positive about EVs after taking part (Carroll & Walsh 2010). This shift was greatest for those who had had no previous experience with EVs and for younger users. Seventy-two percent of test drivers said they would use an electric vehicle as their regular car after their test drive compared with just 47% before the test drive. In a study of hydrogen fuel-cell vehicles, the proportion of people with safety concerns about the vehicle dropped from 30% to 7% (Martin 2009).

Some vehicle features, such as range restrictions and fuel-efficient driving potential, may take time for consumers to understand and accommodate. In a longer term trial, such positive shifts were not found due to concerns about range (Gärling 2001). Kurani et al. (2007) conclude that the in-car instrumentation will provide an important mechanism to develop the value of the vehicle to buyers.

3.9.2 Impacts on car ownership levels and travel behaviour

It is conceivable that the adoption of electric vehicles could have rebound effects or unintended consequences which may counteract the efficiency gains. Direct rebound effects could include the following:

- *Car ownership*: average household car ownership could increase if people adopt an EV without disposing of an already owned vehicle or because the availability of EVs could make acquisition of a car attractive for the first time.
- *Upsizing*: people could tend to switch from already small/fuel efficient cars to a new hybrid car.
- *Car use*: the reduced cost per kilometre travelled and the assuaging of environmental guilt could encourage greater car use. The question is whether people will use EVs differently to conventional vehicles?

On the other hand, EV adoption could have two positive additional benefits:

- *Downsizing:* those who want to adopt EV technology may be forced to downsize in order to be able to afford these vehicles.
- *Driving style*: in order to preserve battery life and attain the highest fuel efficiency, drivers may change their driving style.

Table 16 reviews the evidence on each of these issues. It can be seen from the table that the evidence is limited and mixed on each issue apart from the impact on driving style. From this it can be concluded that it is too early to understand the magnitude of any rebound effects. As a general observation, de Haan et all (2006) observe:

> *"On the long run, hybrid cars, if they prove to be successful, will have a surplus sales price corresponding to the savings on fuel costs in the first, say, five years of car ownership. So rationally speaking, there is no room for economically justified rebound effects, as costs per vehicle kilometre do not change… So if a rebound effect is observed, we argue that its origin is primarily of socio-psychological nature… if the social cost and/or the psychological cost attributed to the cost of a given service is reduced."*
>
> (de Haan et al. 2006, p595)

Table 16: Evidence in support of possible direct or indirect effects of EV adoption

Impact	Evidence
Car ownership	A study of HEV purchasers in Switzerland showed that 14% of new Prius owners had not replaced another car (i.e. that the EV was additional) but this was the same rate for the control group (de Haan et al. 2006). An unusually large proportion of Honda Insight buyers in the US bought the vehicle as an additional household vehicle rather than as a replacement vehicle. Although the fraction of all buyers who added a vehicle, according to Power, was 19% in 2000, the fraction that added the Insight was 43%. Even if the Insight were compared with "sports cars," it still exceeded the 29% adding vehicles for this category (Malesh 2000 cited in Santini & Vyas 2005). A sample of 36 EV owners in the UK showed that most also have access to a non-EV car (Element Energy 2009). The fact that EV owners are likely to reside in multi-car households has been shown elsewhere (e.g. Gärling 2001; Kurani et al. 1996).
Upsizing/ downsizing	De Haan et al. (2006) used empty vehicle weight as a surrogate for vehicle size and found empty vehicle weight only slightly increased after uptake of HEVs. Given that Toyota Prius cars are heavier to start with, the authors say this constitutes a small downsizing. In general, studies have found that households already in possession of a heavier vehicle were less likely to choose a subcompact vehicle (Skinner et al. 2006).
Car use	Little or no evidence. De Haan et al. (2006) comment that it will be very difficult to confirm the occurrence or non-occurrence of this rebound effect for any given community of purchasers of a given car. Element Energy (2009) observe that when an EV is introduced to a multi car household, it competes with the first car for use on trips and is used for a large proportion of short trips. However, they have not observed whether there is a net increase in the number of trips carried out by car. During an EV trial in Sweden, Gärling (2001) reported that relative to the first and eleventh weeks the kilometres driven increased about 10% and the number

	of trips by about 30% per week when the household got an extra car. In families owning one car the increase, both in kilometres and number of trips, was larger than in families owning more than one car. On the other hand, about 15% of the subjects stated that they had had to give up car trips, 30% that they had had problems with the limited driving range, 5% that they had had problems with the relatively long recharging time, and 25% stated that they had had problems with the limited cargo space.
Driving style	PHEVs and potentially BEVs are likely to be equipped with driver displays of fuel economy and state of battery charge. Kurani et al. (2007) recorded many drivers of PHEVs describing their excitement at seeing high mpg figures. They concluded that the driver instrumentation played an important role in making efficiency 'real' and encouraging fuel efficient driving styles. Data from the UK Cenex trial suggests that users modify their driving style when battery state of charge reduces below 50% (Cenex 2010).

4 Implications for survey design

Given that plug-in vehicles are novel technologies that mainstream consumers have no experience of, there is a surprising amount of relevant literature to review. Whilst this body of evidence can essentially only contribute theoretical or experimental evidence regarding plug-in vehicles due to the lack of revealed preference data and empirical studies, there is much to be learned about consumer behaviour by reviewing modelling and empirical research relating to conventional technologies and to HEVs.

However, 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 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 how they might use it.

This review of the literature on consumer preferences for vehicles in general and EVs more specifically provides a number of clear indications of issues to be covered and challenges to be tackled in the design of primary data collection on this subject. It will help to ground any empirical work in the fields of consumer choice and decision making as well as any recent literature on consumer perceptions of or experience with hybrid or plug-in vehicle technology.

The purpose of this section is not to provide a detailed list of all possible issues to be included in qualitative or quantitative work being taken forward, but to briefly reflect on the main areas to be considered.

Firstly, there are challenges with respect to the demographic cohorts to be studied. The assumption is that EV owners will tend to be people who purchase brand new vehicles. Given that only 5% of UK households purchase a new car per annum, it would be very difficult to conduct a survey of new car users using a random probability method. Also, new car purchasers are currently older, but given that the younger people of today are likely to be the new car purchasers of tomorrow (particularly of EVs), it might also be worth surveying some younger purchasers, even though their preferences may change in the future. Also, it cannot be ruled out that some people who have tended to purchase used cars to date may purchase new cars in the future. Indeed, the introduction of a new technology which is less dependent on oil and represents technological and financial prowess, may attract a new type of car consumer to the market.

The main challenge is the accurate and balanced elicitation of economic, functional and psychological factors and allowing trade-offs between them to be observed. There are strong indications as to the symbolic motives that are likely to underpin both the early adopter and early majority markets relating to innovation, status, environmental values and fuel security. Indeed, cars are repositories of many high value meanings, some of which are important but not quantifiable nor can be allocated an equivalent monetary value. For more functional attributes that may provide great consumer value and can be monetised and traded off against one another, there also exists a challenge of accurate measurement. Many relevant attributes such as size, performance, range and refuelling/recharging time have been poorly measured in stated preference and more standard qualitative and quantitative survey techniques. Consequently we have a very poor understanding of the role that these instrumental factors may play in EV uptake.

The review has pointed to some sensitivities around the way in which fuel consumption, performance and size of vehicle are conceptualised. However, the clearest finding is that survey participants find it very difficult to provide realistic answers to willingness to pay questions. This is an extension of the fact that people rarely carry out conscious and systematic comparisons and cost assessments of the various options open to them. Indeed, very few currently know their fuel consumption and calculate their vehicle running costs.

Thirdly, people have limited cognitive capacity and therefore rely on simplifying assumptions and quick decision tools. Hence, it may be that such heuristics are used when distilling information on new car attributes so that only a limited set of characteristics are used to make a decision. Likewise, when eliciting information through surveys such as ‘how much would you pay for better fuel economy’, respondents may answer with an accessible rather than an accurate number. This simplifying effect can be exacerbated with the absence of direct experience when consumers attempt to answer preference questions.

Fourthly, the findings of the review challenge the idea that the use of a single set of coefficients, for a presumed single population, is an appropriate way to model consumer preferences towards EVs. Not only is there likely to be an early adopter and an early majority distinction, proper consideration of symbolic and affective motives leads to a finer grained sub-division of these groups. These segments will represent both demographic characteristics such as lifestage as well as the strength of the underlying personality and value characteristics which can have an overriding impact on preference.

Finally, based on the literature reviewed here, it would also be unwise to assume that preferences will remain static over time. There is no doubt that increased market penetration of EVs will alter the way in which consumers value EVs and choose among and use them. There is some indication of how this may be done, but given that current preferences are hard enough to disaggregate, the estimation of future preferences will be highly speculative.

In conclusion, in order to gain a deeper understanding of likely consumer response to EVs, it will be necessary to move away from traditional market research methods and use alternative approaches. The dominance of stated preference surveys is due to the attempt, since the early 1980s, to overcome the challenge of asking consumers to predict their interest in a radically new product that does not yet exist in the marketplace. However, this literature review forces a rethink of the merit of putting participants in front of predetermined optimisation problems, particularly if these only attempt to capture the functional attributes relating to an EV purchase. Alternative approaches include qualitative deliberative techniques, design games and simulations or providing real experience to participants. The goal is to equip participants with knowledge and mental stimulation equivalent to that which would exist in a more mature market place.

5 Conclusions and recommendations

1. *There is mixed evidence on the role that purchase price plays in the acquisition of (H)EVs and the premium which certain segments may be prepared to pay to own an electric vehicle*.

Overall, studies have found high levels of interest among consumers for EVs, particularly PHEVs, but also a good deal of resistance based on the estimated cost of this new technology. The high price of EVs has been noted as a main barrier to uptake, particularly in modelling evidence based on stated preference experiments. However, consumer responses to the greater price premiums of plug-in vehicles in terms of purchase probabilities is generally greater than can be justified based on purely economic rationale. This means that consumer acceptance is not solely determined by purchase price, but also emotional and other non-economic and functional factors.

Recommendation 1: Evidence so far is heavily based on revealed preference from HEV early adopter segments. A detailed study of expectations around payback periods for EVs has not been explored in the UK context. The willingness to pay a premium for fuel economy, independence from fossil fuels and new technology and other attributes should be studied in detail in the UK context with adequate attention on mainstream consumers and their decision-making parameters. However, caution must be attached to the analysis (see R3).

2. There is likely to be a more useful, finer grained segmentation than the most commonly used 'early adopter / early majority' groupings.

The early adopter (+ innovator) segments are typically thought to represent ca. 15% of the market. However, analysis of the most recent purchasers of HEVs suggests that the early adopter market is itself heterogeneous, particularly in terms of the motivations for purchasing these vehicles. For instance, whilst they appear to be willing to pay a premium for their purchase and many may not even compare the price difference with conventional vehicles, most groups can justify their purchase on a variety of economic grounds. These include being less dependent on volatile oil prices, cash flow considerations rather than detailed payback calculations, and the high value placed on saving time refuelling and possibly parking or driving in HOV and bus lanes. Only a very small proportion is purely environmentally motivated. There is likely to be an equally diverse set of consumer segments within the early majority market.

Recommendation 2: In order to understand the potential uptake of EVs in the UK marketplace, consumer research requires a post-hoc, flexible approach to segmentation that uses as its base a combination of demographic factors and economic and non-economic motivators of behaviour.

3. There is clear evidence to suggest that most consumers do not even have the fundamental building blocks to be able to make detailed payback calculations.

Policy makers and modellers may have a tendency to over-emphasise the importance of rational deliberation of longer term running costs and payback periods. This is set to be exacerbated when fuel costs are subsumed in to electricity bills. Studies in the US show that drivers of PHEVs omitted their grid-based electricity use when discussing fuel economy even though many in-vehicle displays indicated the consumption of both sources of energy. In terms of consumer perception of other costs such as such as battery replacement costs and resale value, there is little to be gleaned from the literature on these factors.

Recommendation 3: Caution must be attached to survey designs which rely on respondents basing decisions on detailed payback period calculations and complex attribute trade-offs. Studies should attempt to gain a better understanding of consumer expectations around electricity prices, maintenance costs and depreciation.

4. Rising oil prices may lead to more economically rational considerations, but the speed of price increases and the relative cost of different fuels has greater influence.

The evidence suggests it is not the cost of oil *per se* that makes the most difference, but the speed with which prices rise and the relative cost *vis-à-vis* electricity prices.

Recommendation 4: Studies should attempt to understand consumer expectations of electricity prices as well as oil prices and the impact of the relative cost differences on car purchasing behaviour.

5. Fiscal incentives need to be designed so that they are conceived separately from the purchase price but purchase and tax incentives are likely to be less important than the relative costs of fuel.

Despite the proliferation of incentive programs, particularly in the US with respect to HEVs, their efficacy is unclear. Evidence from the US shows consumers are more sensitive to sales tax incentives than income tax incentives, but that neither of these have had a greater impact than rising fuel prices. More recent studies of BEV trials in the UK do not shed light on the role of incentives as these participants have generally not gone through a true purchase process or benefited from fiscal inducements.

Recommendation 5: The role of incentives, both fiscal and other inducements such as electricity tariff structures and parking or high occupancy vehicle lane benefits, need detailed and thorough examination in the UK context. Particularly uncertain is the point in the decision making process that fiscal or other incentives are likely to have the most influence on purchasing patterns and the ways in which instruments can be packaged together to have the optimum effect.

6. Other incentives, such as parking, congestion charge and HOV benefits are likely to be less important than purchase price incentives and highly context dependent.

Evidence from the US suggests that HOV lanes could be important, but less important than other incentives and fuel prices, and very dependent on the specific local context including the level of congestion. The higher than average uptake of EVs in London and the location of people owning these vehicles does suggest that parking incentives and the congestion charge can influence the level of adoption.

Recommendation: see Recommendation 5.

7. Studies have generally found the lack of recharging infrastructure to be less of a concern to consumers than range per se. Experience and knowledge does not change desired vehicle range.

Despite acknowledgement by consumers that their travel patterns do not necessarily require ranges longer than around 50 miles for most journeys, there remains a high premium placed on the option to drive longer distances. Experience of driving these vehicles in trials does not necessarily alleviate these concerns. There is a wide variation in willingness to pay for extra range or devote resources to reducing recharging time.

Recommendation 7: A greater understanding of consumer perception and expectation regarding driving range, including willingness to pay for extra range, is required.

8. Evidence from the USA and limited evidence from the UK suggests that PHEVs may be more popular than BEVs.

Experimental and qualitative studies (mainly in the US) 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 blended operation. Theses studies suggest that the optimal solution is likely to be a range of PHEVs/REEVs which offer various degrees of high fuel economy at a range of prices to appeal to a number of segments.

Recommendation 8: Studies need to explore the desire for all electric range verses various degrees of blended operation. The majority of the literature concentrates on insights gained from current HEV owners or from recent short or medium-length trials of BEVs. Less is known, particularly in the UK context, about consumer expectations and experience of PHEVs or REEVs.

9. There are a number of conclusions emerging from the evidence regarding charging behaviour:

- ***trial data consistently shows users are over cautious when planning journeys, using a fraction of available range and charging frequently***
- ***PHEV owners are enthusiastic about wanting to take advantage of the all electric range and take every opportunity to recharge***
- ***home charging is preferred by private consumers and is viewed positively***
- ***range is more important than recharging time and there is a general lack of willingness to devote extra resources to more rapid charging facilities***
- ***public charging infrastructure is not the biggest barrier to uptake and public 'slow' charging facilities will be of limited functional value. However, charging infrastructure will have an important function to diffuse public awareness of EVs and instil confidence in the technology***
- ***in the UK, the majority of households, and the vast majority of car owning households, have dedicated parking facilities***
- ***uncontrolled patterns of recharging are likely to be highly varied at the disaggregate level and there is very little evidence to illuminate the potential impact of tailored electricity charging tariffs and smart (controlled) charging***
- ***many consumers are attracted to the idea of having their own source of fuel at home and to reduce the nuisance cost of refuelling at petrol stations.***

In EV trials, drive data shows that users are overcautious when planning journeys, typically using less than half of the technical range. One study in Tokyo showed that utilisation increased following the installation of a fast charger was installed in the city. The clear consensus in the evidence so far is that consumers will mainly recharge their EVs at home and in workplace car parks and frequent recharging will be the norm - at least at first. Overall there is a positive attitude towards home charging. In the UK, 80% of *car owning* households use dedicated parking facilities at home (although it is not clear how many of these have an electric point nearby) and, given typical driving patterns, public 'slow' charging points would be of limited value. However, public charging infrastructure will play a vital role in spreading awareness and confidence in the technology.

Recommendation 9: An understanding of the symbolic and functional role of public charging infrastructure is urgently required, including the optimum distribution and public

expectations of such infrastructure, especially fast charging facilities. Little is known about the proportion of UK workplaces with existing charging facilities and the relationship between household dedicated parking and access to electricity supply. The acceptability and potential impact of varied electricity charging tariffs and controlled/smart charging is another candidate for research.

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10. Consumers tend to have negative perceptions regarding EV's performance but these are often greatly improved even after a very short exposure to a vehicle. However, it is possible that longer exposure to a vehicle exacerbates negative perceptions of issues such as range and reliability.

Consumers have been found to have generally negative perceptions with regards to alternative vehicles' attributes especially with regards to performance factors such as acceleration and top speed. Importantly, however, in the findings of a few EV vehicle trials that have been conducted, ratings of EV performance tends to increase once consumers have gained some experience of the vehicles. However, in longer term trials, some studies have shown interest in owning EVs have decreased after a few months due to concerns about range and reliability/ maintenance.

Recommendation 10: Changes in consumer perceptions need to be studied after a long exposure time to the vehicles in order that the vehicle becomes fully adopted into the lifestyles of the participant and longer term issues such as range and reliability can be evaluated.

11. Models of car choice are likely to be inadequate without a proper consideration of symbolism and identity.

EVs have been found to be associated with meanings such as lower resource consumption, independence from petroleum producers, advanced technology, financial responsibility, saving money, opposing war as well as environmental and/or resource preservation. These symbolic evaluations can relate to the whole vehicle or to more specific functional or financial attributes such as fuel economy. Consumers then infer connotations to these meanings such as 'behaving ethically', 'concern for others', 'being intelligent' or 'unique' and if these relate to self identities and values, they will be expressed through adoption of EVs. For some segments, symbolic factors are likely to play as strong a role as economic or functional attributes.

Recommendation 11: Survey work should be designed so as to elicit the multiple symbolic meanings attached to EVs and understand their relative role alongside functional and affective motives.

12. Environmental benefits are only one of many symbolic meanings attached to EVs and may play an important role for only a small minority of consumers.

There is debate over the extent to which adopters of EVs have or will have above average environmental awareness. It seems that some consumers would be prepared to pay more to drive cleaner or zero emission vehicles, but this often relies on the idea that the alternative vehicles can match conventional types in performance.

Recommendation 12: See Recommendation 11.

13. Various personality traits may also be associated with early EV adoption.

Innovativeness reflects the degree to which an individual makes innovative decisions independently of the communicated experience of others and, when combined with product knowledge, are powerful individual attributes on which to segment consumers. Narcissism

(individuals who see themselves, and who want others to see themselves, as special or superior) is also hypothesised to be associated with greater interest in the symbolic rather than the functional value of products in the context of EVs. Driving an EV has also been found to be associated with high openness, high conscientiousness and high agreeableness.

Recommendation 13: Studies of potential EV consumer groups should include measures of personality/ innovativeness as part of the basis for segmentation.

14. No conclusions can be drawn as to whether the early adopter groups of EVs are likely to have similar traits to current hybrid and EV owners.

Evidence suggests that current EV and HEV owners are more willing to pay for extended range or be enthusiastic about the adoption of EVs. They are also wealthier, from multi-car households and are willing to pay a higher price premium for a variety of reasons including altruism, bragging rights and a sense of economic 'saviness', particularly due to the importance of fuel economy benefitting their often greater than average driving distances. However, whilst it is likely that the early entrants to the EV market may have similar characteristics, the mainstream consumer will be less preoccupied with running costs. In addition, whilst early adopters will recommend the technology to the early majority, they will need continual improvement in the technology for it to be attractive.

Recommendation 14: Detailed segmentation analysis based on a combination of demographic, revealed preference, stated preference and attitudinal data will allow examination of the relationship between current and likely future car ownership and provide a fine grained segmentation of likely consumer groups.

15. One of the strongest influences on uptake will be the 'neighbour effect' as EVs become more widespread and consumers become influenced by others and more confident in the technology.

Increased market penetration will alter the way in which consumers value EVs and choose among them. There is a tendency for consumer preferences to change as technology becomes more prevalent in the market due to the changes in social concerns, increased credibility and learning from others with more experience as well as marketing, education and shifts in social norms. A consumer may want to have a critical mass of companion owners in order to guarantee reliability and repair capability at many locations and may want to have a sufficient choice of makes and models available to them. A study of market data in the US found that different models of HEV had different patterns of diffusion and this was attributed to different signals of quality across different models fuelled by media stories and word of mouth.

Recommendation 15: Market share ratios can be added to surveys and 'familiarity penalties' added to models to try and elicit consumer preference and account for spillover effects, although these techniques are highly speculative.

16. It is likely that households will adopt a multi-car solution to optimise range and recharging time and the choice of which vehicle to use and it is possible that consumers may use and drive EVs differently to conventional vehicles.

Figures on HEV adoption in Switzerland do not show additional car ownership, but in the US they do. There is some evidence that most BEV owners in the UK have access to another vehicle. In addition, it is possible that consumers may use these vehicles differently to conventional vehicles and this could lead to rebound effects such as increased car ownership, more driving or 'upsizing' which could counteract efficiency gains. There may

also be positive benefits to driving style given the imperative to preserve all electric driving range. There is very little evidence on any of these possible behaviour changes.

Recommendation 16: The uptake of EVs should be examined in the context of household car ownership and the extent to which these cars will substitute for or be additional to other cars in the household.

17. There is very little evidence regarding the decision making processes of public and private fleet purchasers.

The literature is almost entirely dominated by research on private consumers or decision making processes within fleets which assume 'user choosers'.

Recommendation 17: More research on the expectations surrounding EVs and the decision making processes of fleet buyers is urgently needed.

18. Altogether the literature is not sufficient to provide an overall understanding of consumer wants, needs and perceptions.

In particular, in addition to those mentioned above, there are several issues which are hinted at in the literature on EVs or are known to be important in car purchasing behaviour more generally, but where no quality evidence came through in this review:

- (mis)perceptions of the various powertrains (HEVs, PHEVS, BEVs, REEVs)
- various safety concerns such as safety ratings, the volatility of the battery upon impact in an accident and perceived safety of charging arrangements
- concerns around the availability of maintenance expertise and breakdown cover in emergency situations
- feelings in relation to battery disposal and lifecycle costs
- consumer perception of other costs such as such as battery replacement and resale value
- size and practicality are important car purchase factors and is a common starting point for vehicle selection yet perceptions of size in relation to EVs have not been widely studied
- expectations around electricity prices vis a vis oil prices and the potential response to different charging tariffs
- acceptability of controlled/ smart charging
- acceptability and attractiveness of use of the vehicle for energy storage to earn money selling back to the grid or to provide independent or emergency power
- the impact of fiscal and non-fiscal incentives in a UK context
- different models of car and battery ownership and finance
- emotional reactions such as how a car feels to drive and the pleasure gained from the experience
- issues around identity and who is expected to own and use EVs
- potential geographical 'hotspots' from which a shift in consumer behaviour towards EVs will diffuse. This would relate to the settlement types and neighbourhoods most conducive to uptake

Recommendation 18: A mixed method and coordinated qualitative and quantitative research effort is necessary to develop an understanding on a whole array of aspects relating to EV uptake that missing from the literature, particularly in the UK context.

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