Transportation Research Part A 88 (2016) 40–57

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Comparing high-end and low-end early adopters of battery electric vehicles

Scott Hardman [a,*], Eric Shiu [b], Robert Steinberger-Wilckens [a]

[a] University of Birmingham, Chemical Engineering, Edgbaston, B15 2TT, United Kingdom
[b] University of Birmingham, Birmingham Business School, Edgbaston, B15 2TY, United Kingdom

ARTICLE INFO

Article history:
Received 22 January 2015
Received in revised form 27 October 2015
Accepted 22 March 2016
Available online 12 April 2016

Keywords:
Electric vehicle
Marketing
Early adopters
Consumers

ABSTRACT

Battery electric vehicle adoption research has been on going for two decades. The majority of data gathered thus far is taken from studies that sample members of the general population and not actual adopters of the vehicles. This paper presents findings from a study involving 340 adopters of battery electric vehicles. The data is used to corroborate some existing assumptions made about early adopters. The contribution of this paper, however, is the distinction between two groups of adopters. These are high-end adopters and low-end adopters. It is found that each group has a different socio-economic profile and there are also some psychographic differences. Further they have different opinions of their vehicles with high-end adopters viewing their vehicles more preferentially. The future purchase intentions of each group are explored and it is found that high-end adopters are more likely to continue with ownership of battery electric vehicles in subsequent purchases. Finally reasons for this are explored by comparing each adopter group's opinions of their vehicles to their future purchase intentions. From this is it suggested that time to refuel and range for low-end battery electric vehicles should be improved in order to increase chances of drivers continuing with BEV ownership.

1. Introduction

The automotive sector is moving towards a transition from primarily petrol and diesel fuelled internal combustion engine vehicles (ICEVs) to more sustainable plug-in hybrid vehicles (PHEVs) and battery electric vehicles (BEVs) (Poullikkas, 2015; Sierzchula et al., 2014). BEVs are considered to be the most beneficial of these due to them having zero emissions, high efficiencies and having the potential to be fuelled entirely off renewable electricity (Helveston et al., 2014; Nordelöf et al., 2014; Offer et al., 2011; Schneidereit et al., 2015; Sierzchula et al., 2014; Thomas, 2009). In order for these vehicles to have the greatest effect on improving urban air quality, reducing carbon emissions and reducing energy use they need to be deployed in larger numbers than they are at present. Therefore a greater understanding of how to increase market penetration needs to be developed. It is possible to achieve this through understanding early adopters of BEVs (Schuitema et al., 2013). This will lead to an understanding of where the market for these vehicles lies and also how to ensure that BEVs appeal to these markets. This will inform policy makers and automotive OEMs on how best to grow the market of BEVs such that the societal benefits can be maximised. At present the market is at a very early stage of development with recent market introductions beginning in 2008–2010. Since then the BEV market has developed and grown both in terms of the numbers of

* Corresponding author.
E-mail addresses: SXH993@bham.ac.uk (S. Hardman), E.C.Shiu@bham.ac.uk (E. Shiu), R.SteinbergerWilckens@bham.ac.uk (R. Steinberger-Wilckens).

http://dx.doi.org/10.1016/j.tra.2016.03.010
0965-8564/

vehicles available and the numbers being adopted by consumers. At the end of 2014 there were 665,000 BEVs deployed globally, with the top three markets for BEVs being the US (39%), Japan (16%) and China (12%). The market shares of BEVs in these nations are still low and of these only in the US did BEVs achieve a 1% share of 2014 vehicle sales. The highest market shares in terms of yearly sales are in Norway (12.5%) and the Netherlands (4%) (IEA, 2015). These numbers are promising for an early market but are still insignificant compared to the entire transportation market (Rezvani et al., 2015), clearly greater effort is needed in order to increase these numbers.

A significant change in the landscape of the BEV market occurred in 2012 with the introduction of the Tesla Model S. Prior to this all BEVs on the market where what are considered here to be low-end electric vehicles (Hardman et al., 2014, 2013). These vehicles all have prices of $30–40,000 and ranges of <100 miles (Nissan, 2014). The Tesla Model S, which is considered here as a high-end BEV costs $70,000–105,000 and has a range of 270 miles (Tesla Motors Inc, 2014). Therefore the introduction of this vehicle resulted in a new market segment being created. So far, within the literature, adopters of BEVs have been considered as one homogenous group, with studies overlooking potential differences between high and low-end adopters. Existing studies have investigated barriers to the adoption of electric vehicles (Browne et al., 2012; Egbue and Long, 2012), how experience of an BEV relates to intention to adopt (Bühler et al., 2014; Franke et al., 2012; Graham-Rowe et al., 2012), purchase intentions and preferences of potential adopters (Chorus et al., 2013; Koetse and Hoen, 2014; Sierzchula et al., 2014) along with studies that identify potential early adopters of BEVs (Campbell et al., 2012; Plötz et al., 2014). Further literature investigates people with first hand experience with a BEV, such as (Lane et al., 2014). An insightful study by Caperello et al. (2014) used workshops involving BEV adopters and ICEV drivers in order to understand how to bridge the gap between early and later adopters.

At the beginning of this study it was hypothesised that the two groups of adopters would be different. This is due to the significant differences in the price and features of the vehicles (Table 1). It was believed that adopters would have different socio-economic and psychographic profiles. It was also believed that they would have differing opinions of their vehicles owing to their different attributes and features, which can be seen in Table 1. Further to this, an understanding of future purchase intentions of actual BEV adopters was needed. This should be in relation to the attributes of each vehicle in order to understand what circumstances lead to a high likelihood of continued adoption. Consumer intent to purchase a BEV has been investigated in some detail within the literature (Bühler et al., 2014; Chorus et al., 2013; Koetse and Hoen, 2014; Sierzchula et al., 2014). These studies investigate the intent of ICEV drivers to adopt a BEV and not BEV driver's future intention to continue with BEV ownership. In order for the market to grow early adopters will be required to remain users of BEVs and not abandon the technology. Repeat purchases are more important than initial purchases in maintaining long term growth of any new product (Crawford and Benedetto, 2011; Rogers, 2003). The overriding aim of this paper is to explore and understand the difference between adopters of low and high-end BEVs. This distinction between two different adopter groups of BEVs is the major contribution of this paper. The hope is that policy makers can use the results of this study to make more informed policy decisions and that OEMs are able to develop cars that are properly positioned for each market, in order to ultimately grow the BEV market.

1.1. Literature review

BEV adoption research has been on going since the early 1990s (Golob et al., 1997; Kurani et al., 1994, 1996), since then the body of literature has grown considerably with authors in many countries looking towards understanding the complexities of BEV adoption. The vast majority of the literature gathers empirical data from persons who are not adopters of BEVs, often sampling the general public and asking them questions about BEV perception (Egbue and Long, 2012; Krupa et al., 2014; Plötz and Gnann, 2011; Plötz et al., 2014). Only recently has literature begun to report samples of people who have actual experience with BEVs. This data can be more insightful as it is more representative of an actual decision to adopt a BEV, rather than a hypothetical one. Studies that involve actual adopters of BEVs include (Caperello et al., 2014; Lane et al., 2014; Tal and Nicholas, 2013; Tal, 2014; Turrentine et al., 2011). Whilst these studies are becoming more numerous they are still not abundant within the literature, and more studies are needed in order to guide the transition from ICEVs to BEVs. Indeed, a 2015 review by Rezvani et al. (2015) calls for more studies that use data from actual adopters.

Table 1
Comparison of the Nissan Leaf (low-end BEV), of which there were 152 in this study, and the Tesla Model S (high-end BEV), of which there were 153 in this study (Nissan, 2015; Tesla Motors Inc, 2015).

	Nissan Leaf	Tesla Model S
Price	$29,000–35,000	$70,000–105,000
Range	75 miles	270 miles
Acceleration (0–60 mph)	9.9 s	3.1 s
Top speed	93 mph	155 mph
Fastest charge time (0–100%)	4 h	1 h 15 min
Electric motor	80 kW	515 kW
Battery	24 kW h	85 kW h
Length	4.4 m	4.9 m
Width	1.7 m	1.9 m

A number of early publications explored characteristics of potential early adopters by interviewing multi-car households in the US (Kurani et al., 1994, 1996). The authors predicted that early adopters of BEVs would be households with 2 or more cars and have a garage where at least one car can be parked. A study by Carley et al. (2013) predicted intent to purchase a BEV based on a sample of 2302 members of the general public. It was found that the main advantages of BEVs were high fuel economy, low environmental impacts, positive image and BEVs being viewed as cutting edge technology. From their sample they concluded that early adopters are likely to be highly educated, environmentally sensitive and would already tend to be owners of a hybrid vehicle. Studies by Plötz et al involving 210 people with "high interests in EVs" (Plötz and Gnann, 2011; Plötz et al., 2014) predicted that early adopters would be middle-aged males, in technical professions, in rural or suburban multi-person households.

A study of US residents over 17 years of age by Hidrue et al. (2011) predicted that early adopters would be young, educated, have green life styles, and fuel cost concerns. Contrary to other studies, these authors found that income and multiple car ownership would not be key characteristics. They also found a high willingness to pay for a BEV with good range, fast charge time, with fuel cost savings, reduced emissions and good performance. Another study in the US sampled 1000 members of the general public in order to understand Plug-in Hybrid Electric Vehicle (PHEV) market entry (Krupa et al., 2014). Egbue and Long (2012) sampled 500 "Technology Enthusiasts", who owned ICEVs. They found from their sample that sustainability was less important than purchase price and vehicle performance. A UK based study by Campbell et al. (2012) used census data in order to identify locations of early adopters. They identified early adopters as people who were homeowners, commute to work in their own vehicle, own 2 or more cars, have a high socio-economic profile, and are highly educated.

Turrentine et al. (2011) investigated members of the Mini E trial in the US. The goal of the study was to understand user responses to BEVs and to identify a route to market for them. Members of the trial were required to lease the vehicle in order to participate. 54 Mini E drivers took part in the study; data was collected using driving diaries, online questionnaires, and interviews. This was the largest data set of its kind at that time. From the study it emerged that users of the Mini E value the high performance of the vehicle, the sporty handling and the fact that these driving characteristics were available with low environmental impact. It also emerged that the regenerative braking meant that for much of the time acceleration and deceleration could be controlled using only one pedal, making it more convenient to drive. Members of the study were found to look favourably on BEVs post trial, with 100% agreeing that BEVs were suitable for daily use. The results of the trial were positive with 71% of the sample indicating that they were more willing to adopt a BEV after the trial. In addition to this, 64% of respondents indicated that they planned on purchasing a BEV in the next 5 years. A later study on the Mini E in Germany (Bühler et al., 2014) involved 79 participants in a 6 month trial. Respondents were interviewed before, during and after the study. According to the authors, this was the only study that recorded changes in BEV perception over time. They found that high purchase price and limited range still represent the main barriers to adoption. Another European study, this time in the UK, gathered data from 40 participants in an EV trial. In this study 20 people were given a PHEV and 20 people a BEV for a period of 7 days. All participants in the study were drivers of ICEVs. From qualitative interviews it was found that the respondents believed that purchase prices were too high (Graham-Rowe et al., 2012).

A US study by Lane et al gathered data from actual early adopters of BEV (Lane et al., 2014). In their sample 59 of the 76 respondents were BEV owners, and the remainder were fleet users. The study therefore used data from people who had adopted a BEV. It concentrated on early adopters of the THiNK City. The authors reported that users valued the environmental friendliness of the vehicles, and simply being early adopters of a new technology. The advantages of BEV ownership were found to be saving money, environmental protection, high-tech, low maintenance costs, and fun/enjoyable driving style. Three further studies that use data from actual adopters were identified. The publication by Caperello et al. (2014) investigated how to get later adopters or laggards interested in BEV through workshops that were populated with both BEV drivers and ICEV drivers. Tal and Nicholas (2013) explored who is buying BEVs and if these people are different from ICEV drivers. A second paper by the same authors explored the influence of high-occupancy vehicle lanes access for BEV buyers (Tal, 2014). These papers have the highest number of BEV adopters in their sample of any study the authors of this paper are aware of.

More recently, researchers have began looking into how the market for BEVs can be increased and how to encourage consumer adoption. Dumortier et al. (2015) suggested that high costs and deferred financial savings of BEVs lead to reduced rates of adoption. The authors suggest that providing total cost of ownership data could overcome this barrier. Helveston et al. (2014) investigated the impact financial incentives have on the adoption of BEVs. Gnann et al. (2015) suggest that there may be a significant market of BEVs in the commercial passenger vehicle sector.

An important goal of the literature is the identification of early adopters of BEVs. This information is useful in developing and growing the market. At present the literature suggests that early adopters will have pro-environmental and pro-technology attitudes (Wolf and Seebauer, 2014), will be highly educated (Campbell et al., 2012; Carley et al., 2013; Hidrue et al., 2011), have a high economic status (Campbell et al., 2012; Hidrue et al., 2011), have two or more cars (Kurani et al., 1994), be young to middle aged (Hidrue et al., 2011; Plötz et al., 2014), would likely own a hybrid vehicle (Carley et al., 2013), have fuel cost concerns, and be mostly male (Plötz et al., 2014). These generalisations are made from data obtained from potential BEV users but without any empirical evidence from actual early adopters and hence need to be validated using such data. A summary of the assumptions made in the literature can be seen in Table 2. The table shows the authors, sample size, sample population and the expected socio-economic profile of early adopters along with the expected benefits of BEVs.

Currently within the literature there is no data that explores the future purchase intentions of current owners of BEVs. This data is important in order to understand the diffusion of BEVs through the market, and will also reveal if BEVs have

Table 2
Summary of the main literature that explores BEV adoption, by author, sample size and sample population and the main conclusions of these studies that explore the expected socio-economic profile of BEV adopters and the expected benefits of BEVs.

Author(s)	Sample size	Sample attributes	Expected socio-economic profile of early adopters	Expected benefits of battery electric vehicles
Bühler et al. (2014)	79	German Mini E trial participants		Driving pleasure, low running costs, environmental
Campbell (2014a) and Campbell et al. (2012)	413	General public	High income, high education, multi-car household, commuters	
Caperello et al. (2014)	Not stated	General public and BEV adopters		Low running costs significant reason for adoption
Carley et al. (2013)	2302	General public	High education, own a hybrid, have environmental concerns	Fuel economy, environmental, technology
Graham-Rowe et al. (2012)	40	7 day PHEV & BEV trial participants		Low running costs, environmental
Hidrue et al. (2011)	3029	General public	Young, high education, high income	Performance, low running costs, environmental
Kurani et al. (1994)		Households in California	Multi-car households with a garage	
Lane et al. (2014)	76	59 BEV owners and 17 BEV fleet users		Environmental, technology, low running costs, low maintenance, driving fun
Peters and Dütschke (2014)	92	92 BEV users in sample of 969 people with high interest in BEVs	Middle aged, male, multi-car households	Low running costs, environmental
Plötz et al. (2014)	210	General public with high interest in BEVs	Middle aged, technical professions, rural or suburban multi-car households	
Turrentine et al. (2011)	54	USA Mini E trial participants		Performance & handling, environmental, 1 pedal driving

enough benefits to convince adopters to continue with ownership. The majority of current BEV owners have purchased their vehicle as an initial purchase, having not owned a BEV previously. Subsequent purchases will be repeat purchases and it is known that the way in which an initial or repeat purchase decision is made is different (Crawford and Benedetto, 2008). One of the most significant limitations of the literature is that early adopters are considered to be one homogeneous group of consumers. Within the literature they are referred to as having shared socio-economic and psychographic characteristics. No single study makes distinctions between different possible groups of early adopters. This is despite the price of BEVs ranging from $30,000 to $105,000 (Nissan, 2014; Tesla Motors Inc, 2014). It is unlikely that an adopter of a $30,000 vehicle would be similar to the adopter of a $105,000 vehicle. Therefore this paper addresses this major research gap; by identifying differences between high and low-end early adopters. This is achieved by understanding their socio-economic and psychographic characteristics; understanding how they respond to the vehicles that they have adopted and understanding their future BEV purchase intentions.

2. Methods

2.1. Questionnaire survey

By the end of 2014 there were 665,000 BEVs worldwide with 39% (275,000) of these being in the United States. For this reason, the questionnaire was targeted towards North American owners of BEVs. Nevertheless, the questionnaire was left open to all BEV owners across the world. Between July and December 2014, 340 fully completed surveys were collected. The method in which owners were recruited to participate in the questionnaire was via online forums. The following forums were identified and used:

- Telsamotors.com, the official Tesla forum.
- Reddit.com/r/teslamotors, an online forum with a sub-area for Tesla enthusiasts.
- Reddit.com/r/electric vehicles, an online forum with a sub-area for electric vehicle enthusiasts.
- Nissan and Infiniti Car Owners, a forum for Nissan and Infiniti owners, including the Nissan Leaf.
- Leaf Talk, a Nissan Leaf owner forum.
- Speak EV, a forum for owners of any electric vehicle.

The study divided the online questionnaire into three sections: the first gathers socio-economic data, the second psychographic information, the final section asks for information on respondents' opinions of their vehicle's attributes, and also asks them about their future BEV purchase intentions. The methods in which these questions were formulated are explained below.

2.1.1. Socio-economic and psychographic data

The socio-economic profile of respondents was measured to understand if there are any statistically significant differences between low-end and high-end adopters. Questions were developed based on the existing literature, outlined in the review, which makes statements about early adopters gender, age, income, level of education and the number of cars in the household; therefore these 5 attributes were used to understand respondent's socio-economic profile.

Rogers' theory (Rogers, 2003) makes some generalisations about early adopters' psychographic profile. These help towards identifying the types of people that may be adopters of new technologies in general. These generalisations along with findings from existing BEV literature were used to develop 20 questions, which measure respondent's psychographic profile. This allows a more quantitative method in deciding if low-end and high-end adopters are significantly different from one another. All 20 questions can be seen in Table 7.

2.1.2. Vehicle attribute opinion & future data

In order to understand what the benefits and shortcomings of BEVs are, a number of pilot interviews with UK BEV owners were undertaken. In total, 5 BEV adopters were interviewed, they were asked why they chose to adopt a BEV and what the benefits of ownership are. The following 10 attributes measured in this survey emerged as the perceived benefits of the vehicles and reasons for adoption of a BEV:

1. Brand
2. Vehicle image/looks
3. Purchase price
4. Vehicle range
5. Time to refuel
6. Vehicle performance
7. Fuel economy
8. Environmental impacts
9. Life style fit
10. Running costs

Table 3
Summary of the statistical techniques used in this paper, what they are used for and the reason they were selected.

Statistical test	Use	Reason
T-test	Comparing psychographic and vehicle attribute data for each adopter group	Comparison of Likert sale or ordinal scale questions
Chi square	Comparing socio-economic data for each adopter group	Comparison of questions with a nominal scale
Multiple regression	Exploring the relationship between vehicle attribute and future adoption data	Comparing multiple independent variables to one dependant variable

Respondents were asked to compare their vehicle to an ICEV in order to ascertain in what manor the vehicles are worse, similar and superior. After respondents were asked about their vehicle attribute opinions they were asked two questions that measured if they would continue with BEV adoption in the future. The first measured the likelihood of continual ownership of any BEV, the second measured any brand loyalty to the current BEV that they own. This is a measure of consumer perceptions and not the actual performance of the vehicles. As is discussed in (Crawford and Benedetto, 2011), consumer perceptions are more important than actual product performance. Therefore the results reported here may not necessary be representative of the actual attributes of a BEV, but they are representative of how early adopters view these attributes.

2.2. Data analysis

In order to analyse the data three statistical techniques are used. In order to compare means between samples that use a Likert scale the *T*-test is used. In order to compare statistical differences between samples that do not use a Likert scale and use a nominal scale Chi-square is used. Finally linear regression is used to find out whether and which of a number of hypothetical independent variables have a significant impact on the dependent variable. The way in which these techniques are used is summarised in Table 3.

In order to identify the differences between high and low-end adopters the *T*-test is used. The *T*-test compares samples in order to understand if there is a statistically significant difference in the means. In this case it is used to compare questions that use a Likert scale. In order to reject the null hypothesis we use the standard 5% confidence level, meaning we require a significance value (p) of 0.05 or below. If a null hypothesis is rejected this means that there is a significant difference between the two sample populations. Independent samples *T*-test is calculated using the following:

$$T = \frac{X_1 - X_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

T = obtained T value
X_1 and X_2 = means for the two groups
s_1^2 and s_2^2 = variances of the two groups
n_1 and n_2 = number of respondents in each of the two groups

Chi-Square is used to assess differences in the socio-economic data. Chi-square is used here, rather than the *T*-test, because the data is not measured using ordinal scales meaning the *T*-test would be inappropriate. The usual 0.05 significance is used to reject the null hypothesis. Chi-square goodness of fit is calculated using the following:

$$X^2 = \sum \frac{(O - E)^2}{E}$$

O = observed value
E = expected value

In order to understand the data further, multiple regression is used. In this case it is used to understand how early adopter's views of the different attributes of their vehicles, as shown below in Table 8, may relate to their willingness to continue with BEV ownership as shown in Fig. 2 below. The fist stage of analysis is deciding whether the regression model has explanatory power. This is done by testing ANOVA (Analysis of Variance), which is rejected at the usual 0.05 level. In this case the null hypothesis for each variable is rejected at a significance of 0.1. This is less stringent than 0.05. This study focuses on early adopters and investigates the behaviours and opinions, therefore is a study within the field of social science. Within this field, due to the larger number of variables it is permissible to use this less stringent level of significance compared to natural sciences. The variables that are rejected at a significance of 0.1 are then further tested. This time only the values that are significant at a level <0.1 are retained in the regression model. For this final regression the null hypothesis is again set at 0.1. The variables less than 0.1 will be a significant influence on the dependant variable and the model is therefore a good predictor of future vehicle purchase intentions. This method of stepwise regression analysis is known as the backward elimination method. Multiple regression derives from simple Regression, which is calculated using below formula:

Table 4
Table showing the socio-economic profile for each group of adopters and a summary of all of the data within the sample. Income is shown in US income brackets and in US$.

Sample attributes		Low-end total	(%)	High-end total	(%)	Total	(%)
Gender	Male	177	95.7	138	89.0	315	92.6
	Female	8	4.3	17	11.0	25	7.4
Age	17–24	3	1.6	1	0.6	4	1.2
	25–34	30	16.2	9	5.8	39	11.5
	35–44	54	29.2	32	20.6	86	25.3
	45–54	45	24.3	43	27.7	88	25.9
	55–64	43	23.2	34	21.9	77	22.6
	65–74	9	4.9	27	17.4	36	10.6
	75–84	1	0.5	8	5.2	9	2.6
	85+	0	0.0	1	0.6	1	0.3
Education	Doctorate or equivalent	18	10.0	37	23.9	55	16.4
	Masters or equivalent	40	22.2	54	34.8	94	28.1
	Bachelors or equivalent	84	46.7	52	33.5	136	40.6
	High school diploma or equivalent	31	17.2	11	7.1	42	12.5
	Other	7	3.9	1	0.6	8	2.4
Income	<$10,000	1	0.5	2	1.3	3	0.9
	$10,001–40,000	17	9.3	0	0.0	17	5.0
	$40,001–90,000	51	28.0	8	5.2	59	17.5
	$90,001–180,000	90	49.5	48	31.0	138	40.9
	$180,000–400,000	23	12.6	70	45.2	93	27.6
	$400,001+	0	0.0	27	17.4	27	8.0
Number of cars in household	1	22	11.9	19	12.3	41	12.1
	2	96	51.9	67	43.2	163	47.9
	3	45	24.3	39	25.2	84	24.7
	4	13	7.0	24	15.5	37	10.9
	5	9	4.9	6	3.9	15	4.4

$$Y = a + bX$$
$$a = \frac{\sum Y - b\sum X}{N}$$
$$b = \frac{N\sum XY - (\sum X)(\sum Y)}{N\sum X^2 - (\sum X)^2}$$

where
Y = the dependant variable
X = are the independent variable
b = the slope of the regression line
a = the intercept

Multiple regression, which is used in this study, is a more advanced technique and is used to predict the value of a dependent variable based on more than one independent variable. The equation for multiple regression is shown below.

$$Y = a + b_1(X1) + b_2(X2) + b_3(X3) + \cdots + b_K(XK)$$

where
Y = the dependant variable
X = are the independent variables
b = the slope of the line
a = the intercept

3. Results and discussion

The socio-economic profile of the 340 early adopters can be seen in Table 4. The sample is mostly male at 92.6%. Age is spread widely, however most are middle aged with 73.8% of the sample between 35 and 64 years of age. Level of education is high with 16.4% holding a doctorate or equivalent, 28.1% with a master's degree or equivalent and 40.6% with a bachelors or equivalent. This means that 85.1% of the sample has received a University level education. Level of income within the sample is high, with 76.5% earning more than $90,000 per year. The number of vehicles per household in this sample is 2.5, this is higher than the US average of 1.9 (US Department of Transportation, 2009). The sample consists of 359 electric vehicles, a breakdown of vehicles can be seen in Table 5. There are 19 more vehicles than BEV early adopters in this study as some

Table 5
Breakdown of the BEVs in this study by make and model.

Make	Model	Number
BMW	i3	2
Citroën	C Zero	1
Fiat	500e	4
Ford	Focus EV	4
GM	Spark EV	1
GM/Vauxhall	Volt/Ampera	7
Mitsubishi	iMiEV	5
Nissan	Leaf	152
Renault	Zoe	6
Smart	Fortwo EV	3
Tesla	Model S	153
Tesla	Roadster	11
Toyota	Rav4 EV	7
Volkswagen	eGolf	1
Zero Motorcycles	S ZF11.4	2
	Total	359

owners have more than one BEV. The most common vehicles are the Tesla Model S ($n = 153$) and the Nissan Leaf ($n = 152$). The remaining vehicles are all fully electric cars with the exceptions of 2 electric motorcycles. Further to this there are 9 vehicles that are range extended electric vehicles, of these there are 2 BMW i3's and 7 GM Volt's/Vauxhall Ampera's.

The questionnaire also asked adopters about their previous vehicles, this reveals an interesting trend. In order to compare prices of previous vehicles with prices of BEVs the data was standardised to 2014 vehicle prices. Therefore if the respondent's previous vehicle was a 1998 VW Golf, the 2014 price of this vehicle was compared to the 2014 price of the BEV that they currently own. It is found that the average purchase price of low-end adopters previous ICEVs would have been a mean of $25,553 and medium of $23,660. Low-end adopters paid a premium of $4195–5350 for their BEV compared to the ICEV they previously owned. This is an amount of money that could reasonably be recovered due to the low running costs of BEVs. High-end adopters previous vehicles have a mean of $45,144 and medium of $40,285. High-end adopters paid a premium of $37,614–41,575 for their BEV compared to the price of their previous vehicle. This is a significant leap, and goes against some suggestions that the cost of BEVs is too high (Graham-Rowe et al., 2012).

3.1. Socio-economic differences

Based on the results presented in Table 4 above it does appear that the groups have different socio-economic attributes. However in order to define whether these are statistically significant differences Chi-square was used, the results of this can be seen in Table 6. Firstly gender was compared, with the null hypothesis "There is no difference in gender between high and low-end adopters". This was rejected at a significance of 0.019. It is found that whilst both groups have a low number of females, high-end adopters are comprised of more females than low-end adopters. 11% of high-end adopters in this study were female, compared to only 4.3% of low-end adopters. There are, however, a low number of females in this study, only 25 in total, meaning this finding should be treated with caution until a larger sample of female adopters has been gathered. The age of adopters was compared using the null hypothesis "There is no difference between high and low-end early adopters age". This was rejected with a significance value of <0.001. It is found that high-end early adopters are of a higher age than low-end early adopters. The level of education was then compared using the null hypothesis "Level of education does not differ between high and low-end early adopters". This null hypothesis was rejected with a significant value of <0.001. Meaning that there are differences in the level of education between high and low-end adopters. High-end adopters are of higher education than low-end adopters. 23.9% of high-end adopters held a doctorate or equivalent compared to 10% for low-end adopters, and 34.8% of high-end adopters held a masters or equivalent compared to 22.2% for low-end adopters.

Table 6
Results of Chi-square test comparing the significant difference of socio-economic variables between high and low-end early adopters.

Attribute	Chi-square	*df*	Significance (*p*)
Gender	5.464	1	0.019
Age	32.08	7	0.000
Education	28.495	4	0.000
Income	110.755	5	0.000
Number of cars in household	7.086	4	0.131

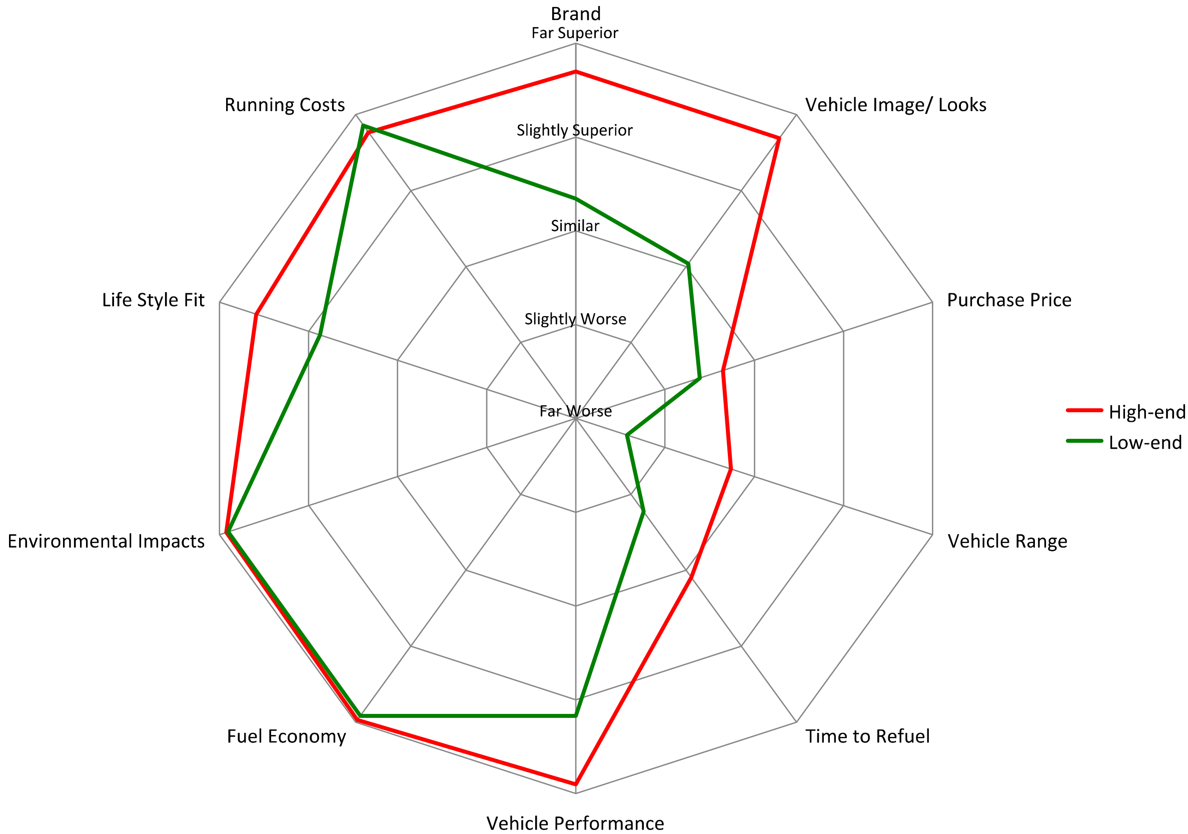

Fig. 1. Figure showing differences in answers to the question "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to a internal combustion engine vehicle?" The axis starts at "Far Worse" in the centre, then through "Slightly Worse" to "Similar", then "Slightly Superior" and finally "Far Superior" on the outer most axis line. This means the closer the line to the outer edge the more superior adopters perceive this attribute.

In total 92.3% of high-end adopters have received a University level education, compared to 78.9% of low-end adopters. The income of adopters was compared with the null hypothesis "There is no difference between high and low-end early adopters level of income". This hypothesis was rejected at a significance of <0.001. It is found that whilst both sets of adopters are high income, the high-end adopters level of income is significantly higher than the low-end adopters. To illustrate this, 12.6% of low-end adopters earn more than $180,000 whilst 62.6% of high-end adopters earn more than this. The number of vehicles in the household does not differ between samples and the null hypothesis could not be rejected. Both household types have a higher car ownership than the US average. In summary there is no difference in car ownership, but clear differences in gender, age, education and income, with on average high-end adopters having higher socioeconomic status than low-end adopters.

3.2. Psychographic differences

In order to understand how high-end and low-end early adopters' psychographic profiles differ, a number of questions measuring psychographic differences were investigated using the *T*-test. From this it appears that in general both groups of adopters are typical early adopters based on the data presented in Table 7, however there are some differences. When comparing each group the null hypothesis was rejected for 2 questions. These were "The level of empathy does not differ between high-end and low-end adopters" and "There is no difference in the length of the innovation decision period between high and low-end adopters". It is found that high-end adopters have a significantly higher level of empathy, and that they often take less time before making a decision to invest in a new technology. In Rogers' theory (Rogers, 2003) it is stated that this would typically apply to early adopters. Therefore it appears that within this sample, high-end adopters are more representative of early adopters based on these two results. These two differences suggest that high-end adopters are slightly more aligned with Rogers theory. In addition to these two differences there is one variable with a significance of <0.1 and a further two that are close to 0.1. These numbers are not low enough for the null hypotheses to be rejected but they do indicate a number of additional subtle differences.

Table 7
T-test results of the comparison between psychographic variables between high-end and low-end early adopters (Liker scale for questions is 1 = Agree Strongly, 2 = Agree Slightly, 3 = Neither Agree or Disagree, 4 = Slightly Disagree, 5 = Strongly Disagree).

Question	Adopter group	*N*	Mean	Std. deviation	Std. error mean	*T*-test for equality of means Sig. (2-tailed)
You regularly participate in social activity	High-end	155	2.13	1.067	0.086	0.518
	Low-end	185	2.05	1.062	0.078	
You regularly interact with people in your local community	High-end	155	2.19	1.057	0.085	0.524
	Low-end	182	2.27	1.117	0.083	
You are often involved in matters that require you to interact with people outside of your local network	High-end	154	2.35	1.169	0.094	0.352
	Low-end	183	2.47	1.171	0.087	
You have a small network of people you know	High-end	151	2.66	1.255	0.102	0.131
	Low-end	183	2.45	1.239	0.092	
People you know are often influential when you are considering buying or trying a new technology	High-end	153	2.95	1.21	0.098	0.18
	Low-end	182	3.13	1.2	0.089	
You are often good at understanding peoples feelings	High-end	154	2.1	0.955	0.077	0.024
	Low-end	184	2.35	1.071	0.079	
You are often contemplative when you are making a decision	High-end	153	1.68	0.908	0.073	0.959
	Low-end	184	1.68	0.892	0.066	
You are often reluctant to change your routine	High-end	155	3.05	1.224	0.098	0.112
	Low-end	185	2.84	1.09	0.08	
You want to be among the first people to try a new technology	High-end	155	2.32	1.024	0.082	0.237
	Low-end	185	2.18	1.026	0.075	
You invest in new technologies soon after they become available for purchase	High-end	154	2.53	1.184	0.095	0.973
	Low-end	184	2.52	1.106	0.082	
Friends will often use you as a point of reference for new technologies	High-end	155	2.23	1.165	0.094	0.136
	Low-end	185	2.04	1.067	0.078	
You often take your time before making a decision to invest in a new technology	High-end	155	2.01	0.929	0.075	0.001
	Low-end	184	1.7	0.82	0.06	
You are often sceptical about new technologies	High-end	153	3.04	1.088	0.088	0.851
	Low-end	184	3.02	1.138	0.084	
You tend to invest in new technology once you have been convinced about the benefits of using it	High-end	152	1.78	0.891	0.072	0.772
	Low-end	184	1.76	0.83	0.061	
You rarely invest in new technologies	High-end	154	4.12	1.037	0.084	0.312
	Low-end	185	4.23	0.924	0.068	
You prefer to stick to existing technologies that you are familiar with	High-end	151	3.72	1.027	0.084	0.305
	Low-end	182	3.84	0.972	0.072	
You would consider yourself willing to take a risk when it comes to investing in new technologies	High-end	152	2.05	0.833	0.068	0.604
	Low-end	183	2	0.777	0.057	
Uncertainty of the success of a technology in the long-term makes you feel uncomfortable about investing in it	High-end	152	3.2	1.01	0.082	0.093
	Low-end	184	3	1.136	0.084	
You keep up to date with what is happening in the media	High-end	155	1.45	0.749	0.06	0.566
	Low-end	185	1.5	0.708	0.052	
You often listen to the views of experts on matters that are important to you	High-end	153	1.73	0.896	0.072	0.16
	Low-end	185	1.87	0.9	0.066	

3.3. Battery electric vehicle attributes

In order to understand how early adopters view their vehicles respondents were asked, "Considering each of the following attributes how do you think your electric vehicle compares to an internal combustion engine vehicle?" The list of attributes given can be seen in Fig. 1 and Table 8. Respondents were given 5 answer options on a Likert scale. These were Far Superior, Slightly Superior, Similar, Slightly Worse and Far Worse. Fig. 1 shows a summary of how adopters view their vehicles in comparison with ICEVs. The scale of the spider diagram starts at "Far Worse" in the centre goes through "Similar" and to "Far Superior" on the outer most axis. Therefore the closer each data point is located to the outer edge of the decagon the more superior the attribute is viewed. The graph shows that high-end adopters view their vehicles as being superior in the 7 following areas; brand, vehicle image/looks, vehicle performance, fuel economy, environmental impacts, lifestyle fit and running costs. This adopter group viewed purchase price, time to refuel and vehicle range as similar to ICEVs. Low-end adopters viewed their vehicles as being superior in the 5 following areas; performance, environmental impacts, fuel economy, lifestyle fit, and running costs. They viewed the vehicles as having similar vehicle image/looks and brand and as having worse purchase price, vehicle range and time to refuel.

Table 8
Table showing differences in answers to the question "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to an internal combustion engine vehicle?" Answers were measured using a Likert scale (1 = Far Superior, 2 = Slightly Superior, 3 = Similar, 4 = Slightly Worse, 5 = Far Worse).

Attribute	Adopter group	*N*	Mean	Std. deviation	Std. error mean	*T*-test for equality of means Sig. (2-tailed)
Brand	High-end	155	1.3	0.616	0.049	0.000
	Low-end	185	2.66	0.833	0.061	
Vehicle image/looks	High-end	154	1.31	0.566	0.046	0.000
	Low-end	185	2.96	0.983	0.072	
Purchase price	High-end	153	3.35	1.115	0.09	0.028
	Low-end	183	3.61	0.994	0.073	
Vehicle range	High-end	155	3.26	1.05	0.084	0.000
	Low-end	185	4.43	0.818	0.06	
Time to refuel	High-end	152	2.91	1.439	0.117	0.000
	Low-end	183	3.77	1.315	0.097	
Vehicle performance (acceleration, top speed)	High-end	155	1.1	0.444	0.036	0.000
	Low-end	184	1.83	0.842	0.062	
Fuel economy	High-end	154	1.03	0.211	0.017	0.189
	Low-end	185	1.08	0.416	0.031	
Environmental impacts	High-end	155	1.08	0.37	0.03	0.633
	Low-end	185	1.1	0.392	0.029	
Life style fit	High-end	155	1.41	0.737	0.059	0.000
	Low-end	183	2.13	0.946	0.07	
Running costs	High-end	154	1.23	0.581	0.047	0.095
	Low-end	184	1.14	0.433	0.032	

In order to understand how each adopter group's opinions compare, the *T*-test was used. The results of the *T*-tests can be seen in Table 8. The null hypothesis for brand, "there is no difference between perceptions of brand between high-end and low-end early adopters" was rejected at a significance of <0.001. High-end adopters find their vehicles to have a superior brand compared to ICEVs whilst low-end adopters believed their vehicles to have a similar brand. The null hypothesis for vehicle image "there is no difference between perceptions of vehicle image between high and low-end early adopters" was rejected at a significance of <0.001. High-end adopters view their vehicles as having a superior image and low-end adopters find their vehicles to be similar to ICEVs. The null hypothesis for purchase price was also rejected, this time at a significance of 0.028. It is found that high-end adopters view the purchase price of their vehicles as similar to ICEVs, whilst owners of low-end BEVs view their vehicles as slightly worse in terms of purchase price. This result is particularly intriguing as previously mentioned low-end adopters paid a far smaller premium for a BEV compared to high-end adopters. It is possible that each adopter group is not comparing their BEV to the ICEV which they previously owned rather they are making comparisons between their BEV and a vehicle which they perceive as being in a similar vehicle class. The null hypothesis comparing the means for vehicle range was rejected at a significance of <0.001. High-end early adopters believed that their vehicles have a similar range as compared to ICEVs. Low-end adopters believed their vehicle's range was worse than that of a comparable ICEV. This result is unsurprising as the EPA estimated range of a Tesla BEV is 270 miles, whilst the range of a low-end BEV can be less than 100 miles.

The null hypothesis "there is no difference in how high and low-end adopters perceive their vehicles' time to refuel compared to that of an ICEV" was rejected. This was rejected at a high level of significance of <0.001. It is found that high-end adopters believe their vehicles have similar time to refuel as ICEVs, low-end adopters believe their vehicles to be worse time to refuel than ICEVs. It is surprising that high-end adopters perceive their vehicles to have similar time to refuel compared to ICEVs. The time to fully recharge a Tesla BEV is far longer than it takes to fill an ICEV with petrol or diesel. However the amount of time required for human interaction with the vehicle is similar, meaning that plugging in a BEV to a socket takes no longer than inserting a petrol or diesel pump into an ICEV. Additionally as will be shown below, some adopters viewed BEVs as being more convenient to refuel/recharge.

The null hypothesis comparing the means for performance was rejected at a significance of <0.001. Both groups of adopters believed their BEVs were superior to ICEVs in this respect, however high-end adopters viewed their vehicles as far superior, with low-end adopters viewing their vehicles as only slightly superior. The null hypothesis "there is no difference between high and low-end adopters' perception of their vehicles' life style fit compared to ICEVs" was rejected at a significance of <0.001. It was found that both groups of adopters do believe their vehicles to be a better life style fit compared to ICEVs, however, high-end adopters found their vehicles to be a better fit than did the low-end adopters. The null hypotheses comparing fuel economy, running costs and environmental impact could not be rejected. There is no difference in how high and low-end adopters view these attributes. Both groups believe that their vehicles are superior to ICEVs in these three areas. Indeed BEVs do have superior fuel economy, running costs and environmental impact compared to ICEVs. Out of 10 vehicle attributes tested, 7 null hypotheses can be rejected. This along with Fig. 1 clearly show that each adopter group responds to their vehicle is significantly different. High-end adopters are found to have more positive opinions of their vehicles compared to low-end adopters, they believe their vehicles are superior compared ICEVs.

Further to the attributes that were tested using Likert scale questions respondents were also able to provide qualitative feedback with the question "Please use the space below to list any advantages you think you (or your household) has experienced by using an electric vehicle?" This question revealed an additional benefit of BEV ownership. Without any prior cues 88 respondents (25.8%) said that BEV ownership had added convenience over ICEVs. Respondents reported that this saved them time and was more convenient for them. Respondent No. 8 answered, *"Not having to waste time to go to gas stations*", and No. 44 responded *"Save Time by never going to the gas station*". Both high and low-end adopters mentioned this as a benefit to BEV ownership. However a larger proportion of high-end adopters mentioned this as a benefit, with 37.9% of them mentioning this, compared to only 18.8% of low-end adopters. Fig. 1 and Table 8 show that high-end adopters view time to refuel more preferentially than low-end adopters. This difference may be due to high-end BEVs having a longer range and a shorter recharge time, which means that when charging more range is added in less time compared to the low-end vehicles. Additionally due to the longer range owners of high-end vehicles will be less likely to charge away from home and they will have to charge less often.

3.4. Differences in future purchase intentions

The way in which early adopters perceive the attributes of their vehicles will have an implication on the likelihood of repeat purchases. Two questions measured respondent's future vehicle choices. The first asked "Will the next car be another battery electric vehicle?" With the following Likert scale for answers "Definitely Not", "Probably Not", "Unsure", "Probably Yes" and "Definitely Yes". The second asked "Will your next car be another Tesla?" or "Will your next car be another vehicle of the same manufacturer as your current vehicle?" The possible answers for this were "Yes", "No" or "Don't Know". Results from the first question (which used the Likert scale) were compared using the *T*-test to compare the means; the null hypothesis of there being no difference between the two groups was rejected at a significance of <0.001 for both questions. It was found that high-end adopters have a higher intent to continue with BEV ownership, and it is likely that they will continue to own a Tesla with their next BEV. 67% of low-end adopters would probably or definitely continue with BEV ownership, compared to 81% of high-end adopters. Of the high-end adopters 59% said they would continue with Tesla ownership. Of the low-end adopters only 23% said they would continue with the same make of BEV. These findings are shown in Figs. 2 and 3. This demonstrates that low-end adopters are less likely to continue with BEV ownership than high-end adopters. This is concerning for the diffusion of BEVs through the market. This lack of willingness to continue with BEV ownership is not "technological rejection" as Rogers defines this as *"The decision to not adopt an innovation*". Within diffusion literature the decision to not continue with the adoption of an innovation is known as discontinuance. Discontinuance has previously been explored in the field of assistive technology for disabled persons (Philips and Zhao, 1993; Scherer, 1996). It has not received attention within automotive literature, and needs to be further understood.

3.5. Understanding differences in future purchase intentions

In order to build a greater understanding of why some adopters may not continue with BEV ownership multiple regression was used to understand how the results from the question "Will the next car be another battery electric vehicle?" compare with how owners perceive the attributes of their vehicles (Table 8). This enables identification of which attributes of BEVs are a good indicator of likelihood of continuing with BEV ownership. The methodology for this is explained in Section 2.2.

The first multiple regression model for low-end adopters had an ANOVA significance value of <0.001 suggesting that the independent variables were a good predictor of the dependant variable. When comparing the significance values for each independent variable the null hypothesis was rejected for 6 attributes. These were vehicle image/looks, purchase price, time to refuel, environmental impacts, life style fit and running costs. Therefore these 6 attributes were tested again. The attributes that had a significance value of more than 0.1 were omitted from this regression analysis. The results of this can be seen in Table 9. The ANOVA significance value for this was <0.001 suggesting a high level of significance for the model. This shows that time to refuel, environmental impacts and running costs are the best predictors of future intent to own a BEV for low-end adopters. In order to confirm that these 3 attributes were the most significant contributors to willingness to continue with BEV ownership one final regression was done. This time only time to refuel, environmental impacts and running costs were included. The ANOVA value was <0.001 and the values for each of the three attributes were all less than 0.05 suggesting that they are indeed excellent predictors of willingness to continue with BEV ownership. The beta value for time to refuel is 0.198, environmental impacts is 0.201 and running costs is 0.173. This means that for every 1 unit increase on the Likert scale measuring opinions of environmental impacts there will be a 0.201 unit increase in willingness to continue with BEV ownership. This rate of increase is slightly higher than the other two significant variables, suggesting that environmental impacts are the most significant contributor to likelihood to continue with BEV ownership into the future for low-end adopters. The results from this can be seen in Table 10.

The same procedure was carried out for high-end adopters. Linear regression was applied to all 10 attributes as the independent variables against the dependant variable "Will the next car be another battery electric vehicle?" The ANOVA significance value for this was 0.025 suggesting the model does have explanatory power. The first regression analysis

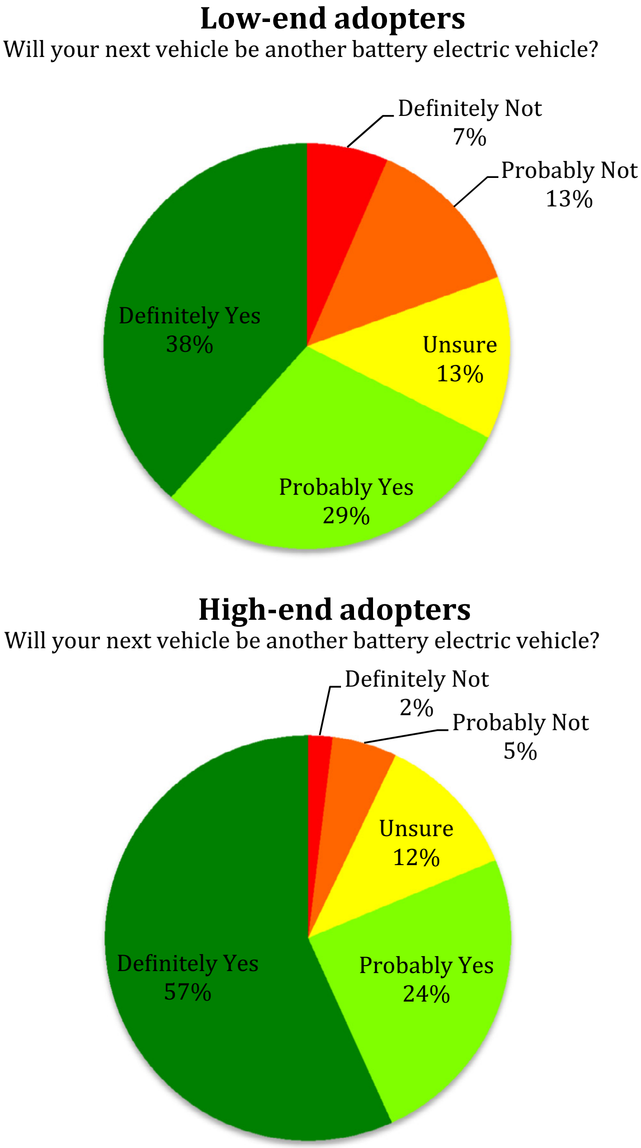

Fig. 2. Comparison of future purchase intentions of BEVs between low-end and high-end adopters.

allowed the null hypothesis for time to refuel, fuel economy, environmental impacts and running costs to be rejected. These 4 attributes were further tested in the absence of the 6 attributes whose significance value was more than 0.1. The ANOVA value for this linear regression was <0.001 suggesting that the model is significant. For these results the null hypothesis was rejected for time to refuel, fuel economy and running costs (Table 11). A second multiple regression was run with only these three attributes. This can be seen in Table 12, this model again had an ANOVA value of <0.001 suggesting the model is significant. In this multiple regression analysis time to refuel and running costs are the most significant contributors to likelihood to continue with BEV ownership into the future. In order to conclusively state that these two attributes are statistically significant a final regression model was run (Table 13), this again had an ANOVA of <0.001 and both independent variables were <0.1. Of these two attributes time to refuel had a Beta value of 0.153 and running costs 0.271. This suggests that for high-end adopters running costs are the most significant contributor to likelihood to continue with BEV ownership in future vehicle choices. Therefore due to the low running costs of a Tesla BEVs compared to the running costs of an ICEV in the same vehicle class, willingness to continue with ownership is high.

Multiple regression analysis suggests that for low-end adopters time to refuel, environmental impacts, and running costs are the best predictors of future intention to adopt. This suggests that these consumers are both motivated by functional considerations but also a social or emotional desire due to their environmental concern. Of these three attributes the beta value is highest for environmental impacts, suggesting that this is the best predictor of future likelihood to continue with BEV adoption. For high-end adopters time to refuel and running costs are the two best predictors of future intention to adopt,

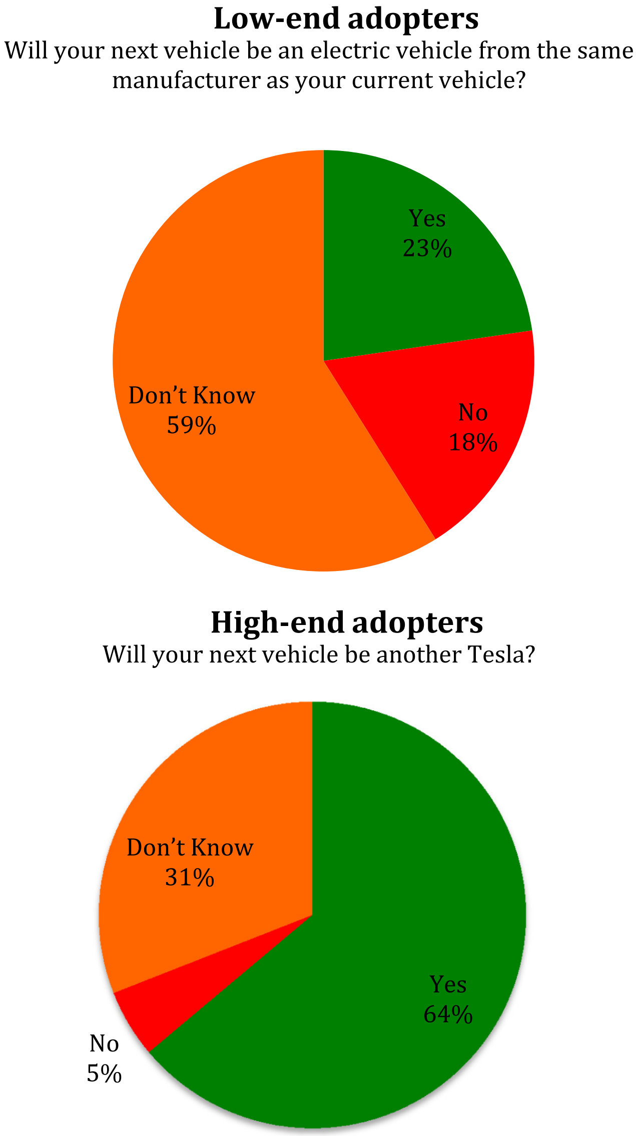

Fig. 3. Comparison between low-end and high-end adopters regarding their future intention to purchase a BEV of the same make as their current electric vehicle.

Table 9

Linear regression results for low-end adopters comparing future adoption behaviour as the dependant variable with answers to "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to a internal combustion engine vehicle?" as the independent variable. Note that Beta values are negative due to the reverse coding of the Likert scale for the independent variable.

Independent variables	Unstandardised coefficients		Standardised coefficients		Sig.
	B	Std. error	Beta	*t*	
Vehicle image/looks	0.113	0.092	0.09	1.23	0.22
Brand	−0.14	0.098	−0.111	−1.432	0.154
Time to refuel	−0.151	0.071	−0.157	−2.131	0.035
Environmental impacts	−0.714	0.265	−0.206	−2.699	0.008
Life style fit	−0.149	0.1	−0.112	−1.485	0.139
Running costs	−0.378	0.227	−0.128	−1.669	0.097

Dependent variable: Will your next vehicle be another battery electric vehicle? Likert Scale 1 = Definitely Not, 2 = Probably Not, 3 = Unsure, 4 = Probably Yes, 5 = Definitely Yes.

Table 10
Final linear regression results for low-end adopters comparing future adoption behaviour as the dependant variable with answers to "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to a internal combustion engine vehicle?" as the independent variable. Note that Beta values are negative due to the reverse coding of the Likert scale for the independent variable.

Independent variables	Unstandardised coefficients		Standardised coefficients		Sig.
	B	Std. error	Beta	*t*	
Time to refuel	−0.189	0.067	−0.198	−2.814	0.005
Environmental impacts	−0.651	0.243	−0.201	−2.677	0.008
Running costs	−0.508	0.219	−0.173	−2.319	0.022

Dependent variable: Will your next vehicle be another battery electric vehicle? Likert Scale 1 = Definitely Not, 2 = Probably Not, 3 = Unsure, 4 = Probably Yes, 5 = Definitely Yes.

Table 11
Linear regression results for high-end adopters comparing future adoption behaviour as the dependant variable with answers to "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to a internal combustion engine vehicle?" as the independent variable. Note that Beta values are negative due to the reverse coding of the Likert scale for the independent variable.

Independent variables	Unstandardised coefficients		Standardised coefficients		Sig.
	B	Std. error	Beta	*t*	
Time to refuel	−0.112	0.053	−0.164	−2.098	0.038
Fuel economy	−0.73	0.416	−0.159	−1.755	0.081
Environmental impacts	0.327	0.231	0.125	1.42	0.158
Running costs	−0.417	0.139	−0.248	−3	0.003

Dependent variable: Will your next vehicle be another battery electric vehicle? Likert Scale 1 = Definitely Not, 2 = Probably Not, 3 = Unsure, 4 = Probably Yes, 5 = Definitely Yes.

Table 12
Third linear regression results for high-end adopters comparing future adoption behaviour as the dependant variable with answers to "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to a internal combustion engine vehicle?" as the independent variable. Note that Beta values are negative due to the reverse coding of the Likert scale for the independent variable.

Independent variables	Unstandardised coefficients		Standardised coefficients		Sig.
	B	Std. error	Beta	*t*	
Time to refuel	−0.108	0.053	−0.158	−2.016	0.046
Fuel economy	−0.475	0.376	−0.103	−1.262	0.209
Running costs	−0.401	0.139	−0.238	−2.885	0.005

Dependent variable: Will your next vehicle be another battery electric vehicle? Likert Scale 1 = Definitely Not, 2 = Probably Not, 3 = Unsure, 4 = Probably Yes, 5 = Definitely Yes.

Table 13
Final linear regression results for high-end adopters comparing future adoption behaviour as the dependant variable with answers to "Considering each of the following vehicle attributes how do you believe your electric vehicle compares to a internal combustion engine vehicle?" as the independent variable. Note that Beta values are negative due to the reverse coding of the Likert scale for the independent variable.

Independent variables	Unstandardised coefficients		Standardised coefficients		Sig.
	B	Std. error	Beta	*t*	
Time to refuel	−0.104	0.053	−0.153	−1.952	0.053
Running costs	−0.446	0.132	−0.271	−3.455	0.001

Dependent variable: Will your next vehicle be another battery electric vehicle? Likert Scale 1 = Definitely Not, 2 = Probably Not, 3 = Unsure, 4 = Probably Yes, 5 = Definitely Not.

suggesting that high-end adopters are more motivated by functional considerations than a social or emotional desire to adopt. Further to this for high-end adopters running costs has the strongest correlation to likelihood to continue with BEV ownership with a beta value of −0.238. Low-end adopters view running costs and environmental impacts as superior and these attributes do contribute to increased propensity to adopt. The third attribute to be found as a good predictor of willingness to continue with BEV ownership, for low-end adopters, was time to refuel. However long recharge times mean that time to refuel is viewed as inferior compared to ICEVs and therefore this is a potential barrier to low-end adopters willingness to continue with BEV ownership in the future. Therefore long recharge times are the most significant contributor to technological abandonment by low-end adopters. The model suggests if this attribute can be improved, or perceptions of this can be improved, willingness to continue with BEV ownership will increase. Therefore in future generations of low-end BEVs, recharge times should be significantly improved over current generations of the vehicles.

4. Conclusion

Based on data from 340 early adopters of BEVs it has been possible to corroborate a number of assumptions previously made within the literature. In this sample it was found that early adopters have a high-income, with 76.5% earning more than $90,000 per year, this is in agreement with (Hidrue et al., 2011). Early adopters are also highly educated with 85.1% having achieved a university level qualification, agreeing with (Campbell, 2014b; Campbell et al., 2012). They are also mostly male (92.6%) something which was suggested by Plötz et al. (2014). In this sample, of mainly US citizens, car ownership was higher than the US national average of 1.9 per household, with each household having 2.5 cars on average, this is in agreement with (Kurani et al., 1996; Plötz et al., 2014). Finally it was found that 25.3% had owned a hybrid vehicle prior to BEV ownership, whilst this is higher than average it suggests that hybrid ownership is not a prerequisite for BEV ownership, therefore the assumption by Carley et al. (2013) only partially holds true. In this sample there was no clear trend in terms of the age of respondents, however they are mostly between 35 and 65 (76.5%) years old suggesting that BEVs may be most popular with people who are around middle aged.

Previous literature overlooked the possibility of there being different groups of adopters. However, results from this investigation reveal two distinct groups, which are referred to here as low-end adopters and high-end adopters. The groups have significantly different socio-economic profiles, with high-end adopters being of higher income, higher education and of higher age. Both groups still align with the assumptions made in the literature (Campbell, 2014b; Hidrue et al., 2011; Kurani et al., 1996; Plötz et al., 2014), however high-end adopters have a far higher socio-economic status compared to low-end adopters. Two statistically significant psychographic differences were identified, with high-end adopters having greater empathy and taking less time to adopt a new technology. These two differences add to the evidence suggesting that both groups of adopters are not homogenous.

It was found that compared to ICEVs, BEVs have beneficial performance, running costs, life style fit, environmental impacts and fuel economy. This is in agreement with (Lane et al., 2014; Turrentine et al., 2011) who found performance to be a benefit, but goes against some suggestions that the performance of a BEV is viewed negatively compared to ICEVs (Schuitema et al., 2013). It agrees with (Lane et al., 2014), who found running costs to be a benefit and (Carley et al., 2013; Lane et al., 2014) who suggest environmental impacts and fuel economy would be benefits of BEV ownership. High-end adopters also found image and brand to be a benefit. Image has previously been suggested as a benefit by Carley et al. (2013). Despite both adopter groups agreeing that running costs, lifestyle fit, environmental impacts, fuel economy and performance are superior there are still statistically significant differences in the way in each group view these attributes. It was found that high-end adopters view their vehicles more preferentially than low-end adopters in these areas. High-end adopters did not believe their vehicles were worse than ICEVs in any area measured, but low-end adopters believed their vehicles had worse range, time to refuel and purchase price compared to an ICEV.

This paper adds further to the literature by measuring future purchase intentions of BEV owners. It was found that each adopter group has different future purchase intentions. High-end adopters appear likely to continue with BEV ownership with 81% continuing with BEV ownership in future purchases. Brand loyalty was also high with 64% stating their next vehicle will be the same make as their current vehicle. Low-end adopters are less likely to continue with BEV ownership with 67% likely to continue with owning a BEV, furthermore only 23% will continue owning a BEV of the same make as their current model. Therefore 33% of low-end adopters may abandon the technology with their next vehicle purchase, and 77% will choose a vehicle of a different brand, this could be harmful for the diffusion of BEVs and the creation of a more electrified transportation system.

It was found that low-end adopters future purchase intentions are significantly correlated to opinions of their vehicles and that time to refuel, environmental impacts and running costs are the most significant influences. Low-end adopters' opinions of environmental impacts and running costs were positive, as were their opinions of running costs. Their opinions of time to refuel however were negative, as they believed that this attribute was slightly or far worse than an ICEV. High-end adopters' future purchase intentions were related to running costs and time to refuel. Running costs were viewed as superior, time to refuel was viewed as similar, meaning it does not contribute to discontinuance.

4.1. Policy and managerial implications

The results from this paper can be used to make a number of policy and managerial implications. These are based on the results that suggest that the groups low and high-end adopters are not homogenous. Low-end adopters may abandon BEVs with their next vehicle purchase and the differing perceptions of the vehicles explain reasons for this abandonment. Even though the results presented here are representative of early adopters in the United States the data may be applicable to other markets globally. It has been previously suggested that early adopters of BEVs will be similar regardless of geographic location due to them having similar socio-economic characteristics, and also because diffusion processes are the same in different markets (Schneidereit et al., 2015). Therefore in markets where BEVs have little market share policy makers and OEMs can seek to target persons with similar socio-economic characteristics as the early adopters of this paper.

This paper has shown that there are two distinct BEV adopter groups. Therefore when introducing and promoting BEVs to markets, policy makers and OEMs should not view early adopters as one homogenous group. The results show that each group has a different socio-economic and psychographic profile, they respond to their vehicles differently and they have different future purchase intentions. When OEMs and policy makers are promoting either high or low-end BEVs they should target the correct markets for each vehicle. The vehicle should address the right demographics, and should have the right attributes. For example low-end adopters appear to be more motivated by environmental reasons compared to high-end adopters, therefore this attribute should be promoted in low-end vehicles, not so much for high-end vehicles.

A second implication of this paper is that it reports that close to a third of all low-end adopters may abandon BEVs in future purchases. Low-end BEVs have more shortcomings and therefore adopters may require more support to be convinced to accept the vehicles. Low-end adopters also have a lower socio-economic profile with lower incomes meaning high costs may be more of a barrier. The results from this paper suggest the primary reason for discontinuance is due to the long recharge times of low-end BEVs. Discontinuance will be damaging to the BEV market and therefore a joint effort by policy makers and OEMs will be needed to encourage low-end adopters to continue with their adoption decision. In order to prevent this from occurring OEMs should concentrate efforts on reducing recharge times of their BEVs. Clearly time to refuel is also linked to range, and if vehicles have longer ranges fewer charging events are required, therefore increasing range may also change opinions of time to refuel. Of all the attributes low-end adopters viewed range the most negatively, and therefore this attribute should also be improved. Policy makers will need to continually support the low-end of the BEV market, perhaps more than the high-end, in order to prevent early adopters from abandoning BEVs.

Finally, automotive OEMs producing low-end BEVs may wish to look at the results presented in this paper for high-end adopters. These results may help to inform OEMs how to improve the perceptions of their vehicles, and which vehicle attributes they should improve. If OEMs producing low-end BEVs can produce a BEV that is perceived by consumers as being similar to a high-end BEVs, especially for refuelling time and range, then rates of adoption may increase and abandonment may not occur. As previously mentioned, the priority will be increasing range and reducing refuelling time, but it will also be beneficial to improve performance, brand perceptions and the vehicles image/looks.

4.2. Limitations and future research

The sample size in this paper is large enough to draw statistically significant conclusions with a margin of error of 5%, but with more electric vehicles being adopted it should be possible to gather even larger sample sizes. Samples larger than 1000 adopters should have a margin of error of 3% meaning results have greater accuracy (Shiu et al., 2009). Therefore future studies should attempt at gathering larger samples in order to ensure increased accuracy of the data.

As with any social study that requires the voluntary participation of questionnaire respondents there is the risk of a response bias. Therefore the sample is not random and is not a statistical representation of the entire population. The sample is however likely to be indicative of early adopters opinions of BEVs, this being the benefit of the sample. Self-selection bias can also occur whereby certain people are more likely to respond to the questionnaire survey, this can further be impacted by the fact that certain people are more likely to be using electric vehicle forums, where the results were gathered. The views expressed by these respondents may be more positive than those of the general populations and perhaps some BEV adopters. A further limitation is that this method will omit any BEV adopters who do use these forums from taking part in the study. In order to address this future studies should contact respondents via other means, for example postal recruitment employed by Tal et al. (2014) could be used.

Much of the data in this paper described early adopters and their opinions of their vehicles post purchase. This paper did not explore reasons for the initial adoption of a BEV by the early adopters. Therefore a future study is being conducted by the authors that will examine and scrutinize the initial reasons for adoption of BEVs by the adopters of them. Potential technological abandonment of BEVs has been observed in this paper, more research is needed in this area in order to understand under which circumstances adopters of BEVs are likely to abandon the technology in the future, this clearly could have a detrimental effect on the market for BEVs. Only 23% will continue with the same brand of vehicle, an understanding of what brand of BEV they are likely purchase next would be valuable, along with reasons for why brand loyalty is so low. The combination of range and time to refuel in a high-end BEVs leads to them being perceived as comparable to an ICEV, despite the fact that in reality they have a shorter range and longer recharge times. The range of a Tesla Model S is 270 miles and it can be recharged fully in as low as 75 min at a Tesla Supercharger Station. The range and time to refuel of a low-end BEV is viewed as worse compared to an ICEV. More research is needed to understand what combination of range and time to refuel leads to them being viewed as similar to an ICEV. Low-end BEVs with 200 miles ranges are expected by 2017 (Chevrolet, 2015); will this range be sufficient to achieve higher levels of adoption and also convince consumers to continually own BEVs in subsequent purchases?

Acknowledgements

Thanks to Amy Campbell from Loughborough University and the Doctoral Training Centre for Hydrogen, Fuel Cells and Their Applications for help in developing the questionnaire that was used in this study. Thanks to EPRSC and UKERC for providing the funding to carry out this research within the University of Birmingham led Doctoral Training Centre for Hydrogen, Fuel Cells and their applications.

References

Browne, D., O'Mahony, M., Caulfield, B., 2012. How should barriers to alternative fuels and vehicles be classified and potential policies to promote innovative technologies be evaluated? J. Clean. Prod. 35, 140–151.

Bühler, F., Cocron, P., Neumann, I., Franke, T., Krems, J.F., 2014. Is EV experience related to EV acceptance? Results from a German field study. Transp. Res. Part F Traffic Psychol. Behav. 25, 34–49.

Campbell, A., 2014a. An Examination of the Factors in Uencing the Decision to Adopt Alternative Fuel Vehicles. Loughborough University.

Campbell, A., 2014b. Identifying the reasons for consumers' non-adoption of zero-emissions vehicles. In: UTSG Newcastle, pp. 1–12.

Campbell, A.R., Ryley, T., Thring, R., 2012. Identifying the early adopters of alternative fuel vehicles: a case study of Birmingham, United Kingdom. Transp. Res. Part A Policy Pract. 46, 1318–1327.

Caperello, N., Tyreehageman, J., Davies, J., 2014. I am not an environmental wacko! Getting from early plug-in vehicle owners to potential later buyers. In: Proceedings of the Transportation Research Board, 15-5047.

Carley, S., Krause, R.M., Lane, B.W., Graham, J.D., 2013. Intent to purchase a plug-in electric vehicle: a survey of early impressions in large US cites. Transp. Res. Part D Transp. Environ. 18, 39–45.

Chevrolet, 2015. The Future of EV [WWW Document]. <http://www.chevrolet.com/culture/article/bolt-ev-concept-car.html> (accessed 7.24.15).

Chorus, C.G., Koetse, M.J., Hoen, A., 2013. Consumer preferences for alternative fuel vehicles: comparing a utility maximization and a regret minimization model. Energy Policy 61, 901–908.

Crawford, C., Benedetto, C.Di., 2008. New Products Management. McGraw-Hill Education.

Crawford, M., Benedetto, A., 2011. New Products Management, tenth ed. McGraw-Hill Irwin.

Dumortier, J., Siddiki, S., Carley, S., Cisney, J., Krause, R.M., Lane, B.W., Rupp, J.a., Graham, J.D., 2015. Effects of providing total cost of ownership information on consumers' intent to purchase a hybrid or plug-in electric vehicle. Transp. Res. Part A Policy Pract. 72, 71–86.

Egbue, O., Long, S., 2012. Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions. Energy Policy 48, 717–729.

Franke, T., Neumann, I., Bühler, F., Cocron, P., Krems, J.F., 2012. Experiencing range in an electric vehicle: understanding psychological barriers. Appl. Psychol. 61, 368–391.

Gnann, T., Plötz, P., Funke, S., Wietschel, M., 2015. What is the market potential of plug-in electric vehicles as commercial passenger cars? A case study from Germany. Transp. Res. Part D Transp. Environ. 37, 171–187.

Golob, T.F., Torous, J., Bradley, M., Brownstone, D., Crane, S.S., Bunch, D.S., 1997. Commercial fleet demand for alternative-fuel vehicles in California. Transp. Res. Part A Policy Pract. 31, 219–233.

Graham-Rowe, E., Gardner, B., Abraham, C., Skippon, S., Dittmar, H., Hutchins, R., Stannard, J., 2012. Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: a qualitative analysis of responses and evaluations. Transp. Res. Part A Policy Pract. 46, 140–153.

Hardman, S., Shiu, E., Steinberger-Wilckens, R., 2014. Changing the fate of fuel cell vehicles: can lessons be learned from Tesla Motors? Int. J. Hydrogen Energy 40.

Hardman, S., Steinberger-Wilckens, R., van der Horst, D., 2013. Disruptive innovations: the case for hydrogen fuel cells and battery electric vehicles. Int. J. Hydrogen Energy 38, 15438–15451.

Helveston, J.P., Liu, Y., Feit, E.M., Fuchs, E.R.H., Klampfl, E., Michalek, J.J., 2014. Will subsidies drive electric vehicle adoption? Measuring consumer preferences in the U.S. and China. Transp. Res. Part A Policy Pract. 73, 96–112.

Hidrue, M., Parsons, G., Kempton, W., Gardner, M., 2011. Willingness to pay for electric vehicles and their attributes. Resour. Energy Econ. 33, 686–705.

IEA, 2015. Global EV Outlook 2015 key takeaways 75739.

Koetse, M.J., Hoen, A., 2014. Preferences for alternative fuel vehicles of company car drivers. Resour. Energy Econ. 37, 279–301.

Krupa, J.S., Rizzo, D.M., Eppstein, M.J., Brad Lanute, D., Gaalema, D.E., Lakkaraju, K., Warrender, C.E., 2014. Analysis of a consumer survey on plug-in hybrid electric vehicles. Transp. Res. Part A Policy Pract. 64, 14–31.

Kurani, K.S., Turrentine, T., Sperling, D., 1994. Demand for electric vehicles in hybrid households: an exploratory analysis. Transp. Policy 1, 244–256.

Kurani, S., Turrentine, T., Sperling, D., 1996. Testing electric vehicle demand in 'hybrid households' using a reflexive survey. Transp. Res. Part C Emerg. Technol. I, 131–150.

Lane, B., Sherman, C., Sperl, J., Krause, R., Carley, S., Graham, J., 2014. Beyond Early Adopters of Plug-in Electric Vehicles? Evidence from Fleet and Household Users in Indianapolis. The University of Kansas.

Nissan, 2014. Nissan Leaf [WWW Document]. <http://www.nissan.co.uk/GB/en/vehicle/electric-vehicles/leaf.html> (accessed 12.1.14).

Nissan, 2015. Nissan Leaf [WWW Document].

Nordelöf, A., Messagie, M., Tillman, A.M., Ljunggren Söderman, M., Van Mierlo, J., 2014. Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles-what can we learn from life cycle assessment? Int. J. Life Cycle Assess., 1866–1890

Offer, G.J., Contestabile, M., Howey, D.a., Clague, R., Brandon, N.P., 2011. Techno-economic and behavioural analysis of battery electric, hydrogen fuel cell and hybrid vehicles in a future sustainable road transport system in the UK. Energy Policy 39, 1939–1950.

Peters, A., Dütschke, E., 2014. How do consumers perceive electric vehicles? A comparison of german consumer groups. J. Environ. Policy Plan. 16, 359–377.

Philips, B., Zhao, H., 1993. Predictors of assistive technology abandonment. Assist. Technol. 5.

Plötz, P., Gnann, T., 2011. Who should buy electric vehicles? The potential early adopter from an economical perspective. ECEEE, 1073–1080.

Plötz, P., Schneider, U., Globisch, J., Dütschke, E., 2014. Who will buy electric vehicles? Identifying early adopters in Germany. Transp. Res. Part A Policy Pract. 67, 96–109.

Poullikkas, A., 2015. Sustainable options for electric vehicle technologies. Renew. Sustain. Energy Rev. 41, 1277–1287.

Rezvani, Z., Jansson, J., Bodin, J., 2015. Advances in consumer electric vehicle adoption research: a review and research agenda. Transp. Res. Part D Transp. Environ. 34, 122–136.

Rogers, E.M., 2003. Diffusion of Innovations, fifth ed. Free Press, New York.

Scherer, 1996. Putcome of assistive technology use on quality of life. Disabil. Rehabil. 18.

Schneidereit, T., Franke, T., Günther, M., Krems, J.F., 2015. Does range matter? Exploring perceptions of electric vehicles with and without a range extender among potential early adopters in Germany. Energy Res. Soc. Sci. 8, 198–206.

Schuitema, G., Anable, J., Skippon, S., Kinnear, N., 2013. The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. Transp. Res. Part A Policy Pract. 48, 39–49.

Shiu, E., Hair, J., Bush, R., Ortinau, D., 2009. Marketing research. In: Research Methods. McGraw Hill.

Sierzchula, W., Bakker, S., Maat, K., van Wee, B., 2014. The influence of financial incentives and other socio-economic factors on electric vehicle adoption. Energy Policy 68, 183–194.

Tal, G., 2014. Evaluating the Impact of High Occupancy Vehicle (HOV) Lane Access on Plug-In Vehicles (PEVs) Purchasing and Usage in California Evaluating the Impact of High Occupancy Vehicle (HOV) Lane Access on Plug-in Vehicle (PEV) Purchase and Usage in Califo.

Tal, G., Nicholas, M., 2013. Studying the PEV Market in California: Comparing the PEV, PHEV and Hybrid Markets. Pevcollaborative.Org, pp. 1–10.

Tal, G., Nicholas, M.A., Davies, J., Woodjack, J., 2014. Charging behavior impacts of electric vehicle miles traveled – who is not plugging in? J. Transp. Res. Board.

Tesla Motors Inc, 2014. Tesla Model S [WWW Document]. <http://www.teslamotors.com/models> (accessed 12.1.14).

Tesla Motors Inc, 2015. Model S [WWW Document]. <http://my.teslamotors.com/models/design> (accessed 7.13.15).

Thomas, C.E., 2009. Fuel cell and battery electric vehicles compared. Int. J. Hydrogen Energy 34, 6005–6020.

Turrentine, T., Dahlia, G., Lentz, A., Woodjack, J., 2011. The UC Davis MINI E Consumer Study. Inst. Transp. Stud. Univ. California, Davis, Res. Rep..

US Department of Transportation, 2009. 2009 National Household Travel Survey [WWW Document]. <http://nhts.ornl.gov/2009/pub/stt.pdf>.

Wolf, A., Seebauer, S., 2014. Technology adoption of electric bicycles: a survey among early adopters. Transp. Res. Part A Policy Pract. 69, 196–211.