Programme Area: Energy Storage and Distribution

Project: Consumers, Vehicles and Energy Integration (CVEI)

Title: Consumer Uptake Trial Report: Mainstream consumers' attitudes and willingness to adopt BEVs and PHEVs

Abstract:

This report represents Deliverable D5.2, Consumer Uptake Trial Report: Mainstream consumers' attitudes and willingness to adopt BEVs and PHEVs. The purpose of this report is to report on:

- the method employed for the Consumer Uptake Trial;
- the data obtained and the analysis performed;
- the results of full statistical analysis of the key data obtained from the Trial;
- answers to the research questions defined in the Consumer Uptake Trial design; and
- evidence-based conclusions from the Trial with regard to how the data have advanced understanding of Mainstream Consumer attitudes to uptake of BEVs and PHEVs, and therefore what the new state-of-the-art understanding of this area is.

Context:

The objective of the Consumers, Vehicles and Energy Integration project is to inform UK Government and European policy and to help shape energy and automotive industry products, propositions and investment strategies. Additionally, it aims to develop an integrated set of analytical tools that models future market scenarios in order to test the impact of future policy, industry and societal choices. The project is made up of two stages:

Stage 1 aims to characterize market and policy frameworks, business propositions, and the integrated vehicle and energy infrastructure system and technologies best suited to enabling a cost-effective UK energy system for low-carbon vehicles, using the amalgamated analytical toolset.

Stage 2 aims to fill knowledge gaps and validate assumptions from Stage 1 through scientifically robust research, including real world trials with private vehicle consumers and case studies with business fleets. A mainstream consumer uptake trial will be carried out to measure attitudes to PiVs after direct experience of them, and consumer charging trials will measure mainstream consumer PiV charging behaviours and responses to managed charging options.

THE FUTURE OF TRANSPORT

PROJECT REPORT

Consumers, Vehicles and Energy Integration Project
PPR899

Deliverable D5.2 - Consumer Uptake Trial Report: Mainstream consumers' attitudes and willingness to adopt BEVs and PHEVs

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Hannah Al-Katib	Project Manager	Stephen Skippon	Technical Reviewer

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Authors

The following individuals have contributed to the development of this report:

George Beard (TRL), Lauren Durrell (TRL), Jonathan Kent (TRL), Stephen Skippon (TRL), Neale Kinnear (TRL), Hannah Al-Katib (TRL), Tristan Dodson (Element Energy), Alex Stewart (Element Energy), and Jillian Anable (University of Leeds).

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Table of Contents

List of Figures

List of Tables

Abbreviations

AER	All-Electric Range
ANOVA	Analysis of Variance
ASC	Alternative Specific Constant
AQEG	Air Quality Expert Group
BEV	Battery Electric Vehicle
CVEI	Consumers, Vehicles and Energy Integration project
DC	Direct Current
DEFRA	Department of Environment, Food, and Rural Affairs
DfT	Department for Transport
DVSA	Driver and Vehicle Standards Agency
EV	Electric Vehicle (including all plug-in vehicles, and non-plug-in hybrids with electric motors)
ETI	Energy Technologies Institute
GB	Great Britain
GPS	Global Positioning System
HOV	High Occupancy Vehicle
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
MC	Managed Charging
MCA	Multi-Criteria Assessment
MPG	Miles Per Gallon
NTS	National Travel Survey
OEM	Original Equipment Manufacturer
ONS	Office for National Statistics
OTR	On The Road
PHEV	Plug-in Hybrid Electric Vehicle
PiV	Plug-in Vehicle
RE-EV	Range-extended Electric Vehicle
SMMT	Society of Motor Manufacturers and Traders
SOC	State of Charge
TCO	Total Cost of Ownership
TRL	Transport Research Laboratory

UK	United Kingdom
ULEV	Ultra-Low Emission Vehicle
VAT	Value Added Tax
VW	Volkswagen
WTP	Willingness-to-Pay
ZEV	Zero Emission Vehicle
ZEEV	Zero Exhaust Emission Vehicle

Glossary

Item	Description
Affective attitudes	Attitudes relating to the emotions and feelings evoked by owning and using a vehicle.
Analytical tools	The quantitative part of the Analytical Framework, used to calculate values for the quantitative Success Metrics.
Analytical framework	Overarching Multi-Criteria Assessment (MCA) framework applied to each narrative to help understand 'what good looks like' for mass-market deployment and use of Ultra-Low Emission Vehicles (ULEVs) and the potential trade-offs, via the assessment of the Success Metrics. This framework comprises the analytical tools which are used to help inform the quantitative assessment as well as a set of supporting qualitative assessment metrics.
Battery Electric Vehicle	A vehicle powered solely by a battery, such battery being charged only by a source of electricity external to and not part of the vehicle itself.
Consumer	A private, domestic, individual driver who owns or leases his/her own vehicle.
Early adopter	Those who adopt after Innovators, and only after awareness, knowledge, and positive attitudes have diffused to them from Innovators. Times to adoption are between one and two standard deviations before the mean time to adopt.
Injunctive norms	Perceptions of what other group members (e.g. family group, friendship group) approve or disapprove of.
Innovators	People high in innovativeness who are first to adopt new technology. They are sources of awareness, knowledge, and positive attitudes towards the innovation whose times to adoption are greater than two standard deviations before the mean time to adopt.
Instrumental attitudes	Attitudes relating to general, practical or functional attributes of a vehicle.
Mainstream Consumer/adopter	All those whose adoption of technology has been influenced by diffusion of awareness, knowledge, and positive attitudes from people who have already adopted the innovation (i.e. everyone except innovators).
Managed charging	The management of vehicle charging in such a way as to control the timing and/or extent of energy transfer to provide Demand Management benefits to the energy system and the vehicle user.
Personal norms	Perceived obligations to act in a way consistent with personal views.
Plug-in Hybrid Electric Vehicle	A vehicle that is equipped so that it may be powered both by an external electricity source and by liquid fuel.

Psychological distance	The cognitive separation between the self and objects or instances. In this context it refers to the closeness of the consumer to PiVs. Where psychological distance is greater, perception and attitudes are more abstract and unreliable.
Range-Extended Electric Vehicle	A vehicle that is equipped so that it may be powered both by an external electricity source and by liquid fuel; similar to a PHEV, except that a RE-EV generally uses the engine solely to charge the battery whereas a PHEV generally uses the engine for direct propulsion.
Symbolic attitudes	Attitudes relating to the symbolic meaning and symbolic value of a vehicle.
Symbolic meaning	What the vehicle says to others about its user.
Symbolic value	The value conferred on a vehicle by virtue of its symbolic meaning.

D5.2 Summary

Background

The Consumers, Vehicles and Energy Integration (CVEI) project investigates challenges and opportunities involved in transitioning to a secure and sustainable low carbon vehicle fleet. The project explores how integration of vehicles with the energy supply system can benefit vehicle users, vehicle manufacturers and those involved in the supply of energy. The project's objective is to inform UK Government and European policy, and to help shape energy and automotive industry products, propositions and investment strategies. In addition to developing new knowledge and understanding, the project aims to develop an integrated set of analytical tools that can be used to model future market scenarios in order to test the impact of future policy, industry and societal choices.

Project scope

The project is made up of two stages: Stage 1 aims to characterise market and policy frameworks, business propositions, and the integrated vehicle and energy infrastructure system and technologies best suited to enabling a cost-effective UK energy system for low-carbon vehicles, using the amalgamated analytical toolset. Stage 2 aims to fill knowledge gaps and validate assumptions from Stage 1 through scientifically robust research, including real world trials with private vehicle consumers and case studies with business fleets.

Purpose and scope of this deliverable

The Consumer Uptake Trial provided high validity measures of attitudes towards adoption of PiVs by Mainstream Consumers who had real-world experience of using a BEV and a PHEV. The trial will provide robust inputs to the Analytical Framework to allow more accurate prediction of the likely future uptake of PiVs by the mass-market, and the resulting impact on UK aggregated EV charging demand. The data collected will ensure that the outputs of modelling the uptake of PiVs are as valid as possible.

This report details the methodology, the results of analysis of the key data obtained from the trial and provides conclusions on the research questions defined for the Consumer Uptake Trial. The report provides evidence-based conclusions from the trial with regard to how the data have advanced understanding of Mainstream Consumer attitudes to uptake of BEVs and PHEVs, and therefore what the new understanding of this area brings.

Method

The Consumer Uptake Trial recruited a stratified sample of 200 Mainstream Consumers, giving them real-world experience with three near-identical VW Golfs that differed by drivetrain: ICEV, BEV and PHEV. The research design had a number of innovative features to increase the validity of the findings:

1. Attitudes towards adoption of PHEVs were measured in addition to attitudes towards adoption of BEVs.
2. Mainstream Consumers were recruited rather than the PiV Innovators who have participated in most UK PiV trials to date, and whose attitudes towards PiVs are known not to be representative of Mainstream Consumers.
3. All participants were given four days of real-world experience with a BEV, PHEV, and equivalent ICEV which replaced their main car in order to reduce their psychological distance from PiVs and enabled them to give responses based on their experiences of these vehicle categories.
4. Self-reported attitudes and willingness to adopt responses were collected before and after experience.
5. Participants completed a choice experiment following their experience of using the vehicles, in order to characterise the importance of PiV attributes.

Participants largely fell into three consumer segments pre-defined in earlier work conducted by CVEI consortium members Element Energy for the Department for Transport: Cost-conscious Greens (26% of sample), Pragmatists (50% of sample), and Uninterested Rejecters (19% of sample). These segments differed from each other in their responses to PHEVs and BEVs.

Key Findings and Conclusions

PHEVs are likely to be adopted more quickly in the mass-market than BEVs, with 23% of participants reporting being very likely to choose a PHEV as a main car in the next five years, versus only 8% for a BEV; though their All-Electric Range (AER) needs to increase to around 50 miles (80 km) for mass-market appeal. The likely prevalence of PHEVs in the next decade has implications for the impact of charging on the energy system, since PHEVs have smaller battery capacity and therefore shorter charging times than BEVs.

BEVs will be adopted more slowly, especially as main cars. AER of 200 miles (320 km) would enable them to appeal to 50% of Mainstream Consumers, while AER of 300 miles (480 km) would enable them to appeal to over 90%.

BEVs have higher appeal as second cars in households, where the range requirements are less. BEV models with ranges that would appeal to 50% of Mainstream Consumers as second cars in households will be present in the market in increasing numbers in the near future.

The appeal of PiVs in this study appears greater than in previous studies. This may be due to differences in the specific questions asked, differences arising from the use of a stratified sample in this trial, greater awareness of PiVs in the population now, and more and better models of PiVs appearing on the market.

Mode 2 charging rates are insufficient for mass-market uptake. Mode 3 7.2kW home chargers would offer sufficient charging rates for 50% of Mainstream Consumers to be likely to choose a PHEV or a BEV as a second car. Higher charging rates would be needed for 50% to be likely to choose a BEV as a main car.

Mainstream Consumers would be willing to pay extra for BEVs if they knew that they will be able to have access to workplace charging or public charging networks. However, they would not be willing to pay extra for PHEVs if they knew they would have access to workplace or public charging networks.

Mainstream Consumers are also likely willing to pay more for BEVs if they know that they will be able to access to rapid chargers every 20 miles on motorways and major A roads. However, a wider network of rapid chargers appears unnecessary.

Among a range of potential incentives to support PiV uptake, those with direct financial impacts were rated highest in importance by participants. A grant towards purchase price was rated most important, likely reflecting the relatively high prices of PiVs in the present (2018) market.

Personal and personal-situational variables are not good predictors of either BEV or PHEV uptake.

Mainstream Consumers can be segmented by attitudinal and behavioural variables. A "Cost-conscious Greens" segment (26% of the trial sample) are more interested than average in adopting PiVs, particularly BEVs, while an "Uninterested Rejecters" segment (19% of the sample) are substantially less interested. Pragmatists (50% of the sample) were meanwhile focused on functional attributes but could be persuaded to adopt PiVs. These differences suggest that policy or market incentives cannot treat Mainstream Consumers as a homogeneous mass-market.

Executive Summary

Background to the Consumers, Vehicles and Energy Integration Project

The UK government is legally bound to reduce CO_2 emissions in 2050 by 80% compared with levels in 1990. In support of this, the government has set a target that no internal combustion engine vehicles (ICEVs) should be sold from 2040 onwards. Plug-in Vehicles (PiVs) are expected to be the major alternative. However, widespread uptake of PiVs will add substantially to the overall demand for electricity. Experience to date suggests PiV users will tend to charge in the early evening, already a time of peak demand, unless measures are taken to encourage alternative charging behaviours.

The Consumers, Vehicles, and Energy Integration (CVEI) project aimed to explore how such integration of PiVs with the energy supply system can benefit vehicle users, vehicle manufacturers and energy suppliers. The objective of the project was to inform UK Government and European policy, and to help shape energy and automotive industry products, propositions and investment strategies.

In addition to developing new knowledge and understanding, the project developed an integrated set of analytical tools that can be used to model future market scenarios in order to test the impact of future policy, industry and societal choices. The Analytical Framework considers possible configurations of Ultra-Low Emission Vehicle (ULEV) deployment and use, and their integration within the wider energy system. It includes estimates of the scale and pace of development of PiV charging demand nationally, based on estimates of PiV uptake by the mass-market; but there is still considerable uncertainty over the latter.

The Consumer Uptake Trial was aimed at reducing the uncertainty over estimates of PiV uptake by obtaining empirical data on Mainstream Consumers' attitudes towards and likelihood to adopt BEVs and PHEVs.

This document is the Summary Report for the Consumer Uptake Trial (Deliverable D5.2), which contains an overview of the method, the key findings and the overall conclusions from the trial. This document accompanies the D5.2 'Technical Appendix' which contains the full methodology and results of statistical analysis of the trial data.

Key features of the Consumer Uptake Trial

The Consumer Uptake Trial recruited a stratified sample of 200 Mainstream Consumers, giving them real-world experience with three near-identical VW Golfs that differed by drivetrain: ICEV, BEV and PHEV. The research design had a number of innovative features to increase the validity of the findings:

1. Attitudes towards adoption of PHEVs were measured in addition to attitudes towards adoption of BEVs.
2. Mainstream Consumers were recruited rather than the PiV Innovators who have participated in most UK PiV trials to date, and whose attitudes towards PiVs are known not to be representative of Mainstream Consumers.
3. All participants were given four days of real-world experience with a BEV, PHEV, and an equivalent ICE vehicle. These vehicles replaced their main car in order to reduce their

psychological distance from PiVs and enable them to give responses based on their experiences of these vehicle categories.

4. Self-reported attitudes and willingness to adopt responses were collected before and after their experience of using the vehicles.
5. Participants completed a choice experiment following their experience of using the vehicles, to characterise the importance of PiV attributes.

Participants largely fell into three consumer segments pre-defined in earlier work (conducted by CVEI consortium members Element Energy for the Department for Transport):

- **Cost-conscious Greens** (26%): The most environmentally-conscious, and most likely to express concern about the environment and the need for energy security. Most likely to say they would pay more for lower running costs. They have an average enthusiasm for new technology. Average annual mileage, medium frequency of journeys over 80km.
- **Pragmatists** (50%): Average interest in new technology and cars. They enjoy driving and somewhat agree that cars indicate status, but also have some pro-environmental motivations and value independence from oil. Average income, with an interest in reducing vehicle running costs. Highest annual mileage among the three segments, and the most frequent makers of journeys over 80km.
- **Uninterested Rejecters** (19%): Attitudinally neutral about the environment, feel moral obligation to reduce greenhouse gases but do not see this as a priority. Do not particularly like cars or driving but recognise strong link between cars and status, and are interested in new technology. Tend to be young, with an even split between males and females. Average annual mileage, least frequent makers of journeys over 80km.

Key findings

Likelihood to choose a BEV or PHEV

Around 50% of participants indicated they were fairly or very likely to choose a PHEV as a main or second household car, or a BEV as a second car, in the next five years. Many fewer (26.5%) indicated the same for a BEV as a main car. The appeal of PiVs in this study appears greater than in previous studies. This may be due to differences in the specific question(s) asked, differences in sampling (for instance, the use of a stratified sample in the Consumer Uptake Trial), greater awareness of PiVs in the population now, or more desirable models of PiVs appearing on the market.

Participants were willing to pay purchase price premiums for PiVs if the running cost benefits would pay this back within 4.5 years (Uninterested Rejecters), 4.7 years (Pragmatists), or 5.3 years (Cost-conscious Greens). These long payback times perhaps indicate some expectation that PiVs would be retained for extended periods after purchase.

Government grants towards purchase price yielded a higher likelihood to choose a PiV, but higher rates of depreciation substantially decreased the proportion that were fairly or very likely to choose one, from around 70% if the vehicle lost 40% of its value in the first three years to around 24% if it lost 60% of its value over three years. Similar effects were found for higher rates of battery degradation (i.e. loss of electric range).

Effect of All-Electric Range (AER) on likelihood to choose a BEV

The data confirmed that the range of BEVs remains a critical factor for uptake. An AER of 320 km (200 miles) is needed for 50% of participants to consider owning a BEV as a main car. An AER of 480 km (300 miles) increased that percentage to over 90%. About 50% would consider owning a BEV as a second car if it had a lower AER, nearer to 240 km (150 miles), and almost 90% would consider it with a range of 320 km (200 miles).

Willingness-to-pay for additional BEV range, measured in the choice experiment, was non-linear: it was £24/km for ranges between 160 and 480 km (100-300 miles), but dropped to £7/km for ranges between 480 and 640 km (300-400 miles). This shows that Mainstream Consumers see additional range as worth paying for up to around 480 km (300 miles) but its importance falls thereafter. Few models in the current market have real-world ranges of 320 km (200 miles) or more, although this is likely to change in the next decade. In the meantime, it is more likely that BEVs will be seen as candidates for use as a second car in the household rather than as a main car.

A greater percentage of Cost-conscious Greens were likely to choose a BEV as a main car than either of the other segments if its AER was between 160 and 320 km (100-200 miles). Likewise, a greater percentage of Cost-conscious Greens were likely to choose a BEV as a second car than either of the other segments if its AER was between 80 and 240km (50-150 miles). This indicates that those with pro-environmental motivations are likely to choose BEVs with lower functional utility, presumably because their environmental benefits compensate to some degree for limited AER.

Effect of AER on likelihood to choose a PHEV

Around 50% of participants would consider owning a PHEV as a main car if it had an AER of 80km (50 miles), with a similar AER required for 50% to consider owning one as a second car. There were no significant differences between the three main segments in this respect. Additional AER increased the appeal of PHEVs, slightly more so for main cars than second cars: if the AER was 160km (100 miles) 70% would consider owning a PHEV as a second car and over 90% as a main car. A range of 80km is a higher AER than PHEVs on the UK market in 2018, so the findings suggest PHEV AER will need to increase from 2018 values for these vehicles to have greater mass-market appeal.

Willingness-to-pay for additional PHEV range was measured in the choice experiment up to 60 miles (100km). For the whole sample it was £34/km; for Cost-conscious Greens it was significantly higher (£44/km). Possibly, the AER of a PHEV is valued more highly by those with pro-environmental motivations because of the environmental benefits associated with driving on electric power.

Effect of charging time on likelihood to choose a BEV or PHEV

Time required to charge a PiV had a substantial impact on likelihood to choose a BEV. If the time required to deliver 160 km (100 miles) of range was eight hours (about the time required with Mode 2 charging) only 6.5% of participants would be likely to choose a BEV as a main car, and 17% as a second household car. About 50% of participants would be fairly or very likely to choose a BEV as a second car if the time required was four hours (about the time required with 7.2 kW Mode 3 chargers) but for 50% to be fairly or very likely to choose a BEV as a main car, this reduced to two hours.

Charging time also impacted on likelihood of choosing a PHEV. Around 20% would be likely to choose a PHEV (as either a main or second car) if the time required to deliver 160 km (100 miles) of range was eight hours; but 50% would be likely to choose a PHEV if the time was four hours (about the time required with 7.2 kW Mode 3 chargers).

Effect of access to public & workplace charging on willingness-to-pay for a BEV or PHEV

Willingness-to-pay for a BEV was influenced by availability of public charging: access to workplace charging added £564 to what participants would be willing to pay for a BEV; access to public charging added £1,677, and access to both added £1,808. These figures were substantially greater for the Pragmatist segment but were negative for the Uninterested Rejecters. A possible explanation for this is that this segment, characterised by negative attitudes to BEVs, conflated access to public and workplace charging with need to use it, making them still less interested in BEVs.

Willingness-to-pay for a PHEV was not influenced by access to either public or workplace charging, suggesting that the ability to run on petrol/diesel made access to charging away from home less relevant when considering a PHEV.

Willingness-to-pay for a BEV increased if there was access to rapid charging on motorways and major A-roads every 20 miles: by £2,674 for Cost-conscious Greens, £2,421 for Pragmatists, but only £1,161 for Uninterested Rejecters. These figures did not increase substantially if the network was more widespread (e.g. on all A-roads), indicating that Mainstream Consumers see a need for rapid charging only on major routes.

Purchase price, running costs, financial incentives, and depreciation

Purchase price was considered “very important” or “extremely important” by over 85% of participants, in relation both to BEVs and PHEVs. Consistent with this, 73% of participants reported being “fairly likely” or “very likely” to have a PHEV in the household in the next five years if government grants were available to reduce purchase costs (67% if the vehicle was a BEV). Cost-conscious Greens had the highest sensitivity to purchase price; Pragmatists the lowest.

In the choice experiment, participants as a whole were willing to pay £4.7 extra for a PiV for every £1 saved per year in running costs. This implies that participants would accept a payback time of 4.7 years for running cost savings to match an initial purchase price premium. Cost-conscious Greens were willing to pay £5.3 extra for every £1 saved per year, Pragmatists £4.7 extra, and Uninterested Rejecters £4.5 extra. About 69% of participants reported being “fairly likely” or “very likely” to have a PHEV in the household in the next five years if it were exempt from Vehicle Excise Duty (VED), an annual running cost (67% if the vehicle were a BEV).

Depreciation rate also had a significant impact on likelihood of purchasing a PiV in the next five years; 73% and 67% reported being either fairly or likely to choose a PHEV or BEV respectively if the depreciation after three years was 40%, but these figures dropped to 23% and 25% respectively if the depreciation after three years was 60%.

Conclusions

- PHEVs are likely to be adopted more quickly in the mass-market than BEVs; 23% of participants reported being very likely to choose a PHEV as a main car in the next five years, versus only 8% for a BEV. The AER of PHEVs needs to increase to around 50 miles (80 km) for mass-market appeal though. The likely prevalence of PHEVs in the next decade has implications for the impact of charging on the energy system, since PHEVs have smaller battery capacity and therefore shorter charging times than BEVs.

- BEVs will be adopted more slowly, especially as main cars. AERs of 200 miles (320 km) would enable them to appeal to 50% of Mainstream Consumers; AERs of 300 miles (480 km) would enable them to appeal to over 90%.
- BEVs have higher appeal as second cars in households, where the range requirements are less. BEV models with ranges that would appeal to 50% of Mainstream Consumers as second cars in households (around 150 miles) will likely be present in the market in increasing numbers in the near future.
- The appeal of PiVs in this study appears greater than in previous studies. This may be due to differences in the specific question(s) asked, differences in sampling (for instance, the use of a stratified sample in the Consumer Uptake Trial), greater awareness of PiVs in the population now, and more and better models of PiVs appearing on the market.
- Mode 2 charging rates are insufficient for mass-market uptake. Mode 3 7.2kW home chargers would offer sufficient charging rates for 50% of Mainstream Consumers to be likely to choose a PHEV or a BEV as a second car. For BEVs to appeal to over 90% of participants as either a main or a second car, charge rates which can deliver 100km of range in one hour are required. This rate of charge is beyond the capability of present home chargers, but can be delivered by rapid chargers at public locations.
- Mainstream Consumers would be willing to pay extra for BEVs if they knew that they will be able to have access to workplace charging or public charging networks. However, they would not be willing to pay extra for PHEVs if they knew they would have access to workplace or public charging networks.
- Mainstream Consumers are also willing to pay more for BEVs if they know that they will be able to have access to rapid chargers every 20 miles on motorways and major A-roads. However, a wider network of rapid chargers appears unnecessary.
- Among a range of potential incentives to support PiV uptake, those with direct financial impacts were rated highest in importance by participants. A grant towards purchase price was rated most important, likely reflecting the relatively high prices of PiVs in the present (2018) market.
- Personal and personal-situational variables are not good predictors of either BEV or PHEV uptake.
- Mainstream Consumers can be segmented by attitudinal and behavioural variables. A "Cost-conscious Greens" segment (26% of the trial sample) were more interested than average in adopting PiVs while an "Uninterested Rejecters" segment (19% of the sample) were substantially less interested. These differences suggest that policy or market incentives that treat Mainstream Consumers as a homogeneous mass-market may face challenges.

1 Introduction

The UK is legally bound by the Climate Change Act (2008) to reduce CO_2 emissions in 2050 by 80% compared with levels in 1990. Light duty road vehicles account for about 70% of all transport emissions (BEIS, 2018), so major reductions in CO_2 emissions from light duty vehicles will be needed to meet this target. Reductions in vehicle emissions at the tailpipe will also bring about improvements in local air quality, particularly in urban areas. Accordingly, the UK government has set the target that no conventional petrol or diesel (Internal Combustion Engine, ICE) vehicles should be sold from 2040 onwards; Plug-in Vehicles (PiVs) are expected to be the major alternative.

There are concerns, however, that widespread uptake of PiVs could add substantially to the overall demand for electricity, at a time when decarbonisation of electricity generation through wider use of renewable supply sources will make supply-demand balancing more difficult (Greenleaf, Chen & Stiel, 2014). Experience to date suggests that users will tend to charge PiVs in the early evening, which is already a time of peak demand, exacerbating the potential impact (Kinnear, Anable, Delmonte, Tailor & Skippon, 2017; EA Technology & Southern Electric Power Distribution, 2016). High PiV charging demand will also create challenges for operation within distribution network constraints at a local level. Forthcoming changes such as the widespread installation of smart meters may lead to some changes in this pattern, and there is potential to mitigate concerns through the application of Managed Charging (MC), which aims to shift PiV charging load to times when other demands are low (such as overnight). This would facilitate better integration of PiV charging demand into the wider energy system.

1.1 The Consumer Uptake Trial within CVEI

The Consumers, Vehicles, and Energy Integration (CVEI) project sought to explore how the integration of PiVs with the energy supply system could benefit vehicle users, vehicle manufacturers and energy suppliers. The project developed an Analytical Framework that considered a range of possible configurations of ULEV deployment and use, and their integration within the wider energy system. The Framework can be used to explore which configurations are optimal, considering commercial and market structures and customer propositions. The Framework includes estimates of the scale and pace of development of PiV charging demand nationally, based on estimates of PiV uptake. There remains considerable uncertainty over the latter.

The Consumer Uptake Trial was, therefore, aimed at reducing uncertainty in the estimates of PiV uptake by providing empirical data to understand Mainstream Consumers' attitudes towards PiV adoption. The trial outputs do not in themselves provide estimates of future uptake or charging demand – those estimates are provided by the Analytical Framework – but they provide an evidence base for input into the accuracy of the data, assumptions and the analysis.

Adoption of two types of PiVs were investigated in the trial; Battery Electric Vehicles (BEVs), which operate purely on an electric motor, and Plug-in Hybrid Electric Vehicles (PHEVs), which operate on an electric motor, an ICE, or a combination of the two. Mainstream Consumer participants were given direct experience of using both a BEV and a PHEV, alongside an ICE control vehicle, in order to capture their attitudes and likelihood to choose these types of vehicles in future.

1.2 PiV uptake: gaps in existing knowledge

In 2013, BEVs had a UK market share of 0.11% and PHEVs a share of 0.004%. By 2017 these shares had risen to 0.54% and 1.36% respectively. There is clearly an upward trend in PiV adoption, but it would be unwise to extrapolate from these figures to levels of adoption in coming decades. The development of a PiV market in the UK is at a very early stage, and developments in PiV technology and costs are likely to make them more competitive options for the mass-market – what we term here "Mainstream Consumers". An alternative is to consider, not current adoption, but attitudes towards PiVs. Research on attitudes can yield information about what improvements in which attributes could lead to PiV adoption by Mainstream Consumers.

1.2.1 Attitudes to PiVs

The comprehensive literature review conducted during Stage 1 of the CVEI project (Kinnear *et al*., 2017) found that research on consumer attitudes to uptake of PiVs in the UK and elsewhere falls into one of two categories: (1) research (including trials) with people who have already adopted a PiV, or were willing to adopt as part of a trial, e.g. by leasing a vehicle at their own expense; (2) survey research with people who have not adopted a PiV. Both of these categories have substantial limitations for our purpose.

The review also showed that very little research has been conducted to date on attitudes to PHEVs. Given that PHEV sales now lead BEV sales by a ratio of more than 2:1, this represents a substantial gap in our knowledge.

1.2.2 PiV Innovators are not representative of Mainstream Consumers

Uptake of innovations is frequently described using Rogers' (2003) diffusion theory, which characterises times to adoption within a population as normally distributed (Figure 1). Rogers allocated adopters to segments according to statistical criteria in which the segment boundaries corresponded to multiples of the standard deviation of the distribution. The first people to adopt innovations form a segment, "Innovators", who adopt largely without direct social influence from others because they have particular personal goals that are supported by such behaviour. Innovators are those whose times to adoption lie earlier than two standard deviations before the population mean time to adoption; that is, they represent the first 2.5% (approximately) of the eventual adopter population. Assuming an eventual transition to close to 100% PiV adoption, all those who have already adopted a PiV at the time of writing (2018) are Innovators in diffusion model terms.

The segmentation study carried out in the ETI's earlier Plug-in Vehicles project (Anable, Kinnear, Hutchins, Delmonte, & Skippon, 2011) showed that attitudes towards PiVs differed substantially between consumer segments, and in particular that the attitudes of what was termed the innovator "Plug-in Pioneers" segment (2% of the sample) were unrepresentative of those of the other segments, being much more favourably disposed towards BEVs and PHEVs than other segments. This suggests that the attitudes of PiV Innovators, including those who have already adopted PiVs, are not representative of the attitudes of Mainstream Consumers.

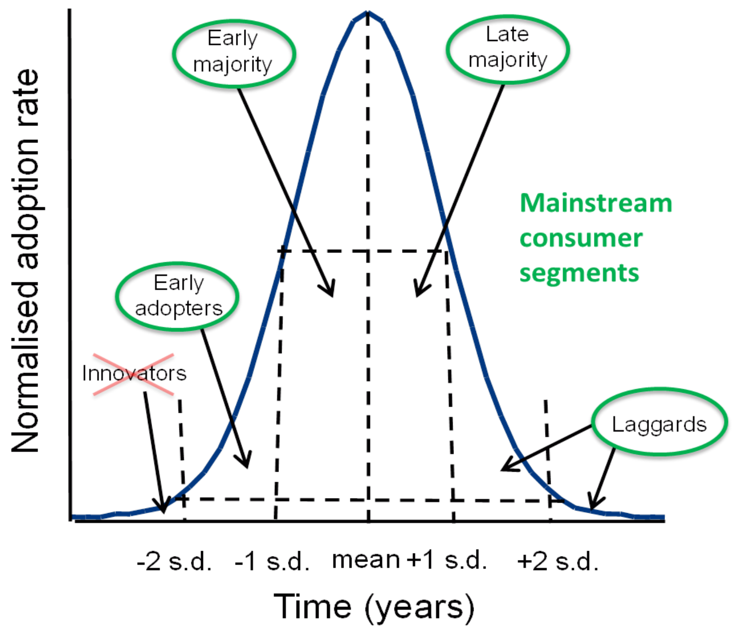

Figure 1: Rogers' (2003) diffusion model, showing adoption segments. Mainstream Consumer segments, defined here as all those who are not Innovators, are circled in green (s.d. = standard deviation)

1.2.3 Psychological distance

As the attitudes and attributions of Mainstream Consumers cannot be represented by Innovators, it is necessary to collect data from Mainstream Consumers themselves. The problem is that most participants in such research have little or no direct experience of PiVs – novelty and unfamiliarity make them *psychologically distant* from this new category of vehicles (Eyal, Liberman, & Trope, 2004). According to Construal Level Theory (Eyal *et al*., 2004; Liberman, Trope, & Stephan, 2007; Trope & Liberman, 2003) a psychologically distant object is construed in higher-level, more abstract terms, while a psychologically close object is construed in lower-level, more concrete terms. Psychological distance thus distorts the attitudes that Mainstream Consumers (without direct experience of PiVs) have towards PiVs.

The Consumer Uptake Trial addressed all three of these gaps in existing knowledge:

1. it specifically explored attitudes to PHEVs as well as BEVs;
2. it used a stratified sample of Mainstream Consumers rather than Innovators; and,
3. it reduced the psychological distance of participants from PiVs by giving them direct experience of using a BEV and a PHEV.

1.3 Research questions

The review in Stage 1 of the CVEI project identified a range of PiV attributes such as AER, cost, and recharge time, plus external factors such as availability of public charging, as being relevant to uptake. Stage 1 also identified other factors from a stakeholder workshop and qualitative interviews with PiV Innovators (see Deliverable D2.1). These considerations generated a set of research questions (see Table 1) which were addressed in this trial.

Table 1: Research Questions

	Consumer Uptake Trial Research Questions
1	How much does the potential All-Electric Range (AER) of a BEV or PHEV influence willingness to consider adoption?
2	How much does the potential purchase price of a BEV or PHEV influence willingness to consider adoption?
3	How much does the potential running cost saving associated with using a BEV or PHEV influence willingness to consider adoption?
4	How much does the recharge time associated with a BEV or PHEV influence willingness to consider adoption?
5	How much are personal characteristics (personality, innovativeness, liminality, self-congruity, driving style, demographic variables, etc.) predictive of willingness to consider adoption of a BEV or PHEV?
6	How much are personal-situational variables (e.g. income, mileage) predictive of willingness to consider adoption of a BEV or PHEV?
7	What effect does varying the perceived level of access to public charging stations (e.g. density, type of location, type of charger) have on willingness to adopt BEVs or PHEVs?
8	What effect does convenient access to public transport options for longer journeys have on willingness to consider adoption of a BEV?
9	What effect does the rate of depreciation of residual value have on willingness to consider adoption of a BEV or PHEV?
10	What effect does access to additional ULEV benefits (e.g. access to bus lanes, free congestion charge, free parking) have on willingness to consider adoption of a BEV or PHEV?
11	What other factors might compensate users for lack of long-range mobility sufficiently for them to consider adoption of a BEV?
12	What effect does convenient access to a long-range vehicle (whether within the household or hired) for longer journeys have on willingness to consider adoption of a BEV?

This report summarises the design, approach, and findings of the Consumer Uptake Trial. Discussion of the results is reported with respect to pertinent topics relevant to attitudes and influences on PiV adoption. A more detailed account of the method, the analyses, and the findings, addressing each research question in turn, is provided in the accompanying Technical Appendix.

2 Summary of method

2.1 Trial design

The Consumer Uptake Trial was designed to reduce the psychological distance of a sample of Mainstream Consumers from BEVs and PHEVs. Two hundred Mainstream Consumers were given three types of vehicle to use as a replacement for their own vehicle:

- A **Battery Electric Vehicle (BEV)**: VW e-Golf hatchback
- A **Plug-in Hybrid Electric Vehicle (PHEV)**: VW Golf GTE hatchback
- An **Internal Combustion Engine (ICE) vehicle** for control purposes: VW Golf hatchback (GT Edition)

The three models of VW Golf were similar in functional capability (other than the drivetrain differences) and (as closely as possible) matched in trim; this minimised the risk of observing differences in behaviours and attitudes between vehicle types which were associated with vehicle characteristics other than the drivetrain configuration.

Participants were given each vehicle for a four-day period. The trial vehicles replaced participants' own vehicles, which were stored with the research team for the duration of the trial. To control for order effects, the order in which the participants experienced the three vehicles was counterbalanced using a Latin square design in which, across the participant pool, each combination of ordinal positions was repeated a similar number of times. The day of the week on which participants started their trial was varied to ensure a mix of experience across the trial of using the vehicles on weekdays and weekends.

To ensure participants were able to adequately and safely charge the BEV and PHEV during the four-day periods, each participant was provided with a Mode 2 charging socket (installed on a separate circuit) at their residence. Participants were asked to charge the BEV and PHEV at least twice each during the four-day period; this could take place at home or at public chargepoints. Participants were also given free access to the 'POLAR plus' public charging network via a membership card (key fob) provided with each vehicle.

The research questions for this trial were addressed through a series of questionnaires and a choice experiment (see Table 1). The questionnaires included a two-stage filter survey process to inform recruitment, a pre-trial questionnaire, an attitudinal questionnaire which was repeated before (Time Point 1: TP1) and after the trial (Time Point 2: TP2), and interim questionnaires completed after each vehicle was returned. The choice experiment was included in the TP2 Questionnaire.

Data were also collected from the vehicles using a telematics data logger (provided by FleetCarma) to capture information on vehicle journey and charge events (trip duration and distance, vehicle speeds, battery State-of-Charge, etc.).

The key aspects of the method are illustrated in Figure 2.

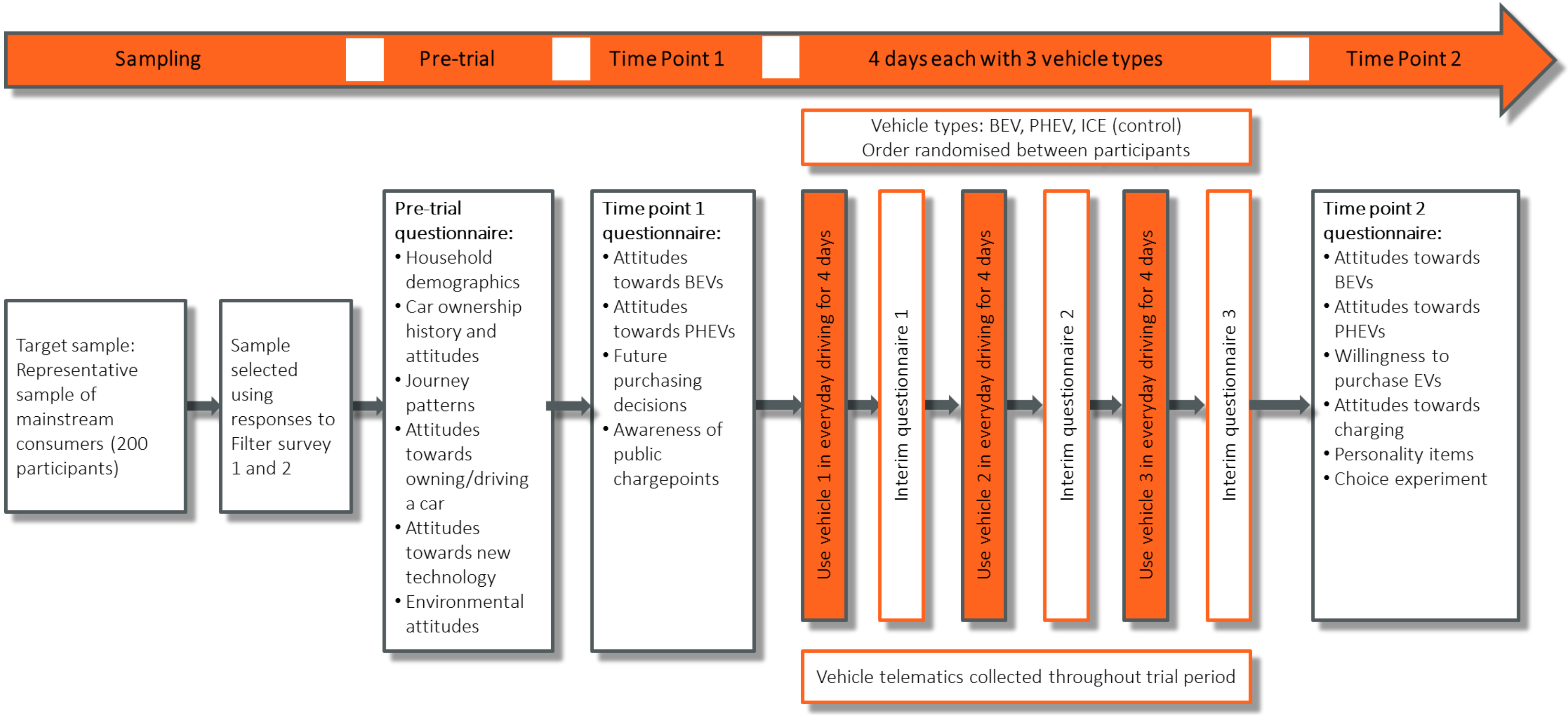

Figure 2: Overview of Consumer Uptake Trial method

2.2 Mainstream Consumer sample

The target sample for the Consumer Uptake Trial was 200 mainstream vehicle consumers. As shown in Figure 1, Mainstream Consumers were defined as all consumers in Rogers' (2003) Diffusion Model segments except for Innovators; that is the Early Adopter, Early Majority, Late Majority, and Laggard segments. Innovators were excluded at the recruitment phase. They were defined behaviourally as individuals who currently have, or have had regular driving experience with a plug-in vehicle in the last five years, and those who were currently considering acquiring a plug-in vehicle in the next six months. Full details of the eligibility criteria and recruitment strategy can be found in the Technical Appendix.

The sample was recruited to be representative of the driving population in Great Britain using a stratified sampling approach based on driving licence data from the Driver and Vehicle Standards Agency (DVSA), and population and travel data from the National Travel Survey (NTS) and the Office of National Statistics (ONS) (see Table 2).

Table 2: Target sample matrix stratified using DVSA, NTS and ONS data

Resident area[1]	Age group[2]	Gender		Total
		Male	Female	
Urban	**19-29**	14	12	**26**
	30-49	34	30	**64**
	50+	39	32	**71**
Rural	**19-29**	2	2	**4**
	30-49	6	6	**12**
	50+	12	11	**23**
Total		**107**	**93**	**200**

Participants were recruited from within a 50-mile radius of TRL (RG40 3GA) and Cenex (LE11 3QF), with an approximate 50/50 split between the two trial locations.

Participants received £200 compensation for their participation in the trial in a mix of cash and Amazon vouchers, administered at different points during the trial to ensure participants felt compensated for their time and remained engaged.

[1] The ONS 2011 rural-urban classification (RUC2011) was used:

https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification

[2] 17-18 year olds were excluded to mitigate increased crash risk associated with young and novice drivers.

2.3 Data collection

2.3.1 Questionnaires

Participants completed a series of questionnaires at different points during the trial.

Recruitment Filter Surveys	• Completed during the recruitment process. • Determined the eligibility of participants to take part in the trial.
Pre-trial questionnaire	• Completed following receipt of consent to participate. • Collected data for the segmentation and descriptive analysis to understand how participants fitted into the different consumer segments. • Contained questions relating to the participant's household, vehicle ownership history, travel patterns, attitudes about owning and driving a car, driving style, Mobility-as-a-Service (MaaS), attitudes about new technology, personal travel and the environment.
Time Point 1 questionnaire (TP1)	• Completed approximately 7-10 days before participants collected their first vehicle. • Recorded participants' attitudes towards BEVs and PHEVs before experience of the vehicles. • Contained BEV and PHEV specific questions comparing them with conventional cars, affective, symbolic and instrumental attitudes towards BEVs and PHEVs, and willingness to consider a BEV or PHEV as a main or second car.
Interim questionnaires	• Completed during vehicle handovers directly after experience with each vehicle. • Interim questionnaire 1 contained the core willingness to consider questions from the Time Point 1 questionnaire; included again at this point to allow testing of whether there was a Hawthorne Effect in which participants' attitudes are changed merely by participation. The questionnaire also contained questions on perceived performance (vehicle acceleration, responsiveness, comfort, noise etc.) of the first vehicle the participant had experienced. • Interim questionnaires 2 and 3 repeated only the vehicle performance questions for the second and third vehicles respectively.
Time Point 2 questionnaire (TP2, including Choice Experiment)	• Completed approximately seven days after the return of the final vehicle. • Extended version of the Time Point 1 questionnaire. • Included the Choice Experiment and repeated all the questions in the Time Point 1 questionnaire, enabling exploration of how far attitudes change with experience of the vehicles. In addition, it contained questions on preferred charging locations, and a personality inventory.

Further details about the content, origin, and purpose of each questionnaire are provided in the Technical Appendix.

2.3.2 Choice experiment

A 'stated preference' choice experiment was included as part of the TP2 questionnaire to investigate how participants valued different attributes of conventional and plug-in cars once they had had experience of using BEVs and PHEVs. This employed Discrete Choice Analysis which simulates as far as possible the purchase decision-making process followed by consumers in the real world. Participants were presented with a set of hypothetical car alternatives, each described by a range of attributes, and asked to choose which one they would purchase. Each participant was presented with hypothetical choices between a conventional ICE car, a PHEV, and a BEV, and in each case had to choose one option. An example choice question is shown in Figure 3.

	Petrol/ diesel car (A)	*Plug-in hybrid electric car (B)*	*Battery electric vehicle (C)*
Purchase price	**£20,000**	**£22,000**	**£24,000**
Annual running cost	**£1000** per year	**£500** per year	**£750** per year
Official driving range (average real-life range)	**400 (300)** miles	**20 (13) miles in electric mode,** 400 (300) miles using petrol engine	**200 (130) miles**
Charge point availability at trip destinations	Refuel at petrol stations	Charging available at **your home and workplace**	Charging available at **your home, workplaces** and in **public car parks / spaces**
Rapid charge points for long distance journeys	Refuel with petrol/diesel at any petrol station	Refuel with petrol/diesel at any petrol station for long journeys	Rapid charging sites **every 20 miles on motorways and major A roads** (i.e. at all motorway services) Rapid charging provides an additional **75 miles** of driving range for every 10 minutes of charging

If you could choose between these three cars, which one would you choose?

☐ ☐ ☐

If you had to choose between the plug-in hybrid and battery electric car, which one would you choose?

☐ ☐

After this example, you will be presented with the first choice question. The descriptions of the cars will change in each question, so please remember to read the information each time before making your choice.

Figure 3: Example choice question featured in the choice experiment

The vehicle attributes that were varied across the choice sets are presented in Table 3.

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Table 3: Description of each attribute and their levels in the choice experiment

Attribute	Description	Values shown to participants
Purchase price	Upfront cost of purchasing the car, including VAT and grants (£).	Prices in the range £10,000-£14,000, £16,000-£24,000 or £24,000-£36,000 depending on the price of the participant's last car purchase.
Running cost	On-going costs of running the car, such as fuel/charging, maintenance, insurance and road tax (£/year).	Costs in the range £500-£2,000 or £1,000-£4,000 depending on the participant's annual mileage.
Driving range	Official (type-approval) distance the car can travel on either a full battery or tank of fuel (miles).	For ICEs the range was fixed at 400 miles. For PHEVs the ranges shown were between 10 and 60 miles. For BEVs the ranges shown were between 100 and 400 miles. In all cases, participants were also shown an average real-world range (66% of official for electric, 75% for fuel).
Destination chargepoint availability	Chargepoint availability at work and public spaces.	Four possible access combinations were shown: 1. Home only 2. Home & work 3. Home & public car parks/spaces 4. Home, work & public car parks/spaces
Rapid chargepoint coverage	Density of rapid chargepoints, expressed as availability every "x" miles on "y" roads. This applied to BEVs only.	Participants were shown one of the following levels of coverage: 1. Rapid charging not available 2. Rapid charging sites every 20 miles on motorways and major A roads (equivalent to charging at all motorway services) 3. Rapid charging sites every 20 miles on all motorways and A roads 4. Rapid charging sites every 20 miles on motorways and all A roads, and at a similar frequency to petrol stations on all other road types
Rapid charging rate	Average charge rate of rapid chargepoints, expressed as miles added per 10-minutes of charging. This applied to BEVs only.	If rapid charging was available, participants were shown a charging rate in 50 and 100 miles of electric range added per 10-minute charge.

Details of how the choice experiment results were analysed is provided in section 2.4.

2.3.3 Vehicle journey and charge data

Data on journeys and charge events undertaken with the trial vehicles were collected using FleetCarma telematics dongles.

The devices collected event-based data (e.g. at ignition on/off, or charge start/stop), journey data and battery and fuel use data, whilst the vehicles were in operation. The full list of data fields collected during the trial is provided in the Technical Appendix.

2.4 Data analysis

This section provides an overview of the types of statistical analysis techniques used to analyse the data from this trial. More detail can be found in the Technical Appendix.

2.4.1 Segmentation

The questionnaires used attitude statements originally developed for previous ETI PiV research (Anable *et al*., 2011). These were further developed for a Shell-TRL PiV trial (Skippon, Kinnear, Lloyd & Stannard, 2016) and variants were used by Element Energy for a study commissioned by DfT of consumer attitudes towards plug-in vehicles in 2015 (Element Energy, 2015)[3].

In the DfT study, Element Energy developed a segmentation of car consumers using a sample of 2,020 participants. This segmentation and the derived purchasing behaviour of each segment was incorporated into Element Energy's Electric Car Consumer model (ECCo), a choice model used to forecast uptake of different car and van drivetrains in Great Britain. The ECCo model has subsequently been integrated into the CVEI Analytical Framework.

For the Consumer Uptake Trial, analysis was undertaken on the data collected for the DfT study to identify a set of 'golden questions' – that is, the smallest number of questions from the DfT study questionnaire that could be used to assign participants in the Consumer Uptake Trial to the ECCo segments.

Based on responses to the attitudinal 'golden questions', participants were assigned to one of the five pre-defined ECCo consumer segments. Figure 4 shows the percentage of each of these segments in the sample. Assignment to segments was estimated to be around 70-80% accurate. The percentages of each segment in the sample differed from those in Element Energy's original research; this is likely due to different sampling processes in the two studies.

[3] This research is not publically available, but a summary is provided in the Technical Appendix.

Segment	Count
Uninterested Rejecters	38
Cost-conscious Greens	51
Pragmatists	100
Car-loving Rejecters	5
Unmet Needs	6
Total	**200**

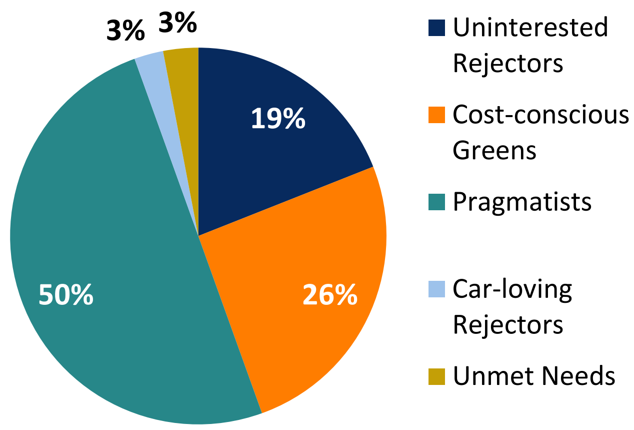

Figure 4: Participant segments

Three of the segments (Uninterested Rejecters, Cost-conscious Greens and Pragmatists) accounted for 94% of the sample, with the remaining two segments (Unmet Needs and Car-Loving Rejecters) only containing 5 and 6 participants in each. There were too few of the latter two segments for useful statistical analysis, so results are presented in this report only for the first three. Table 4 shows a summary of the characteristics of these three segments (based on segment descriptions from the original 2015 research).

Table 4: Description of ECCo consumer segments (based on Element Energy's original research for Department for Energy)

Cost-conscious Greens	Generally drive medium sized cars; average annual mileage, frequent long trips; strongly link cars to status; do not particularly like cars/driving; interested in new technology; relatively high interest in fuel economy; strong pro-environmental attitudes; positive attitudes to PiVs; young, medium income, 50/50 female/male.
Pragmatists	Generally drive medium sized cars; average annual mileage, few long trips; do not link cars to status; do not particularly like cars/driving; not interested in new technology; very interested in fuel economy; neutral attitudes to environment; negative attitudes to PiVs; young, low income, 50/50 female/male.
Uninterested Rejecters	Generally, drive medium sized cars; low annual mileage, few long trips; do not link cars to status; do not particularly like cars; not interested in new technology; do not see benefits in changing from hydrocarbon fuels; negative attitudes to environment; negative attitudes to PiVs; older, low income, slight male predominance.

2.4.2 Statistical techniques

A number of statistical techniques were used to analyse the data and answer the research questions. Full details of the approaches taken for statistical analysis can be found in the Technical Appendix.

All results were considered statistically significant if the *p* value was less than 0.05. If the *p* value is less than 0.05 it means that there is a more than 95% probability that the results observed did not occur by chance alone, hence it is referred to as a statistically significant result.

2.4.3 Choice coefficients

Data from the choice experiment were analysed using the statistical package NLogit (Version 4.0), which fits a simple multinomial logit model to predict the share of participants choosing each alternative based on the alternatives' attribute values. Details of this model and the equations used to model the utility of the ICE, PHEV and BEV alternatives are shown in the Technical Appendix.

The derived choice coefficients for each attribute are expressed in this report in terms of Willingness-to-Pay (WTP). Willingness-to-pay for an attribute shows the change in upfront cost that would have an equivalent effect on a vehicle's utility as a change in that attribute's value. For example, if WTP for a vehicle attribute is £1,000, then participants are willing to spend £1,000 more upfront on a vehicle with that attribute than an equivalent vehicle without it. Coefficients are converted to WTP by dividing by the coefficient of the purchase price attribute.

The coefficients were tested for statistical significance using their probability value (known as a *p* value) reported by NLogit. A coefficient was considered statistically significant if its *p* value was less than 0.05. The derived WTP values for each attribute are detailed in section 3 and in the Technical Appendix.

3 Results and discussion

3.1 Overview of potential Mainstream Consumer PHEV and BEV adoption

Figure 5 summarises Mainstream Consumers' likelihood to choose either a BEV or a PHEV in the next five years, either as the main car in their household or as a second car. These data were gathered at Time Point 2, after participants' psychological distance from BEVs and PHEVs had been reduced by direct experience of using them.

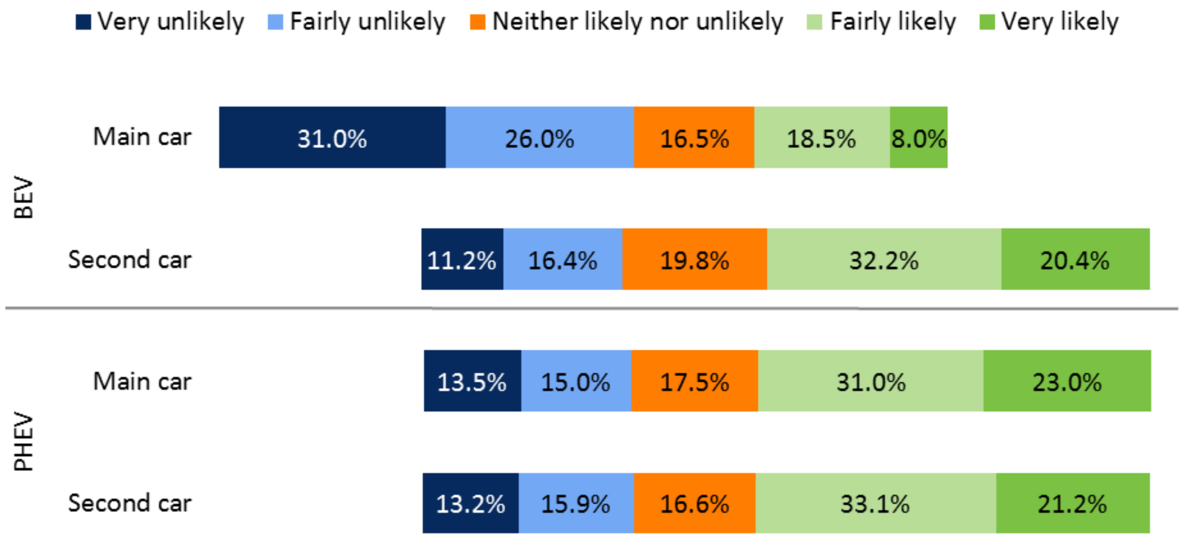

Figure 5: Likelihood to choose a BEV or PHEV as main and second car in the next five years, after experience with these categories of vehicles

Over 50% of participants gave positive responses (fairly or very likely) for PHEVs as main or as second cars. A similar percentage gave positive responses for BEVs as second cars in the household, but the percentage was much smaller for BEVs as main cars (26.5%). A more conservative interpretation of these data focuses on the 'very likely' responses as predictors of uptake. Over 20% of participants reported being very likely to choose to have a PHEV (as either a main or second car), or a BEV as a second household car. However, only 8% reported being very likely to choose to have a BEV as the main car in their household.

The appeal of PiVs in this study appears greater than in previous studies (Kinnear *et al.*, 2017). This may be due to differences in the specific question(s) asked, differences in sampling (for instance, the use of a stratified sample in the Consumer Uptake Trial), greater awareness of PiVs in the population now, or more desirable models of PiVs appearing on the market.

The findings predict a relatively healthy short-term outlook for PHEVs, with around half of Mainstream Consumers seeing themselves as likely to choose one in the next five years. This favourable outlook for PHEV adoption is consistent with the findings of the earlier ETI PiV study (Energy Technologies Institute, 2013), but has higher validity because participants in the present study could base their judgements on direct experience of using a PHEV. In addition, in the time since the original ETI PiV study, PHEVs have entered the UK market and are to some degree a more familiar category of vehicle.

The findings predict that the outlook for BEVs is less favourable. Only as second cars in households are BEVs as likely to be chosen as PHEVs. A substantial majority of participants did not consider themselves likely to choose a BEV as a main car in their household. The finding that Mainstream Consumers are reluctant to choose a BEV as main household cars reflects that of the earlier survey of UK Mainstream Consumers' willingness to consider BEVs (Skippon, Kinnear, Lloyd, & Stannard, 2016). It similarly showed a substantially higher willingness to consider BEVs as a second car than as a main household car.

3.2 Overview of vehicle usage during the trial

The primary purpose of providing participants with experience of a BEV and PHEV during the trial was to reduce their psychological distance from those categories of vehicles to increase the validity of their responses to the survey and choice experiment at Time Point 2. Participants were provided with each vehicle for four days; this period of time was based on previous trial experience suggesting that 1-2 days experience was sufficient to identify statistically significant differences in questionnaire responses from before and after experience, suggestive of having reduced psychological distance to the product (Skippon et al., 2016).

This section presents a brief overview of the journey and charge data collected from vehicle telematics during each four day trial experience. Whilst driver behaviour over these four days should not be considered to be representative of real-world PiV usage, these data provide some insight into the types of trips and charge events undertaken by participants during the trial. More detailed analysis of these data is provided in the Technical Appendix. In addition, Deliverable D5.3 provides analysis of journey and charge data collected in the Consumer Charging Trials, which provided participants with a PiV for a more representative eight week period.

3.2.1 Journey data

Composite metrics were generated by aggregating data across all journeys per participant and per vehicle. Descriptive statistics for these metrics are shown in Table 5.

Table 5: Comparison of journey metrics by vehicle type (shaded rows indicate that statistically significant differences were identified)

Journey metric	Mean values		
	BEV	PHEV	ICE
Total number of trips	18.8	18.9	18.2
Mean trip distance (mi)	7.4	8.6	8.0
Mean trip duration (mins)	17.3	18.2	17.6
Mean SOC start of journey (%)	79.8	59.4	-
Mean SOC end of journey (%)	73.4	45.2	-

In general, the characteristics of the journeys undertaken in the three vehicle types were similar. No significant differences were identified between vehicle type in terms of number of trips or the trip duration. A small but significant difference in mean trip distance was identified between the BEV and the PHEV; shorter journeys were undertaken, on average, in the BEV than in the PHEV. Participants generally started their journeys with more charge in their BEVs than the PHEVs and also ended their journeys with more change; this was likely due to the larger batteries in the BEV, and the ability to fall back on petrol power in the PHEV.

Driving style metrics were also calculated using measures of the proportion of hard acceleration and braking, and mean and maximum speeds recorded per journey. Here it was identified that there was a statistically significant lower proportion of hard acceleration, on average, in PHEV journeys compared with BEV and ICE journeys, and higher mean speeds in PHEV journeys compared with BEV journeys. Hard braking did not differ between BEV and PHEV, but both were higher, on average, than the ICE. However, the magnitude of these differences was small (as can be seen in Table 6).

Table 6: Mean driving style metrics (shaded rows indicate that statistically significant differences were identified)

Driving style metric	Mean values		
	BEV	PHEV	ICE
Mean % hard acceleration	16.9%	15.3%	16.3%
Mean % hard braking	17.7%	18.1%	20.1%
Mean speed (mph)	19.95	20.72	20.42
Mean maximum speed (mph)	48.14	48.81	47.99

Taken together these findings suggest that participants' experiences with the BEV and PHEV were broadly similar, but with some differences that might be expected due to the vehicle type. Thus, the experiences were likely to have elicited similar reductions in psychological distance, providing confidence in the validity of the attitudinal responses to the questionnaires.

3.2.2 Charge data

Composite charge metrics were also calculated to explore the total number of home charges, the total number of public charges and the mean SOC at the start and end of charges (see Table 7).

Comparisons between the BEV and PHEV charge events revealed significantly fewer home charge events with the BEV compared with the PHEV, and significantly higher SOC at charge start and end with the BEV compared with the PHEV. These differences are likely to be driven by differences in the vehicle specification; the larger battery in the BEV, and the ICE back-up in the PHEV. Supportive of this conclusion, analysis of charge data in the Consumer Charging Trials confirmed similar patterns between BEV and PHEV charging over an eight week period, much longer period than the four days examined here. Crucially, these data show that participants obtained real-world experience of charging both the BEV and PHEV, at home and in public locations, in line with the objective of reducing their psychological distance from these categories of vehicles.

Table 7: Comparison of charge metrics by vehicle type (shaded rows indicate that statistically significant differences were identified)

Travel pattern	Mean values	
	BEV	PHEV
Total number of home charge events	3.10	4.45
Total number of public charge events	2.94	2.74
Mean SOC start of charge (%)	61.59	30.99
Mean SOC end of charge (%)	90.87	86.72

3.3 PHEV adoption and the factors that influence it

3.3.1 Likelihood to choose a PHEV

3.3.1.1 How far were participants' views affected by the experience of using a PHEV?

Figure 6 shows how participants' expressions of likelihood to choose a PHEV as a main or second car in their household changed after experience of using one, by comparing their responses at TP1 (before experience) and TP2 (after experience).

Experience of using a PHEV resulted in similar overall increases in likelihood to choose a PHEV as either a main or second household car in the next five years. The most striking effect was a large increase in the proportion of participants who reported they were very likely to choose a PHEV after experience of using one. The percentage of those reporting that they were *fairly* likely to choose a PHEV in the next five years actually decreased; but as shown in Figure 6 the largest share of those respondents reported they were *very* likely to choose a PHEV after experience. This suggests the experience in the trial served to firm up their previous positive appraisals of a PHEV. The effect was similar for PHEVs as main and as second household cars.

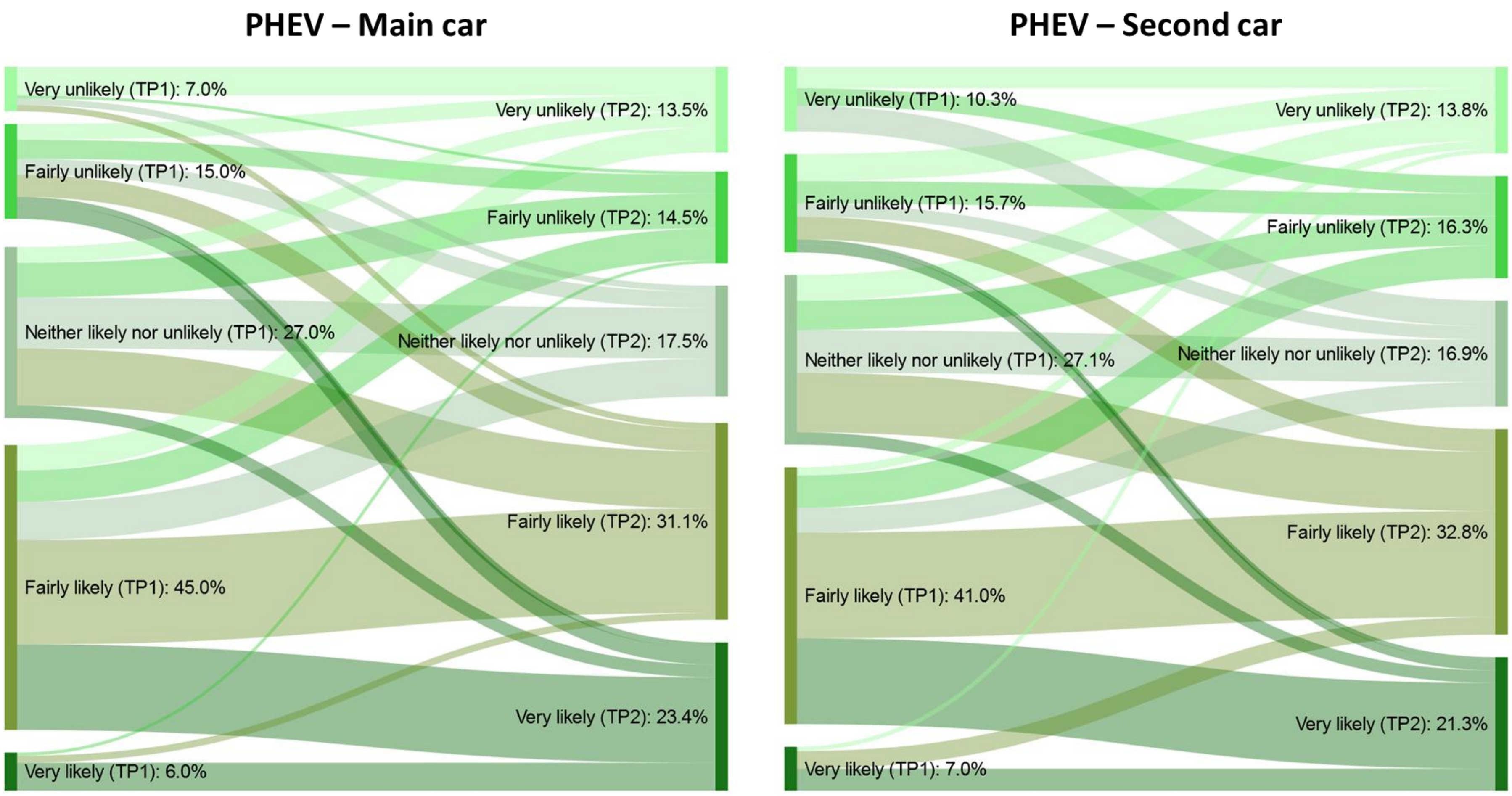

Figure 6: How experience of using a PHEV affected participants' expressed likelihood of choosing a PHEV as a main or second car in the next five years (comparison of responses at Time Point 1 and Time Point 2)

3.3.1.2 *How did participants' expressed likelihood of choosing a PHEV in the next five years vary by consumer segment?*

Likelihood to choose a PHEV in the next five years differed between the three largest ECCo segments (see section 2.4.1 for segment descriptions). The differences are shown in Figure 7. Members of the Pragmatist segment reported being substantially more likely to choose a PHEV, as both a main or second household car, than members of the Cost-conscious Greens segment, who in turn were substantially more likely to choose a PHEV as both a main or second household car than members of the Uninterested Rejecters segment. The difference between the distributions of responses for the Pragmatist and Uninterested Rejecter segments was statistically significant.

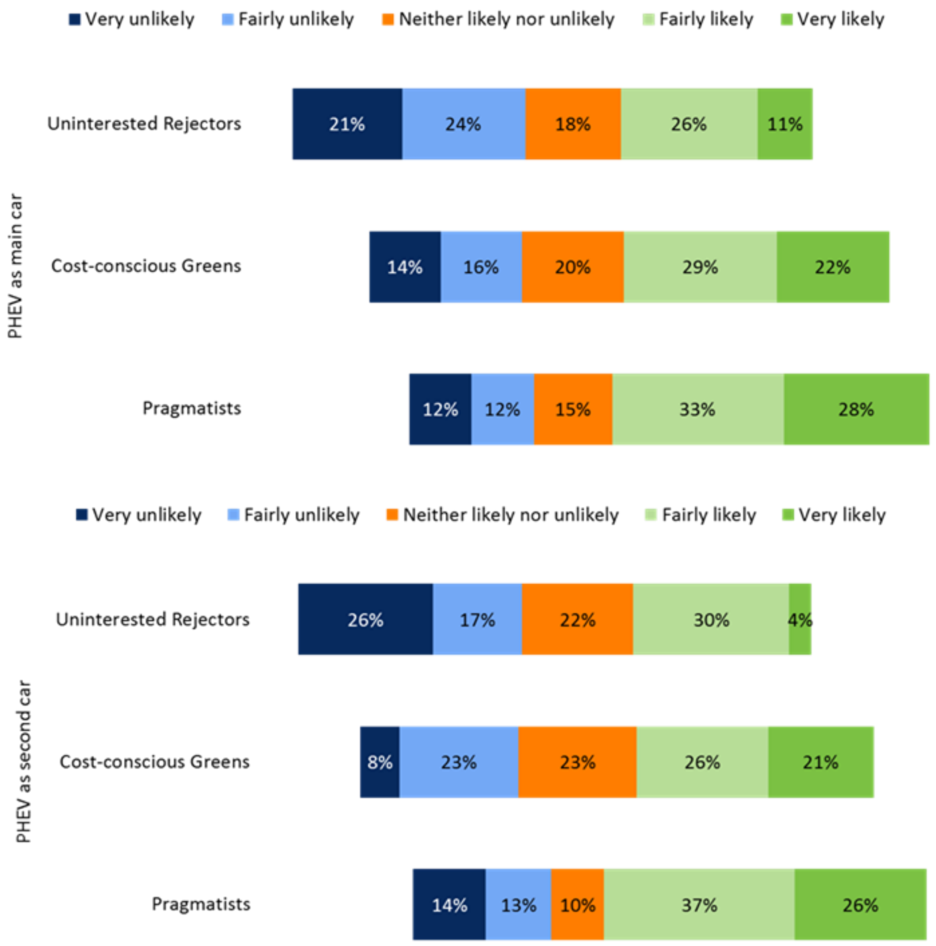

Figure 7: Likelihood to choose a PHEV as main and second car in the next five years after experience with the vehicles (responses to TP2 questionnaire, by consumer segment)

This pattern is relatively straightforward to interpret. PHEVs to some extent represent a pragmatic compromise between the running cost, performance, and environmental benefits of a BEV, and the driving range and speed of refuelling of an ICEV. It is perhaps to be expected that the Pragmatist segment expressed greater likelihood to choose a PHEV. Likewise, it is to be expected that Uninterested Rejecters would be less likely to choose a PHEV in the next five years than either of the other segments. It is particularly interesting that even among the Uninterested Rejecters, 11% were very likely to choose a PHEV as a main car, along with 26% who were fairly likely: in total, over a third of Uninterested Rejecters expressed some likelihood to choose a PHEV.

This suggests that PHEVs can appeal to some extent even to the most sceptical of Mainstream Consumer segments.

The effect of experiencing the use of a PHEV on likelihood to choose one within the next five years also differed between the ECCo segments, as shown in Figure 8. A 'difference score' was calculated for each participant by subtracting their response at TP1 before experience with any vehicles from their response at TP2 after experience with all three vehicles. A positive score indicates that participants reported higher likelihood to choose a PHEV after the vehicle experience than before it, whereas a negative score indicates that they reported a reduced likelihood to choose.

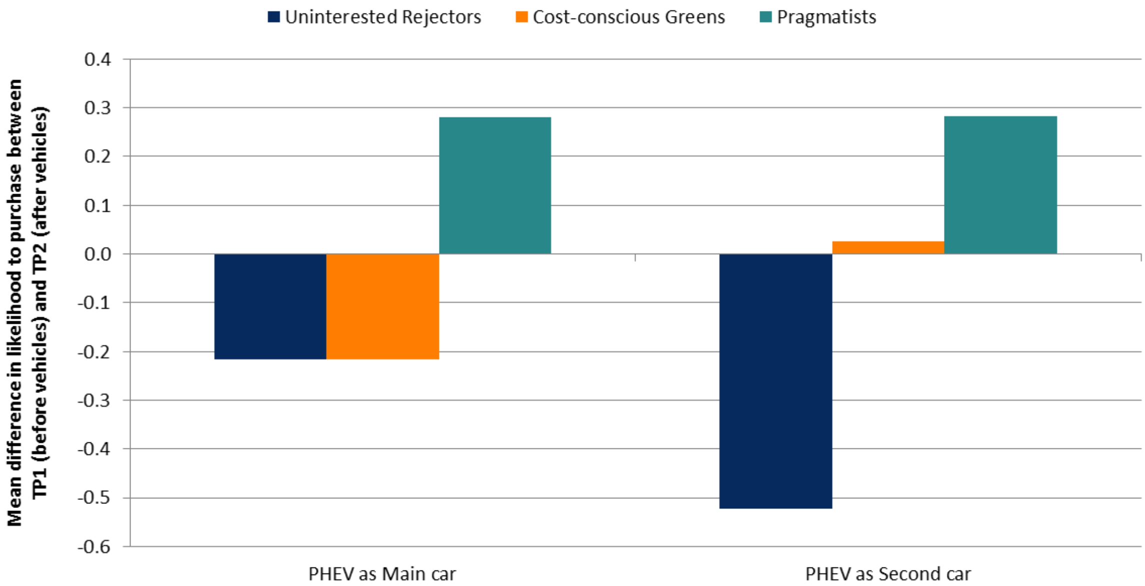

Figure 8: Mean difference scores in likelihood to choose a PHEV in the next five years (score after experience – score before experience), for each main ECCo segment

Members of the Pragmatists segment on average became more likely to choose a PHEV as a main car in the next five years; whereas members of the other two segments became less likely. Members of the Pragmatists segment also became more likely to choose a PHEV as a second household car after experience of using one, whereas Cost-conscious Greens, on average, did not change their reported likelihood to choose a PHEV. Members of the Uninterested Rejecters segment became substantially less likely to choose a PHEV as a second household car. The difference in attitudinal shift by segment following experience requires further investigation through qualitative research that could explore the in-depth reasoning that underlies the pattern.

3.3.2 Influence of AER on potential PHEV adoption

The CVEI Stage 1 literature review found that AER was "widely assumed to be much less of a barrier for PHEVs as opposed to BEVs" (Kinnear *et al*., 2017, p.229). However, very little data about the influence of AER on PHEV uptake had been gathered from Mainstream Consumers prior to the Consumer Uptake Trial. This trial generated three strands of evidence relevant to this question.

First, when asked to rate the importance of PHEV range, 83% of participants rated it as either very or extremely important.

Second, participants' willingness to consider owning a PHEV increased over each increment from 16km AER to 160km AER, as shown in Figure 9. Around 50% of participants would consider owning a PHEV as a main household car, and around 60% as a second car, if its AER when fully charged was 80km (50 miles), rising to around 90% (for both main and second cars) if the AER when fully charged was 160km (100 miles). Figure 10 shows these data for each ECCo consumer segment. The data for the Pragmatist and Cost-conscious Greens segments was similar to the global sample data, though a higher percentage of both segments would be willing to consider a PHEV with an AER of 120km (75 miles). The Uninterested Rejecters segment was less willing to consider a PHEV at all AERs, except for lower AERs as a second car.

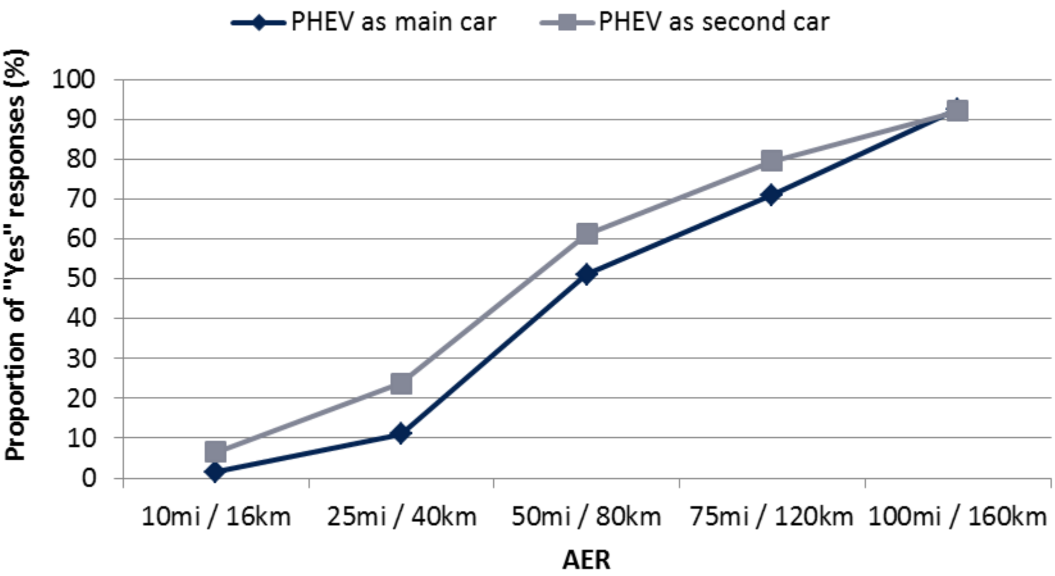

Figure 9: Proportion of participants who would consider owning a PHEV at each level of AER

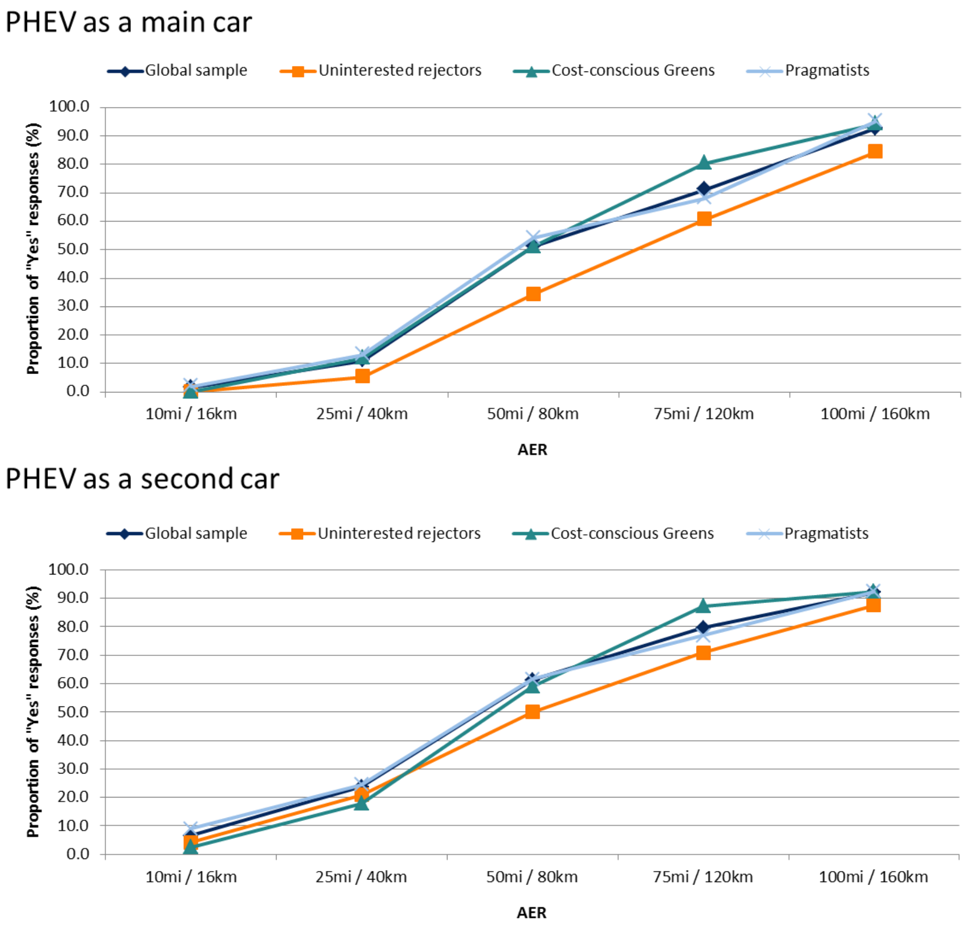

Figure 10: Proportion of participants who would consider owning a PHEV at each level of AER, by ECCo segment

Thirdly, the choice experiment found that willingness to pay extra for a PHEV for each additional 1km increase in its AER (measured up to 100km (60 miles) was £34/km averaged across the whole sample, and significantly higher for Cost-conscious Greens (£44/km). This implies that participants would be willing to pay an extra £1,020 for a PHEV with an AER of 80km, compared with today's (2018) typical 50km.

These strands of evidence suggest that AER is an important consideration in Mainstream Consumers' willingness to adopt PHEVs. Clearly, the greater the AER, then the larger the proportion of total distance travelled that can be under electric power, and thus the greater the running cost saving per kilometre. In addition, higher AER enables a wider range of destinations to be reached entirely under electric power. These findings suggest that such considerations are relevant to Mainstream Consumers' vehicle choices.

Table 8 lists all current (2018) models of PHEVs in the Supermini, Small family, Large family and Crossover classes. All have AERs lower than 80km (50 miles). The highest range cited is 62km (39 miles), for both the Toyota Prius PHEV and Hyundai Ioniq PHEV. The findings suggest that to appeal to half of the Mainstream Consumer population, PHEV AERs will need to increase beyond these levels. It would not seem necessary to increase AER beyond 160km, as PHEVs with this AER would appeal to 90% of Mainstream Consumers.

Table 8: Specifications of currently available models of PHEV (OTR = On the road)

Model	Class	Base variant	Battery size	AER (km; miles)	OTR price (£)
Audi A3 e-tron	Small family	1.4 TFSI e-tron 150PS S Tronic	8.8 kWh	48; 30	£33,965.00
Toyota Prius PHEV	Large family	1.8 VVT-I Business Edition Plus Aut	8.8 kWh	62; 39	£29,195.00
Hyundai Ioniq PHEV	Large family	1.6 GDi Premium 141h	8.9 kWh	62; 39	£25,345.00
Kia Optima PHEV	Large family	2.0 GDi PHEV 202hp Auto	9.8 kWh	53; 33	£31,495.00
VW Passat GTE	Large family	1.4 TSI GTE DSG	9.9 kWh	50; 31	£34,930.00
Kia Niro PHEV	Crossover	1.6 Gdi PHEV 139bhp DCT	8.9 kWh	58; 36	£28,345.00
Mini Countryman PHEV	Crossover	1.5i S E PHEV ALL4 Auto	7.6 kWh	42; 26	£29,395.00

3.3.3 Influence of charging rate on potential PHEV adoption

Research indicates that long recharge times have been identified as a barrier to PiV adoption (e.g. Biresselioglu *et al*., 2018). Refuelling an ICEV takes a matter of minutes, but recharging a PiV with a depleted battery using a home charger (rated at 2.3kW, 3.6kW or 7.2kW) can take a matter of hours, during which the vehicle is not available for use.

Recharging time for PHEVs was rated as either very important or extremely important by 74% of participants. This is lower than the figure of 90% of participants who rated recharging time as either very important or extremely important for BEVs, but it is clearly a relevant factor.

The effect of recharging time on participants' willingness to consider a PHEV was measured after experience of using one by using a set of items of the form[4] "Please indicate whether you would consider owning a Plug-in Hybrid Electric Vehicle (PHEV) as the MAIN car in your household if the charging time required to provide 100 miles of range was: 8, 6, 4, 2, or 1 hours". In each case, participants gave a yes/no response, and the set of items was repeated for a PHEV as a second car in the household.

The proportion of participants who indicated that they would consider owning a PHEV with each of these charge times is shown in Figure 11. As the charge time required to deliver 100 miles (160km) of range reduced from eight hours (roughly comparable to Mode 2 charge rates) to one hour (comparable to approximately 25kW charge rates), the proportion of participants who indicated they would consider owning a PHEV as a main car increased from around 20% to around 95%, and willingness to consider owning a PHEV as a second car from around 30% to around 92%. If the time to add 100 miles (160 km) of range was four hours, 55% of participants would consider owning a PHEV as a main car, and 68% would consider owning one as a second car.

[4] The variable was constructed in this way so that (a) it was an attribute of the vehicle, independent of any participant's particular needs; (b) it was expressed in terms of the readily understood construct of *time*, rather than the somewhat more cognitively complex concept of *rate*.

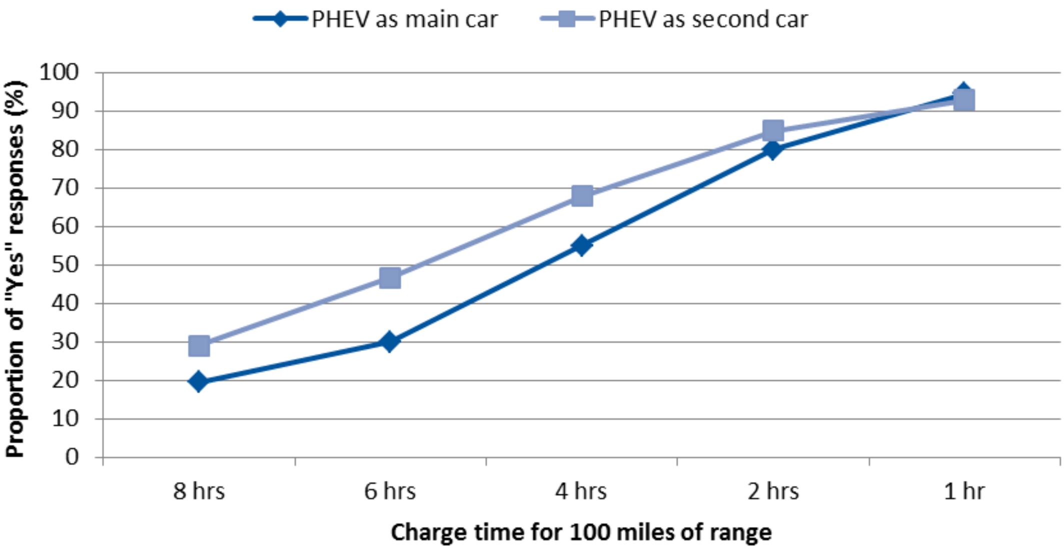

Figure 11: Influence of recharge time on willingness to choose a PHEV after experience of use

This result suggests that the majority of Mainstream Consumers surveyed would be willing to consider owning a PHEV as a main or second car provided that it could be recharged at the charging rates delivered by a 7.2kW Mode 3 charging units. These are increasingly being deployed as home chargers and are likely to become the default option in the near future, which is encouraging for the prospects of PHEV adoption.

3.3.4 *Influence of public charging infrastructure on potential PHEV adoption*

Lack of charging infrastructure has also been cited as one of the main barriers to PiV adoption by Biresselioglu *et al*. (2018). Another recent literature review investigating the infrastructure needs of PiV consumers suggested that home chargepoints are the most important, followed by work and then public chargepoints (Hardman *et al*., 2018). The CVEI Stage 1 literature review concluded that while a perceived lack of public charging infrastructure is a frequently reported anecdote, “evidence on the link [to PiV uptake] is weak” (Kinnear *et al*., 2017, p.61). Further, it concluded that public charging infrastructure had less impact on PHEV uptake than on BEV uptake.

The Consumer Uptake Trial (via the choice experiment at Time Point 2) investigated WTP for PiVs if access was available to destination charging at work, and/or in public places. No significant WTP values for PHEVs with access to destination charging were identified, indicating that the availability of workplace and/or public charging infrastructure does not significantly influence Mainstream Consumer decisions to choose a PHEV. This to some extent runs counter to the finding of Element Energy’s previous choice experiment for DfT (Element Energy, 2015), that access to work charging and public charging added to the price participants were willing to pay for a PHEV. It is probable that the differences may be due to higher psychological distance in the earlier sample.

3.3.5 *Influence of personal factors on potential PHEV adoption*

The Consumer Uptake Trial analysis examined the extent to which willingness to consider a PHEV was correlated with a range of individual and personal factors. Some of these items were in the form of pre-defined scales, while others were combined post-hoc using factor analysis to identify related variables in order to reduce the total number included in the correlation analysis. Details of this process are given in the Technical Appendix.

Overall, personal factors proved to be poor predictors of the willingness to adopt PHEVs as main or second cars, and only a few significant correlations with willingness to consider a PHEV emerged.

Willingness to consider a PHEV as a main car was correlated with general interest in new technology. In addition, three personal-characteristic factors correlated significantly with willingness to consider a PHEV as a second car:

1. “Most people I know do their bit for the environment these days” – suggesting a role for social influence (Axsen, Orlebar & Skippon, 2013);
2. “Bias towards car” factor – a negative correlation indicated that the greater a person’s bias towards cars as a means of transport, the lower their willingness to consider a PHEV as a second car;
3. “Angry” driving style scale – another negative correlation indicated that the more angry their self-reported driving style, the lower their willingness to consider a PHEV as a second car.

All of these associations were small effects according to Cohen’s (1988) criteria for effect size, except for the association between willingness to consider a PHEV as a second car and responses to the item “Most people I know do their bit for the environment these days”, which was a medium effect. All of them appear to be plausible associations, but taken together they do not amount to a coherent picture of a potential PHEV adopter. From the data, it must be concluded that personal-characteristic factors are not strong predictors of willingness to consider a PHEV.

None of the attitudinal items included in the TP2 questionnaire were significantly associated with willingness to consider a PHEV, although many attitudes were more positive after the experience of use (see next section). The expression of more positive attitudes following experience does not, therefore, necessarily translate into increased likelihood to consider a PiV, replicating previous research (Skippon *et al*., 2016).

3.3.6 Attitudes towards PHEVs

Attitudes towards PHEVs in general became more positive after the experience of using one; very few were rated more negatively. The attitudes with the most consistent and substantial increase in positivity were related to vehicle performance (acceleration, smoothness when cruising, etc.). Attitudes that became more negative after the trial were related to PHEVs and their benefits in terms of independence from oil. Since PHEVs in reality confer some degree of independence from oil (in the form of gasoline or diesel), then this finding is perhaps surprising. It could be interpreted as indicating that high expectations in this respect prior to the experience were not met by actual experience of using a PHEV; this would be consistent with the data discussed above suggesting that most Mainstream Consumers would consider a PHEV only if its AER was greater than that of the Golf PHEV used in the Consumer Uptake Trial. Some attitudes remained unchanged after the experience of using a PHEV: these were attitudes relating to environmental benefits, affective attitudes towards PHEVs, cost-related attitudes, attitudes towards reliability of PHEVs, and travel needs related to PHEVs.

It should be noted that the expression of more positive attitudes following experience does not necessarily translate into increased likelihood to consider a PiV, as seen in the previous section.

Participants were more positive about PHEVs than BEVs with regards to driving enjoyment and practical attributes such as purchase price and depreciation, range, charging, safety, and meeting travel needs. These differences are consistent with the findings that participants were more likely to consider adopting a PHEV in the next five years than a BEV.

At the consumer segment level, it was observed that Uninterested Rejecters were consistently more negative about both PHEVs than Cost-conscious Greens and Pragmatists, and expressed the greatest concerns about adapting to charging. Pragmatists tended to have mixed views, but had a similar level of concern over adapting to charging. Cost-conscious Greens, on the other hand, were the most positive about PHEV attributes and were less concerned about adapting to charging.

3.3.7 Evaluations of PHEV performance

No previous research has reported consumers' perspectives of PHEV performance (Kinnear *et al*., 2017).

Participants' evaluations of dynamic and cruising performance[5] in this study were recorded using the Borg CR-10 scale (as used by Skippon *et al*., 2016) which is designed for measurement of intensity of perception of stimuli. The PHEV was rated higher on all dynamic and cruising performance attributes than the ICEV, but lower than the BEV except for the attribute "sportiness" in which it was rated higher.

The Cost-conscious Greens and Pragmatists segments rated the PHEV higher for smoothness, acceleration from 0-20 mph, and responsiveness than did the Uninterested Rejecters. This may have been related to differences in the driving modes each segment tended to use; however, no statistical differences between the proportions of journeys driven on electric power (%) (i.e. 'EV-Fraction') were found through examination of the telematics data. It may be that these higher evaluations of performance contributed to the Cost-conscious Greens' and Pragmatists' more positive dispositions towards PHEVs. It is also possible that their positive dispositions may have influenced their evaluations, but it is not possible to distinguish the direction of causality from these data.

The evaluations of specific performance attributes by those participants who would consider having a PHEV in the next five years as a main or second car did not differ significantly from those of participants who would not. However, the former did rate both overall performance and enjoyment higher than the latter. Again, it is not possible to distinguish whether higher evaluations contributed to higher willingness to consider, or whether a greater willingness to consider led to higher ratings for these aspects of performance for a PHEV.

[5] Qualitative research with consumer drivers by Skippon (2014) found that drivers view vehicle performance in two dimensions: dynamic performance and cruising performance. Dynamic performance is associated with the driver being "actively engaged in changing the state of motion of the vehicle using the accelerator" (Skippon, 2014, p.28), and includes attributes such as acceleration, responsiveness, and power. Cruising performance refers to the driver "maintaining the state of motion of the vehicle keeping the accelerator position approximately constant" (Skippon, 2014, p.28) and is associated with smoothness when cruising and cruising noise levels.

3.4 BEV adoption and the factors that influence it

3.4.1 Likelihood to choose a BEV

3.4.1.1 How far were participants' views affected by the experience of using a BEV?

Figure 12 shows how participants' expressions of likelihood to choose a BEV as a main or second car in their household changed after experience of using one, by comparing their responses at Time Points 1 (before experience) and 2 (after experience).

Likelihood to choose a BEV as a main car in the next five years reduced after experience of using one; in particular, those very unlikely to choose a BEV almost doubled, from 17% to 31%. The decreased likelihood to choose a BEV following experience with one is consistent with the findings of Skippon *et al*., (2016). There was, however, a modest increase in those very likely to choose a BEV, from 3% to 8%. It appears that the experience had the effect of polarising participants' responses, increasing certainty at either end of the likelihood scale at the expense of reducing responses in the middle of the scale.

The opposite pattern was found for likelihood to choose a BEV as a second car. Negative responses remained relatively unchanged, but 'very likely' responses increased from 7% to 20%, largely at the expense of 'neither likely nor unlikely' responses, which decreased from 31% to 20%.

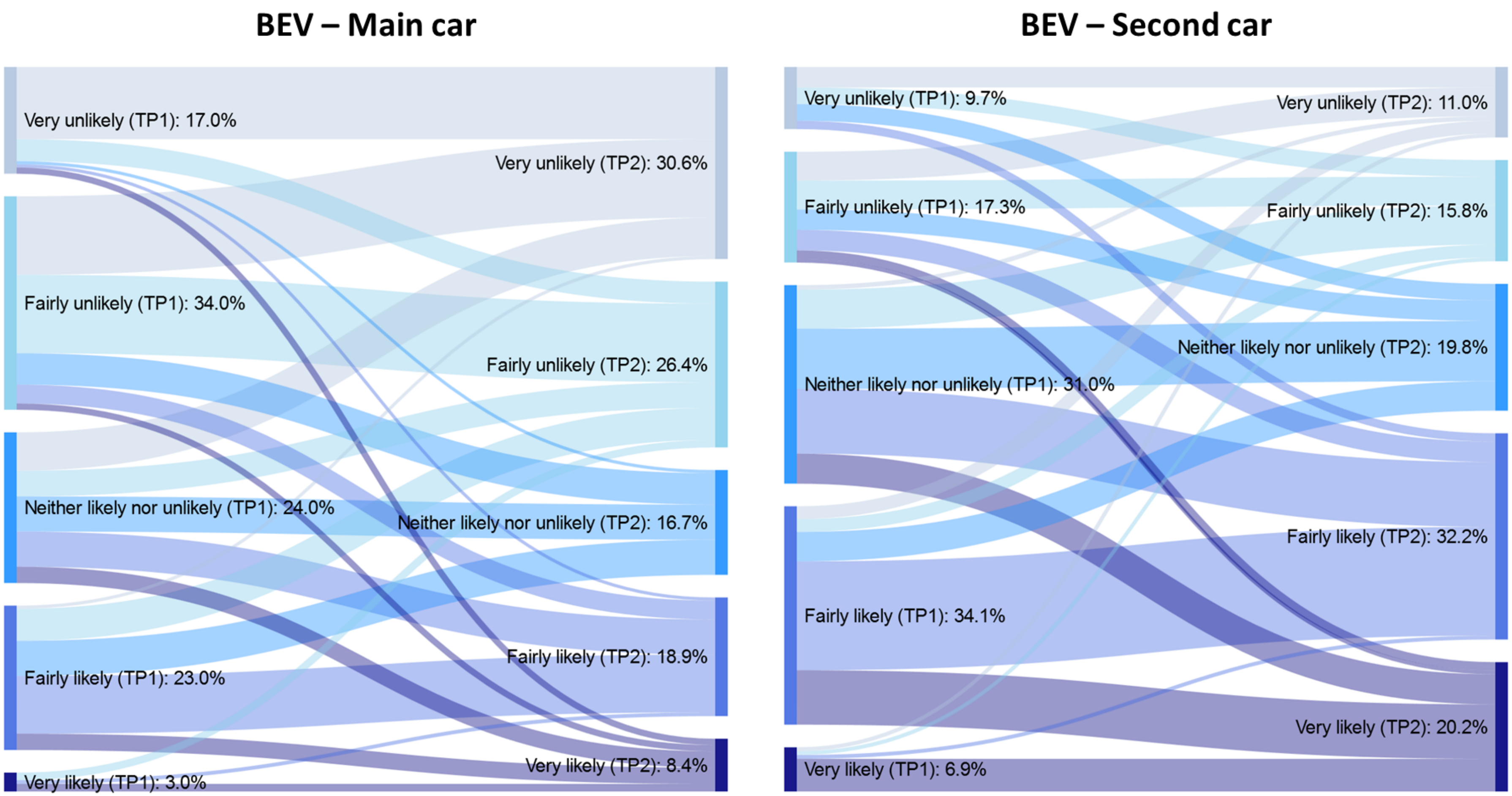

Figure 12: How experience of using a BEV affected participants' expressed likelihood of choosing a BEV as a main or second car in the next five years

3.4.1.2 How did participants' expressed likelihood of choosing a BEV in the next five years vary by consumer segment?

Likelihood to choose a BEV in the next five years differed between the three largest ECCo segments. The differences are shown in Figure 13.

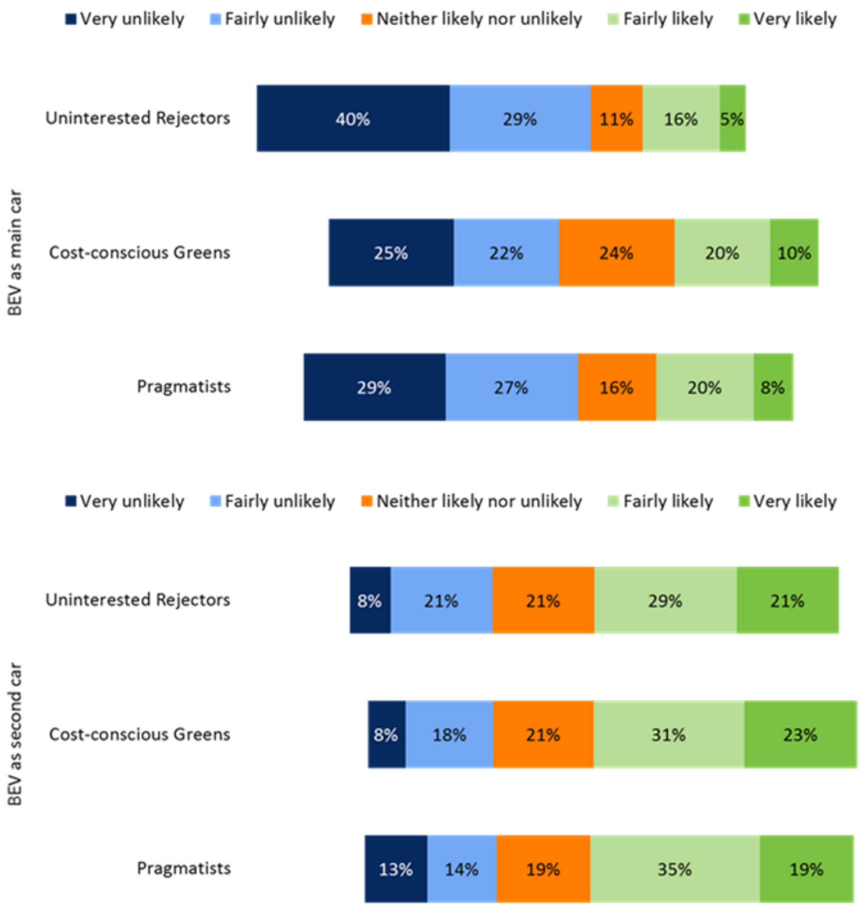

Figure 13: Likelihood to choose a BEV as main and second car in the next five years after experience with the vehicles by consumer segment

Likelihood to choose a BEV as a second car was similar for all three segments. Likelihood to choose a BEV as a main car, however, was substantially lower among the Uninterested Rejecter segment than the other two: 40% of Uninterested Rejecters reported being very unlikely to choose one, as opposed to 29% of Pragmatists and 25% of Cost-conscious Greens.

Uninterested Rejecters were much more rejecting of BEVs as a main car than as a second car. This was also the case for Pragmatists, though to a lesser extent, and for Cost-conscious Greens, to an even lesser extent.

The effect of experiencing the use of a BEV on likelihood to choose one within the next five years also differed between the ECCo segments, as shown in Figure 14. A 'difference score' was calculated for each participant by subtracting their response at TP1 (before experience with any vehicles) from their response at TP2 (after experience with all 3 vehicles). A positive difference score indicates participants reported higher likelihood to choose a BEV after the vehicle experience than before it; whereas a negative difference score indicates they reported a reduced likelihood to choose.

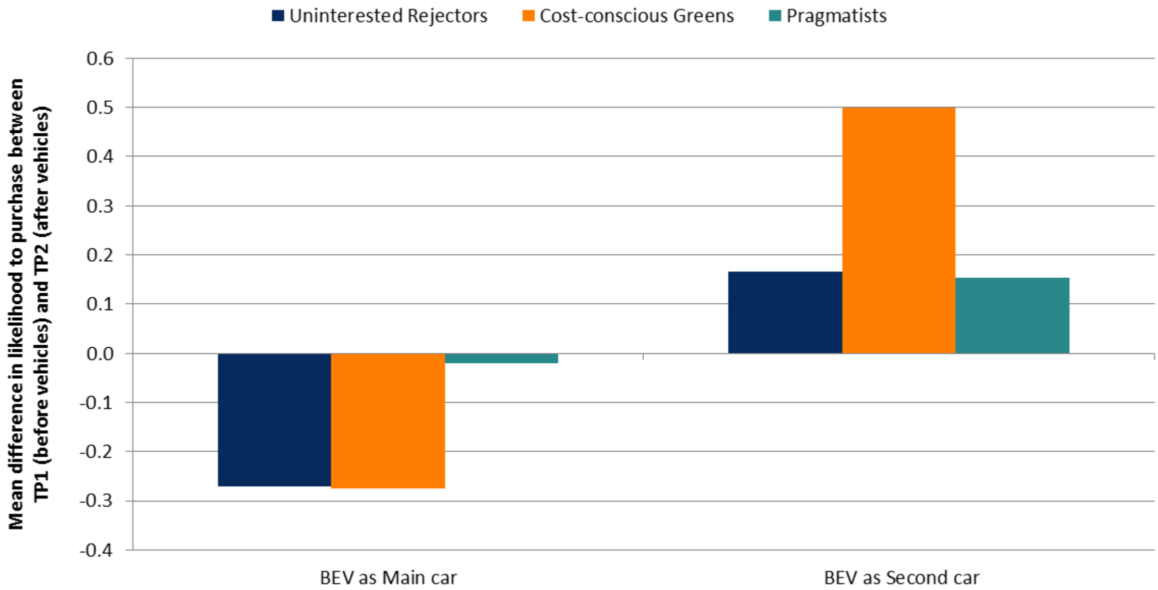

Figure 14: Mean difference scores in likelihood to choose a BEV in the next five years (score after experience – score before experience), for each main ECCo segment

Uninterested Rejecters and Cost-conscious Greens reduced their stated likelihood of purchasing a BEV in the next five years as a main car after experiencing of using one, whereas Pragmatists' stated likelihood did not change. A different picture emerged for BEVs as a second car: likelihood to choose increased for all three segments. The mean increase was modest for the Uninterested Rejecters and Pragmatists, but substantial for the Cost-conscious Greens.

3.4.2 Influence of AER on potential BEV adoption

As with PHEVs, there were three strands of evidence relating to the influence of AER on BEVs adoption.

First, at Time Point 2 over 98% of participants indicated range was either very or extremely important when considering the choice of a BEV. Likelihood to adopt a BEV as a main car was also found to be significantly predicted by the level of importance consumers attributed to electric range; the higher a person rated the importance of the electric range, the less likely they were to say they would buy a BEV as a main car in the next 5 years. This suggests that AER is a central consideration when choosing a BEV, particularly as a main car, as found in previous research (Kinnear *et al*., 2017).

Second, participants' willingness to consider owning a BEV increased over each increment from 80km AER to 480km AER, as shown in Figure 15. Around 50% of participants would consider owning a BEV as a second household car if its AER when fully charged was between 160km (100 miles) and 240km (150 miles); but AER would need to be substantially higher, 320km (200 miles) before 50% of participants would consider owning a BEV as a main car.

An AER of 480km (300 miles) would be required for more than 90% of participants to consider owning a BEV, as either a main or a second car. These findings are consistent with those of Skippon *et al*. (2016), and provide guidance to vehicle manufacturers as to the AERs required to achieve mass-market penetration by BEVs.

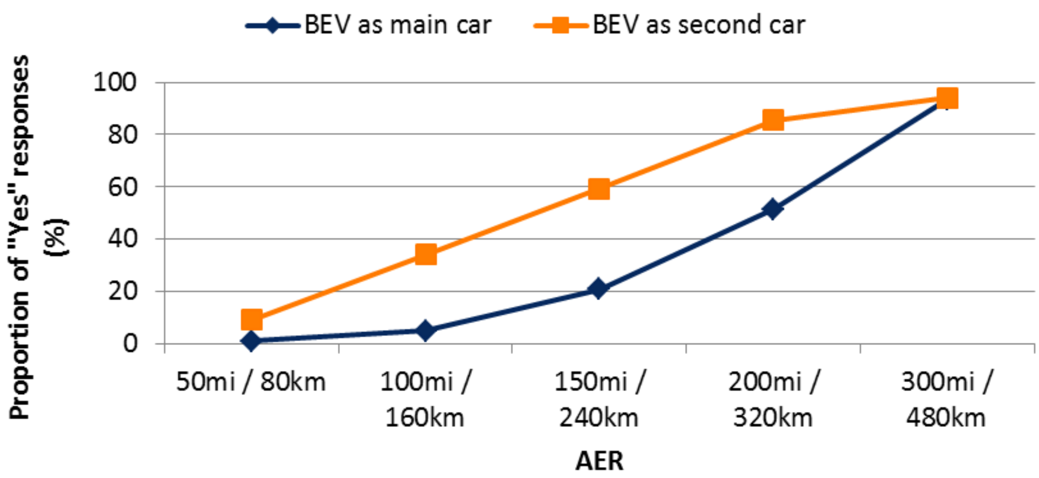

Figure 15: Proportion of participants who would consider owning a BEV at each level of AER

Figure 16 shows these data broken down by ECCo consumer segment.

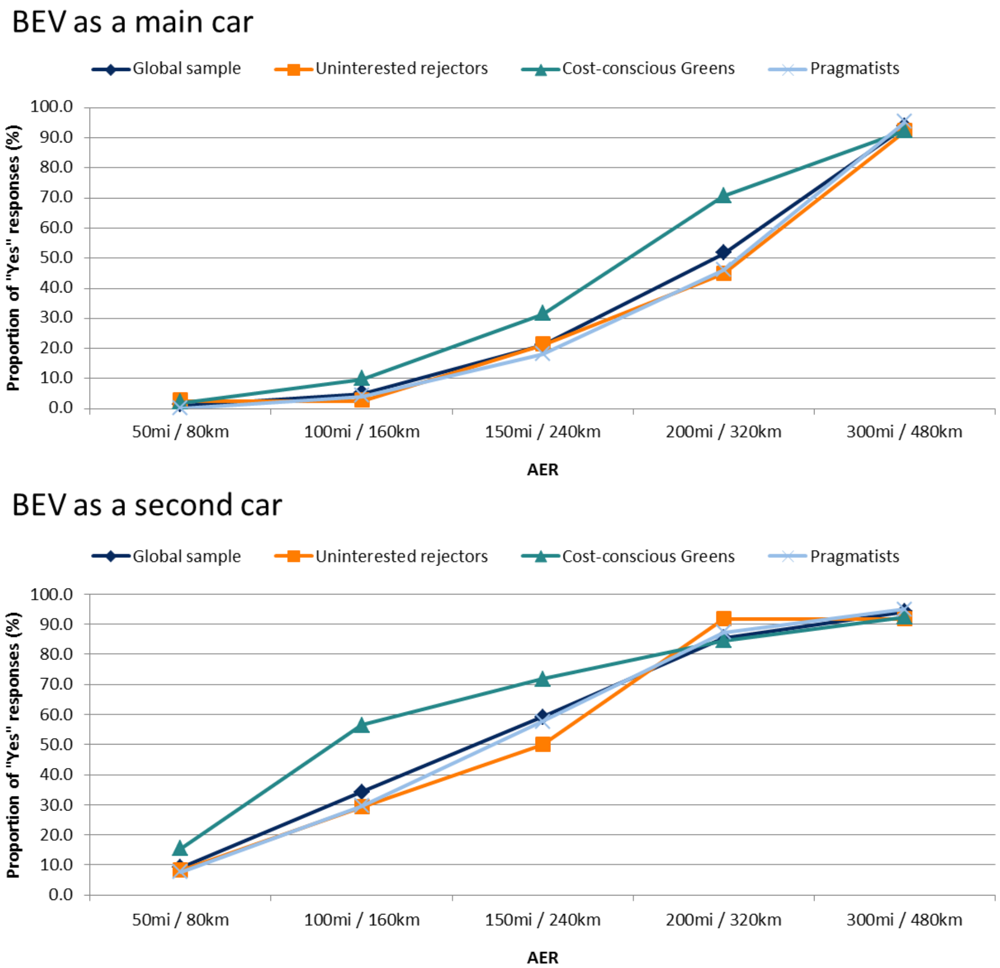

Figure 16: Proportion of participants who would consider owning a BEV at each level of AER, by ECCo segment

Compared with the other segments, a greater percentage of Cost-conscious Greens were willing to consider owning a BEV as a main car if its AER was between 160km (100 miles) and 320km (200 miles). Similarly, a greater percentage of Cost-conscious Greens were willing to consider owing a BEV as a second car if its AER was between 80km (50 miles) and 240km (150 miles). These data indicate that those with pro-environmental motivations are willing to adopt BEVs with lower pragmatic utility, presumably because their environmental benefits compensate to some degree for AER deficits. This is consistent with the picture that has emerged in the research literature that BEV Innovators (the first to adopt, in Rogers' (2003) Diffusion model) tend to have pro-environmental motivations (Kinnear *et al.*, 2017).

Third, the choice experiment found that willingness to pay extra for a BEV for each additional 1km increase in its AER (between 160km and 480km (100 and 300 miles) was £24/km averaged across the whole sample, but only £7/km for each additional km of AER at higher values of AER (between 480km and 640km (300 and 400 miles)). This is consistent with the data in Figure 15 and Figure 16, and indicates that an AER of 480km (300 miles) would be sufficient for the needs of most Mainstream Consumers. Participants would be willing to pay an extra £7,680 for a BEV with an AER of 480km (300 miles) compared to one with an AER of 160km (100 miles).

These various strands of evidence go further than simply confirming what is already known, that low AER is a barrier to BEV adoption (Kinnear *et al.*, 2017): they also provide a clear guide to the values of AER that are needed to drive mass-market uptake of BEVs. They also demonstrate that BEVs with relatively short AER (below 320km (200 miles) are more likely to be adopted as second household cars, providing some guidance as to which classes of cars manufacturers might focus on producing in the early market.

To put these findings into context, Table 9 shows currently available models of BEV in the UK in the most common consumer car segments, the Supermini, Small family, Large family and Crossover vehicle classes. The electric car consumer website 'NextGreenCar.com' lists a total of seven BEV models in these four classes, the specifications of the base variants of these models are outlined in the table below.

Table 9: Specifications of models of BEV currently available (2018) in the UK (OTR = "On the road")

Model	Class	Base variant	Battery size	AER (km; miles) [6]	OTR price (£)
BMW i3	Supermini	120Ah Auto	42.2 kWh	359 (223)	£31,680.00
SMART forfour EQ	Supermini	Prime premium 60kW Auto 7 kWch	17.6 kWh	154 (96)	£16,915.00
Renault Zoe	Supermini	Dynamique Nav R11080kW Auto	41 kWh	400 (250)	£18,420.00
Nissan Leaf	Small family	Visia 40kWh Auto	40 kWh	375 (235)	£22,790.00
VW e-Golf	Small family	100 kW Auto	35.8 kWh	299 (186)	£29,740.00

[6] Range estimates based on the New European Driving Cycle (NEDC). These were correct at the time of the trials, but as of September 2018, the NEDC was superseded by the Worldwide Harmonised Light Vehicle Test Procedure (WLTP).

Hyundai Ioniq EV	Large family	Electric Premium Auto	28 kWh	278 (174)	£25,345.00
Hyundai Kona EV[7]	Crossover	100kW SE 39kWh 136PS Auto	39 kWh	342 (214)	£29,495.00
Kia Soul EV	Crossover	Electric Car 81.4kW Auto	30 kWh	248 (155)	£25,995.00

The ranges quoted are manufacturers' claimed AERs; real-world range achieved during normal driving will be shorter. For example, the Environmental Protection Agency in the USA reported a real-world range of 200km (125 miles) for the VW e-Golf (VW, 2017), whilst the OEM maximum reported range was 298km (186 miles). It is currently not well understood how Mainstream Consumers interpret 'range'. In the choice experiment, it was made clear to participants that 'range' referred to NEDC type-approval range; estimates of real-world range were also shown in the choice sets. In the TP1 and TP2 questionnaires, however, when answering questions about range, consumers may have interpreted range to mean the maximum OEM-reported range, or they might have interpreted it as the real-world range they can achieve under normal driving conditions.

Taking the view that participants interpreted 'range' to mean manufacturers' reported ranges, then Table 9 shows that, at the time of writing (2018) there were four base model BEVs available in the UK (in the Supermini, Small family, Large family or Crossover classes) with an AER of 240km (150 miles) or more. These were the Renault Zoe, Nissan Leaf, Hyundai Kona EV, and Kia Soul EV. The first three have AERs higher than 320km (200 miles). This would suggest that manufacturers are already producing BEVs with AERs that would appeal to around 60% of Mainstream Consumers as second cars in households and 50% as main cars. However, if a more conservative assumption was made, that participants interpreted 'range' to mean real-world range, then none of the vehicles have sufficient AER to appeal to more than 50% of Mainstream Consumers as main cars. Indeed, only the Renault Zoe and Nissan Leaf have AERs that would appeal to more than 50% of Mainstream Consumers as second cars. This assumption seems more reasonable given that the data in Figure 15 were recorded after participants had had experience of using BEVs. This suggests that although manufacturers are beginning to offer BEVs with AERs that are appropriate for the mass-market as second household cars, they are not yet offering BEVs with AERs appropriate for the mass-market as main cars. However, given the pace of development of BEV AER in recent years it is likely that BEVs with the necessary AERs will reach the market in the near future.

Higher AERs can be achieved by increasing the vehicle battery capacity, but this incurs a greater vehicle cost. Manufacturers must manage this trade-off between cost and AER to maximise demand for their vehicles. If increasing the battery capacity leads to a price increase greater than the willingness to pay for the AER added, then demand for this vehicle will fall. However, it appears that even at today's battery costs, manufacturers are able to price an increase in AER in line with consumer willingness to pay for it. For example, the Hyundai Kona EV is available in standard range and long range variants, with NEDC type approval ranges of 340km and 540km, respectively. The results of the choice experiment show that willingness to pay for this increase

[7] The Hyundai Kona EV is also available in a 64kWh Premium 150kW Auto model with a NEDC range of 339 miles (540 km), excluded here as it is not a base variant of the model.

in range is £3,800, which is comparable to the price difference between these model variants of £4,100 (including VAT). In future, cheaper batteries will enable manufacturers to increase AER for an even smaller price premium, below consumers' willingness to pay, which will lead to increased demand. However, note that at very high AER, increasing AER further is unlikely to be cost-effective, as consumer willingness to pay is so much lower above 480km.

3.4.3 Influence of charging rate on potential BEV adoption

Recharging time of a BEV was rated as either very important or extremely important by 90% of participants. These importance ratings were also found to be predictive of likelihood to adopt a BEV as a second car; those who rated the charge time as important were generally less likely to indicate they would consider choosing a BEV as a second car in the next five years.

As noted in section 3.3.3, previous research indicates that long recharge times are a barrier to PiV adoption (Biresselioglu *et al*., 2018; Kinnear *et al*., 2017). While refuelling an ICEV takes a matter of minutes, recharging a PiV with a depleted battery using a home charger (rated at 2.3kW, 3.6kW or 7.2kW) takes a matter of hours, during which the vehicle is not available for use. To deliver sufficient charge to provide 100km of range to an e-Golf BEV, as used in the Consumer Uptake Trial, would take 9.7 hours using a 2.3kW Mode 2 charger (as supplied to participants in the Consumer Uptake Trial), six hours using a 3.6kW Mode 3 charger, and three hours using a 7.2KW Mode 3 charger.

The effect of recharging time on participants' willingness to consider a BEV was measured after experience of using a BEV (at Time Point 2) using a set of items of the form "Please indicate whether you would consider owning a Battery Electric Vehicle (BEV) as the MAIN car in your household if the charging time required to provide 100 miles of range was: 8, 6, 4, 2, or 1 hours." In each case participants gave a yes/no response, and the set of items was repeated for a BEV as a second car in the household.

The proportion of participants who indicated that they would consider owning a BEV with each of these charge times is shown in Figure 17.

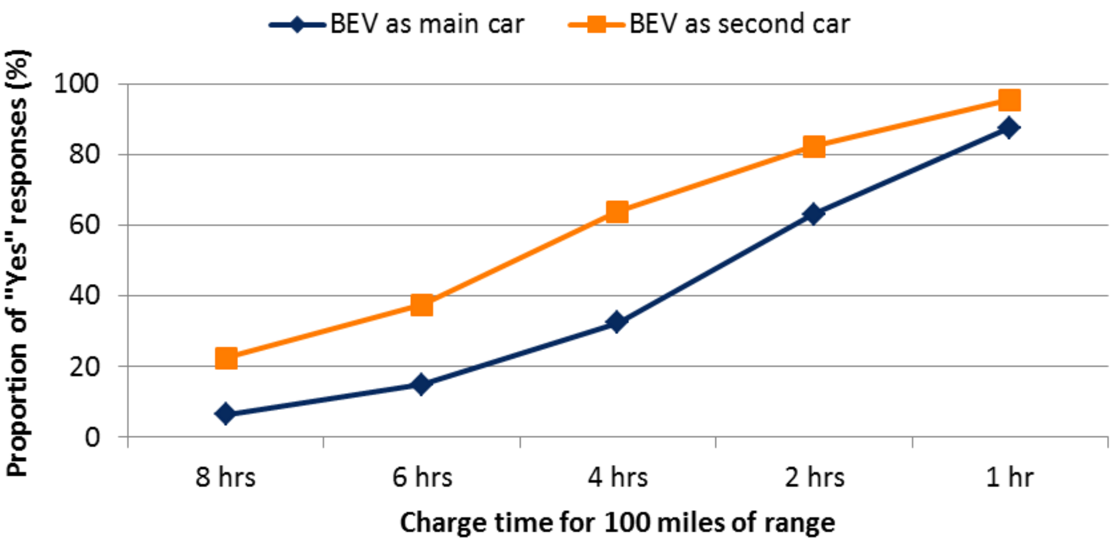

Figure 17: Influence of recharge time on willingness to choose a BEV (measured after experience of using of a BEV)

Willingness to consider owning a BEV increased continuously as recharge time decreased from eight hours down to one hour. Interpolating between data points, the recharge time at which 50% of participants would be willing to consider a BEV as a main car was under three hours, and as a second car was around five hours. This latter charging can readily be achieved using a 7.2kW Mode 3 home charger, while the former is not far short of the rate that can be achieved with the same charger. To appeal to over 90% of participants as either a main or a second car, 100km of range would need to be delivered in one hour of charging. This rate of charge is beyond the capability of present home chargers, but can be delivered by rapid chargers at public locations. Whether it is practical to install a widespread network of public rapid chargers to meet this apparent need remains to be seen.

3.4.4 Influence of public charging infrastructure on potential BEV adoption

3.4.4.1 Destination charging: workplace and public locations

The choice experiment at Time Point 2 investigated WTP for PiVs if access was available to destination charging at work, and/or in public places. The results are shown in Figure 18. Participants were willing to pay an extra £564 for a BEV if there was access to Mode 3 charging at work. Access to public charging increased the extra they were willing to pay to £1,677; access to both increased the extra they were willing to pay to £1,808.

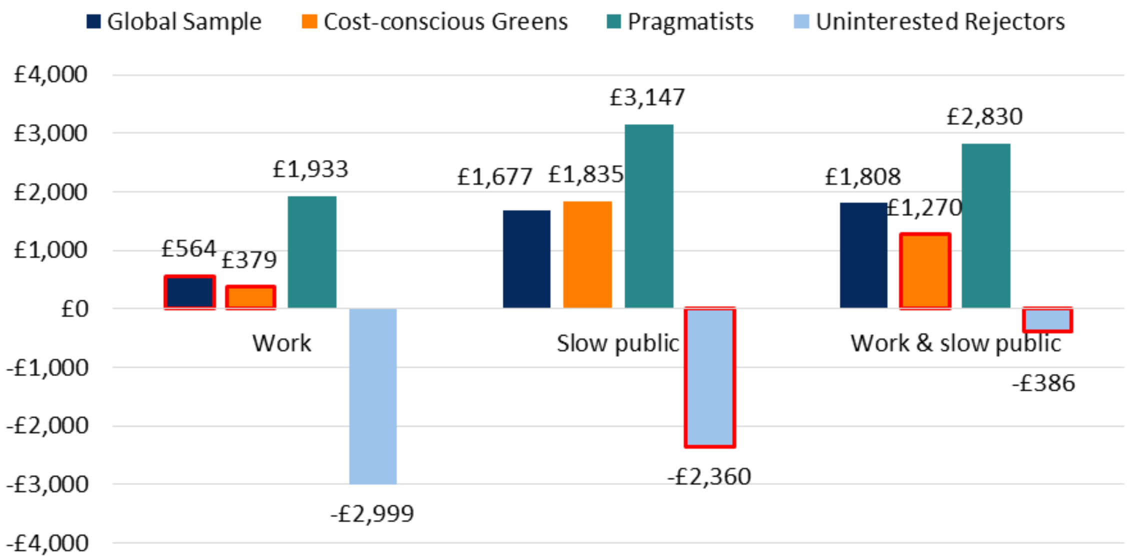

Figure 18: Willingness to pay extra for a BEV if access to work and public destination charging is available (red border means the result is not statistically significant)

A less clear picture emerged when choices were analysed by consumer segment. Pragmatists were willing to pay an extra £1,933 for a BEV if they had access to workplace charging, and over £3,147 extra if they had access to public charging. However, their willingness to pay extra for a BEV if they had access to work and public charging together was less than if they had access to public charging alone. This might be interpreted as Pragmatists perceiving no further utility in having work charging if public charging is already available. A similar pattern was observed for Cost-conscious Greens, except that the overall magnitude of their WTP was lower and the coefficients for access to work charging and work & public charging were not statistically significant. Willingness to pay extra for a BEV if there was access to work or public charging was negative. The utility of destination charging access appeared to become less negative as coverage increased from work only, to public only and work & public, suggesting that these participants recognised the benefits of more charging access. However, the coefficient for public charging access was not significant and neither was that for work & public charging access. Therefore, it is not possible to infer a trend in WTP at different levels of charging access beyond it being highly negative. The reason for this result may be that Uninterested Rejecters, who are characterised by negative attitudes towards PiVs, were conflating the notion of having access to destination charging with the need to use it. Therefore, in the case where charging is available at their workplace, it may be they were interpreting this as needing to charge at work in addition to home, which adds to their perceived inconvenience of owning a BEV.

3.4.4.2 Rapid charging on motorways and major A roads

BEVs might be more appealing as main cars if there were a network of rapid chargers on motorways and major A roads to facilitate journeys longer than the maximum AER of the car. This was investigated (for BEVs) in the choice experiment. Three levels of network coverage were tested: every 20 miles on motorways and major A roads; every 20 miles on motorways and all A roads; every 20 miles on motorways and all A roads, and at a similar frequency to petrol stations on all other road types. However, choice coefficients were very similar at all three levels, suggesting that participants perceived no further utility from increasing the coverage beyond every 20 miles on motorways and major A roads.

WTP for BEVs with access to rapid (Mode 4) public charging was £2,224 at the whole sample level; this was for a rapid public charging network with chargepoints available every 20 miles on motorways and major A roads. WTP values were very similar for denser rapid public charging networks suggesting that participants perceived no further utility from increasing the coverage beyond every 20 miles on motorways and major A roads. Across the whole sample, participants were willing to pay £2,224 extra for a BEV if such a network of rapid chargers was available. This figure was £2,674 for Cost-conscious Greens, £2,421 for Pragmatists, and £1,161 for Uninterested Rejecters.

This finding contrasts with that for PHEVs, where participants were not willing to pay any extra for if there was access to a network of rapid chargers. Such a network is unnecessary for PHEVs, since they can complete longer journeys in ICE mode, but the data suggests participants would be more interested in paying for BEVs if such a network existed.

Note that in the choice experiment the network of public rapid charging locations was assumed to have sufficient charging points at each location that drivers would not have to queue for one. While the results suggest further locations for charging points will not make adoption of PiVs more likely, investment to ensure the number of charging points at each location is sufficient to ensure no queuing may need to keep pace with PiV market penetration.

3.4.5 Influence of personal factors on potential BEV adoption

The Consumer Uptake Trial analysis examined the extent to which willingness to consider a PHEV was correlated with a range of individual and personal factors. Some of these items were in the form of pre-defined scales, while others were combined post-hoc using factor analysis to identify related variables in order to reduce the total number included in the correlation analysis. Details of this process are given in the Technical Appendix.

Significant correlations with likelihood to choose a BEV as a main or second car are shown in Table 10. There appears to be a pattern in the correlation with likelihood to choose a BEV as a second car, in that three variables associated with pro-environmental motivations were each associated with higher likelihood[8]. 'Green' identity was also positively correlated with likelihood to choose a BEV as a main car, though other variables associated with pro-environmental motivations were not. Interest in new technology and careful driving style were also positively correlated with likelihood to choose a BEV as a main car, while age was negatively correlated, indicating lower appeal for older participants.

Table 10: Significant correlations with likelihood to choose a BEV

Main or second car	Variable	Correlation coefficient r	Probability *p*
BEV as a main car	The 'interest in new technology' factor	0.23	0.003
	Age (of participant)	-0.19	0.014
	The 'green' identity factor	0.17	0.029
	Careful driving style	0.17	0.028
	Item "I tend to buy the same type/size of car (e.g. small car, family estate)"	-0.15	0.049
BEV as a second car	Gender	0.19	0.032
	The 'green' identity factor	0.24	0.009
	The 'belief in environmental threats' factor	-0.18	0.047
	Item "Most people I know do their bit for the environment these days"	0.18	0.048
	Weekend mileage	0.23	0.012

All of these associations were small effects according to Cohen's (1988) criteria for effect size. All of them appear to be plausible associations, but taken together they do not amount to a coherent picture of a potential BEV adopter, except for the evidence that pro-environmental motivations may be involved. With this exception we conclude that personal-characteristic factors are not strong predictors of willingness to consider a BEV.

None of the attitudinal items included in the TP2 questionnaire were significantly associated with willingness to consider a BEV, although many attitudes were more positive after the experience of use (see next section). The expression of more positive attitudes following experience does not necessarily translate into increased likelihood to consider a BEV, as demonstrated in previous research (Skippon *et al.*, 2016).

Regression models developed from these predictor variables are discussed in the Technical Appendix.

[8] For the "belief in environmental threats" factor, a person with a low score believed the environment is under threat but that people can do something about it; a person with a high score thought that threats to the environment have been exaggerated and that individuals have little impact on the environment.

3.4.6 Attitudes towards BEVs

Attitudes towards BEVs in general became more positive after the experience of using one. The attitudes with the most consistent and substantial increase in positivity were related to vehicle performance (acceleration, smoothness when cruising, etc.). Some attitudes remained unchanged after the experience of using a BEV: these were attitudes relating to environmental benefits, cost-related attitudes, and attitudes about charging and range. Note that the expression of more positive attitudes following experience does not necessarily translate into increased likelihood to consider a BEV, as mentioned in the previous section.

Participants were more positive about BEVs than PHEVs with regards to their environmental benefits, performance and running costs. BEVs were, however, rated as less likely to meet participants' travel needs than PHEVs.

At the consumer segment level, it was observed that Uninterested Rejecters were consistently more negative about BEVs (and PHEVs) than Cost-conscious Greens and Pragmatists, and expressed the greatest concerns about adapting to charging. Pragmatists tended to have mixed views, but a similar level of concern over adapting to charging. Cost-conscious Greens, on the other hand, were the most positive about BEV attributes and were less concerned about adapting to charging.

Findings from the choice experiment showed that overall, there were underlying positive attitudes towards BEVs for all consumer segments. Values of the 'unobserved factors' in the choice experiment[9] showed that there was no inherent net negative bias against battery electric technology, i.e. the positive factors strongly outweighed the negative. This is likely to be largely due to the value the participants placed on the convenience of being able to charge at home, which offers a significant benefit over ICEs. Were this trial and choice experiment to be carried out with car owners who did not have access to home charging, it is probable that the value of the unobserved factors for BEVs would be lower.

3.4.7 Evaluations of BEV performance

Participants' evaluations of dynamic and cruising performance in this study were recorded using the Borg CR-10 scale (as used by Skippon *et al*., 2016) which is designed for measurement of intensity of perception of stimuli. Significant differences between the performance ratings of BEV, PHEV and ICEV were identified; the mean performance scores for each vehicle type are presented in Table 11 below.

The analysis showed that the BEV was rated higher on all dynamic and cruising performance attributes than both the ICEV and the PHEV, except the attribute "sportiness" in which it was rated lower than both the PHEV and ICEV. On perceived safety it rated higher than the ICEV and lower than the PHEV; in terms of ride comfort it rated slightly higher than the PHEV, both higher than the ICEV; in terms of enjoyment, the BEV and PHEV were rated the same, and substantially higher than the ICEV.

[9] See Technical Appendix for a full explanation of the unobserved factors.

Table 11: Mean vehicle performance scores measured using a Borg CR-10 Category-Ratio 12-point non-linear scale ranging from 0-10; statistically significant differences identified for all measures

Performance measure	Mean score		
	BEV	PHEV	ICE
Acceleration 0-20	9.21	8.40	7.02
Acceleration 30-50	8.67	8.16	6.97
Acceleration 50-70	8.17	7.95	7.09
Responsiveness	9.21	8.44	6.97
Cruising noise	3.49	4.23	4.95
Stationary noise	2.45	2.90	3.69
Sportiness	3.05	5.69	5.45
Smoothness	9.64	8.88	8.08
Power	8.81	8.49	7.30
Safety	9.29	9.51	9.09
Comfort	9.38	9.32	8.74
Enjoyment	9.02	9.01	7.59
Performance	9.20	9.04	7.86

There were no significant differences between the Cost-conscious Green, Pragmatist, and Uninterested Rejecter segments in mean ratings of BEV performance, on any attribute.

There were significant differences in ratings for several attributes between those who stated they were likely to choose as BEV as a main car in the next five years and those who were not. The former rated acceleration from 0-20mph, responsiveness, comfort, enjoyment, and overall performance higher than the latter. In the equivalent comparison for a BEV as a second car in the next five years, those who stated they were likely to choose one rated both enjoyment and overall performance higher than those who did not.

These results present a convincing picture that the driving experience with a BEV is rated more highly than that with a PHEV, and substantially more highly than with an ICEV. This suggests that were the AER, cost, and recharge time barriers with BEVs to be addressed to Mainstream Consumers' satisfaction, BEVs could have a considerable advantage over PHEVs and ICEVs.

3.5 Financial influences on PiV adoption

This section summarises findings relating to the influences of purchase cost, financial incentives, running costs, and depreciation rates on potential PiV adoption.

3.5.1 Influence of purchase cost on potential PiV adoption

When asked to rate the importance of purchase price when considering a PHEV, 35.5% of participants rated it extremely important, and 49.5% rated it very important. Similar patterns were seen for BEVs; with 37.5% rating purchase price as extremely important and 50.5% as very important, and there were no significant differences between the BEV and PHEV ratings. This does not necessarily reflect a specific importance for BEVs or PHEVs, since cars in general are amongst the costliest products that consumers buy. It is consistent with the findings of the Department for Transport (DfT)'s annual Public Attitudes to Electric Vehicles survey, in which over 80% of participants in 2014, 2015, and 2016 selected purchase cost as one of the three cost factors they consider when purchasing a car (DfT, 2016), making it the highest scoring item (the next highest, in order, were fuel/recharging cost, insurance, and then maintenance).

Purchase price was also a vehicle attribute in the choice experiment. Figure 19 shows the choice coefficients for purchase price for the global sample and by ECCo segment. Separate coefficients were not calculated for PHEVs and BEVs; these data give an indication of the value Mainstream Consumers attach to PiVs in general.

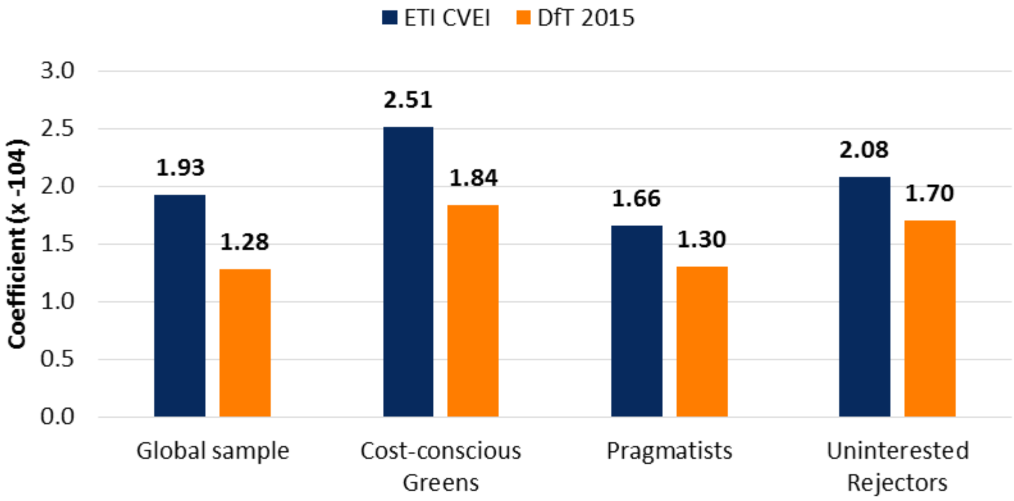

Figure 19: Purchase price choice coefficients for the global sample and individual ECCo segments, derived from the ETI CVEI uptake choice experiment, compared with the DfT 2015 survey results

A larger coefficient signifies greater price sensitivity. Cost-conscious Greens had the largest coefficient so were the segment most sensitive to vehicle purchase price. The coefficients measured in the Consumer Uptake Trial are compared with the equivalent coefficients reported in the choice experiment carried out by Element Energy for the DfT (2015). Coefficients measured in the Consumer Uptake Trial were larger than in the previous DfT study, indicating a generally higher sensitivity to purchase price, but the relative pattern across segments was similar.

3.5.2 Influence of financial incentives on potential PiV adoption

The importance of PiV cost can also be seen in terms of the positive impact of financial incentives on reported likelihood to adopt. When presented with a range of alternative ULEV benefits, a government grant towards the purchase price was found to yield the highest average likelihood to adopt a BEV or PHEV (4.1 on a five-point scale); this was the case for the global sample and for each consumer segment. The Stage 1 literature review found that PiV owners typically do not state purchase price incentives as the reason for adopting a PiV, but that most indicated they would not have adopted without an incentive (Kinnear *et al*., 2017). A positive relationship between financial incentives and PiV uptake is often cited, although direct causal relationships are difficult to prove and impact varies widely (e.g. Kinnear *et al*., 2017; Hardman, Chandan, Tal & Turrentine, 2017). At least in terms of stated likelihood to choose, this study shows evidence that financial incentives can have a positive impact.

3.5.3 Influence of running cost savings on potential PiV adoption

When asked to rate the importance of running costs when considering purchasing a BEV or PHEV, 84% of participants responded either very important or extremely important in each case.

In the choice experiments, participants as a whole were willing to pay £4.7 extra for a PiV for every £1 saved per year in running costs. This implies that participants would accept a payback time of 4.7 years for running cost savings to match an initial purchase price premium. Cost-conscious Greens were willing to pay £5.3 extra for every £1 saved per year, Pragmatists £4.7 extra, and Uninterested Rejecters £4.5 extra. Despite being the most sensitive to purchase price, Cost-conscious Greens were found to accept the longest payback period. Thus, although Cost-conscious Greens were the most price-sensitive segment at the point of purchase, they were willing to pay the most extra in order to achieve running cost savings. This suggests a general sensitivity to costs, and also perhaps a willingness to retain vehicles for longer once purchased.

The price of fuel (including petrol, diesel and electricity) can confound estimates of WTP for running cost savings (Kinnear *et al*., 2017). Such a bias can be observed through comparison of the current findings with those from the previous survey for DfT (Element Energy, 2015). In 2015, WTP for running cost savings was found to be £7 per year (i.e. a payback period of 7 years), significantly higher than the £4.7 per year observed in the current study. This difference is attributed to the unusually low petrol prices in 2015 when the DfT survey was undertaken; consumers may have factored in an expected rise in fuel prices at that time, and therefore a future increase in potential running cost savings and a greater WTP for them.

3.5.4 Influence of rate of depreciation on potential PiV adoption

Relative to ICEVs, BEVs and PHEVs are new to the market and so data on the rate of depreciation of residual value is limited. Some studies have shown that the resale value of PiVs is a concern for a significant number of PiV owners (e.g. Figenbaum, Kolbenstvedt, & Elvebakk, 2014), but purchase price and other cost factors are generally considered as more important motivators for purchasing (e.g. DfT, 2016). The current study found that rate of depreciation had a significant negative relationship with likelihood to adopt a BEV and PHEV. As the expected value of a BEV/PHEV after three years decreased (i.e. as the rate of depreciation increased), the willingness to choose one also decreased. Substantial changes in the reported likelihood to choose were observed, from about 70% being likely or very likely to choose in the next five years if the vehicle lost 40% of its value over three years, to about 5% if that rate of depreciation doubled to 80% in three years (see Figure 20). These large changes suggest that rate of depreciation is a factor in consumers' likelihood to choose BEVs and PHEVs.

Evidence from the literature suggests that PiVs lose a larger proportion of their value than ICEV equivalents, possibly due to continual developments in PiV technology which get filtered through to new models (Biresselioglu *et al*., 2018). This is illustrated by analysis from motor insurance firm 'InsuretheGap.com' in March 2018 which found that the rate of depreciation for BEVs and PHEVs between 2015 and 2018 was generally higher than ICE vehicles (Segal, 2018). The Renault Zoe, Nissan Leaf and Kia Soul EV were found to have the highest rates of depreciation, losing 69%, 63% and 59% of their value, respectively, in the three years between 2015 and 2018. Financial incentives, such as the Plug-in Car Grant in the UK that reduce the upfront purchase price of PiVs may help to offset the rate of depreciation of their residual value, however. Taking the grant into account, the rates of depreciation over three years for the Zoe, Leaf and Soul EV dropped to 60%, 55% and 51%, respectively. These rates are closer to those for the most rapidly depreciating petrol cars: Ford Focus (52%), Vauxhall Astra (47%) and Vauxhall Corsa (47%) (Segal, 2018).

Nevertheless, depreciation rate is still high, and evidence from this trial suggests it could have an impact on consumers' likelihood to choose. This may indicate that vehicle leasing options could be more attractive to consumers than purchasing, since residual value at the end of the lease has no impact on the cost of ownership.

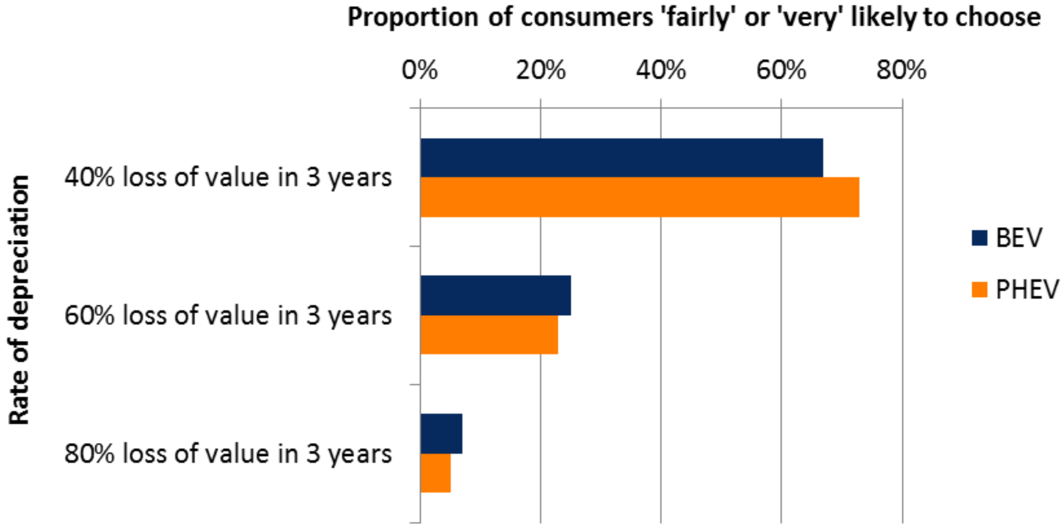

Figure 20: Proportion of participants 'fairly' or 'very' likely to choose a BEV or PHEV in the next five years, by rate of depreciation

3.6 Influence of other incentives on PiV adoption

A range of ULEV incentives are available in the largest PiV markets (such as Canada, China, USA, Norway, The Netherlands and the UK) including access to bus or transit lanes, funding for charging infrastructure, parking incentives and exemptions from road tax (Hardman, 2017). Norway is considered to be the prime example of BEV success (e.g. Berkeley, Bailey, Jones & Jarvis, 2017) and has the greatest PiV market share in Europe (EAFO, 2018). The range of incentives in Norway make it an attractive market environment for BEVs; this includes strong financial incentives in the form of relief from otherwise high VAT and sales taxes, coupled with non-financial incentives such as free access to toll roads and free charging from public chargepoints (Berkeley *et al.*, 2017).

In Norway, as in any other market, it is difficult to isolate effects of specific incentives because consumers are influenced by the entire market landscape. As summarised in the Stage 1 literature review for the CVEI project (Kinnear *et al.*, 2017), robust evaluation of monetary and non-monetary ULEV incentives is challenging since "there are no circumstances in which additional incentives such as EV access to bus lanes or exemption from road tolls has been introduced in the absence of more substantive financial incentives on purchase or running costs" (p.42). Another literature review by Hardman (2017) examined the evidence for the effectiveness of a range of similar benefits including bus lane access, parking incentives, toll road exemption, and tax exemptions. The author concluded that varying incentive types have emerged as being the most important for promoting PiV sales in different studies. The reason for the varied findings is due to the different methods used, the different regions studied, along with differing private motivations of the PiV consumers studied. Isolating the effects of independent incentives is almost impossible.

This trial investigated the stated intentions of Mainstream Consumers in terms of their PiV purchasing preferences, and so direct evaluation of the success (or failure) of varying ULEV incentives was not possible. Nevertheless, the findings from the trial provide useful evidence about the relative rankings of ULEV benefits by Mainstream Consumers; this is valuable for policy and PiV marketing strategies. The range of ULEV benefits explored had varying impacts on likelihood to choose a BEV and PHEV. As noted in previous sections, government grants towards the purchase price were perceived as the most beneficial, resulting in significantly higher likelihood to choose both a BEV and a PHEV compared with all other types of ULEV benefit. This is consistent with the high importance of vehicle purchase price (see section 3.5.1) and the relatively high price of PiVs in the present (2018) market. The next three benefits with the greatest influence on stated likelihood to choose were exemption from car tax (Vehicle Excise Duty), access to free parking and provision of a free home chargepoint. These 'top four' most important incentives were also consistent across the three largest segments: Uninterested Rejecters, Cost-conscious Greens, and Pragmatists. There is some evidence in the literature suggesting parking incentives and exemption from road tax can be effective motivators for adoption (Hardman, 2017). The least effective benefits were discounted access to alternative transport modes (either public transport or hire cars); these yielded the lowest likelihood to choose responses.

Permission to drive in bus lanes was ranked roughly in the middle of the list. In the USA, a similar ULEV benefit in the form of access to High Occupancy Vehicle (HOV) lanes is available, and there is some evidence to suggest this is an effective motivator for prospective PiV owners, but ranking its effectiveness relative to other benefits is challenging due to contradictory findings in the literature (Hardman, 2017). Further, effectiveness of HOV lane access was shown to be dependent on the proximity of such lanes to consumers' homes or whether or not they use them for day-to-day journeys (Hardman, 2017). It is unlikely that bus lane access will be the primary driving force behind Mainstream Consumer decisions to choose a BEV or PHEV, but such benefits could tip the balance for certain individuals, such as those who are less price sensitive (e.g. Pragmatists; see section 6.5), or those who live in areas with high amounts of traffic congestion (e.g. Bjerkan, Nørbech & Nordtømme, 2016). This is likely to apply to other types of incentive as well; while evidence for individual benefits is mixed, and challenging to robustly isolate, the combination of a range of incentives serves to increase attractiveness of the PiV market landscape, and so policy makers are recommended to introduce as many as possible, and ensure they apply at a national level (Hardman, 2017).

4 Potential adoption of PHEVs and BEVs compared

Table 12 provides a comparative summary of the influences on adoption of PHEVs and BEVs discussed in Section 3.

Table 12: Comparison of influences on potential adoption of PHEVs and BEVs

Potential uptake and influences on it	PHEV	BEV
Likelihood to choose as main car in next five years (after experience)	Fairly likely: 31.0% Very likely: 23.0%	Fairly likely: 18.5% Very likely: 8.0%
Likelihood to choose as second car in next five years (after experience)	Fairly likely: 33.1% Very likely: 21.2%	Fairly likely: 32.2% Very likely: 20.4%
Change in likelihood to choose as main car after experience	Fairly likely: -14.2% Very likely: +17.5%	Fairly likely: -4.0% Very likely: +5.0%
Change in likelihood to choose as second car after experience	Fairly likely: -8.3% Very likely: +14.6%	Fairly likely: -2.0% Very likely: +13.0%
AER at which at least 50% would consider owning	Main car: 50 miles (80km) Second car: 50 miles (80km)	Main car: 200 miles (320km) Second car: 150 miles (240km)
AER at which at least 90% would consider owning	Main car: 100 miles (160km) Second car: 100 miles (160km)	Main car: 300 miles (480km) Second car: 300 miles (480km)
Recharge time for 100mi range at which 50% would consider owning as a main car	~ 4 hours	~ 3 hours
Recharge time for 100mi range at which 50% would consider owning as a second car	~ 6 hours	~ 5 hours
Willingness to pay extra for vehicle if access available to workplace charging	No significant value	£564
Willingness to pay extra for vehicle if access available to public charging	No significant value	£1,677
Willingness to pay extra for vehicle if access available to workplace and public charging	No significant value	£1,808
Willingness to pay extra for BEV if access available to rapid charging every 20 miles on motorways and major A roads	Not tested for PHEVs	£2,224
Change in attitudes after experience of use	Generally became more positive after experience, particularly those related to vehicle performance; attitudes relating to environmental benefits, affective attitudes towards PHEVs, cost-related attitudes, attitudes towards reliability of PHEVs, and travel needs were unchanged; attitudes relating to independence from oil became more negative.	Generally became more positive after experience, particularly those related to vehicle performance; attitudes relating to environmental benefits, affective attitudes towards BEVs, cost-related attitudes, attitudes towards reliability of BEVs, and travel needs were unchanged.
Evaluations of dynamic and cruising performance	Rated higher on all dynamic and cruising performance attributes than the ICEV, but lower than the	Rated higher on all dynamic and cruising performance attributes than both the ICEV and the PHEV,

Potential uptake and influences on it	PHEV	BEV
	BEV except for the attribute "sportiness" in which it was rated higher.	except the attribute "sportiness" in which it was rated lower than both the PHEV and ICEV. On perceived safety it rated higher than the ICEV, lower than the PHEV; in terms of ride comfort it rated slightly higher than the PHEV, both higher than the ICEV; in terms of enjoyment, BEV and PHEV were rated the same, both substantially higher than the ICEV.
Proportion 'fairly' or 'very' likely to choose in next five years if depreciation rate = 40% in 3 years	73%	67%
Proportion 'fairly' or 'very' likely to choose in next five years if depreciation rate = 60% in 3 years	23%	25%
Proportion likely to have a PHEV/BEV in the household if government grant towards purchase was available	72%	78%
Proportion likely to have a PHEV/BEV in the household if exemption from Vehicle Excise Duty was available	69%	67%
Proportion likely to have a PHEV/BEV in the household if access to free parking was available	64%	67%

5 Consumer segments' potential adoption of PHEVs and BEVs compared

5.1 Summary of ECCo segments' responses

5.1.1 Cost-conscious Greens

Cost-conscious Greens were the most environmentally-conscious segment, and had an average enthusiasm for new technology. Their annual mileage was average, as was their frequency of journeys over 80km. They tended to be young, on average incomes, and had two defining characteristics: strongly pro-environmental attitudes, and, despite their medium incomes, a focus on keeping costs down. The first characteristic was associated with positive attitudes to PiVs, while the second was associated with relatively high interest in fuel economy. Their expressed likelihood to choose a BEV in the next five years was similar to that of Pragmatists, but they were substantially more willing to consider a BEV with a lower range (e.g. 240km, see Table 13) than either of the other segments, even as a main car. This was the case despite them making frequent long journeys, suggesting the influence of their pro-environmental motivations is a strong influence on their willingness to consider PiVs. It may be linked to their cost-consciousness; in the choice experiment they were less willing to pay extra for a BEV with additional range than were the Pragmatists. They were, however, willing to pay extra for a BEV if they knew that a network of public chargers was available; something that perhaps links to their being willing to have a BEV with a shorter range than the other segments. They were rather less interested in PHEVs than the Pragmatist segment, which may be linked to the influence of their pro-environmental motivations, PHEVs perhaps being seen as a less pro-environmental option than BEVs. The patterns in the evidence suggest trade-offs and compromises being made between pro-environmental motivations and motivations to minimise costs.

5.1.2 Pragmatists

Having an average income, with an interest in reducing vehicle running costs, pragmatists also tended to be young, though more likely to be male than female. They had average incomes, with an interest in reducing vehicle running costs. They had average annual mileage, but were the most frequent makers of journeys over 80km. Attitudinally they had average interest in new technology and cars. They reported enjoying driving and somewhat agreed that cars indicate status, but also had some pro-environmental motivations and valued independence from oil. Pragmatists were the segment most likely to choose a PHEV in the next five years, which can be seen perhaps as a pragmatic choice of vehicle, offering reduced running costs without compromising on other aspects of utility. They were the segment least willing to consider a BEV as a main car if its AER was shorter (240km), though they were substantially more interested if its range was longer (480km), and they were the segment willing to pay the most extra for BEV per km of extra range. Pragmatists were also the segment that would pay the most extra for a BEV if they knew that workplace charging (£1,933) or public charging (£3,147) was available. This pattern of responses differs from Cost-conscious Greens in that it appears to be driven rather more by practical, functional considerations. In the early market they will prefer PHEVs and are unlikely to choose BEVs, especially as main cars, while AER is limited. In the later market though, as BEV AER increases, they are likely to become more willing to include BEVs in their choice sets; especially if they perceive that workplace and public charging networks will be available.

5.1.3 Uninterested Rejecters

Uninterested Rejecters tended to be somewhat older than participants in the other segments, were split approximately 50/50 between males and females, and were on lower incomes. They tended to have average annual mileage, and were the least frequent makers of journeys over 80km. Attitudinally they were neutral about the environment, feeling a moral obligation to reduce greenhouse gases but not seeing this as a priority. They did not report particularly liking cars or driving but did recognise a strong link between cars and status. They were relatively uninterested in new technology, did not see benefits in changing from hydrocarbon fuels. They have negative attitudes to the environment, and tended to have negative attitudes to PiVs. Uninterested Rejecters were the segment that reported the least likelihood of purchasing a PiV in the next five years – with one exception, a BEV as a second car, where their likelihood was similar to that of the other two segments. Their willingness to consider either a PHEV or a BEV as a function of AER was lower than that of the other two segments for lower values of AER, though it converged for the highest values studied (160km for a PHEV, 480km for a BEV). Interestingly, their willingness to pay extra for a BEV with higher AER followed the same pattern as that of Cost-conscious Greens – low when AER was short (160-320 km), indicating a general unwillingness to pay for a BEV with restricted AER, but higher when AER was above 320km, indicating a willingness to pay for extra AER if it met some minimum standard of utility. Their willingness to pay extra for a BEV if there was access to work or public charging was negative – availability of destination charging reduced what they were willing to pay for a BEV. A speculative explanation for this apparently perverse response might be that the presence of a network of destination chargers reinforces a perspective that BEVs have insufficient AER to be useful, so reduces their apparent value. It may also be indicative of an emotionally negative response to BEVs.

5.1.4 ECCo segments compared

An interpretation of the responses of the three segments might be that Pragmatists evaluated PHEVs and BEVs from an objective, functional perspective, based on how far they were perceived as meeting objective travel needs. Cost-conscious Greens additionally evaluated PiVs from a subjective, emotional perspective that was positive; whilst Uninterested Rejecters additionally evaluated them from a subjective, emotional perspective that was negative.

Table 13 provides a comparative summary of the responses of the Cost-conscious Greens, Pragmatists, and Uninterested Rejecters consumer segments.

Table 13: Comparison of responses of Cost-conscious Greens, Pragmatists, and Uninterested Rejecters ECCo consumer segments

Response item	Cost-conscious Greens	Pragmatists	Uninterested Rejecters
Likelihood to choose PHEV as main car in next f years (after experience)	Fairly likely: 29% Very likely: 22%	Fairly likely: 33% Very likely: 28%	Fairly likely: 26% Very likely: 11%
Likelihood to choose PHEV as second car in next five years (after experience)	Fairly likely: 26% Very likely: 21%	Fairly likely: 37% Very likely: 26%	Fairly likely: 30% Very likely: 4%
Likelihood to choose BEV as main car in next five years (after experience)	Fairly likely: 20% Very likely: 10%	Fairly likely: 20% Very likely: 8%	Fairly likely: 16% Very likely: 5%
Likelihood to choose BEV as second car in next five years (after experience)	Fairly likely: 31% Very likely: 23%	Fairly likely: 35% Very likely: 19%	Fairly likely: 29% Very likely: 21%
Proportion willing to consider a PHEV as a main car if its AER was 80km	52%	55%	35%
Proportion willing to consider a PHEV as a main car if its AER was 160km	92%	92%	85%
Proportion willing to consider a PHEV as a second car if its AER was 80km	58%	60%	50%
Proportion willing to consider a PHEV as a second car if its AER was 160km	91%	91%	87%
Proportion willing to consider a BEV as a main car if its AER was 240km	31%	18%	22%
Proportion willing to consider a BEV as a main car if its AER was 480km	92%	95%	93%
Proportion willing to consider a BEV as a second car if its AER was 240km	72%	58%	50%
Proportion willing to consider a BEV as a second car if its AER was 480km	92%	95%	92%
Willingness to pay extra for a PHEV for each additional 1km increase in its AER	£44/km	£25/km	£32/km
Willingness to pay extra for a BEV for each additional 1km increase in its AER (between 160 & 320km)	£14.9/km	£38.7/km	£13.1/km

Response item	Cost-conscious Greens	Pragmatists	Uninterested Rejecters
Willingness to pay extra for a BEV for each additional 1km increase in its AER (between 320 & 480km)	£29.0/km	£38.7/km	£25.8/km
Willingness to pay extra for a BEV if access to workplace charging is available	£379	£1,933	-£2,999
Willingness to pay extra for a BEV if access to public charging is available	£1,835	£3,147	-£2,360
Willingness to pay extra for a BEV if access to workplace and public charging is available	£1,270	£2,830	-£368
Evaluation of PHEV acceleration from 0-20mph	Uninterested Rejecters < Pragmatists < Cost-conscious Greens		
Evaluation of PHEV responsiveness	Uninterested Rejecters < Cost-conscious Greens < Pragmatists		
Evaluation of other performance metrics for BEVs and PHEVs	No significant differences		

6 Discussion of method

This study addressed several limitations with previous research by implementing a controlled trial in which a Mainstream Consumer sample was given direct experience of using a BEV, a PHEV and an ICE control vehicle before exploration of their PiV purchasing preferences and attitudes. This design yielded three key benefits: (1) it explored attitudes to PHEVs as well as BEVs; (2) it avoided the sample bias in other studies whose participants were PiV Innovators, by recruiting a Mainstream Consumer sample; and (3) it reduced bias associated with collecting responses from individuals who are psychologically distant from PiVs, by providing them with real-world experience of using two types of PiV for their everyday driving. For these reasons it provides the most valid picture to date of potential PiV adoption in the UK market.

As with all research, there were a number of limitations with the study. First, participants were only eligible to take part if they had access to private, dedicated off-street parking (typically in the form of a garage or driveway) where installation of a chargepoint was possible. Further, permission from the home owner to install the chargepoint was required, meaning in over 85% of cases this meant that the participants themselves were the home owners. About 8% of the sample lived with their parents, and 6.5% of the sample were tenants. These biases mean that occupiers of houses or apartments without access to dedicated off-street parking were under-represented in the sample. If PiV adoption is to surpass that of conventional ICE vehicles, adoption by households without off-street parking needs to occur as well. This is especially important for the UK government's 2040 air quality target (Road to Zero, 2018), since air pollution is worst in cities where housing without off-street parking is more common than in less urban areas.

The eligibility requirements for the trial also led to under-representation of some other demographic groups, namely households with only one car, households with annual mileage of less than 5,000 miles, and households with annual gross incomes of less than £30,000. This means that caution should be exercised in applying the findings from this trial to those types of households. Arguably, the per household contribution of these groups to emissions at the tailpipe and PiV charging demand may be lower than other households since they only have a single car, and travel fewer miles by car by year. However, the net contribution of this demographic is unlikely to be negligible and so understanding how best to increase PiV adoption in these types of consumer remains important.

The majority of PiV consumer research to date, including the current study, has focused on the adoption of new vehicles. In Q1 of 2018, the SMMT reported over two million used car transactions, compared with approximately 700k new car registrations over the same time period (SMMT, 2018). Of the two million used car sales, only about 1.2% were PiVs. To truly maximise the spread of PiVs in the UK, the barriers and motivators to adoption of used PiVs must also be understood. Issues such as depreciation and battery deterioration will be highly relevant, not just when a PiV is first sold, but at each subsequent sale. This will ensure policy approaches cater for the purchasing habits of the majority of Mainstream Consumers.

In this trial, participants' own vehicles were replaced with the trial vehicles for use with their everyday driving. Where participants owned more than one vehicle, their 'main' vehicle was replaced. Participants were permitted to allow up to one additional driver in their household to drive the vehicles during the trial; no more than one additional driver was permitted due to trial insurance restrictions. Telematics data was collected for all journeys and charges in all vehicles, but classification of the data according to driver in each household was not possible. Instead, journey and charge telemetry are classed per participant, even if particular uses of the vehicle were completed by the 'additional drivers'. This limitation, along with a lack of information on the vehicle usage dynamics within each participant's household, means that there is a gap in knowledge of the impact of PiV adoption on the ways in which different household members use different vehicles in the household.

This study explored the impact of electric range on likely adoption of a BEV and PHEV. Mainstream Consumers' interpretation of range is an area that has received little attention and should be addressed in future research. In the TP1 and TP2 questionnaires, a deliberately simple approach was adopted whereby participants were asked to indicate whether or not they would consider a BEV or PHEV with a given electric range. It was not specified whether this range referred to a realistic real-world figure achievable in everyday driving, or manufacturer reported range estimates (at TP1, pre-experience, participants may have been confused by this distinction). As such, it is possible that some participants took varying interpretations when answering these questions. If a view is taken that consumers interpret range to refer to the manufacturer reported values, then the findings from this study suggest some current models of BEV have a stated AER which would enable them to appeal to at least 50% of Mainstream Consumers (i.e. 200 miles+). However, if a more conservative approach is taken and it is assumed that consumers' interpreted real-world range achievable in normal driving conditions, then there is a larger gap to fill in terms of the current specifications of BEVs meeting the needs of the market. Further research is required to understand how Mainstream Consumers construe range, to aid interpretation of these findings.

To achieve a balance between scientific robustness and project delivery, participants were provided with a four-day experience with each type of vehicle. Increasing the experience to one week or even one month might have increased the validity of the trial, as participants would have had more time to get used to the novel types of PiV. However, analysis of the reported likelihood to choose and attitudes towards PiVs (see section 6.2) showed that the four-day experience was sufficient to result in statistically significant changes in Mainstream Consumer perceptions and stated purchasing intentions of PiVs. This suggests that psychological distance from these vehicles was sufficiently reduced through experience in the trial. It is also notable that this length of experience was greater than previous BEV only trials; for example, Schmalfuß *et al*.'s (2017) 24-hour BEV trial and Skippon *et al*.'s (2016) 36-hour BEV trial.

7 Suggested further research

The findings from the Consumer Uptake Trial suggest several areas for further inquiry. These are shown in Table 14.

Table 14: Suggestions for further research arising from the findings of the Consumer Uptake Trial

Research question	Description
To what extent do PHEVs serve as a "gateway vehicle", promoting future adoption of BEVs?	PHEVs have been described as 'gateway vehicles'. This implies their adoption by Mainstream Consumers serves to familiarise them with the nuances of owning a plug-in vehicle, and in turn increases the likelihood of future adoption of a fully electric, zero-emission BEV. This study confirmed that Mainstream Consumers are more likely to adopt PHEVs than BEVs in the next five years. Research evidence is required on the long-term ownership cycles of PHEVs and BEVs to quantify the extent to which the 'gateway effect' holds true in the UK market. This will help to predict the long-term impacts of PHEVs on emissions, and shape policy surrounding promotion and sale of PHEVs.
How do Mainstream Consumers construe 'range'?	The current study provides further evidence of the importance of BEV range on future adoption, and defines useful thresholds for range which can help to understand uptake of different BEV models. A full understanding of how Mainstream Consumers construe range is still lacking, meaning there may be disparity between consumers' range needs, and the figures communicated by OEMs and other stakeholders.
How do multi-car households use their vehicles, and how does this change with PiVs?	In the current trial it was not possible to segregate vehicle usage data between different drivers in each household. In multi-car households, replacement of one vehicle with a PiV may change the household vehicle usage dynamics. Research is required to quantify such changes in Mainstream Consumer households. This will enable more accurate prediction of PiV charging demand across different types of household.
What conditions are necessary to increase adoption of PiVs by consumers without off-street parking?	A large proportion of the UK population live in housing without access to private off-street parking, meaning installation of a home chargepoint is problematic. Some solutions have been proposed for this problem, for example, increasing charging infrastructure in the workplace, and installing resident charging infrastructure in street lamp-posts. However, research is required with these types of Mainstream Consumer to understand the likely success of these interventions.
What are the barriers and motivators to adoption of used PiVs?	The majority of mainstream vehicle consumers in the UK purchase used cars; the barriers and motivators for purchasing a used PiV may differ to those understood to affect new PiV purchases. For example, there may be greater importance on issues surrounding loss of range and rate of depreciation. To fully understand the barriers to the complete electrification of transport, research is required to understand these issues.

Research question	Description
Qualitative exploration of reasons behind inter-segment differences in PiV attitudes to adoption following experience	The results indicate that for PHEVs in particular, the effect of experience with a vehicle can have a different impact on the likelihood to choose one in future. The change from pre- to post-experience suggested that members of the Pragmatists segment became more likely to choose a PHEV as a main car in the next five years; whereas members of the other two segments became less likely. This effect requires further investigation through qualitative research to explore the in-depth reasoning that underlies this pattern. This would provide further insight on the motivations of different types of consumers when considering PiVs in future.
Investigation of mainstream consumer willingness to lease PiVs	Willingness to pay in this trial was explored in terms of the purchase price of the vehicle. Many new cars in the market today are available to lease, and leasing is likely to remain a common acquisition model in the future. As such, future research into consumers' attitudes to PiV leasing options, and how that might impact adoption, should be undertaken to fill this gap.

8 Conclusions

Based on analyses and interpretation of the data emerging from the Consumer Uptake Trial, the following conclusions can be made:

- PHEVs are likely to be adopted more quickly in the mass market than BEVs, with 23% of participants reporting being very likely to choose a PHEV as a main car in the next five years, versus only 8% for a BEV. However, their AER needs to increase to around 50 miles (80 km) to achieve mass-market appeal. The likely prevalence of PHEVs in the next decade has implications for the impact of charging on the energy system, since PHEVs have smaller battery capacity and therefore shorter charging times than BEVs.
- BEVs will be adopted more slowly, especially as main cars. AER of 200 miles (320 km) would enable them to appeal to 50% of Mainstream Consumers; AER of 300 miles (480 km) would enable them to appeal to over 90%.
- BEVs have higher appeal as second cars in households where the range requirements are less. BEV models with ranges that would appeal to 50% of Mainstream Consumers as second cars in households will be present in the market in increasing numbers in the near future.
- The appeal of PiVs in this study appears greater than in previous studies. This may be due to differences in the specific question(s) asked, differences in sampling (for instance, the use of a stratified sample in the Consumer Uptake Trial), and greater awareness of PiVs in the population now or more desirable models of PiVs appearing on the market.
- Mode 2 charging rates are insufficient for mass market uptake. Mode 3 7.2kW chargers would offer sufficient charging rates for 50% of Mainstream Consumers to be likely choose a PHEV or a BEV as a second car. For BEVs to appeal to over 90% of participants as either a main or a second car, charge rates which can deliver 100km of range in one hour are required. This rate of charge is beyond the capability of present home chargers, but can be delivered by rapid chargers at public locations.
- Mainstream Consumers would be willing to pay extra for BEVs if they knew that they will be able to access workplace charging or public charging networks. However, they would not be willing to pay extra for PHEVs if they knew they would have similar access to networks.
- Mainstream Consumers are also likely to be willing to pay more for BEVs if they know that they will be able to access rapid chargers every 20 miles on motorways and major A roads. However, a wider network of rapid chargers appears unnecessary.
- Among a range of potential incentives to support PiV uptake, those with direct financial impacts were rated highest in importance by participants. A grant towards purchase price was rated most important, likely reflecting the relatively high prices of PiVs in the present (2018) market.
- Personal and personal-situational variables are not good predictors of either BEV or PHEV uptake.
- Mainstream Consumers can be segmented by attitudinal and behavioural variables. A “Cost-conscious Greens” segment (26% of the trial sample) are more interested than average in adopting PiVs, particularly BEVs, while an “Uninterested Rejecters” segment (19% of the sample) are substantially less interested. Pragmatists (50% of the sample)

were meanwhile focused on functional attributes but could be persuaded to adopt PiVs. These differences suggest that policy or market incentives cannot treat Mainstream Consumers as a homogeneous mass market.

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T: +44 (0) 1344 773131
F: +44 (0) 1344 770356
E: enquiries@trl.co.uk
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Authors

The following individuals have contributed to the development of this report:

George Beard (TRL), Lauren Durrell (TRL), Jonathan Kent (TRL), Stephen Skippon (TRL), Neale Kinnear (TRL), Hannah Al-Katib (TRL), Tristan Dodson (Element Energy), Alex Stewart (Element Energy), and Jillian Anable (University of Leeds).

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Table of Contents

List of Figures

List of Tables

Abbreviations

AC	Alternating Current
ACT	Active Cylinder Technology
AER	All Electric Range
ANOVA	Analysis Of Variance
ASC	Alternative Specific Constant
BEAMA	British Electrotechnical and Allied Manufacturers' Association
BEV	Battery Electric Vehicle
BP	British Petroleum
CAN	Controller Area Network
CCG	Cost-conscious greens
CO2	Carbon Dioxide
CVEI	Consumers, Vehicles and Energy Integration project
CYC	Charge Your Car
DA	Discriminant Analysis
DC	Direct Current
DSG	Dual Shift Gearbox
DVLA	Driver and Vehicle Standards Agency
ETI	Energy Technologies Institute
EV	Electric Vehicle (including all plug-in vehicles)
GPS	Global Positioning System
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
ICE	Internal Combustion Engine
ID	Identification
ISO	International Organization for Standardization
KG	Kilogram
Km/h	Kilometres per hour
kW	Kilowatt
kWh	Kilowatt hour
MDSI	Multi-Dimensional Driving Style Inventory
MPH	Miles Per Hour
MPV	Multi-Purpose Vehicle

NEDC	New European Driving Cycle
Nm	Newton metre
NPA	Newcastle Personality Assessor
NTS	National Travel Survey
OBD	On-Board Diagnosis
ONS	Office for National Statistics
PCP	Personal Contract Purchase
PHEV	Plug-in Hybrid Electric Vehicle
PiV	Plug-in Vehicle
PS	Pferdestrke
PTQ	Pre-Trial Questionnaire
RCD	Residual Current Device
SMMT	Society of Motor Manufacturers and Traders
SOC	State of Charge
TRL	Transport Research Laboratory
UK	United Kingdom
ULEV	Ultra-Low Emission Vehicle
VAT	Value Added Tax
VED	Vehicle Excise Duty
VGFS	Volkswagen Group Financial Services
VKT	Vehicle Kilometres Travelled
VW	Volkswagen
WTP	Willingness-to-Pay

Glossary

Item	Description
Affective attitudes	Attitudes relating to the emotions and feelings evoked by owning and using a vehicle.
Analytical tools	The quantitative part of the Analytical Framework, used to calculate values for the quantitative Success Metrics.
Analytical framework	Overarching Multi-Criteria Assessment (MCA) framework applied to each narrative to help understand 'what good looks like' for mass market deployment and use of ULEVs and the potential trade-offs, via the assessment of the Success Metrics. This framework comprises the analytical tools which are used to help inform the quantitative assessment as well as a set of supporting qualitative assessment metrics.
Battery Electric Vehicle	A vehicle powered solely by a battery, such battery being charged only by a source of electricity external to and not part of the vehicle itself.
Consumer	A private, domestic, individual driver who owns or leases his/her own vehicle.
Demand management	The modification of one or more energy consumers' demand for energy through various methods including financial incentives, time of use tariffs and/or education.
Early adopter	Those who adopt after Innovators and only after awareness, knowledge, and positive attitudes have diffused to them from Innovators. Times to adoption are between one and two standard deviations before the mean time to adopt.
Innovators	People high in innovativeness who are first to adopt new technology. They are sources of awareness, knowledge, and positive attitudes towards the innovation whose times to adoption are greater than two standard deviations before the mean time to adopt
Instrumental attitudes	Attitudes relating to general practical or functional attributes of a vehicle.
Mainstream consumer/adopter	All those whose adoption of technology has been influenced by diffusion of awareness, knowledge, and positive attitudes from people who have already adopted the innovation (i.e. everyone except innovators)
Plug-in Hybrid Electric Vehicle	A vehicle that is equipped so that it may be powered both by an external electricity source and by liquid fuel.

Psychological Distance	The cognitive separation between the self and objects or instances. In this context it refers to the closeness of the consumer to PiVs. Where psychological distance is greater, perception and attitudes are more abstract and unreliable.
Self-identity	Perception of oneself including how one sees oneself and how one perceives others see one.
Symbolic attitudes	Attitudes relating to the symbolic meaning and symbolic value of a vehicle
Symbolic meaning	What the vehicle says to others about its user
Symbolic value	The value conferred on a vehicle by virtue of its symbolic meaning

Appendix A Detailed method

This Appendix provides a full description of the method employed for the Consumer Uptake Trial. A summary of this method is provided in the accompanying Summary Report.

A.1 Overview of experimental design

The trial was designed to provide a sample of mainstream ICE consumers' with direct experience of using a BEV and a PHEV in their everyday life. By definition, the sample of participants was unfamiliar with these vehicle types. A total of 200 mainstream consumers (see section A.2) were given direct experience of using three types of vehicle for four days each:

- A **Battery Electric Vehicle (BEV)**: VW e-Golf hatchback (5dr, 2017 model)
- A **Plug-in Hybrid Electric Vehicle (PHEV)**: VW Golf GTE hatchback (1.4 TSI 5dr, 2017 model), and
- An **Internal Combustion Engine (ICE) vehicle** for control purposes: VW Golf hatchback (1.4 TSI DSG GT Edition 5dr, 2016 model)

Four days' experience was substantially longer than the 36 hours' experience received by participants in the previous BEV trial of Skippon, Kinnear, Lloyd, and Stannard (2016).

The trial vehicles replaced participants own vehicles, which were stored with the research team for the duration of the trial. To control for order effects, the order in which the participants experienced the three vehicles was counterbalanced using a Latin square design in which, across the participant pool, each combination of ordinal positions was repeated a similar number of times. The day of the week on which participants started their trial was varied using a 'Trial Block' design (see section A.5) which meant participants' experience of the vehicles on weekdays and weekends was also balanced across the trial.

The three variants of the Volkswagen Golf were selected because the Golf was the only vehicle model that was commercially available at the time of the study with all three drivetrains (ICEV, BEV and PHEV). Since the three models were similar in functional capability (other than the drivetrain differences) and as closely as possible matched in trim (see section 0), this minimised the risk of observing differences in behaviours and attitudes between vehicle types that were associated with vehicle characteristics other than the powertrain configuration.

To ensure participants were able to adequately and safely charge the BEV and PHEV during the four-day periods, each participant was provided with a Mode 2 charging socket (installed on a separate circuit) at their residence.

Data were collected through a series of questionnaires and a choice experiment. The questionnaires included:

- **Recruitment Filter Surveys**: screening questionnaires administered during the recruitment process;
- **Pre-trial questionnaire:** administered following receipt of consent to participate;

- **Time Point 1 questionnaire**: administered approximately 7-10 days before participants collected their first vehicle;
- **Interim questionnaires**: administered during vehicle handovers directly after experience with each vehicle;
- **Time Point 2 questionnaire (including Choice Experiment)**: administered approximately seven days after the return of the final vehicle.

Data were also collected from the vehicles using a telematics data logger to capture information on vehicle journey and charge events (trip duration and distance, vehicle speeds, battery State-of-Charge, etc.).

Participants received £200 compensation for participation in the trial (see section A.4) and were also entered into a prize draw for a chance to win £2,500. At the end of the trial, they were also given the option to keep the charge point or have it removed (seven of the 200 participants requested to have theirs removed). The study was approved by the TRL Ethics committee.

An overview of the trial method is provided in Figure 1.

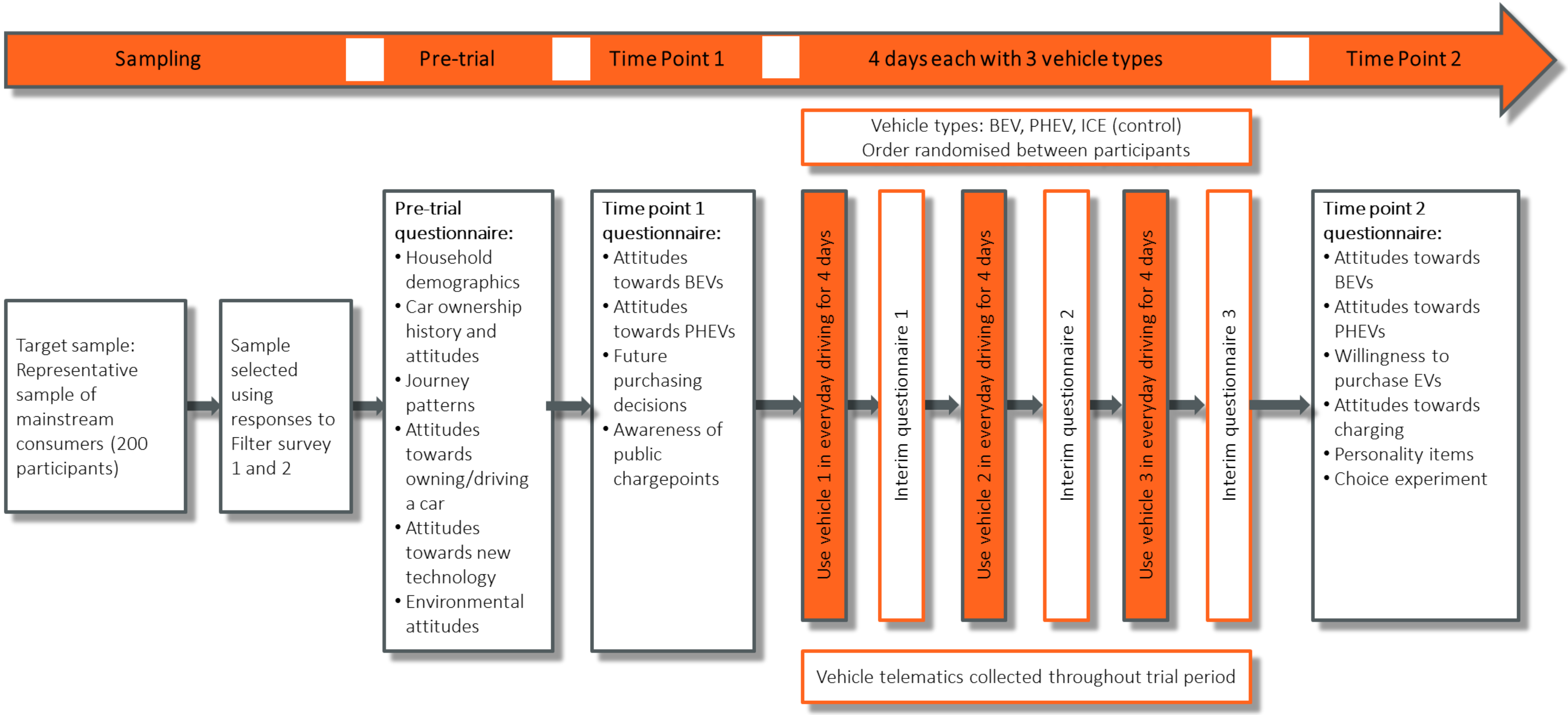

Figure 1: Overview of Consumer Uptake Trial method

A.2 Research questions

The research questions addressed by the Consumer Uptake Trial are shown in Table 1.

Table 1: Research Questions

	Consumer Uptake Trial research questions	How they were addressed	
		Questionnaires	Choice Experiment
1	How much does the potential All Electric Range (AER) of a BEV or PHEV influence willingness to consider adoption?		✓
2	How much does the potential purchase price of a BEV or PHEV influence willingness to consider adoption?		✓
3	How much does the potential running cost saving associated with using a BEV or PHEV influence willingness to consider adoption?		✓
4	How much does the recharge time associated with a BEV or PHEV influence willingness to consider adoption?		✓
5	How much are personal characteristics (personality, innovativeness, liminality, self-congruity, driving style, demographic variables, etc.) predictive of willingness to consider adoption of a BEV or PHEV?	✓	
6	How much are personal-situational variables (e.g. income, mileage) predictive of willingness to consider adoption of a BEV or PHEV?	✓	
7	What effect does varying the perceived level of access to public charging stations (e.g. density, type of location, type of charger) have on willingness to adopt BEVs or PHEVs?		✓
8	What effect does convenient access to public transport options for longer journeys have on willingness to consider adoption of a BEV?	✓	
9	What effect does the rate of depreciation of residual value have on willingness to consider adoption of a BEV or PHEV?	✓	
10	What effect does access to additional ULEV benefits (e.g. access to bus lanes, free congestion charge, free parking) have on willingness to consider adoption of a BEV or PHEV?	✓	
11	What other factors might compensate users for lack of long-range mobility sufficiently for them to consider adoption of a BEV?	✓	
12	What effect does convenient access to a long-range vehicle (whether within the household or hired) for longer journeys have on willingness to consider adoption of a BEV?	✓	

A.3 Participants

A.3.1 Sampling strategy

A.3.1.1 Sample size

The sample size for the Consumer Uptake Trial was informed by power calculations based on effect sizes obtained in the previous BEV uptake trial performed by TRL for Shell (Skippon *et al.*, 2016). In that trial, 200 experimental group participants experienced use of a Nissan Leaf BEV for 36 hours, while 200 control group participants experienced use of an equivalent unfamiliar ICE car (Ford Focus diesel) for 36 hours.

Based on the effect sizes observed in this previous study, the target sample for the Consumer Uptake Trial was 200 mainstream vehicle consumers.

A.3.1.2 Sample characteristics

Mainstream consumers were defined as all those whose adoption of technology has been influenced by diffusion of awareness, knowledge, and positive attitudes from people who have already adopted the innovation. This includes all consumers in Rogers' (2003) Diffusion Model segments except for Innovators; that is the Early Adopter, Early Majority, Late Majority, and Laggard segments (see Figure 2).

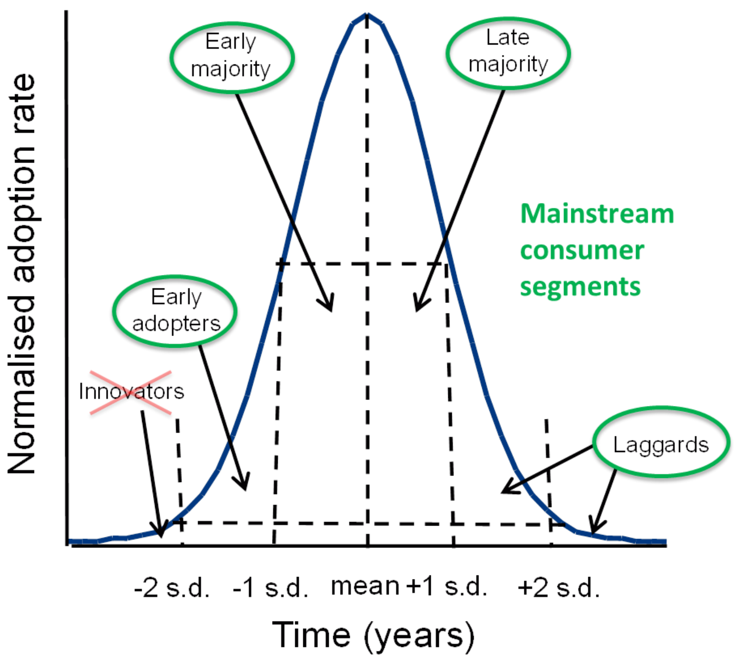

Figure 2: Segments from Rogers' (2003) Diffusion Model which are included in the 'mainstream consumer' population

Innovators were excluded at the recruitment phase. Innovators were defined behaviourally as individuals who currently have, or have had regular driving experience with a plug-in vehicle in the last 5 years, and those who were currently considering acquiring a plug-in vehicle in the next six months. In addition to this, employees of TRL, Cenex, and the ETI were also excluded from the sample due to the possibility that they might have a particular interest in PiVs by virtue of their employment.

The sample was also recruited to be representative of the driving population in Great Britain using a stratified sampling approach based on driving licence data from the Driver and Vehicle Standards Agency (DVSA), and population and travel data from the National Travel Survey (NTS) and the Office of National Statistics (ONS) (see Table 2).

Table 2: Target sample matrix stratified using DVSA, NTS and ONS data

Resident area[1]	Age group[2]	Gender		Total
		Male	Female	
Urban	19-29	14	12	**26**
	30-49	34	30	**64**
	50+	39	32	**71**
Rural	19-29	2	2	**4**
	30-49	6	6	**12**
	50+	12	11	**23**
Total		**107**	**93**	**200**

Participants were recruited from within a 50-mile radius of TRL (RG40 3GA) and Cenex (LE11 3QF), with an approximately equal split between the two trial locations (i.e. 100 participants recruited from around TRL and 100 recruited from around Cenex).

A.3.2 Recruitment

A filtering process was employed to exclude ineligible participants; this is described below, and illustrated in Figure 3.

[1] The 2011 rural-urban classification (RUC2011) from the Office for National Statistics (ONS) was used to define the rural/urban classification:

https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification

[2] 17-18 year olds were excluded to mitigate increased crash risk associated with young and novice drivers.

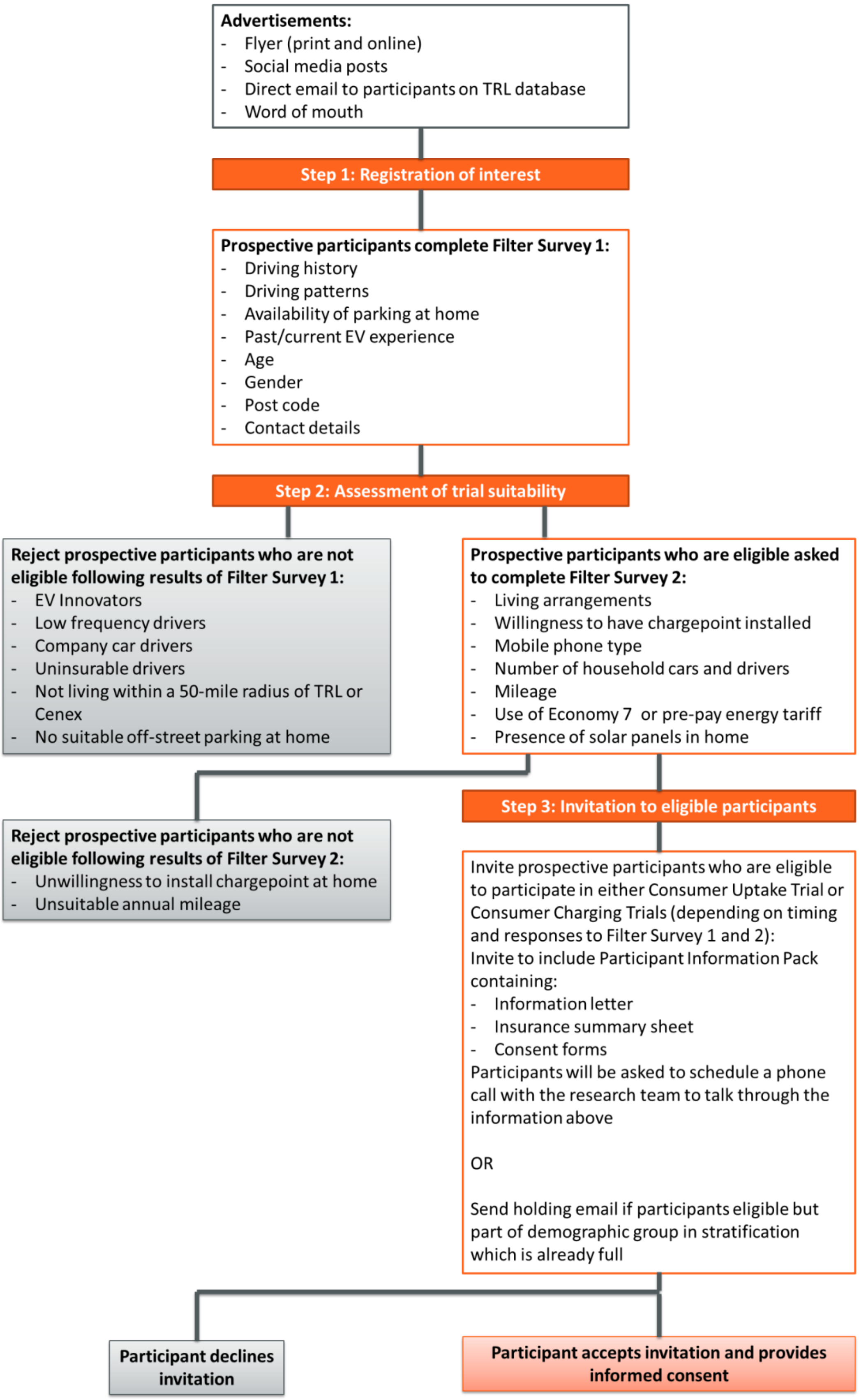

Figure 3: Overview of recruitment process up to the point of trial invitation

The initial stages of the recruitment process were common to both the Consumer Uptake Trial and the Consumer Charging Trials (reported in Deliverable D5.3).

- **Advertise**: A variety of advertisements were published via different channels to reach a wide variety of prospective participants.
- **Step 1**: Interested prospective participants completed Filter Survey 1 to register their interest, using the URL provided in the advertisements.
- **Step 2**: Prospective participants who were eligible (based on responses to Filter Survey 1) were invited to complete Filter Survey 2; a short but more detailed questionnaire to further filter prospective participants and assess suitability specifically for each trial (the Consumer Uptake Trial, and the Consumer Charging Trials – see Deliverable D5.3).
- **Step 3**: Prospective participants who were eligible (based on responses to Filter Survey 2) were invited to participate in the trial. In cases where an eligible prospective participant fit into a stratified category that was already full, they were asked if they would be happy to be kept on a reserve list.

Prospective participants were not informed about the nature of the trial until Step 2 so as to avoid biasing the recruitment towards people interested in low carbon vehicles.

A.3.2.1 Step 1: Registration of interest

Prospective participants were asked to complete Filter Survey 1 (see section A.8). To avoid attracting interest from PiV enthusiasts, in particular Innovators, Filter Survey 1 contained minimal information about the design and aims of the research. The survey provided information about the incentives and the trials' contact email address, and questionnaire items covering essential information to filter out unsuitable prospective participants, including: Innovators, low frequency drivers, company car drivers and uninsurable drivers.

Eligible prospective participants were contacted by email informing them that they might be suitable and inviting them to progress to Step 2. Two reminder emails were sent to prospective participants who did not complete Step 2 in the two weeks after the initial invite email.

A.3.2.2 Step 2: Assessment of trial suitability

Step 2 of the process was used to further assess trial suitability using Filter Survey 2 (see section A.8). Filter Survey 2 contained a more detailed questionnaire to obtain data on living arrangements, practicability of chargepoint installation, smartphone ownership, the number of cars and drivers within the household, annual mileage, and household energy use.

Filter Survey 2 also included an outline of both trials on the cover page to ensure prospective participants could indicate informed interest at this stage in the process. The survey also allowed prospective participants to indicate if they had a preference for participating in either trial (Consumer Uptake Trial or Consumer Charging Trials).

Completion of the Filter Survey 2 questionnaire provided the research team with sufficient information for assessing prospective participants' suitability for the Consumer Uptake Trial:

- **General suitability criteria:**
    - Must live within 50 miles of the TRL or Cenex headquarters

- Must not currently own, have previously owned or had previous regular experience driving a PiV in the last five years
- Must not be considering acquiring a PiV in the next six months
- Must have held a valid UK driving licence for a minimum of two years
- Must have received no penalty points if under 25 OR no more than 3 penalty points if aged 25 and over[3]
- Must not have had an 'at fault' insurance claim in the last three years
- Must be a current car owner
- Must drive regularly (at least once every two or three days)
- Must not have a company car as their main vehicle
- Must not require Class 2 or 3 business insurance for their vehicle (i.e. does not require business travel beyond regular commute to work and occasional trips to external locations, such as for meetings)
- Must have access to off-street parking at a location where a chargepoint could be installed safely
- Must be willing to have a chargepoint installed in a suitable location

- **Other information required for the purposes of sample stratification:**
  - Age group
  - Gender
  - Postcode (for urban/rural classification)
  - Living arrangements (home owner[4], living with parents etc.)
  - Number of drivers in the household
  - Number of cars registered at the household address
  - Contact details (name, email address, and contact number)

[3] According to data from the DVLA, the proportion of drivers with more than 3 points on their licence is 1.7%. New drivers (of whom 70% are aged 17-25 years) are impacted by the New Drivers Act which restricts them to a maximum of 6 points within the first two years of gaining a full driving licence. Introduction of the Act has been associated with a reduction in the proportion of young drivers with penalty points. Approximately 10% of new drivers commit a violation within the first two years of licenced driving; implying that around 90% of drivers under 25 will have no points on their licence. As such, the effect of these insurance conditions on the representativeness of the sample was minimal.

[4] Home owners were preferred over tenants where multiple potential participants were available within sampling categories to ensure they were able to consent to chargepoint installation.

A.3.2.3 Step 3: Invitation to participate

Step 3 in the recruitment process involved inviting eligible prospective participants to participate in the Consumer Uptake Trial, BEV Consumer Charging Trial or PHEV Consumer Charging Trial, depending on their responses to Filter Survey 1 and 2 and the spaces within the target samples for each trial.

Once a prospective participant had been allocated to the Consumer Uptake Trial, they were sent an invitation to participate by email. As part of the invitation to participate, prospective participants were sent a Participant Information Pack containing:

- An information letter providing a description of the trial
- A description of the key terms and conditions of the vehicle insurance policy
- The consent form and a link to a webpage where the consent form can be completed online

A.3.2.4 Exclusion points

In line with ethical practice, participants were free to withdraw from the trial at any time without giving a reason. There were also circumstances where participants were deemed unsuitable by the research team, these included:

- **Uninsurable drivers**
    - All drivers were requested to provide permission for TRL to electronically access their DVLA records to ensure that their licence was valid and met trial insurance requirements in terms of penalty points, violations and time held. Participants who did not meet the insurance criteria were unable to continue in the trial. No drivers failed the DVLA checks.
- **Household unsuitable for installation of chargepoint**
    - Prior to installation of the chargepoint, they checked the property was suitable for safe installation of the chargepoint. Where no safe or suitable installation was possible the participant was unable to continue in the trial. The number of participants who completed each step in the trial process is shown in Figure 4; this includes a record of the number of installations which were not completed successfully, and why.
- **Unsafe or illegal driving**
    - Vehicle familiarisation drives with a TRL or Cenex staff member were completed at vehicle handover (see section A.5). The purpose of these drives was to allow the participant to become familiar with the vehicle. If the participant exhibited behaviours which were unsafe or illegal then this resulted in the researcher terminating the trial for that participant. There was only a single case where the participant withdrew after the familiarisation drive; the participant reported they were not comfortable with the vehicle.

A.4 Participant compensation

Participants received £200 worth of compensation for their participation in the trial. This was administered at different points during the trial so as to ensure participants felt compensated for their time and remained engaged with the trial. The breakdown was as follows:

- £20 Amazon voucher given upon completion of the Pre-trial questionnaire
- £20 Amazon voucher given upon completion of the Time Point 1 questionnaire
- £20 cash given upon return of Vehicle 1
- £20 cash given upon return of Vehicle 2
- £20 cash given upon return of Vehicle 3
- £100 cash upon completion of the Time Point 2 questionnaire

In addition to these fixed rewards, participants were entered into a prize draw for a chance to win £2,500.

A.5 Trial procedure

The trial procedure was standardised to minimise any potential bias resulting from the use of two trial locations (TRL and Cenex). TRL ran a training workshop with all vehicle handover staff (including those from TRL and Cenex) prior to commencing the trials which included specific training on the vehicles from VW representatives, a full safety briefing, and training on how to brief participants and manage vehicle handovers. A standardised set of handover documents was also produced, which included a protocol for staff to follow.

The various stages of the trial procedure are illustrated in Figure 4; the number of participants who completed each step are shown in parentheses.

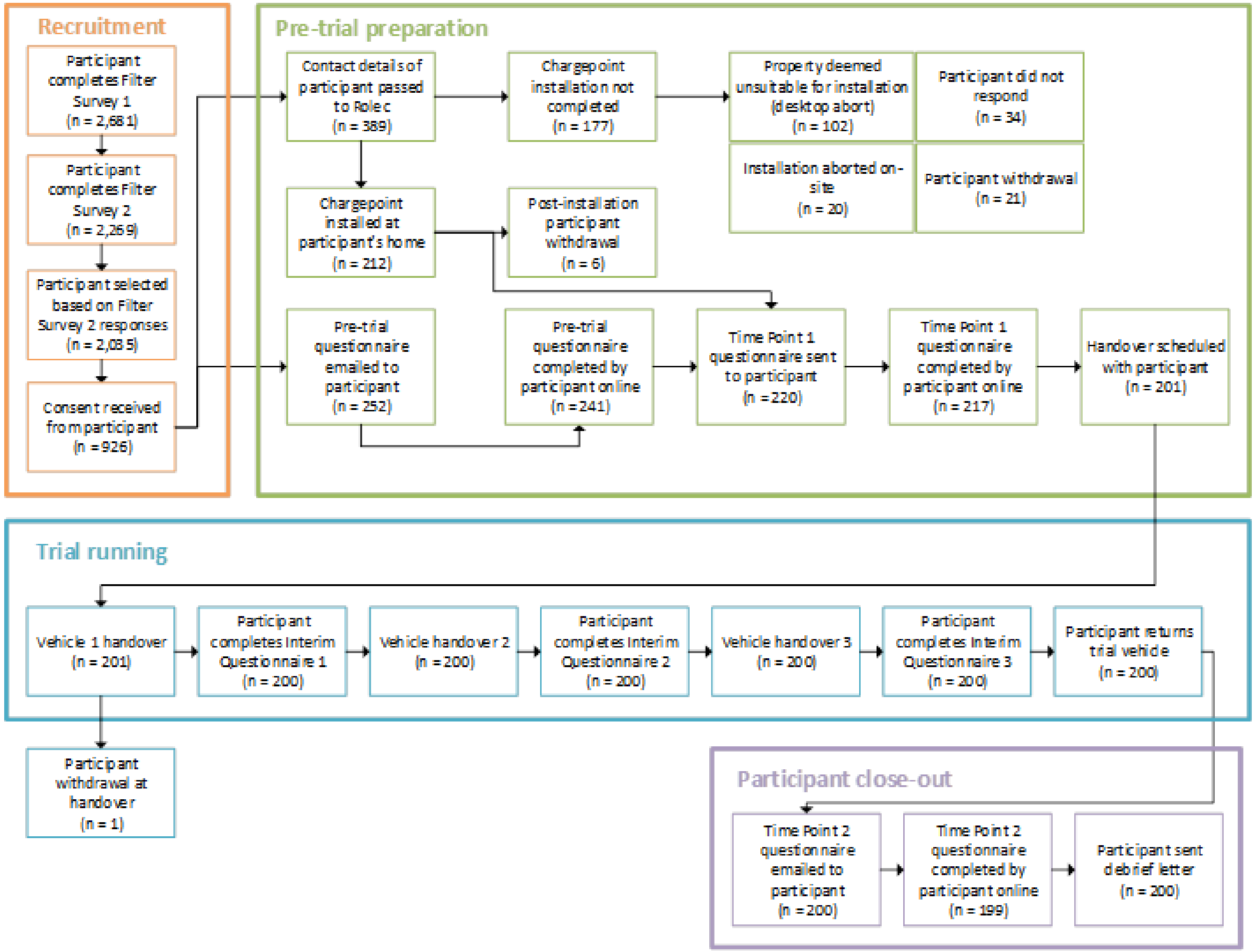

Figure 4: Trial procedure flow diagram; number of participants who completed each step shown in parentheses

Each stage of the remaining trial procedure is described in the following sections.

A.5.1 Pre-trial preparation phase

A.5.1.1 Installation of charging sockets

Mode 2 charging sockets (for use with 3-pin Mode 2 cables with built-in RCD-protection) were installed by experienced professional contractors, trained by and working on behalf of the manufacturer of the socket. Installations were only completed after a participant survey and/or site inspection had taken place with the participant to make sure their property was suitable. Around 100 households were deemed unsuitable for installation following this survey (see Figure 4); the reasons for this included:

- ISO switch required
- Household already at maximum demand
- No spare ways on consumer board
- Groundwork required
- Landlord only gave permission for installation in garage and garage consumer board incompatible
- Main fuse needs to be upgraded
- Old style fuseboard not compatible

All installations were also preceded by a dynamic on-site risk assessment. These assessments were carried out with the participant to inspect the area of works and to identify any unreported hazards in order to ensure that:

a) all hazards were captured sufficiently

b) suitable control measures were identified that mitigated the risks and were agreeable with the participant

c) suitable control measures were implemented where possible (e.g. participant moving household items to allow safe access to the fuse box and sufficient work space for the engineer to use their equipment safely)

In addition, an abort arrangement was setup with criteria to determine when it was not safe to undertake installation. The abort arrangement was an agreed process between ChargedEV, Rolec and TRL to carry out certain steps when one or more of the predefined abort criteria were met. Those steps included:

1. Engineer informs householder of requirement for abort and reason(s) why and participant signs a form which outlines why the install was aborted
2. Engineer informs ChargedEV office staff of abort and reason(s) why
3. Information cascaded down to TRL who accept or reject abort decision based on the information provided by ChargedEV

At the end of the trial, participants were given the option of keeping the socket, or having it removed and any rectification work required undertaken, at no cost to them.

A.5.1.2 Scheduling vehicle handovers

Once confirmation had been received that the Mode 2 charging socket had been successfully installed at a participant's home, the participant was contacted by the research team to schedule the vehicle handovers.

The full sample of 200 participants was achieved by splitting the trial schedule into 5'blocks' (see Table 3).

Table 3: Trial blocks

Block	Dates when block was scheduled	Number of participants completed in block
1	19th Oct 2017 – 3rd Dec 2017	31
2	28th Nov 2017 – 19th Dec 2017	18
3	5th Jan 2018 – 12th Feb 2018	41
4	15th Feb 2018 – 4th Apr 2018	54
5	6th Apr 2018 – 31st May 2018	56
Total		**200**

This block structure was used to facilitate the sequencing of vehicles to participants at each location, and to ensure there was sufficient time contingency (2 days) between when a vehicle was returned by one participant and when it had to go out to the next participant.

The block structure was also designed to control for order effects; both in terms of balancing the order in which participants experienced each vehicle type (using a Latin square), and balancing the experiences across weekdays and weekend days. An illustration of the Block structure used at Cenex is shown in Figure 5; this shows the schedule used to run the first 36 participants from Cenex; a similar structure was run simultaneously at TRL).

<table>
<tr><td></td><td></td><td colspan="38">BLOCK 1 - 38 DAYS</td></tr>
<tr><td rowspan="2">Vehicle ID</td><td>Trial day</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td></tr>
<tr><td>Vehicle type</td><td colspan="38"></td></tr>
<tr><td>B1</td><td>BEV</td><td colspan="4">1</td><td></td><td></td><td colspan="4">8</td><td></td><td></td><td colspan="4">13</td><td></td><td></td><td colspan="4">20</td><td></td><td></td><td colspan="4">25</td><td></td><td></td><td colspan="4">32</td><td></td><td></td><td></td><td></td></tr>
<tr><td>B2</td><td>BEV</td><td colspan="4">4</td><td></td><td></td><td colspan="4">11</td><td></td><td></td><td colspan="4">16</td><td></td><td></td><td colspan="4">23</td><td></td><td></td><td colspan="4">28</td><td></td><td></td><td colspan="4">35</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>B6</td><td>BEV</td><td></td><td></td><td></td><td></td><td colspan="4">5</td><td></td><td></td><td colspan="4">12</td><td></td><td></td><td colspan="4">17</td><td></td><td></td><td colspan="4">24</td><td></td><td></td><td colspan="4">29</td><td></td><td></td><td colspan="4">36</td></tr>
<tr><td>P1</td><td>PHEV</td><td colspan="4">3</td><td></td><td></td><td colspan="4">7</td><td></td><td></td><td colspan="4">15</td><td></td><td></td><td colspan="4">19</td><td></td><td></td><td colspan="4">27</td><td></td><td></td><td colspan="4">31</td><td></td><td></td><td></td><td></td></tr>
<tr><td>P2</td><td>PHEV</td><td colspan="4">5</td><td></td><td></td><td colspan="4">12</td><td></td><td></td><td colspan="4">17</td><td></td><td></td><td colspan="4">24</td><td></td><td></td><td colspan="4">29</td><td></td><td></td><td colspan="4">36</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>I2</td><td>ICE</td><td colspan="4">6</td><td></td><td></td><td colspan="4">10</td><td></td><td></td><td colspan="4">18</td><td></td><td></td><td colspan="4">22</td><td></td><td></td><td colspan="4">30</td><td></td><td></td><td colspan="4">34</td><td></td><td></td><td></td><td></td></tr>
<tr><td>I3</td><td>ICE</td><td></td><td></td><td colspan="4">8</td><td></td><td></td><td colspan="4">1</td><td></td><td></td><td colspan="4">20</td><td></td><td></td><td colspan="4">13</td><td></td><td></td><td colspan="4">32</td><td></td><td></td><td colspan="4">25</td><td></td><td></td></tr>
<tr><td>I4</td><td>ICE</td><td></td><td></td><td colspan="4">12</td><td></td><td></td><td colspan="4">5</td><td></td><td></td><td colspan="4">24</td><td></td><td></td><td colspan="4">17</td><td></td><td></td><td colspan="4">36</td><td></td><td></td><td colspan="4">29</td><td></td><td></td></tr>
<tr><td>I5</td><td>ICE</td><td></td><td></td><td></td><td></td><td colspan="4">3</td><td></td><td></td><td colspan="4">7</td><td></td><td></td><td colspan="4">15</td><td></td><td></td><td colspan="4">19</td><td></td><td></td><td colspan="4">27</td><td></td><td></td><td colspan="4">31</td></tr>
<tr><td>I6</td><td>ICE</td><td></td><td></td><td></td><td></td><td colspan="4">4</td><td></td><td></td><td colspan="4">11</td><td></td><td></td><td colspan="4">16</td><td></td><td></td><td colspan="4">23</td><td></td><td></td><td colspan="4">28</td><td></td><td></td><td colspan="4">35</td></tr>
</table>

Figure 5: Illustration of Block 1 structure used to run the Consumer Uptake Trial at Cenex (similar block with 15 vehicles and 30 participants per block ran simultaneously at TRL)

As shown in the figure above, Participant 1, for example, picked up their first vehicle (a BEV) on day 1, then swapped it for a PHEV on day 5, followed by an ICE on day 9, before returning it and completing the trial on day 13. Participant 2, on the other hand, collected an ICE on day 1, then a BEV on day 5, and a PHEV on day 9. This sequence repeated for the full block which lasted 38 days.

A.5.1.3 Pre-trial and TP1 questionnaires

Once participants' vehicle handovers had been scheduled, they were sent links to the Pre-trial questionnaire (PTQ) to complete in their own time, but before their first handover. Once the completed PTQ had been received by the research team, participants were sent the Time Point 1 (TP1) questionnaire, for completion in the week preceding their first handover. As part of the handover procedure, the research team checked that both questionnaires had been completed prior to participants taking away their first vehicle.

A.5.2 Trial running phase

A.5.2.1 Vehicle handovers

The standardised vehicle handover process is described below:

Vehicle 1 handover

1. Participants arrived at trial headquarters (TRL or Cenex) at the date and time specified and were met by the researcher.
2. Participants were directed to the secure parking area where their personal vehicles were stored for the duration of the trial. A researcher accompanied each participant on a walk-around of their personal vehicle to ensure that the existing condition of the vehicle, including any damage and the current mileage, was noted.
3. Participants were asked to show their driving licence to verify validity, the types of vehicles that the participant could drive, and any penalty points or disqualifications. Participants were also asked to provide another form of ID to confirm their identity and address (e.g. utility bill or bank statement). If a participant wished to add an additional driver in the household to the insurance, they were also required to provide the additional driver's licence and proof of address.
4. Participants undertook an eyesight test, to check their eyesight was to the standard required for safe driving.
5. All licence and eyesight checks were passed by participants; they were then subsequently given a trial briefing by the researcher. The briefing covered background information about the trial, what was expected of the participant and points regarding health and safety.
6. Participants then completed a walk-around inspection of the trial vehicle, including an interior inspection, with the researcher. The condition of the vehicle and any existing damage was noted on a vehicle condition form.
7. Researchers provided participants with an explanation of the vehicle controls and key features; this explanation followed a set protocol in order to ensure that information given to participants was standardised and accurate.

8. When receiving a BEV or PHEV, participants were familiarised with the features and controls unique to these vehicles. This included a demonstration of how to access the charging port on the vehicle, locate the charging cable, how to safely plug in the charging cable at both the vehicle and chargepoint ends, and how to remove the charging cable on completion of charging. Information on the AER of the vehicle and the likely impact when operating it under various driving conditions (e.g. urban driving vs. motorway driving) was also provided.
9. On completion of the vehicle briefing, participants were asked to complete a short familiarisation drive, accompanied by the researcher, to ensure that they had understood how the vehicle operates and were comfortable with driving the vehicle. The familiarisation drive also gave the researcher the opportunity to appraise the driving of the participant and assess whether it could be considered unsafe, or if any illegal manoeuvres were performed.
10. On completion of a successful familiarisation drive the participant was issued with an In-vehicle Information Pack containing key information about how the vehicles operated, how to charge (if applicable), health and safety information, and a list of key contacts, including what to do in the event of a breakdown or incident.
11. The ICE and PHEV trial vehicles were given to participants with a full tank of fuel. The BEV and PHEV vehicles had a battery State of Charge (SOC) of at least 80%. Participants were asked to return the vehicles with the same amount of fuel, and where relevant, as much charge as possible.
12. On completion of all briefing and handover activities, participants were given the opportunity to ask any questions before signing a consent form. Researchers assigned participants to their vehicle on the trial's 'Admin Portal'[5].
13. Participants took Vehicle 1 away for use during their normal day-to-day activities for a period of four days.

Return of Vehicle 1

1. Participants returned Vehicle 1 to TRL/Cenex at the pre-arranged time at the end of the four-day period. Participants were accompanied by a researcher on a walk-around of the vehicle, and interior inspection, to check the returned condition against the condition of the vehicle when it was taken away. If there was any new damage to the vehicle this was recorded and the participant was encouraged to provide an explanation. If the damage required repair, the participant was notified that they might be liable for any costs up to a maximum excess.
2. The researcher recorded the mileage, fuel level and charge level of the vehicle (as applicable), and checked that all original equipment (owner's manual, first aid kit, locking wheel nut, and charge cable where applicable) was still with the vehicle.
3. Researchers unassigned participants from their vehicles using the Admin Portal.

[5] A web portal used for managing the allocation of vehicles to participants during the trial.

4. Participants completed Interim Questionnaire 1 on a computer or tablet located in the TRL/Cenex offices. Upon completion of the questionnaire participants were given a cash payment of £20. The handover process for Vehicle 2 then commenced.

Vehicle 2 handover

1. Handover of Vehicle 2 followed the same process as for Vehicle 1 (except for the driving licence and other ID checks, the eyesight checks, and the initial trial briefing).
2. On completion of all briefing and handover activities, participants were given the opportunity to ask any questions before signing a consent form. Researchers assigned participants to their vehicles using the trial's Admin Portal.
3. Participants took Vehicle 2 away for use during their normal day-to-day activities for a period of four days.

Vehicle 2 return

1. The return of Vehicle 2 followed the same process as for Vehicle 1.
2. Participants completed Interim Questionnaire 2 on a computer or tablet located in TRL/Cenex offices. Upon completion of the questionnaire participants were given a cash payment of £20. The handover process for Vehicle 3 then commenced.

Vehicle 3 handover

1. The handover of Vehicle 3 followed the same process as Vehicle 2.
2. On completion of all briefing and handover activities, participants were given the opportunity to ask any questions before signing a consent form. The Researchers assigned participants to their vehicle using the trial's Admin Portal.
3. Participants took Vehicle 3 away for use during their normal day-to-day activities for a period of four days.

Vehicle 3 return

1. The return of Vehicle 3 followed the same process as Vehicle 2.
2. Participants completed Interim Questionnaire 3 on a computer or tablet located in TRL/Cenex offices. Upon completion of the questionnaire participants were given a cash payment of £20.
3. Participants were shown to their personal vehicle by a researcher and accompanied on a walk-around of the vehicle, and interior inspection, to check the current condition against the condition of the vehicle when it was first brought in by the participant. If there was any new damage to the vehicle this was recorded and the participant was notified that an investigation would be undertaken. Participants were informed that TRL would organise and cover the costs of repairing any damage. Twelve trial vehicles and three participant vehicles were damaged during the trial. The damage to the trial vehicles was minor, with no participant being involved in a serious accident during the trial period. Minor surface damage (e.g. scratch to paintwork) that had not been recorded at drop-off was noted at pick-up for three participants' cars. No participant was required to pay for any damage to either their car or the trial cars during the trial.

4. Researchers unassigned participants from their vehicle using the Admin Portal.
5. Participants were notified that the final questionnaire (Time Point 2) would be sent to them by email within one week and that upon completion they would receive £100.

A.5.2.2 Participant use of vehicles

A key aim of this trial was to reduce the psychological distance of a sample of mainstream consumers from BEVs and PHEVs. Several steps were taken to ensure that participants' experience of the vehicles during the trial was sufficient to reduce their psychological distance:

1. Prospective participants were excluded if they reported in Filter Survey 1 that they usually drove only once per week or less.
2. Participants were requested to store their own vehicle with the research team for the duration of the trial. This increased the likelihood that participants used the trial vehicle for their regular day-to-day journeys, and ensured that participants with limited parking space at home were still able to participate. Where the household had multiple vehicles, preference was given to replace the participant's main vehicle (i.e. the vehicle they usually drove).
3. Participants were requested to drive each vehicle at least once per day, and to recharge BEVs and PHEVs at least twice during each of the four day periods.

A.5.2.3 Vehicle safety checks and cleaning

Safety checks were performed on the vehicles between vehicles being returned by one participant and collected by the next (this was two days between participants during blocks and four days between blocks). Safety checks covered items such as tyre wear and condition, seatbelt functioning, lights, and oil, coolant and washer fluid level. All vehicles were also given an interior and exterior valet by a third-party valet company between participant sessions.

A.5.3 Participant close-out phase

A.5.3.1 TP2 questionnaires

Once participants' had completed their four-day trial with all three vehicles they were sent a link to the Time Point 2 questionnaire and were asked to complete the questionnaire within one week of returning their final vehicle.

A.5.3.2 Participant debrief

Upon receipt of the completed Time point 2 questionnaires, participants were given £100 cash as compensation for their time. Participants were sent a debrief letter to thank them for their time and to confirm what would happen to their data and when the findings of the research would be published.

A.6 Vehicle management

A.6.1 Trial vehicle fleet

The trial used three variants of the Volkswagen Golf, selected because this was the only vehicle model that was commercially available with all three drivetrains (ICE, BEV and PHEV). The vehicle fleet consisted of 33 new Volkswagen Golf vehicles; 11 petrol (ICE) GT Edition models, 11 PHEV GTE models, and 11 BEV e-Golf models (see Table 4).

Table 4: Consumer Uptake Trial vehicle fleet

Model		Total number	Number at TRL	Number at Cenex
VW Golf 1.4 TSI GT Edition	ICE	11	5	6
VW e-Golf	BEV	11	5	6
VW Golf GTE	PHEV	11	5	6

The three models were similar in functional capability[6] (other than the drivetrain differences) and were (as closely as possible) matched in trim and accessories. This minimised the impact of any differences between vehicle types that were associated with vehicle characteristics other than the powertrain configuration. The specifications of the three models are shown in Table 5.

The vehicles were leased directly from Volkswagen Group Financial Services (VGFS). The manufacturer's warranty covered all vehicles for the duration of the trial. Vehicle maintenance and servicing was covered under the terms of the lease agreement, and Volkswagen dealerships local to TRL and Cenex were used for this purpose. Servicing or maintenance was, wherever possible, scheduled in-between participant experiences or blocks so as to minimise disruption to the trial. The lease agreement also provided comprehensive breakdown cover and tyre replacement; participants were provided with full details of this cover (and what to do in the event of an incident) as part of the In-vehicle Information Pack.

[6] Functional capability refers to the utility of the vehicle as a means of fulfilling a user's functional goals: the transporting of people or materials from one place to another. Functional capability includes range between refuelling, number of seats, legroom, volume and weight of luggage that can be carried, occupant safety, etc.

Table 5: Vehicle manufacturer[7] reported specifications for the VW Golf ICE, PHEV and BEV models

Manufacturer reported specification	VW Golf GT Edition TSI (ICE)	VW Golf GTE (PHEV)	VW e-Golf (BEV)
Engine	1.4 TSI ACT (petrol)	1.4 TSI (petrol)	Electric motor
Gearbox	7 speed auto DSG	6 speed auto DSG	Direct drive
Nominal Capacity, i.e. units to full charge (kWh)	n/a	8.7	35.8
Maximum AER (miles)[8]	n/a	30	186
Expected AER (miles)[9]	n/a	25	175
Fuel economy (combined)	58.9	166.2	n/a
Time to full charge (AC - 2.3kW) (hours)	n/a	3.75	17
Time to full charge (AC - 3.6kW) (hours)	n/a	2.25	10.5
Time to 80% charge (DC – 50kW) (hours)	n/a	n/a	0.75
Power Output (PS)	150 PS	204 (combined)	136
Max torque (Nm)	250	350 (combined)	290
Mass - kerb weight (kg)	1290 - 1316	1615	1615 - 1687
Mass - gross weight (kg)	1800 - 1820	2040	2020
Emissions (CO2 g/km)	113	38	0
Acceleration (0-100km/h)	8.2	7.6	10.4
Vmax (km/h)	216	222	150

A.6.2 Vehicle storage

The trial vehicles were stored at TRL's head office in Crowthorne, Berkshire and at Cenex's offices on the campus of the University of Loughborough in Leicestershire. Participants were asked to leave their personal vehicles at either the Crowthorne House site or the University of Loughborough campus for the duration of the trial. As part of the vehicle handover process, participants' vehicles were inspected on arrival to record any damage and log the mileage (see section A.5.2.1).

[7] Volkswagen Financial Services (Personal communication, July 2017)

[8] New European Driving Cycle (NEDC) range (July 2017). These rates were correct at the time of running the trials and as such were the values communicated to participants. Worldwide Harmonised Light Vehicle Test Procedure (WLTP) figures have since been released (September 2018). These report a maximum range of 144 miles and a real-world range of 125 miles for the VW e-Golf.

[9] Real-world range estimated by Volkswagen (July 2017)

A.7 Vehicle charging

Both the e-Golf (BEV) and the Golf GTE (PHEV) were supplied with Mode 2 and Mode 3 charging cables (see Table 6 for an explanation of the charging modes). Participants were asked to charge the BEV and PHEV at least twice each during the four-day period; this could take place at home or at public chargepoints. At the vehicle handover sessions, the research team provided participants with a demonstration of how to charge the vehicles (see section A.5.2.1); hard-copy instructions were also provided to participants as part of the In-vehicle Information Pack.

Table 6: Explanation of charging modes[10]

Mode	Summary	Details	Safety
Mode 1	• AC charging • Non-dedicated circuit • Non-dedicated plug/socket	• Connects to an existing non-specialised circuit (e.g. a standard socket in a house) using a cable with no control equipment. • Although protected by a BS 1362 fuse, RCD protection not guaranteed	• Not recommended for EV charging.
Mode 2	• AC charging • Non-dedicated circuit • Non-dedicated plug/socket • Cable-incorporated RCD	• Cable that connects the vehicle to the electrical supply incorporates an In-Cable Control and Protection Device (IC-CPD) • Provides RCD protection downstream of the unit • In residential applications Mode 2 charging power will often be limited by vehicle protocols to charging at 1.4kW to 2.3kW (6-10A). • Limited to 3kW (13A) in residential use or 7.4kW (32A) for industrial	• Regular charging should only be carried out using a dedicated EV circuit • Occasional charging from a non-dedicated circuit is acceptable

[10] Adapted from 'A Guide To Electric Vehicle Infrastructure' (BEAMA, 2015)

Mode	Summary	Details	Safety
Mode 3	• AC charging • Dedicated EV charging system • Dedicated plug/socket • Control, communications and protection functions incorporated in the chargepoint with "smart" charging potential and other functions • Wide range of charging capabilities, single or three phase AC up to 50kW	• Control, communications and protection functions incorporated in the chargepoint with "smart" charging potential and other functions • Specialised system for EV charging used in residential, commercial and public charging • Always runs from a dedicated circuit • Wide range of charging capabilities, single or three phase AC up to 50kW • Commonly operates at 3.7kW (16A) or 7.4kW (32A) in residential applications but power may be significantly higher in commercial or public applications.	• Designed for EV charging
Mode 4	• DC charging • Dedicated EV charging system • Dedicated plug/socket • CHAdeMO or CCS (Combined Charging System) connectors and communication protocols	• Provides a DC charge to the vehicle and carries out the control functions within the chargepoint • Bypasses the charger carried on the vehicle so can utilise large and heavy equipment needed to provide particularly high charge currents • Wide range of charging capabilities from tens of kW to over 100kW	• Designed for EV charging

A.7.1 Charging at home

For long-term use of plug-in vehicles, Mode 3 charging (involving the use of a dedicated PiV charging station with its own circuit) is the recommended method for domestic charging. However, given the time, cost and practical constraints of this short-term trial, an assessment was made that use of Mode 2 charging would be a suitable alternative charging solution for use in this trial. Mode 2 charging involves the use of a dedicated charging cable equipped with a residual current device (RCD) that can be connected to a domestic 3-pin socket, and which is suitable for occasional use.

Therefore, for the purposes of the Consumer Uptake Trial, a Mode 2 charging socket on a dedicated circuit, with RCD protection, was installed in participants' homes to enable them to safely charge the BEV and PHEV during the trial. This therefore limited the charging rate to 2.3kW.

A.7.2 Public charging

Participants were given free access to the 'POLAR plus' public charging network via a membership card (key fob) provided with each vehicle. POLAR is the UK's largest public charging network and contains thousands of charge points across the UK, ranging from 3-pin and Type 2 sockets, to their rapid charger, 'The Ultracharger'. POLAR plus customers can also access the Charge Your Car (CYC) network of charge points.

Around 80% of the network's charge points are free to use. For other chargepoints, the costs associated with charging were charged directly to a TRL account; participants were not directly charged for the use of public charge points in this trial. Maps showing the location of POLAR network chargepoints[11] in the areas surrounding TRL and Cenex are shown in Figure 6 and Figure 7, respectively. Participants were directed to the POLAR plus map web page during vehicle handover so that they were aware of how to find a local public chargepoint.

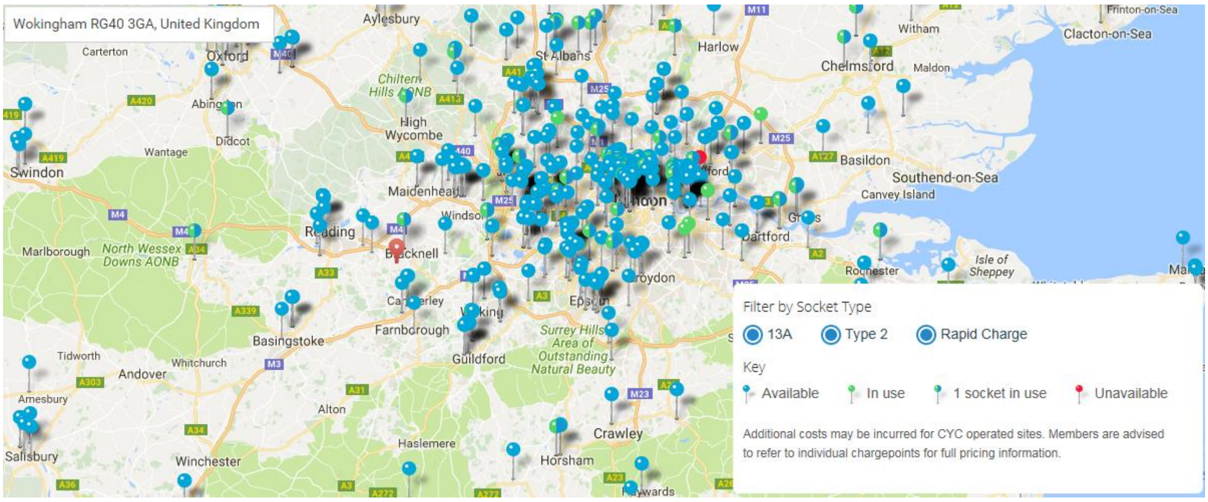


Figure 6: Public chargepoints on the Polar network in the area surrounding TRL

[11] https://polar-network.com/map - up to date at the time of starting the trials (September 2017).

Figure 7: Public chargepoints on the Polar network in the area surrounding Cenex

A.8 Questionnaires

Participants completed a number of questionnaires during the trial including a two-stage filter survey process to inform recruitment (see section A.3.2), a pre-trial questionnaire, an attitudinal questionnaire which was repeated before and after the trial, and interim questionnaires completed after each vehicle was returned.

The questionnaires were based on those developed for previous ETI PiV research (Anable, *et al.*, 2011). These were further developed for a Shell-TRL PiV trial (Skippon *et al.*, 2016) and variants were used in a segmentation survey study for DfT by Element Energy (2015a).

A summary of the content and data collected by each questionnaire is provided in Table 7.

Table 7: Breakdown of data collected by each questionnaire

Questionnaire	Data collected
Filter survey 1	**Section 1: Driving history** • Time holding a UK driving licence • Penalty points on driving licence • At fault insurance claims **Section 2: Vehicles and driving information** • Driving regularity • Car owner • Company car driver • Off-street parking • PiV ownership • Intention to adopt a PiV **Section 3: Information about you** • Age group • Gender

<table>
<tr><th>Questionnaire</th><th>Data collected</th></tr>
<tr><td></td><td>Contact details</td></tr>
<tr><td>Filter survey 2</td><td>Section 1: Trial interest
Trial interest
Living arrangements
Willingness to install a chargepoint
Section 2: Your car(s)
Number of cars in the household
Number of licensed drivers in the household
Car type
Annual mileage
Long journey (i.e. >typical BEV range) regularity
BEV acceptability
Section 3: Domestic energy information
Smartphone suitability
Economy 7 and pre-pay tariffs
Solar panels</td></tr>
<tr><td>Pre-trial</td><td>Section 1: General background
Educational attainment
Employment status
Household income
Relationship status
Living status
Section 2: Your household and cars
Household membership
Cars in the household
Car types
Car purchase method
Car mileage
Main car year of purchase
Main car purchase type (e.g. new or old)
Main car purchase price
Main car purchase choice factors
Main car fuel economy
Main car purchase decision influence
Section 3: Your journeys
Commuting
Weekday and weekend typical mileage</td></tr>
</table>

Questionnaire	Data collected
	• Journey distance • Urban/rural driving • Mode use and regularity • Current car club membership • Current mobility services user • Journey app planning user **Section 4: Owning and driving a car** • Attitudes to car ownership (car-authority identity) • Driving style (Multidimensional Driving Style Inventory) **Section 5: New technology** • Attitudes to new technology **Section 6: The environment** • Attitudes to Driving and the Environment Inventory
Time Point 1	**Section 1: Battery Electric Vehicles** • Instrumental, Symbolic and Affective attitudes towards BEVs • Self-congruity to BEVs • Willingness to adopt a BEV • Willingness to adopt a BEV by range • Willingness to adopt a BEV by time to charge • Important factors in decision to adopt a BEV • Influence of access to long-range vehicle options on willingness to adopt • Influence of depreciation on willingness to adopt • Current level of knowledge **Section 2: Plug-in Hybrid Vehicles** • [Repeat Section 1 for PHEVs] **Section 3: Next vehicle purchase** • Future car purchase intentions **Section 4: Plug-in Vehicle charging** • Awareness of PiV public charging points
Interim 1	**Section 1: Battery Electric Vehicles** • Willingness to adopt a BEV • Willingness to adopt a BEV by range • Willingness to adopt a BEV by time to charge • Current level of knowledge **Section 2: Plug-in Hybrid Vehicles** • [Repeat Section 1 for PHEVs]

Questionnaire	Data collected
	Section 3: Next vehicle purchase • Future car purchase intentions **Section 4: Experience with the vehicle** • Evaluation of vehicle performance • Household driver use
Interim 2 & 3	**Section 1: Experience with the vehicle** • Evaluation of vehicle performance • Household driver use
Time Point 2	**Section 1: Battery Electric Vehicles** • Instrumental, Symbolic and Affective attitudes towards BEVs • Self-congruity to BEVs • Willingness to adopt a BEV • Willingness to adopt a BEV by range • Willingness to adopt a BEV by time to charge • Important factors in decision to adopt a BEV • Influence of access to long-range vehicle options on willingness to adopt • Influence of depreciation on willingness to adopt • Current level of knowledge **Section2: Plug-in Hybrid Vehicles** • [Repeat Section 1 for PHEVs] **Section 3: Next vehicle purchase** • Future car purchase intentions • Information on PHEVs or BEVs sourced **Section 4: Plug-in Vehicle charging** • Future charge location predictions • Awareness of PiV public charging points **Section 5: About you** • Self-identity to PiVs • Newcastle Personality Assessor **Section 6: Choice experiment** • See section A.9

The **filter survey questionnaires (Filter Survey 1 and Filter Survey 2)** were used to determine the eligibility of participants to take part in the trial, as described earlier.

The **Pre-trial questionnaire** was used to collect data for the segmentation and descriptive analysis to understand how participants fitted into the different consumer segments based on their willingness to adopt. It contained questions relating to the participant’s household, vehicle ownership history, travel patterns, attitudes about owning and driving a car, driving style, Mobility-as-a-Service, attitudes about new technology, personal travel and the environment.

The **Time Point 1 questionnaire** was used to record participants' attitudes towards BEVs and PHEVs before experience of the vehicles. The questionnaire contained BEV and PHEV specific questions comparing them with conventional cars, affective, symbolic and instrumental attitudes towards BEVs and PHEVs, and willingness to consider a BEV or PHEV as a main or second car.

Interim questionnaire 1 contained the core willingness to consider questions from the Time Point 1 questionnaire; included again at this point to allow testing of whether there was a Hawthorne effect in which participants' attitudes are changed merely by participation in the trial. This was examined by comparing responses with those from TP1 for participants who experienced the ICE vehicle first. The questionnaire also contained questions on the evaluation of vehicle performance (vehicle acceleration, responsiveness, comfort, noise etc.) of the first vehicle the participant had experienced.

Interim questionnaires 2 and 3 repeated only the vehicle performance questions for the second and third vehicles respectively.

Finally, the **Time Point 2 questionnaire** was an extended version of the Time Point 1 questionnaire. It included the Choice Experiment and repeated all the questions in the Time Point 1 questionnaire, enabling analyses that explore how attitudes change with experience of the vehicles. In addition, it contains questions on preferred charging locations, and a personality inventory.

A.9 Choice experiment

The choice experiment included in the Time Point 2 Questionnaire was the principal means of addressing several of the research questions concerning attitudes towards vehicle attributes. Choice experiments, which employ Discrete Choice Analysis, enable the relative values consumers place in vehicle attributes to be quantified.

A.9.1 Introduction to Discrete Choice Analysis

The purpose of Discrete Choice Analysis is to simulate as far as possible the decision-making process followed by consumers in the real world. When choosing between various products or services (for example different vehicle powertrains or different public transport options), consumers are assumed to make a trade-off between the attributes of each in order to come to a decision. For a car, these attributes could include purchase price, fuel consumption and range etc. Discrete Choice Analysis is used to quantify the different weighting consumers apply to each attribute, and thus the overall 'utility' that each alternative would provide. An example would be the relative importance of purchase price versus on-going fuel savings, in other words what value of fuel savings is required from a low emission vehicle to compensate for a higher purchase price. Mathematically, the utility, U, of a choice alternative, i, can be expressed as:

$$U_i = \sum_{j=1}^{j=T} \beta_j x_{ij} + \varepsilon_i$$

- x_{ij} is the value of the j^{th} observed attribute for choice alternative i (e.g. fuel consumption for a petrol ICE).
- β_j is the choice coefficient (weighting) for the j^{th} observed attribute for choice alternative i (e.g. weighting of fuel consumption).
- ε_i is the utility value of the unobserved factors[12] for choice alternative i.
- T is the total number of observed attributes.

A consumer will choose the alternative that offers the greatest 'utility', and so the results can be used to predict the likely uptake of each member of a choice set. Critically, the technique simulates a choice between discrete alternatives which correctly represents the real-world process car-buyers go through when choosing between several distinct vehicles and choose only one (and cannot mix and match the attributes of each). The results of Discrete Choice Analysis enable the value consumers place in various vehicle attributes to be quantified and investigated. Models based on Discrete Choice Analysis have shown to be better predictors of vehicle uptake than those based on simpler methods, such as 'diffusion curves', as they account for changes in individual vehicle attributes, which do not necessarily change at similar or constant rates (Greene, 2001; Leiby and Rubin, 1997).

A.9.2 Choice experiment design

Discrete Choice Analysis requires a large dataset containing the results of consumer choices made between alternative products with known attribute values. For products which are already established in the market, this data can be gathered simply from historic market shares and the specifications of each product available. This is known as 'revealed preference' data. This has the advantage of being based on actual real-world decisions. However, for novel products, such as plug-in vehicles, where the models currently available are not necessarily representative of future models, revealed preference data either does not exist or is of limited range of variation (i.e. restricted to attribute combinations that currently exist in the market). Instead, a 'stated preference' choice experiment can be employed in which consumers in a survey are presented with a set of hypothetical product alternatives and asked to choose to purchase one of them. By varying the values of the product attributes between choice sets, a large dataset of consumer choice behaviour can be generated, including combinations of attributes that may be available in the future (for instance, values of AER that are not presently available but might be in some years' time). This allows the contribution of each attribute towards overall utility to be derived independently. This technique has been employed in this study.

A 'stated preference' choice experiment was included in the Time Point 2 Questionnaire, to understand how participants valued different attributes of conventional and plug-in cars once they had had experience of using BEVs and PHEVs, and therefore what factors carried most weight in a vehicle purchase decision. The choice experiment presented each

[12] Unobserved factors are the vehicle attributes not explicitly investigated through an observed attribute (x_i). This could be because they were not included in the choice experiment to quantify the utility of each attribute (e.g. acceleration) or because they are intangible or difficult to quantify (e.g. perceived risk associated with novel technology).

participant with 10 hypothetical choices between a conventional internal combustion engine car (ICE), a plug-in hybrid car (PHEV), and a battery electric car (BEV). In each case they were asked which one they would choose to buy. The attributes of the vehicles were varied across each of the choices.

The following section outlines which attributes were included in the choice experiment.

A.9.2.1 Selection of choice experiment attributes

The Time Point 2 Questionnaire choice experiment was designed to answer the following research questions:

- RQ1: How much does the potential All Electric Range (AER) of a BEV or PHEV influence willingness to consider adoption?
- RQ2: How much does the potential purchase cost of a BEV or PHEV influence willingness to consider adoption?
- RQ3: How much does the potential running cost saving associated with using a BEV or PHEV influence willingness to consider adoption?
- RQ4: How much does the recharge time associated with a BEV or PHEV influence willingness to consider adoption?
- RQ7: What effect does varying the perceived level of access to public charging stations (e.g. density, type of location, type of charger) have on willingness to adopt BEVs or PHEVs?

However, a secondary aim was to compare results from this choice experiment with a previous choice experiment carried out by Element Energy for DfT in 2015 (Element Energy, 2015a). The choice coefficients derived from that choice experiment underpin the choice module in Element Energy's Electric Car Consumer (ECCo) uptake model[13]. This was implemented with a sample of 2,020 new car buyers. Due to the limited uptake of PiVs at the time of the survey, very few of the survey participants reported having any experience of PiVs . Therefore, by comparing results with the Consumer Uptake Trial choice experiment, the impact of PiV experience on attitudes towards PiVs can be inferred. Consequently, the attributes selected for this choice experiment were represented in a similar form to the previous study to allow for comparisons to be made.

The choice experiment for DfT in 2015 included the following seven vehicle attributes:

- Purchase price (£)
- Annual running cost (£, presented as annual fuel cost in the choice experiment)
- Electric range (miles)
- Access to charging for local journeys

[13] The ECCo model has been integrated into the CVEI Analytical Framework to forecast the uptake of various vehicle powertrains.

- Access to rapid charging for long distance journeys (intervals between charge points on motorways and A-roads)
- Rapid charging rate (additional range obtained from 20-minute charge)
- Brand supply (number of brands selling similar vehicle)

The derived choice coefficients for each of these attributes have provided ECCo with a comprehensive view of consumer purchasing behaviour and it has been shown to successfully recreate observed market shares. However, since the Consumer Uptake Trial consists of a much smaller sample (n = 200) it was decided that the number of attributes should be reduced to six. These were prioritised as follows: (1) must be relevant to the Research Questions, and consistent with the Element Energy (2015a) choice experiment; (2) must be easily quantifiable and understood by participants; (3) it must be possible to estimate how the attribute will differ between conventional ICE and plug-in cars, both today and in the future. The following section outlines the justification for which attributes were included in the Consumer Uptake Trial choice experiment, as well as how they were presented. This is supported by a literature review of choice experiments simulating car purchases featured in Appendix L of CVEI 170922-6.1 D5.1 - Part 2 - Appendices for Consumer Uptake Trial.

Purchase Price

This is a critical attribute and is the largest contributory factor to consumer purchase behaviour. The importance of the purchase price is indicated by its prevalence in the previous choice experiments. Only one choice experiment reviewed for this trial did not feature a purchase price (Lieven, 2015). However, this study looked specifically at the relative value that consumers placed in various incentive packages when purchasing an EV, rather than the car itself. Consequently, it was implied that all cars offered in the choice set were identical (including their purchase price). Of the other studies identified in the literature review, seventeen of them presented the purchase price as an absolute monetary value. The remaining four studies presented the purchase price relative to a standard ICE either as a percentage (Kim *et al*., 2014; Element Energy, 2011) or absolute value (Ida *et al*., 2014; Tanaka *et al*., 2014). All choice experiments reviewed, therefore, allow participants to calculate an absolute purchase price for the vehicles they must choose from. To reduce the cognitive burden and ensure that participants correctly value the capital cost premium of a plug-in car, against which all other attributes are compared, the absolute purchase price was used in this choice experiment. In similar fashion to Element Energy (2015), the purchase prices presented in the choice sets were scaled according to the participant’s previous car purchase price to make the choice more realistic for that specific participant.

Annual Running Cost

The cost components considered in annual running cost include fuel and electricity cost, maintenance, insurance and on-going ownership taxes (e.g. vehicle excise duty and company car tax). The original choice experiment used to populate the first version of ECCo (Element Energy, 2011) presented participants with a total annual running cost attribute and found over the whole sample that consumers were willing to pay £5 upfront per £1 of annual cost saving. Element Energy (2015a), however, provided participants with just an annual fuelling cost, as previous Element Energy focus groups had highlighted difficulty with conflating maintenance costs with reliability. It was assumed that because fuelling costs constitute the dominant component of on-going costs, the willingness to pay for the former could be applied to the latter. Analysis of results for the whole sample yielded an estimated willingness to pay of £7 per £1 saving in annual fuel costs. Some discrepancy with the 2011 choice experiment (Element Energy, 2011) was due to the different compositions of the two samples; however, it is possible that participants were factoring in the unstated costs, such as maintenance and vehicle tax, when making their choices.

There is no consensus on how to present on-going costs in the choice experiments featured in the literature. Some choose to show fuel/electricity spend and other ownership costs separately, while others include only fuel/electricity spend or total on-going costs. In addition, this can be on both a per km and per year basis. Bahamonde-Birke and Hanappi (2016) presented both fuel and maintenance costs in €/100 km and found consumer's willingness to pay was identical for both, suggesting they do correctly evaluate the different on-going cost components of the total running cost.

For this study, a total running cost attribute was used, and its component parts were explained beforehand to participants. Since all participants had experience of PiVs when they answered the choice experiment, they may have been more knowledgeable about the maintenance and tax savings that can be made through owning one, and thus the risk of these costs being factored into the choice if just a fuel cost was shown was greater. This could have a significant effect on the perceived running cost. For example, during the market research carried out as part of Element Energy (2015a), it was found that maintenance savings for ULEVs are of the order of £100 - £250 per year depending on powertrain and segment. From 2017, UK vehicle excise duty levied a flat rate of £140/year for conventional petrol and diesel ICE cars, £130/year for hybrids and alternatively fuelled vehicles and zero for zero-emission vehicles (cars with a list price of >£40,000 also pay a supplement of £310/year for five years). Thus, BEV users save £140 per year in on-going costs compared to ICE users. It is, therefore, not necessarily valid to say that fuel costs are the dominant component of running costs when comparing conventional and ULEV powertrains. Indeed, Figure 8 reveals that maintenance costs, which are known to be lower for electric powertrains, in particular play a significant role in a car buyer's decision (raw data stratified to ensure results are representative of the UK population at large).

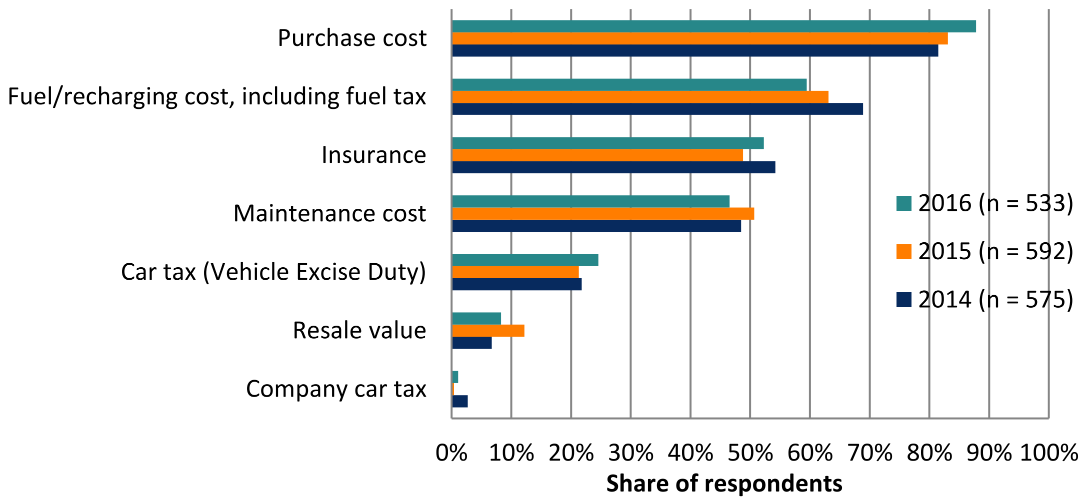


Figure 8: Cost factors when buying a car or van, from DfT's Public Attitudes towards Electric Vehicles survey (DfT, 2016). Participants asked to select up to three cost factors they think about when purchasing a car

Electric Range

Figure 9 reveals that electric range is a significant factor in consumers' decisions not to buy a plug-in car, and as a result features in nearly all of the choice experiments found in the literature.

The ranges of conventional ICEs are usually more than 500km and refuelling takes less than five minutes, thus range under liquid fuel power is much less of a concern. Jensen *et al*. (2013) presented participants with both fuel and electric range and found that participants valued an additional kilometre of range in a petrol ICE car less than for a BEV with 100km of range.

The influence of all electric range on willingness to consider a plug-in car is a key research question and it was necessary to include in this choice experiment. In the other choice experiments reviewed, range is either presented as total, electric only, or distinguished by fuel and electric range, but the willingness to pay for range under liquid fuel power is often ignored. However, in this case it was still shown (as 400 miles) to remove the ambiguity of not showing a total range for ICEs and PHEVs.

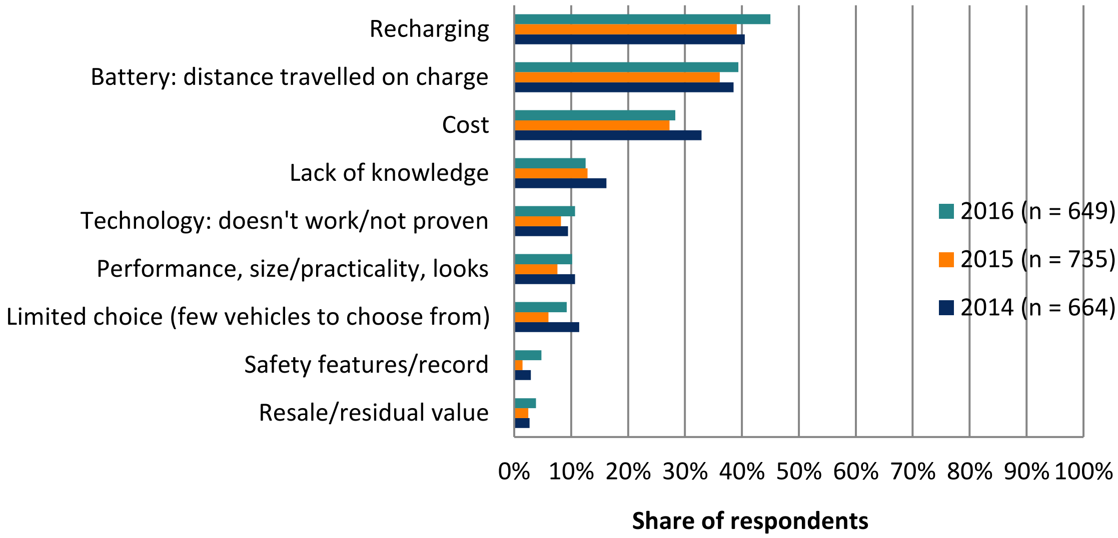


Figure 9: Factors deterring people from buying an electric car or van, from DfT's Public Attitudes towards Electric Vehicles survey (Department for Transport, 2016. Participants asked to select which factors would put them off buying an electric vehicle in the next 12 months.

To simulate an actual car purchase, the choice experiment presented all electric range in a similar manner to that used by vehicle manufacturers in their marketing documents. This normally features an 'official' type approval range, as measured under laboratory conditions, and a suggested range that owners should expect under real world driving. For electric range this was set at 66% of the NEDC range in line with what is currently published by vehicle manufacturers. Since this ratio was not varied between choice sets, this remains a single range attribute. For range under liquid fuel, a value of 75% of the NEDC range was shown, to reflect the current real-world emissions gap (Element Energy, 2015b). In addition, in the description of attributes that participants saw before the choice questions, information was provided on how range under highway and urban driving conditions compares with the official type-approval range.

Charging time

Figure 9 also shows that recharging is the biggest barrier to PiV adoption in the UK. In Element Energy (2015a) only recharge time while rapid charging was considered, since it is assumed that the opportunity for home and work charging makes them time-unconstrained i.e. if the vehicle is parked overnight for nine hours then owners should show little concern for the total charge time as long as it is less than nine hours. Older studies have featured a generic recharging time which can range from minutes to hours and have a significant impact on vehicle utility (Hackbarth & Madlener, 2013; Hoen & Koetse, 2014; Jacobs, Laurenz, Keuchel & Thiel, 2016). However, with the advent of >50 kW charging rates and a rapid charging network with near national coverage, providing a single charge time value is an ambiguous representation of PiV charging, since the requirements for destination and in-journey charging are so different. The average daily mileage for cars in the UK is ~40 km, and so daily electricity usage for a BEV is only 5-10 kWh. Even at a minimum of 3 kW charging power, the time available for overnight charging is more than enough for daily energy needs. Once drivers become accustomed to charging overnight, rather than periodically at filling stations as with conventional cars, they are unlikely to perceive home and work charging time as a major barrier to adoption. Evidence from the My Electric Avenue EV trial (Quirós-Tortós, Ochoa, & My Electric Avenue, 2015), where participants established a regular charging routine in less than one week, suggests that this aspect of PiV ownership is easily understood by consumers. Regardless, in most homes the electricity supply limits charging rate to only 3-7 kW, and so charging time at home is not something that will change in future. The inconvenience, if any, associated with home charging time is captured in the Alternative Specific Constant (see section B.5.1.6), and does not need to be explicitly investigated as a variable attribute in the choice experiment.

However, the occasional requirement to rapid charge during a journey is likely to influence the decision to purchase a vehicle, since it adds journey time. Both charge rate and density of the rapid charge network are set to increase significantly in future. For example, the UK Government has committed to supporting the development of the public charging network through its £400m Charging Infrastructure Investment Fund (DfT, 2018), while investment from the private sector is growing. Major automotive OEMs, such as BMW, Volkswagen, Mercedes and Ford, have created a joint venture, Ionity, to deliver 350 kW highway charging at 400 sites across Europe by 2020 (compared with the current 50 kW standard). It is important to explicitly capture how these developments will affect PiV uptake in the future.

Since the intention of in-journey rapid charging is to provide enough electricity to get the car to its destination, and the charge rate slows considerably as the state of charge approaches full capacity, the time spent to fully charge a battery is a less important characteristic of charging time. For Element Energy's (2015a) choice experiment rapid charge time was represented as driving range added per 20-minute charge. This was considered easier to understand than expressing rate in terms of kW, since the value to the participant is clearer. Converting between kW and rate of range added requires information unavailable to the participants, as it depends on the electricity consumption rate of the vehicle and the driving conditions. Therefore, expressing charging rate in terms of rate of range added was also employed for this study. The charging time of 20 minutes was originally chosen as this matched the average length of stay by all drivers at motorway service stations[14]. However, this duration makes testing faster rapid charging rate challenging, since additional mileage becomes limited by battery capacity as well as charging duration. For example, a charge point rated at 350 kW could supply ~120 kWh in 20 minutes which is considerably more than the usable battery capacity of a typical BEV now (~35 kWh) and in the future (40-60 kWh). Consequently, the choice sets presented the miles added per 10 minutes of charging as this allowed higher charging rates (e.g. 350 kW) to be considered and is easily multipliable should participants want to quickly calculate miles delivered for longer charges. A constraint was also put in place to avoid choice sets that include an electric range lower than the distance that can be added per 10-minute charge. A base level of 25 miles added per 10-minute charge was used as this is approximately equal to 50 kW, which is the current maximum rate of the vast majority of rapid charge points in the UK.

[14] According to Ecotricity (the UK's largest rapid charging network operator by number of charge points): https://www.current-news.co.uk/news/ecotricity-to-begin-charging-electric-highway-motorists [accessed 28/08/2017]

Additional level of 75 and 150 miles, which are approximately equal to 150 kW and 300 kW, were also employed.

Rapid charging rate was included in the choice experiment only for the BEV option. Currently only one PHEV, the Mitsubishi Outlander, is capable of using a DC rapid charger, although due to its small battery it charges at a considerably slower rate. Since PHEVs are not dependent on battery power to drive long distances it is unlikely that any further models will be released with rapid charging compatibility.

Access to charging/refuelling infrastructure

Along with charging time, the other aspect of recharging that heavily influences consideration of a PiV is access to charge points. Since all participants in this choice experiment had access to off-street parking, investigating the value of access to home charging was not necessary. In Element Energy (2015a) access to work and slow public charging were combined into a single attribute, charge point availability for local journeys, for which participants were presented with one of four levels: home access only; home & work access; home & slow public access; and home, work & slow public access. For the Consumer Uptake Trial choice experiment, these levels were re-used, but the attribute was described as availability of 'destination' charging, which has become the industry standard term.

Attitude towards rapid charging was one of the focus points of the Element Energy choice experiment (Element Energy, 2015a) and so was treated as an entirely separate attribute: charge point availability for long distance journeys. A continuous variable was used to characterise the density of rapid charge point coverage, employing the metric of miles between charge points and their location (motorways and/or A-roads). During the cognitive testing stage this proved easier to understand than total number of rapid charging sites on the road network. The results of the choice experiment showed that the additional willingness to pay for a PiV when there is a rapid charge point network with charge points on average 40 miles apart on motorways was around £1,000 (compared with no network). However, willingness to pay was not found to increase for higher coverage, such as rapid charging every 20 miles on motorways and A-roads. This was a novel finding since no other choice experiments identified in the literature distinguished between slow/fast alongside destination/in-journey charging in the same way.

The base level in the Consumer Uptake Trial choice experiment described the current state of the rapid charging network in the UK. In February 2016, charge points had been installed at 70 service stations which meant that 98% of (GB) motorway traffic was within 20 miles of a service station charge point[15]. At the time of designing the choice experiment (January 2017), rapid charge points had been installed at all major UK service stations (Moto, Welcome Break, RoadChef and Extra), and 88 of the 97 service stations nationwide. The base attribute level was therefore set at rapid charge points installed every 20 miles on all major motorways and A-roads and stated to be equivalent to installing at all UK service

[15] Charge points at two thirds of motorway service stations, RAC Foundation, 12th February 2016 [online], available at http://www.racfoundation.org/media-centre/electric-charge-points-at-two-thirds-of-motorway-service-stations [accessed 11/01/2017]

stations. Figure 10 shows a map of motorways and major A-roads which was shown to all participants.

The medium level of rapid charging coverage had them installed in 20-mile intervals on all motorways and A-roads. This is in line with the Department for Transport's aim to have charge points every 20 miles along 95% of the strategic road network by 2020 (DfT, 2018). The third level explored rapid charging coverage equivalent to existing petrol station coverage. This was in response to growing attention towards urban rapid charging, for example, through the UK Government-funded Go Ultra Low Cities Scheme, as well as signs of intent by petrol station operators to install rapid charge points. Subsequently, both BP and Shell, two of the UK's largest fuel retailers, have acquired charge point operators (Chargemaster and NewMotion, respectively) and have announced plans to install charge points at their petrol station sites[16,17]. Although in future rapid charge points will not necessarily be co-located at petrol stations, this was considered a suitable reference point as all participants should have a clear view of what this level of coverage entails, and is less ambiguous than stating, for example, they are located at all major car parks or shopping areas.

Finally, a 'no network at all' was also included to calculate the value of rapid charging in general. This allows the utility of BEVs that are not capable of rapid charging to be evaluated.

[16] *BP to acquire the UK's largest electric vehicle charging company*, 28th June 2018 [online], available at https://www.bp.com/en/global/corporate/media/press-releases/bp-to-acquire-uks-largest-electric-vehicle-charging-company.html [accessed 28/08/2018]

[17] Shell switches on "Shell Recharge" electric vehicle charging service in the UK, 18th October 2017 [online], available at https://www.shell.co.uk/media/2017-media-releases/shell-switches-on-shell-recharge-electric-vehicle-charging-service-in-the-uk.html [accessed 28/08/2018]

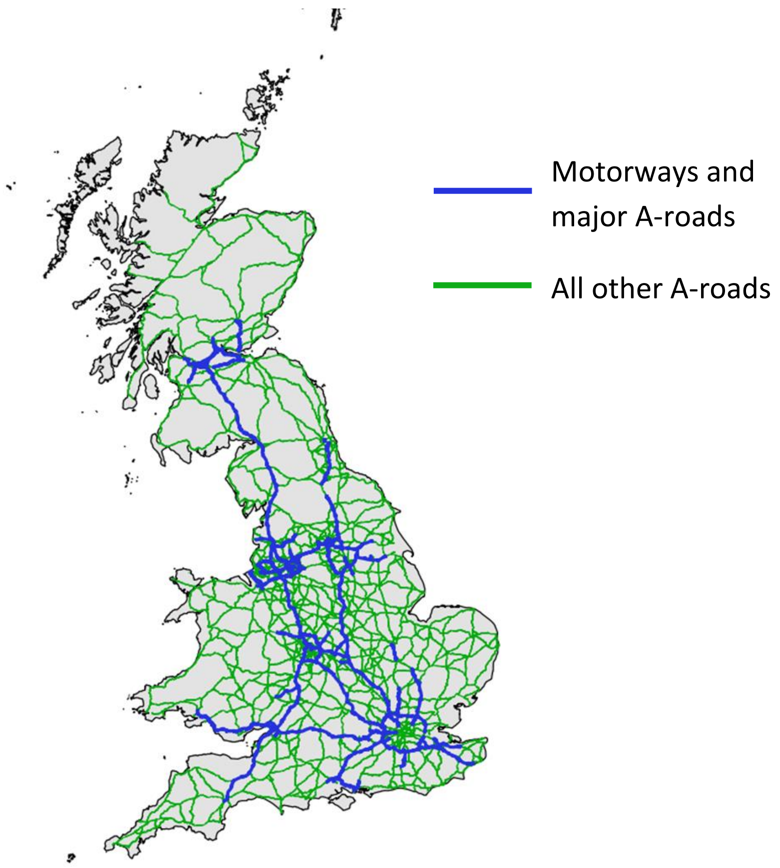


Figure 10: Map of Great Britain's motorways and major A-roads, and all other A-roads

In the information prior to the choice experiment participants were told at each level of rapid charge point coverage there will be sufficient rapid chargers at each location to ensure that queuing is unlikely. This meant that the choice experiment tested the value of perceived coverage; since consumers will likely discount occupied rapid charge points as they fail to meet the fast charge requirement for in-journey charging.

Availability of plug-in vehicle models

The DfT's 2016 survey of public attitudes towards electric vehicles (see Figure 9) revealed that 11% of car buyers were deterred from purchasing a PiV due to limited choice. The Element Energy choice experiment for DfT (Element Energy, 2015a) tested whether the lack of ULEVs across a wide range of manufacturers is a barrier to purchase. For each ULEV choice, participants were told whether the vehicle was available from three brands (either their preferred or other manufacturers), the majority of brands or all brands. The choice experiment showed that participants' values availability in three preferred brands over non-preferred brands at £1,285, but no statistically significant additional value for more availability was observed. It would appear, therefore, that consumers assign little value to model availability once they have a small number of models to choose from. At the time of the Consumer Uptake Trial there were 16 different BEVs and 19 PHEVs eligible for the UK Plug-in Car Grant; based on announcements by OEMs this is expected to increase markedly over the next 5-7 years.

As a consequence of these future releases, the suppression of plug-in car sales due to brand supply is a short-term phenomenon which is unlikely to continue into the 2020s. Since this study is focussed on decision making of mass market consumers in the future, brand supply was not included as an attribute in the choice experiment.

For additional detail on attribute selection, including other attributes which were considered but not included in the choice experiment, see section 2.9.2 of CVEI 170922-6.1 D5.1 - Part 1 - Consumer Uptake Trial Study Plan.

A.9.2.2 Final choice experiment attribute list and design

The attributes included in the choice experiment, as well as the possible values ('levels') seen by participants, are presented in Table 8:

Table 8: Description of each attribute in the choice experiment and levels shown

Attribute	Description	Levels
Purchase price	Upfront cost of purchasing the car, including VAT and grants (£).	*5 levels*, scaled based on the price of last main car purchased by the respondent • £10k / £11k / £12k / £13k / £14k if last car purchase <£15k • £16k / £18k / £20k / £22k / £24k if last car purchase between £15k and £25k or participant does not know • £24k / £27k / £30k / £33k / £36k if last car purchase >£25k
Running cost	On-going costs of running car, such as fuel/charging, maintenance, insurance and road tax (£/year).	*4 levels*, scaled based on respondents' stated annual mileage • £500 / £1000 / £1500 / £2,000 for mileage <15k miles • £1,000 / £2,000 / £3,000 / £4,000 for mileage >15k miles
Driving range	Official (type-approval) distance car can travel on either a full battery or tank of fuel (miles).	*4 levels* • For PHEVs: 10 / 20 / 40 / 60 electric miles, 400 fuel miles • For BEVs: 100 / 200 / 300 / 400 miles Participants were also shown an average real-world range (66% of official for electric, 75% for fuel)
Destination chargepoint availability	Chargepoint availability at work and public spaces.	*4 levels* 1. Home only 2. Home & work 3. Home & public car parks / spaces 4. Home, work & public car parks / spaces

Attribute	Description	Levels
Rapid chargepoint coverage	Density of rapid chargepoints, expressed as availability every “x” miles on “y” roads.	*4 levels (for BEVs only)* 1. Rapid charging not available 2. Rapid charging sites every 20 miles on motorways and major A roads (equivalent to charging at all motorway services) 3. Rapid charging sites every 20 miles on all motorways and A roads 4. Rapid charging sites every 20 miles on motorways and all A roads, and at a similar frequency to petrol stations on all other road types
Rapid charging rate	Average charge rate of rapid charging points, expressed as range (miles) added per 10-minute charge.	*3 levels (for BEVs only)* • Additional 25/75/150 miles per 10-minute charge

The choice sets were generated with the software package Ngene by ChoiceMetrics. This used so-called D-efficient design, which aims to avoid unbalanced choice sets which occur when the utility of one choice is considerably higher than the others (for example, a case where a conventional car has a lower purchase price and running costs than both the PHEV and BEV and no charging infrastructure is available). In this case the choice will be obvious for the vast majority of participants and little useful information will be gathered. Efficient design creates only choices where participants must carefully consider the full range of attributes, thereby optimizing the amount of useful information that can be drawn from the limited number of choice questions.

An example choice question is shown in Figure 11. In total, 100 choice questions were generated, and these were arranged in blocks of 10. Each participant was randomly assigned to one of the blocks, and so answered 10 choice questions. For each choice question, participants were asked to choose between the ICE, PHEV and BEV alternatives. Participants were also asked to choose between only the BEV and PHEV. This ensured that if a participant always chose the ICE option in their initial choice, information on their attitude towards PiV attributes was still collected.

	Petrol/ diesel car (A)	*Plug-in hybrid electric car (B)*	*Battery electric vehicle (C)*
Purchase price	**£20,000**	**£22,000**	**£24,000**
Annual running cost	**£1000** per year	**£500** per year	**£750** per year
Official driving range (average real-life range)	**400 (300)** miles	**20 (13) miles in electric mode,** 400 (300) miles using petrol engine	**200 (130) miles**
Charge point availability at trip destinations	Refuel at petrol stations	Charging available at **your home and workplace**	Charging available at **your home, workplaces** and in **public car parks / spaces**
Rapid charge points for long distance journeys	Refuel with petrol/diesel at any petrol station	Refuel with petrol/diesel at any petrol station for long journeys	Rapid charging sites **every 20 miles on motorways and major A roads** (i.e. at all motorway services) Rapid charging provides an additional **75 miles** of driving range for every 10 minutes of charging

If you could choose between these three cars, which one would you choose?

☐ ☐ ☐

If you had to choose between the plug-in hybrid and battery electric car, which one would you choose?

☐ ☐

After this example, you will be presented with the first choice question. The descriptions of the cars will change in each question, so please remember to read the information each time before making your choice.

Figure 11: Example choice question featured in the choice experiment

A.10 Telematics

The trial vehicles were equipped with a telematics device (‘dongle’) in the form of a self-contained lightweight cellular data logger fitted to the OBD-II port (see Figure 12). The dongles were supplied and maintained by FleetCarma; a Cleantech Information and Communications Technology company based in Ontario, Canada.

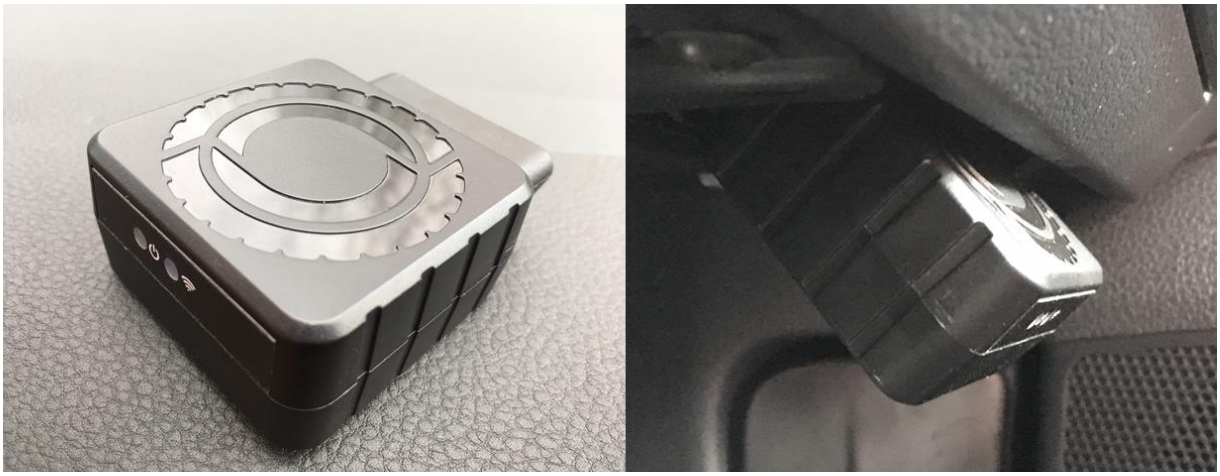


Figure 12: FleetCarma ‘C2’ telematics dongle (left) and in situ in vehicle (right)

The devices:

- integrated with the FleetCarma web portal to allow real-time capture of vehicle status and location;
- were compatible with all CAN bus and Legacy protocols dating back to 1996, and interface with J1979 OBD-II data;
- were powered by the vehicle battery, with low power consumption;
- automatically transmitted encoded and encrypted data via the cellular SIM card;
- had an on-board backup capacity to store data locally in the event that there was poor cellular signal or a fault with the network; stored data were transmitted automatically once network connection was restored;
- fitted quickly and easily within the vehicle without obstructing the driver or the operation of the vehicle.

The devices collected GPS coordinates, event-based data (e.g. at ignition on/off), and journey and charge data at up to 1Hz whilst the vehicles were in operation.

The data were output into raw datasets (containing the second-by-second data within each journey and charge event) and aggregated ‘Journey logs’ and ‘Charge logs’, containing summarised data for each journey and charge event (e.g. average speed during journey, and SOC at start and end of charge event). Full details of the contents of these datasets are provided in Table 9 to Table 12.

Table 9: Telematics data collected for each vehicle – Journey Logs

Data collected	Description	Sampling frequency
Trip Id	Unique ID for each journey; different journeys saved on different rows within the dataset	1 per journey
Start Date & Time	Start date and time for each journey	1 per journey
Trip Distance (mi)	Total distance of journey (ignition on to ignition off)	1 per journey
Trip duration (hh:mm:ss)	Total duration of journey (ignition on to ignition off)	1 per journey
Starting Odometer (mi)	Odometer at start of journey	1 per journey
Ending Odometer (mi)	Odometer at end of journey	1 per journey
Fuel Consumed (gal)	Total fuel consumed during journey	1 per journey
Fuel Consumption (MPG)	Average fuel consumption in journey (this is calculated in the portal by dividing the number of miles driven by the total gallons of petrol used)	1 per journey
Electricity Consumed (kWh)	Total electricity used during journey	1 per journey
Total Energy Consumption (MPGeq)	Average electricity consumption in journey	1 per journey
Start SOC (%)	Vehicle SOC at start of journey	1 per journey
End SOC (%)	Vehicle SOC at end of journey	1 per journey
Ambient Temperature (°F)	Average ambient temperature during journey	1 per journey
Average Speed (MPH)	Average speed during journey	1 per journey
Max Speed (MPH)	Maximum speed reached during journey	1 per journey
EV-Fraction	Proportion of time during journey in which PHEV was powered by the electric motor as compared to the ICE (PHEV only)	1 per journey
Auxiliary Load (kW)	Amount of energy consumed from the battery for non-driving functions, such as HVAC (PHEV and BEV only)	1 per journey
% Hard Acceleration	Total percentage of all acceleration events that are classified as “hard” acceleration.	1 per journey
% Hard Braking	Total percentage of all braking events that are classified as “hard” braking.	1 per journey
% Time Idle	Percentage of time during the journey in which the vehicle was idling (engine turned on but stationary) (PHEV or ICE)	1 per journey
Number of Idle Events	The count of the total number of idling sessions, where the engine was operating but the vehicle was stationary for more than 60 seconds continuously (PHEV or ICE)	1 per journey

Table 10: Telematics data collected for each vehicle – Charge Logs

Data collected	Description	Sampling frequency
Charge Session Id	Unique ID for each charge session; different charge sessions saved on different rows within the dataset	1 per charge event
Start Date & Time	Start date and time for each charge session	1 per charge event
Charge duration (hh:mm:ss)	Total duration of charge session (charge start to charge stop)	1 per charge event
Charging Power	Power output of the charger, categorised in levels ((1 = Slow charge, 2 = Normal charge, 3 = DC fast charge)	1 per charge event
Charger Energy (kWh)	The total amount of energy the vehicle gains during the charging session	1 per charge event
Charger Loss (kWh)	The total amount of energy lost during charging due to heat and other factors	1 per charge event
Start SOC (%)	Vehicle SOC at start of charge session	1 per charge event
End SOC (%)	Vehicle SOC at end of charge session	1 per charge event
Latitude	Latitude GPS coordinates of charge session	1 per charge event
Longitude	Longitude GPS coordinates of charge session	1 per charge event

Table 11: Telematics data collected for each vehicle and journey – Raw journey data

Data collected	Description	Sampling frequency (s)
Start Time (MetaData)	Start time and date of the journey	1 per journey
Timestamp(ms)	Timestamp (ms) for each row in dataset	N/A
Odometer [kilometers]	Odometer reading (km)	30
Vehicle Speed [kph]	Vehicle speed (kph)	1
RPM	Engine speed (PHEV)	1
ABS_LOAD	Absolute Engine Load (normalized air mass per intake stroke)	1
Fuel Level [%]	Fuel tank level as a percentage of the maximum nominal tank capacity: The Golf GT Edition (ICE) has a 50 litre tank capacity. The Golf GTE (PHEV) has 40 litre tank capacity.	10
HV Battery Current[A]	DC Electrical current measured at the high voltage battery terminal in amps. + is defined as charging the battery. – is discharging the battery.	1
HV Battery Voltage[V]	DC electrical voltage measured at the high voltage battery terminal in volts. This number will always be positive, and will remain within a consistent range.	1
HV Battery SOC[%]	State of Charge (SOC) (%)	10
HV Battery Temperature [degC]	High-voltage battery pack temperature (°C)	60
OAT [DegC]	Ambient temperature (°C)	60
Is Driving [bool]	Represents a 1 or a 0 to indicate if the vehicle is driving	1
Latitude [deg]	Latitude GPS coordinates	10
Longitude [deg]	Longitude GPS coordinates	10

Table 12: Telematics data collected for each vehicle and journey – Raw charge data

Data collected	Description	Sampling frequency (s)
Start Time (MetaData)	Start time and date of the charge	1 per charge event
Timestamp (ms)	Timestamp (ms) for each row in dataset	N/A
HV Battery Current[A]	DC Electrical current measured at the high voltage battery terminal in amps. + is defined as charging the battery. – is discharging the battery.	1
HV Battery Voltage[V]	DC electrical voltage measured at the high voltage battery terminal in volts. This number will always be positive, and will remain within a consistent range.	1
HV Battery SOC [%]	State of Charge (SOC) (%)	120
HV Battery Temperature [degC]	High-voltage battery pack temperature (°C)	60
Is Charging[bool]	Represents a 1 or a 0 to indicate if the vehicle is charging	1
Latitude[deg]	Latitude GPS coordinates	300
Longitude[deg]	Longitude GPS coordinates	300

A.11 Data management

All data storage and handling was performed in accordance with the International Standard for Information Security Management System (ISO 27001:2013).

On completion of the first recruitment survey, all participants were assigned a unique Participant ID number. All subsequent data collected was then linked to this Participant ID to ensure all data sources were linked, but participants' anonymity was retained. Data was excluded for any participants who dropped out during the trial by failing to complete the full four-day experience with each of the three vehicle types or the final Time Point 2 questionnaire (which included the key items necessary for analysis, including the choice experiment).

Full details of how the various sources of data were processed can be found in the following sections.

A.11.1 Questionnaire data

The Pre-trial, Time Point 1 and Time Point 2 questionnaires were hosted online by Accent. The Filter Survey questionnaires and the Interim questionnaires were hosted online through TRL's corporate SmartSurvey account. Questionnaire data was downloaded by TRL in electronic format. Each questionnaire was recorded with the Participant ID to enable linking between the different questionnaires (e.g. Filter Surveys, Time Point 1 and Time Point 2) and to enable linking with other sources of data (e.g. telematics).

All questionnaire data was cleaned by TRL, including checking for missing or invalid values and unusual patterns in the data. For example, if participants always answered the first option for each question in a particular set then it suggested they may not have answered honestly and openly; data were flagged for such cases. The completion time for core questionnaires (Pre-trial, Time Point 1, Time point 2) was logged by Accent. Average completion times were assessed for each questionnaire, and extreme outliers were identified. Any outliers which are deemed to represent invalid responses were flagged (such as those which were completed unusually quickly or unusually slowly[18]).

A.11.2 Choice experiment data

Element Energy cleaned and processed the raw data from the choice experiment before undertaking the required consumer choice analyses. These analyses are described in more detail in section A.12.5 and in response to the research questions outlined in Appendix B.

A.11.3 Telematics data

Telematics data was provided by FleetCarma (see section A.10). All datasets were cleaned by TRL in order to remove data which did not represent valid participant use cases. The cleaning process included:

- Removing journeys less than 0.1km (100m) in distance or one minute in time (whichever was lesser) – to remove instances where, for example, the driver turned the vehicle on and off in order to check the charge, or moved the car in the driveway to enable recharging.
- Removing journeys carried out by TRL or Cenex staff as part of the vehicle handover process, or when the vehicle required maintenance (i.e. non-participant events).

GPS coordinates during charge events were anonymised by recoding the location data as either 'Home' or 'Away from home'. Repeated charge events which occurred away from home were identified using appropriate labels, e.g. Away from home 1, Away from home 2, etc., to enable analysis of journey patterns. For example, if a participant charged at work on multiple occasions, all charge events at this location were given a single location label (e.g. Away from home 1).

GPS coordinates captured within journeys (i.e. in the raw journey data files) were also anonymised and recoded to ensure protection of personal data.

To retain potential future value of the dataset, additional spatial information was coded into the journey dataset prior to anonymisation:

[18] Completion times were captured for all questionnaires completed during piloting and during the trial. Using these data, an acceptable range of completion times was defined based on the average completion time +/- three standard deviations.

- Road type
- Distance from nearest chargepoint
- Distance from home
- Land use (e.g. urban major conurbation, rural hamlets and isolated dwellings)

A.12 Data analysis

An overview of the types of statistical analysis techniques used to analyse the data from this trial is provided in the following sections.

A.12.1 Segmentation

The majority of the questions developed for the ETI PiV study were subsequently used by Element Energy in a study commissioned by DfT of consumer attitudes to plug-in vehicles (Element Energy, 2015a). In that study, a fresh clustering analysis was applied to data from the new sample of 2,020 participants. This new segmentation analysis (though on a very similar set of questions to the PIV study) resulted in 6 segments (as shown in Figure 13) and it was these consumer choice coefficients that were incorporated into the ECCo model.

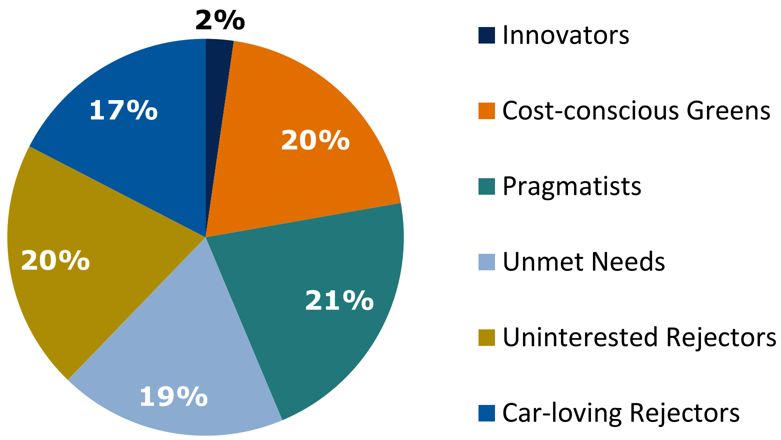


Figure 13: Consumer segment shares in choice experiment sample of the DfT survey (Element Energy, 2015)

For this Consumer Uptake Trial, the sample size was too small to undertake a new clustering analysis to see whether a set of segments could be derived. On a sample of 200, and with a large question set even when reduced through factor analysis, there would be many possible answer combinations that it would be very difficult to find a robust cluster structure.

The solution to this was to rely on the robustness of the DfT study, which had itself been based on a large sample size of over 2,200 to derive its segments. Therefore, this dataset was used to generate a set of question weightings. These could then be assigned to the responses for each person in the current study in order to allocate them into a segment – i.e. the same segments as in the DfT study. The steps to do this were as follows:

1. The questions which featured in both the DfT study and the current Consumer Uptake Trial[19] were identified; this was restricted to numerical or ordinal variables only. A set of 68 were identified.
2. A discriminant analysis (DA) was undertaken using these 68 questions. DA identifies which combination of attitude questions contributes the most to the separation between the segments (rather like multiple linear regression, but this time on a set of interval/categorical variables). This process was used to identify a set of 'golden questions' and a set of weightings for each one. The golden questions comprised the smallest number of questions that can be used to most accurately replicate the segment solution (using the question weights generated) on a new sample.

   The DA was carried out at four separate levels to derive different sized sets of 'golden questions' and associated question weightings. The difference between these sets was the trade-off between the number of questions and the assignment accuracy. Each question set is compared in Table 13: Reliability of the allocation algorithms for each segment for each DA solutions.

   It is inevitable when using a reduced subset of the original survey questions (i.e. not using every single variable that was used in the original segmentation) that the accuracy of the allocation procedure will never be 100%. Statistically, the minimum requirement is that the model accuracy performs 25% better than would happen by chance. For instance, if there were two equally sized segments there would be a 50/50 chance that someone would be accurately classified in the correct group by random. For these segments, the chance of accurately classifying someone in the correct group is 20%, leaving a minimum acceptable hit ratio of 45%, although it is desirable to aim for a hit ratio of 70-80%.

[19] Where the CVEI survey made a distinction between BEV and PHEV in some questions, but the DfT survey just asked about 'EVs', the average of the two CVEI questions was used.

Table 13: Reliability of the allocation algorithms for each segment for each DA solutions[20]

	Predicted accuracy of question set (%)				
Segment	**All 68 variables**	**(1) 42 variables**	**(2) 29 variables**	**(3) 25 variables**	**(4) 21 variables**
Uninterested Rejecters	85%	82%	81%	79%	76%
Cost conscious greens	79%	76%	76%	74%	74%
Pragmatists	76%	76%	73%	75%	73%
Car-loving Rejecters	84%	83%	81%	80%	78%
Unmet needs	65%	63%	57%	56%	57%

3. Although it would have been possible to just choose the solution from above that has the most accuracy, there was not much difference between them. Given that the goal was to try and find the smallest number of questions that could be used, all four solutions were applied to the new Consumer Uptake Trial data. The DA function generated a set of weightings for each question and these were applied to each participant's scores on the predictor variables to predict the segment to which the individual belonged.
4. The four sets of segment assignments were compared in terms of how well they had generated a sensible and well discriminated set of segments from the new data. The solution with the greatest and clearest degree of separation was chosen. This involved using ANOVA analysis[21] and comparing the F-ratio (which computes the variance between groups relative to the variance within groups) and choosing the highest. The solution with the highest F-ratio was solution (3) with 25 variables (Total F for each solution (1) = 160.624, (2) = 177.772, (3) = 188.232, (4) = 156.29).
5. A check was undertaken on the DfT survey data to see whether it was also possible to derive a set of question weights to predict the Innovator segments in order to see whether any had inadvertently made it into this Consumer Uptake Trial sample.

[20] Note: only 5 segments were predicted because the Innovator segment was derived in the DfT study (as with the original PiV study) using a set of a-priori criteria (based on purchase price of last car, plans to purchase an EV) and not through the cluster analysis

[21] This measures the degree of discreteness of the clusters for each of the solutions. The best solution is one where the centres of each cluster (mean (factor) scores on the clustering variables) should be as distant from one another as possible and the cloud of data points surrounding each cluster centre should be as concentrated as possible. Moreover, the differences in mean values of the variables at each cluster centre should be statistically significant. The higher the 'F' ratio, the more there is variability between groups compared to within them and the more discrete and concentrated are the clusters.

However, a DA with sufficient accuracy could not be generated from the data. This is not a surprise given very small number of them in that survey. Given the main characteristic of the Innovator was a near-term intention to by an EV and these people had been screened out of the Consumer Uptake Trial sample, it can be concluded that this sample did not include Innovators.

This process enabled participants in the Consumer Uptake Trial to be allocated to the existing ECCo segments. The final set of 25 variables used, and the resulting 5 segment solution are introduced in section B.3. The segment which is earliest to adopt (i.e. Innovators, or the previously entitled 'Plug-in Pioneers' in the PiV study) was not identified in the Consumer Uptake Trial sample, in keeping with the objectives of the trial to eliminate Innovators during the recruitment process.

In interpreting the results of the segments, some caveats need to be considered:

- The original PiV and subsequent DfT segmentations were carried out on random samples of the national UK population, whereas this Consumer Uptake Trial has been conducted on geographically specific samples.
- In addition, there is no way of avoiding some bias in a study which asks people to take part in a trial (especially one that requires certain infrastructure such as off-street parking/ garage which is already an unrepresentative subset of the whole population). Although the nature of the study (low carbon vehicles) was not disclosed to participants until they were some way in to the trial, they still had to be prepared to invest time and effort into such an activity. In some cases this could mean they were disproportionately keen to be involved in vehicle trials which could introduce attitudinal bias. It is not possible to control or correct for these biases as they are non-observable characteristics.

These differences between the samples, combined with several years between the different surveys in which the general population have gained greater awareness of EVs, plus the smaller sample size of the Consumer Uptake Trial, will have introduced a variety of reasons why the different segmentation exercises will result in different group proportions.

A.12.2 Factor analysis and reliability measures

The questionnaires were made up of many attitudinal items which measured participants' attitudes and personality traits. For example, the driving style questions were made up of 44 items, each on a six-point scale from 'not at all' to 'very much', which provided information on self-reported driving style.

In order to reduce the number of variables to a more manageable number for statistical analysis, factor analysis was applied to these items. Factor analysis combines the information from a large number of similar items into a smaller set of factors, by assessing the inter-correlations between items and identifying common groups. The resulting factors represent coherent subscales which can be used in subsequent analysis.

The reliability of these subscales was confirmed using reliability measures such as Cronbach's alpha. A scale is considered to have good internal consistency if the output from the reliability of the scale gives a Cronbach's alpha coefficient of 0.7 or higher; this was the criterion used in this trial.

A.12.3 Statistical comparisons

Comparison of the factors was conducted using repeated-measures[22] statistical methods. For example, this enabled identification of differences in attitudes before and after experience of the three vehicles, and differences in travel behaviour (e.g. average journey distance, or average speed) and the ratings of vehicle performance (e.g. vehicle acceleration, responsiveness, comfort and noise) between the three vehicle types.

Repeated-measures techniques included:

- **Analysis of Variance (ANOVA)**: a one-way ANOVA with repeated measures compares whether the mean score of a continuous variable differs between three or more related conditions. This test determines whether the conditions differ and whether this is unlikely to have occurred by chance, but does not identify where the significant differences lie (post-hoc t-tests are required for this).
- **Friedman test**: a non-parametric alternative to the one-way ANOVA with repeated measures, used to test for differences between conditions when the dependent variable being measured is ordinal, or is continuous but the data do not meet parametric assumptions (Wilcoxon tests are used post-hoc).
- **Paired samples t-test**: a parametric test which determines whether a difference between the mean values of a continuous variable for two paired samples (e.g. samples from before and after a treatment) is unlikely to have occurred by chance.
- **Wilcoxon signed rank test**: a non-parametric alternative to a paired samples t-test, is used to compare measures for the same participants that have been collected at multiple time points.
- **Cochran's Q test**: a non-parametric test used to determine if there are differences on a dichotomous (has only 2 values, e.g. yes/no), dependent variable between three or more related conditions (similar to a one-way repeated measures ANOVA but for a dichotomous, instead of continuous, dependent variable).
- **McNemar dichotomous variables test**: similar to Cochran's Q, a non-parametric test used to identify differences between two related groups on a dichotomous dependent variable.

Each test is reported with a test value (e.g. a Z or χ^2 value) and a measure of statistical significance (otherwise known as a *p*-value). The test value is a statistical calculation and relates to the degree of difference in the data being compared. Generally speaking, the greater the magnitude of a test value, the more significant the result. The test values each relate to a *p* value. The typical *p*-value used in social science is 0.05; if the *p*-value is less than 0.05 it means that there is a more than 95% probability that the results observed (or more extreme results) did not occur by chance alone and is referred to as a statistically significant result.

[22] 'Repeated measures' or 'within-participants' analysis was required since participants' attitudes and behaviours were measured at multiple times at different time points.

The specific techniques selected for each analysis are documented alongside the results, and depended on the characteristics of the data obtained. For example, parametric statistical tests such as ANOVA or t-tests rely on underlying assumptions about the distribution of the data; tests were performed to check these assumptions before analysis was carried out. Where assumptions were not validated, non-parametric equivalents were used instead. In particular, non-parametric tests were used for questionnaire items that produced ordinal data (such as Likert Scales) rather than interval data (such as year of birth).

A.12.4 Regression analysis

Regression modelling was used to address Research Questions 5 and 6 (see section A.2).

Regression modelling was also used to explore the extent to which variance in willingness to consider BEVs and PHEVs was accounted for by participants' attitudes towards PiVs (measured from questionnaire responses), their usage behaviours with the different types of vehicles (measured from telematics data), and other factors not included in the regression analyses that address the research questions above.

Firstly, correlation matrices were produced to assess the relationships between the predictive variables (e.g. personal characteristics such as age, gender and personality, or personal-situational variables such as income or mileage) and the outcome variables (willingness to consider a BEV or PHEV). This enabled identification of the key variables that were highly correlated with the outcome variables. This approach also enabled identification of multicollinearity; that is, where two or more predictor variables were highly correlated with one another. Insertion of large numbers of highly correlated predictor variables (i.e. with high multicollinearity) is unlikely to result in a regression model which provides informative conclusions of the impact of personal characteristics on willingness to adopt. This initial analysis of the relationships between variables therefore informed the methodology for multiple logistic regression.

Logistic regression was used to determine the extent to which a smaller sub-set of the most important predictor variables (which were not highly correlated with one another) were significant predictors of willingness to adopt a BEV or PHEV. The analysis used responses to the question: "In the next 5 years, I would choose to have a BEV/PHEV …as my main car" (from the Time Point 2 questionnaire) as the outcome variable. A stepwise approach was used to assess which variables best predict the answer to this question.

For this analysis, the predictor variables were expressed as single scalar values for each participant. For example, although variables such as speed, trip length, etc. were obtained from the telematics data, time-resolved individual data points from the telematics outputs could not be used directly as predictors in the regression analyses. Instead, they were aggregated in the form of single scalar values per participant. For example, mean speed over all the trips made by a participant in each car, mean trip length per car and total distance travelled per car, etc.

A.12.5 Choice experiment

The results of the choice experiment were analysed using the statistical package NLogit (Version 4.0), which fits a simple multinomial logit model to derive the choice coefficients (β) for each of the vehicle attributes investigated. The logit model used is presented in Table 14 and consisted of utility equations for each of the three powertrain alternatives.

Table 14: Components of the utility equations for each alternative (ICE, PHEV & BEV) in the choice experiment. Total utility is the sum of each column

Attribute	U_{ICE}	U_{PHEV}	U_{BEV}
Purchase price (£)	$\beta_{purchase\ price} \times Purchase\ Price_{ICE}$	$\beta_{purchase\ price} \times Purchase\ Price_{PHEV}$	$\beta_{purchase\ price} \times Purchase\ Price_{BEV}$
Annual Running Cost (£/yr)	$\beta_{running\ cost} \times Running\ Cost_{ICE}$	$\beta_{running\ cost} \times Running\ Cost_{PHEV}$	$\beta_{running\ cost} \times Running\ Cost_{BEV}$
Official driving range (km)		$\beta_{range,PHEV} \times Range_{PHEV}$	$\beta_{range=320km,BEV} \times Range[320km]_{BEV} + \beta_{range=480km,BEV} \times Range[480km]_{BEV} + \beta_{range=640km,BEV} \times Range[640km]_{BEV}$
Charge point availability at trip destinations			$\beta_{work\ charging,BEV} \times Charging\ Access_{work,BEV} + \beta_{public\ charging,BEV} \times Charging\ Access_{public,BEV} + \beta_{work\ \&\ public\ charging,BEV} \times Charging\ Access_{work\ \&\ public,BEV}$
Rapid charge point availability for long distance journeys			$\beta_{rapid\ charging,BEV} \times Charging\ Access_{rapid,BEV}$
Rapid charging rate (miles added per 10min charge)			$\beta_{rapid\ rate=75\ miles,BEV} \times Rapid\ Rate[75\ miles]_{BEV} + \beta_{rapid\ rate=150\ miles,BEV} \times Rapid\ Rate[150\ miles]_{BEV}$
Alternative Specific Constant[23]		ASC_{PHEV}	ASC_{BEV}

This model resulted in a log-likelihood function value for the whole sample that was closest to 0, and therefore demonstrated the greatest statistical significance. The log-likelihood function provides a measure of the model fit (Hensher, Rose, & Greene, 2005). Attributes with only a single choice coefficient, such as purchase price and running cost, are modelled as continuous and the coefficient represents the change in utility for each unit change in the attribute's value (for example, each additional pound of purchase price). This is sufficient if the relationship between attribute value and utility is assumed to be linear. For other attributes, each attribute level featured in the choice experiment is modelled with its own choice coefficient. This is required if the attribute values are categorical (i.e. do not lie on a numerical scale), such as availability of destination charging, or the relationship between attribute value and utility appears to be non-linear, such as rapid charging rate. In this case,

[23] Note the Alternative Specific Constant encompasses the value of the unobserved factors not explicitly investigated in the choice experiment, as well as correcting for the fact that some powertrains gain utility from attributes that are not relevant to others (e.g. access to rapid charging applies only to BEVs)

utility is measured relative to one of the attribute levels (i.e. the base level), for example a rate of 50 kW for rapid charging rate.

A.12.5.1 Choice coefficients

The choice coefficients, β, were derived at the whole sample level as well as for each of the consumer segments (see section B.3). Derived coefficients were tested for statistical significance, using their probability value (known as a *p* value) reported by NLogit. A coefficient is considered statistically significant if its *p* value is less than 0.05. This signifies that the null hypothesis can be rejected with 95% confidence, or in other words, there is only a 5% chance that a non-zero coefficient was identified due simply to random sampling error. Where relevant, results which are not statistically significant are still shown here but caveated with their *p* value.

The responses of four participants were excluded from the choice experiment analysis as they were shown blank purchase price and running cost attributes. Since the Unmet Needs and Car-Loving Rejecters consumer segments contained only six and five participants respectively, the sample sizes were too small to derive choice coefficients and they were not considered at the consumer segment level.

The derived choice coefficients for each attribute are expressed in terms of willingness-to-pay (WTP) by dividing by the purchase price coefficient, $\beta_{purchase\ price}$. WTP shows the change in upfront cost that would have an equivalent effect on the vehicle's utility as a change in that attribute's value. For example, if WTP for a vehicle attribute is £1,000, then participants are willing to spend £1,000 more upfront on a vehicle with that attribute than an equivalent vehicle without it. In other words, adding that attribute to a vehicle would increase the share of participants choosing that vehicle by the same amount as reducing its purchase price by £1,000.

The derived WTP values are presented in Appendix 0. In each case, these are shown at the whole sample and consumer segment levels. The values are also compared with those derived from the consumer survey carried out in 2015, from which the choice coefficients currently used in ECCo were derived (Element Energy, 2015a). When comparing the coefficients at the whole sample level, it must be noted that the sample compositions differed, as evidenced by the different proportions of each consumer segment in the DfT 2015 survey participants (see section B.3).

A.12.5.2 Simple choice model

To illustrate the impact of each attribute on consumer preference, a simple choice model was constructed, using the derived choice coefficients. For a particular set of attribute values, the model predicts the share of trial participants that would choose each of the three alternatives (ICE, PHEV and BEV) under choice experiment conditions. Note that this is not the same as the predicted sales share under market conditions, as is calculated in ECCo. A model to predict sales share requires additional steps to account for the fact that participants are not spending real money in a choice experiment, other alternatives may be available, and there are other non-financial factors such as limited vehicle supply. Instead, this choice model is used purely to illustrate the influence each attribute has on choice between three specific alternatives.

The model reproduces the multinomial logit model used to derive the choice coefficients. The share for alternative i is calculated via the logit equation:

$$share_i = \frac{e^{U_i}}{\sum_j^n e^{U_j}}$$

- U_i is the utility of alternative i
- n is the total number of alternatives, which in this case is three (ICE, PHEV and BEV).

The choice model contains a set of 'reference' values for each attribute. The impact of changing the value of a single attribute on participant choice can then be illustrated by keeping all other attributes at their reference values. The reference values are based on the three Volkswagen Golf models used in the trial (see Table 15).

Table 15: Vehicle characteristics used to calculate reference values for each attribute

Powertrain	ICE	PHEV	BEV
Model	Volkswagen Golf GT Edition 1.4 TSI DSG GT Edition 5dr, 2016 model, 7 speed auto DSG	Volkswagen Golf GTE 1.4 TSI 5dr, 2017 model, 6 speed auto DSG	Volkswagen e-Golf 5dr, 2017 model
Price (P11D value, as quoted by comcar.co.uk)	£26,445	£30,635	£32,190
Plug-in Car Grant	£0	£2,500	£4,500
First-year VED	£165	£10	£0
Subsequent year VED	£140	£130	£0
Fuel consumption, NEDC combined (L/100km)	4.8	1.8	0
Electricity consumption, NEDC combined (kWh/100km)	0	11.4	12.7
Insurance Cost (£/yr)[24]	£303	£397	£275
Maintenance Cost (£/yr)[25]	£186	£178	£275
Electric Range, NEDC (km)	0	50	300
Rapid Charging Rate (kW)	-	-	50

[24] Cheapest quotation from moneysupermarket.com for a 45 year old teacher from South East England driving 9,500 miles per year

[25] Maintenance cost as reported by the Money Advice Service for each model (September, 2017): https://www.moneyadviceservice.org.uk/en/tools/car-costs-calculator/

The reference values for each attribute used when considering the whole sample are shown in Table 16.

Table 16: Example reference values for each attribute in the choice model. Values shown are for the whole sample

	ICE	PHEV	BEV
Purchase price (£)	£26,610	£28,145	£27,690
Annual running cost (£/yr)	£1,574	£1,322	£837
Official electric range (km)	0	50	300
Chargepoint availability at trip destinations	-	Home only	Home only
Rapid chargepoint availability for long distance journeys	-	-	Every 20 miles on motorway and major A-roads
Rapid charging rate (miles added per 10 mins charge)			41 (equivalent to 50 kW with e-Golf electricity consumption)

Note that at the consumer segment level (consumer segmentation is described in full in Section B.3), the annual running costs differ due to the different annual mileages of each consumer segment. The reference annual running costs are shown in Table 17. These are calculated using the average annual mileages reported for each consumer segment, and the official NEDC fuel and electricity consumption values, as this information is what is shown to a potential buyer. The NEDC test-cycle is known to underestimate energy consumption under real-world conditions so, in reality, annual fuel and electricity costs are likely to be higher. Note that the reference values themselves are relatively unimportant as the model is merely used to illustrate the sensitivity of consumer preference to a particular attribute, rather than attempting to recreate observed market shares. This is particularly true of the ICE purchase price, which is for a relatively high trim variant, whereas a buyer in the real world would have the option of choosing cheaper ICE trim levels. The result is that the share of participants that are predicted to choose an ICE is likely to be lower than current market shares.

Table 17: Reference values for the annual running cost attribute for each consumer segment[26].

	ICE	PHEV	BEV
Global sample	£1,574	£1,322	£837
Cost-conscious Greens	£1,472	£1,255	£805
Pragmatists	£1,582	£1,327	£839
Uninterested Rejecters	£1,469	£1,253	£804

Outputs from the choice model are displayed in Appendix B to support answers to the study research questions. Results from the segmentation analysis, including a description of the segments, are provided in section B.3.

Appendix B Results from statistical analysis

This Appendix provides full details of the results from statistical analysis of the trial data. A discussion of the key findings and overall conclusions from the trial can be found in the accompanying Summary Report.

B.1 Sample characterisation

- → **The target sample of 200 mainstream consumer participants completed the trial.**
- → **The final sample closely matched the target stratification criteria for age, gender and resident area.**
- → **The types of main car owned by participants aligned with the most popular car segments in the UK (Lower medium, Upper medium, Supermini and Dual purpose)**
- → **Some differences between the sample and the wider national population were identified, likely due to the recruitment criteria used for the trial:**
    - → **Households with two or more cars were overrepresented.**
    - → **Annual car mileage broadly matched national travel patterns, except the sample underrepresented drivers who travel less than 5,000 miles per annum**
    - → **The distribution of household income in the sample was similar to the national population, but underrepresented households with an annual income of less than £30,000**
    - → **The sample overrepresented married individuals, and underrepresented single, divorced and separated individuals.**

The final sample of Consumer Uptake Trial participants is shown in Table 18.

[26] Calculated with NEDC fuel and electricity consumption figures. Assumes a petrol price of £1.28/L and an electricity price of £0.15/kWh.

Table 18: Final sample of Consumer Uptake Trial participants (differences between final and target sample shown in parentheses)

Resident area	Age group	Gender		Total
		Male	Female	
Urban	19-29	13 (-1)	9 (-3)	**22 (-4)**
	30-49	33 (-1)	29 (-1)	**62 (-2)**
	50+	40 (-1)	33 (+1)	**73 (-2)**
Rural	19-29	3 (+1)	3 (+1)	**6 (+2)**
	30-49	8 (+2)	6 (0)	**14 (+2)**
	50+	14 (+2)	9 (-2)	**23 (0)**
Total		111 (+4)	89 (-4)	**200 (0)**

Differences between the final sample and the target sample are shown for each cell; this confirms that the final sample represented a very close match to the original target sample stratification matrix (see section A.3.1.2).

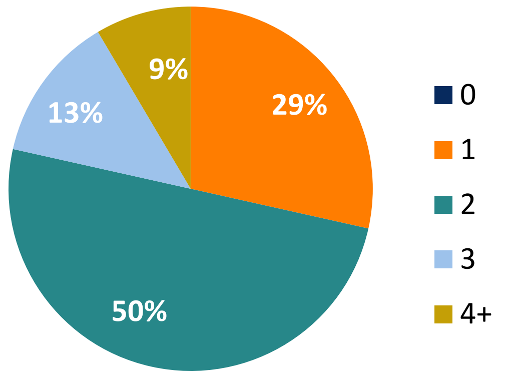
Resident area, age group and gender were used for stratifying the sample (as shown in Table 18) to ensure it was representative (on these variables) of the GB driving population. Additional data were collected from each participant using the Filter surveys, Pre-trial Questionnaire and TP1 questionnaire to enable further characterisation of the final sample; these data are summarised at the global sample level in the following sections. Further profiling of the sample at the consumer segment level is provided in section B.3.

B.1.1 Household vehicle ownership and use

Participants were asked to provide information on the number and type of cars, and number of drivers in the household. Half of the participants reported having two cars in their household, 28% reporting having only one car, and the remaining 22% had more than 2 cars. These data are compared to data from the National Travel Survey (NTS, 2017) to assess the extent to which the distribution of car ownership in the sample was representative of the wider population[27] (see Figure 14).

[27] The National Travel Survey, published by the UK's Department for Transport, provides statistics on personal travel within Great Britain by a sample of residents of England:

https://www.gov.uk/government/collections/national-travel-survey-statistics



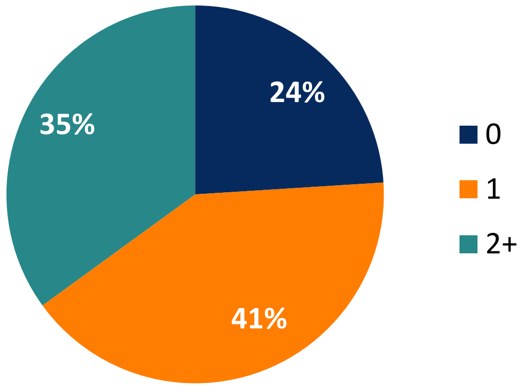


Figure 14: Number of cars owned by participants in trial (left) and distribution of household car ownership from the NTS (2017) (right)

Households with 2 or more cars were overrepresented in the Consumer Uptake Trial sample compared with the national population as a whole; more than 70% of participants reported having 2 or more vehicles, compared with 35% of households in the wider population. This was at least in part due to the recruitment criteria for the trial; firstly, participants were required to have access to their own private vehicle (ruling out households with no cars) and secondly participants were required to have off-street parking for at least one vehicle, meaning the majority of participants lived in houses with driveways and/or garages where it is more common for there to be multiple vehicles compared with other types of accommodation.

The distribution of different types of cars owned by participants in the sample is shown in Figure 15.

Type of car	Count of participants
Lower Medium	67
Upper Medium	42
Supermini	34
Dual Purpose	13
Specialist Sports	13
MPV	12
Mini	9
Executive	9
Luxury	1
Total	**200**

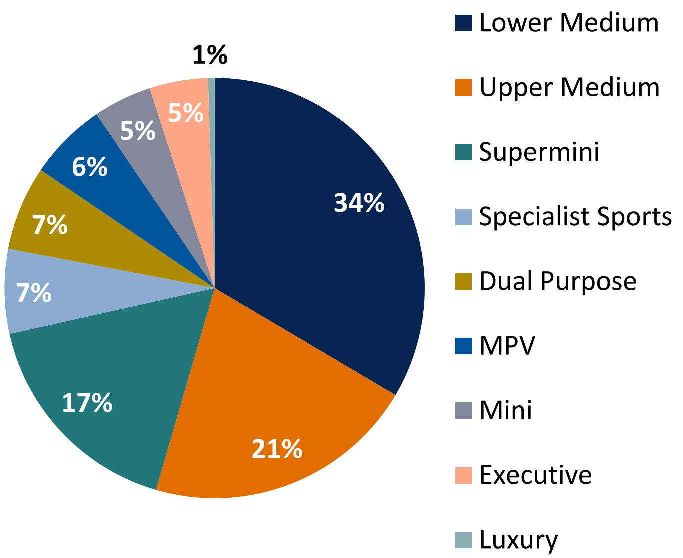


Figure 15: Type of car owned by participants

The Lower Medium, Upper Medium, and Supermini segments were the most common categories of cars owned by participants. The Society of Motor Manufacturers and Traders (SMMT) reports the number of annual new car registrations by segment type. These data show the top four segments with the highest number of registrations in 2017 were Supermini (29.5%), Lower medium (28.7%), Dual purpose (18.1%) and Upper medium (9.6%) (SMMT, 2018); thus suggesting the types of vehicles owned by participants in the sample followed a broadly similar pattern to national trends.

Figure 16 presents the number of licensed drivers in participants' households. The large majority of the sample had either one driver (22%) or two drivers (59%) in the household.

Number of drivers in household	Count of participants
1	44
2	118
3	26
4	11
5	1
Total	**200**

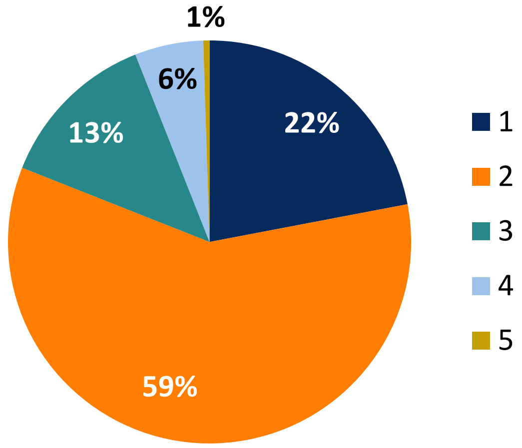


Figure 16: Number of drivers in the household

Figure 17 displays participants' reported number of private and company cars which were kept at their households. The majority of participants (81%) reported having either 1 or 2 private cars. Very few participants (5%) reported having a company car, in line with the recruitment criteria for the trial which ruled out any prospective participants who had a company car as their main vehicle (see section A.3.2.2).

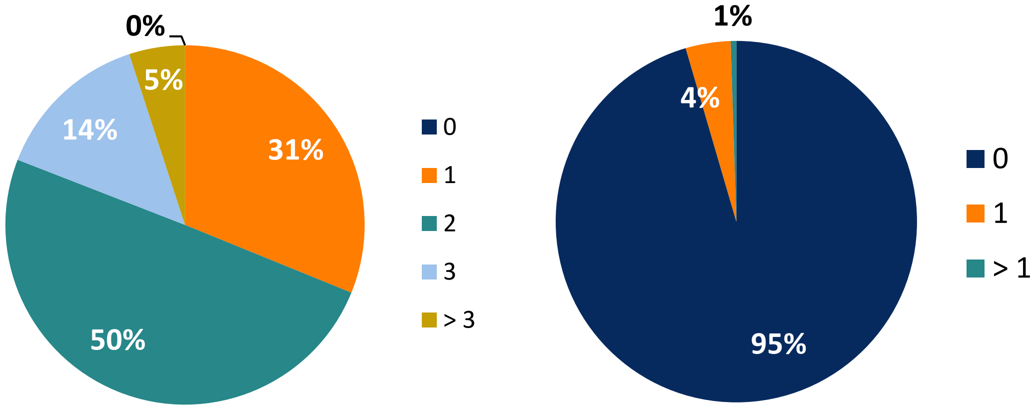


Figure 17: Number of private cars (left) and company cars (right) kept at the households of participants

The characteristics of participants' main cars at the time of purchase are shown in Figure 18, in terms of the age of the vehicle and the purchase price. The majority of the sample (78%) paid £20,000 or less for their main car.

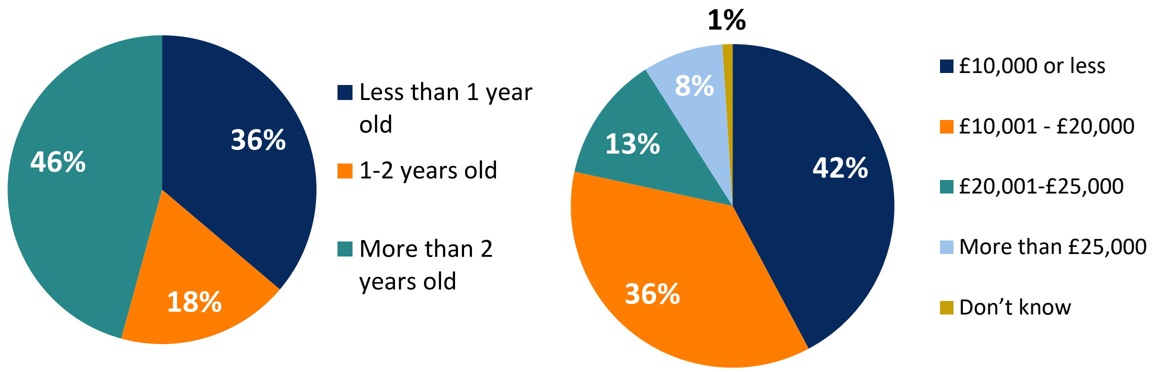


Figure 18: Age (left hand panel) and value (right hand car) of main car at time of purchase of participants in the final sample

B.1.2 Car mileage

Participants' reported annual mileage travelled by car is shown in Figure 19 along with the distribution of annual mileage from the NTS (2017).

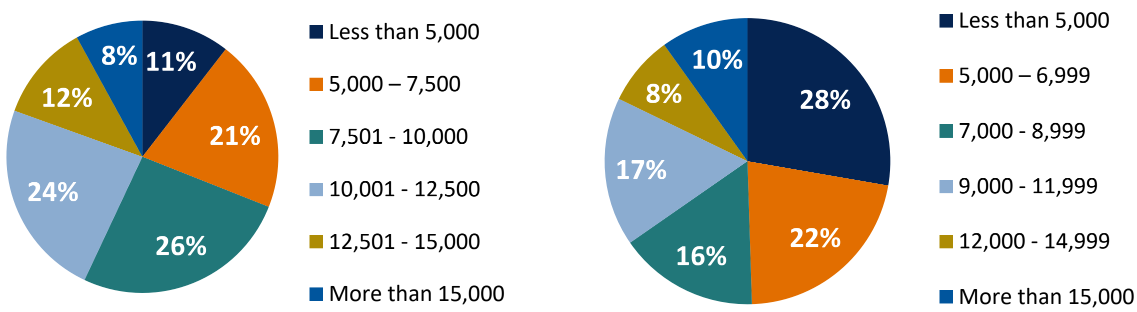


Figure 19: Annual mileage of participants in the trial (left) and distribution of annual mileage from the NTS (2017) (right)

Comparison of the distribution of participants' annual mileage with data from the National Travel Survey (2017) shows a broadly similar pattern, except the proportion of people who travel less than 5,000 miles per annum was underrepresented in the Consumer Uptake Trial sample compared with the wider population. This is in line with the recruitment criteria for the trial which required participants to be a current car owner and drive regularly (at least once every two or three days). Although the proportion of the sample who reported high annual mileage (more than 15,000 miles) was similar to that in the NTS data, it should be noted that company car drivers (who are typically have very high annual mileage) were excluded from the study for insurance reasons (see section A.3.2.2). As such the sample does not represent this high mileage group and instead only represents private vehicle users; the findings should therefore be interpreted with caution when extrapolating to the wider population.

Evidence in the literature related to how accurately people report their own mileage is mixed. The telematics data from the 12-day experience with the vehicles is not large enough to extrapolate to annual mileage patterns.

Figure 20 presents information on the typical weekly mileage of participants. The left hand panel summarises the typical car driving mileage on a weekday, and the right hand panel summarises the typical mileage on a day at the weekend. The two distributions are fairly similar, although a higher proportion of participants drive more than 70 miles on a typical weekday (14%) compared with on a typical weekend day (9%).

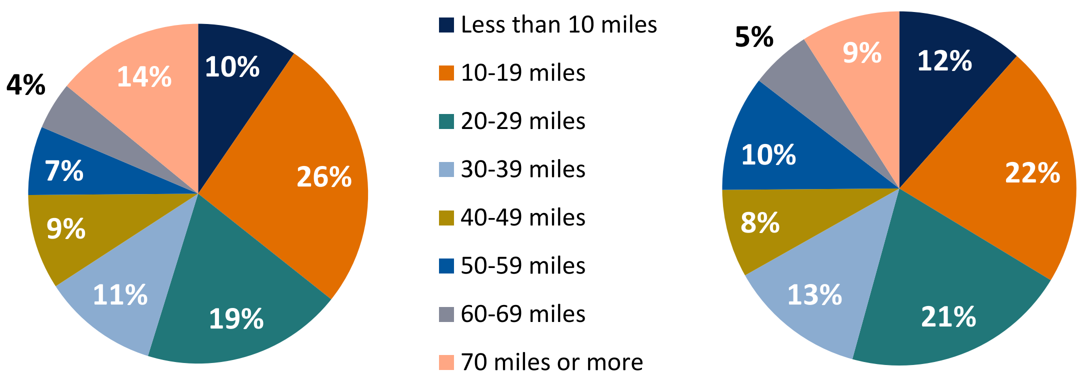


Figure 20: Typical car driving mileage on a typical weekday (left) and weekend day (right)

B.1.3 Education, income and living situation

The highest educational qualifications achieved by participants, and their employment status at the time of the trial, are summarised in Figure 21.

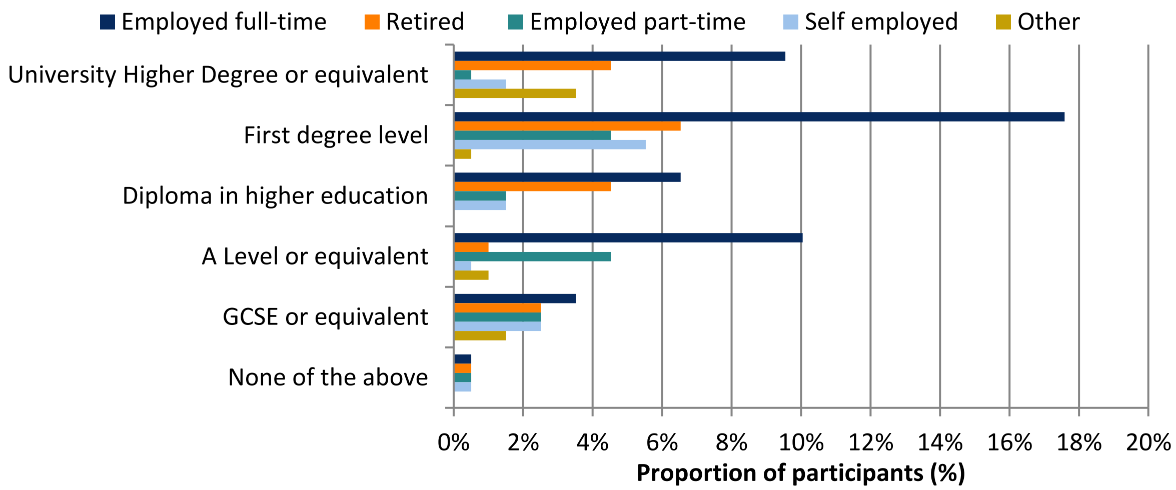


Figure 21: Highest educational qualification and employment status of participants

Participants were asked to indicate their total household income (from all sources before tax and other deductions). Figure 22 summarises these data, and shows a fairly even distribution across the income brackets. This figure also shows the proportion of households in the UK by gross annual income band, as reported by the Office of National Statistics (ONS) for 2016/17. This shows that in general the distribution of household income in the sample is similar to the wider population (for 2016/17 financial year), except that households with an annual income of less than £30,000 are underrepresented in the Consumer Uptake Trial sample (around 21%) compared with the wider population (46%). This is again likely to be a consequence of the recruitment criteria.

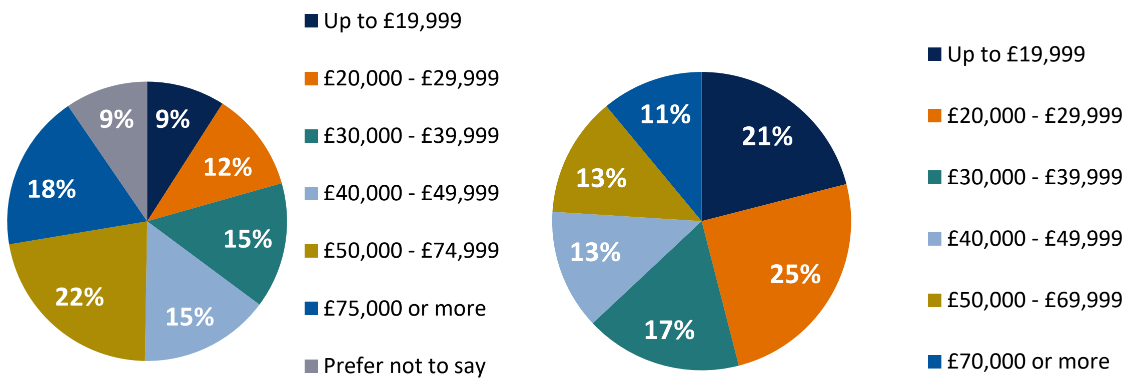


Figure 22: Participants' reported total household income (left) and average annual household gross income UK 2016/17 (ONS, 2018a) (right)

The relationship status and living arrangements of participants are summarised in Figure 23. The large majority of the sample were married/in a civil partnership and living with their family/partner (64%).

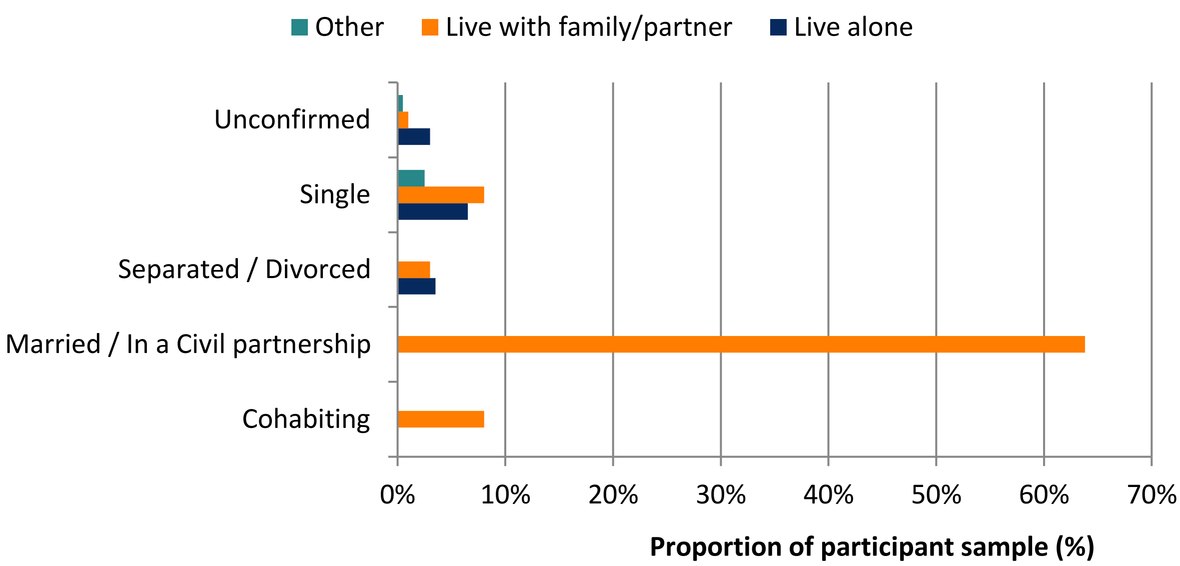


Figure 23: Participants' reported relationship status and living arrangements)

In 2017, the ONS reported 49% of the UK population aged over 16 years old were married/civil partners and living in a couple, and around 38% were not living in a couple (having never married/civil partnered, or previously married/civil partnered) (ONS, 2018b). This suggests married individuals were slightly overrepresented and single, divorced or separated individuals were underrepresented in the Consumer Uptake Trial sample.

B.2 Assessment of bias

- → **No systematic bias on participants' reported likelihood to purchase a BEV or PHEV was identified between participants who took part in the trial and those who withdrew.**
- → **No recruitment bias was identified: the method of participant recruitment was not found to affect participants' likelihood to purchase a PHEV or BEV.**
- → **The order in which participants experienced the vehicles in the trial did not impact their reported likelihood to purchase a PHEV or BEV.**
- → **A slight but significant increase in reported likelihood to purchase a PHEV as a second car was observed in the group of participants who experienced the ICE first indicating participation in the trial alone may have been sufficient to result in a small change in attitudes (that is, a Hawthorne effect).**

Four separate analyses were performed to test for systematic biases:

1. Bias in withdrawals: Comparison of Time Point 1 likelihood to purchase a BEV and PHEV responses between participants who withdrew and participants who completed the trial.
2. Recruitment bias: Comparison of Time Point 1 likelihood to purchase a BEV and PHEV responses between participants who were recruited for the study via different means.
3. Hawthorne effects: Comparison of likelihood to purchase a BEV and PHEV responses between Time Point 1 and Interim Questionnaire 1 for participants who experienced the ICE vehicle first.
4. Order effects: Comparison of Time Point 2 likelihood to purchase a BEV and PHEV responses between participants who experienced the vehicles in different orders.

The results from these analyses are described in the following sections.

B.2.1 Withdrawn participants

Withdrawn participants were defined as those who completed the TP1 questionnaire, but did not complete the full trial.

To test for systematic biases in the participants who chose to withdraw from the study (e.g. that participants who withdrew were systematically less interested in PiVs), their responses to the likelihood to purchase a BEV or PHEV items in the TP1 questionnaire were compared with those of the final sample of participants who completed the trial.

Of the sample of 200 participants, valid TP1 were obtained for 199 participants. For the purpose of this comparison, these 199 participants represented the 'Completed trial' group. There were 14 participants who completed TP1 but did not complete the trial and so were withdrawn from the sample; representing the 'Withdrawn' group. The age, gender and location (rural / urban) of the 14 withdrawn participants are shown in Table 19.

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Table 19: Demographics of withdrawn participants

Location	Age group	Female	Male	Total
Rural	**50-54**	1		**1**
	60-64	1		**1**
	65-69		1	**1**
Urban	**19-24**	1		**1**
	30-34	1	1	**2**
	45-49	1	3	**4**
	50-54	2		**2**
	65-69	1		**1**
	70+		1	**1**
Total		8	6	**14**

The proportions of responses to the likelihood to purchase questions are shown in Figure 24 for the participants who completed the trial and those who were withdrawn.

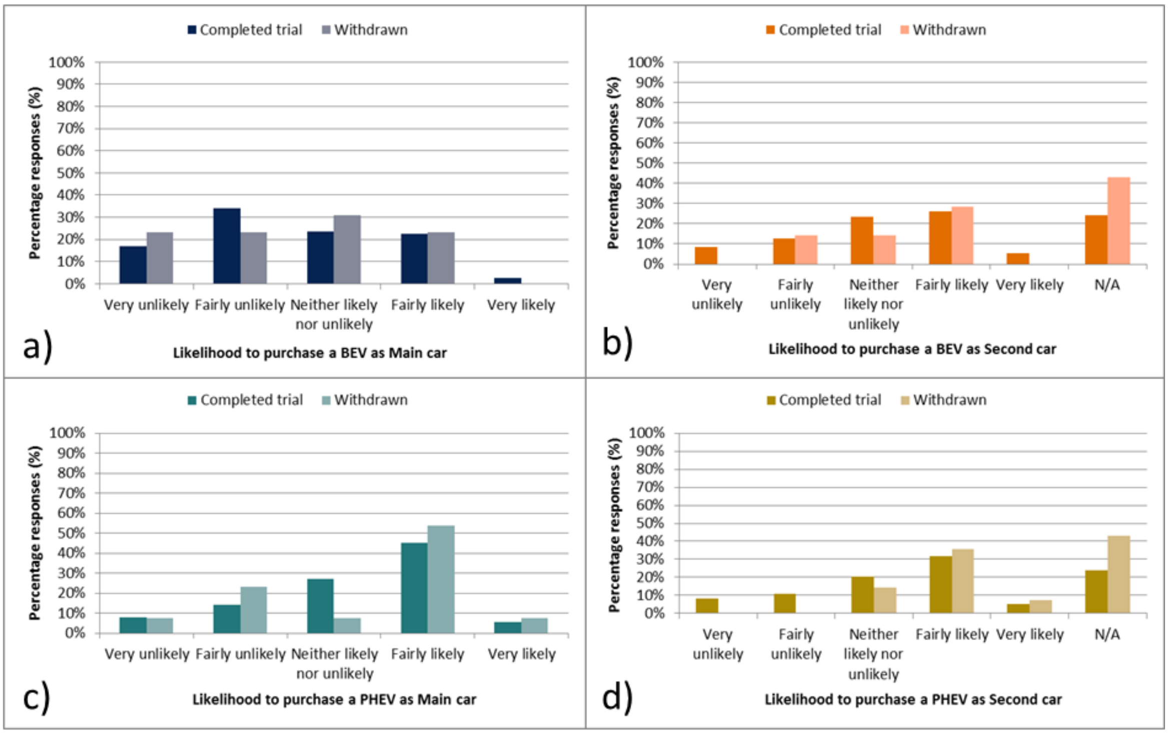

Figure 24: Proportion of responses to TP1 questionnaire items for completed and withdrawn participants on likelihood to purchase a BEV as main (a) and second (b) car and a PHEV as main (c) and second (d) car

The likelihood to purchase TP1 responses were compared between the participants who completed the trial and those who were withdrawn using a non-parametric independent samples Mann Whitney U test. The test revealed no statistically significant differences between withdrawn and completed participants' likelihood to purchase a BEV or PHEV as either a main or second vehicle .

B.2.2 Recruitment method

To maximise chances of achieving the stratified sample requirements, participants were recruited using a variety of methods; details of each of these methods can be found in section A.3.2. To test whether the method of recruitment resulted in any systematic biases in participants' reported likelihood to purchase a BEV or PHEV, responses to the TP1 questionnaire were compared between the nine distinct recruitment approaches:

1. Advert emailed to contacts on TRL's Participant Database ('TRL database email')
2. Email advert sent to local businesses ('Business email')
3. Email advert with Flyer for printing (containing QR code) sent to local businesses ('Business email: QR')
4. Flyer emailed to prospective participants – participants clicked link ('Flyer: URL')
5. Flyer emailed to prospective participants – participants scanned QR code ('Flyer: QR')
6. Printed flyer handed out to prospective participants – participants scanned QR code ('Printed flyer: QR')
7. Survey link emailed directly to prospective participants who contacted TRL about getting involved ('General advert link')
8. Advert posted on TRL's LinkedIn account ('LinkedIn')
9. Advert posted on TRL's Twitter account ('Twitter')

The proportions of the final sample of participants who were recruitment via each of these methods are shown in Figure 25.

The majority of participants (49%) were recruited using TRL's Participant Database, email adverts distributed to businesses local to TRL and Cenex, and to a lesser extent through a general advert link. For the remaining six groups, the number of participants recruited via these means was too small to enable statistical comparisons. However, the responses to the TP1 likelihood to purchase a BEV and PHEV items were compared between the first three groups. An independent samples non-parametric Kruskal-Wallis test revealed no statistically significant differences in the TP1 likelihood to purchase responses between participants recruited by these three means.

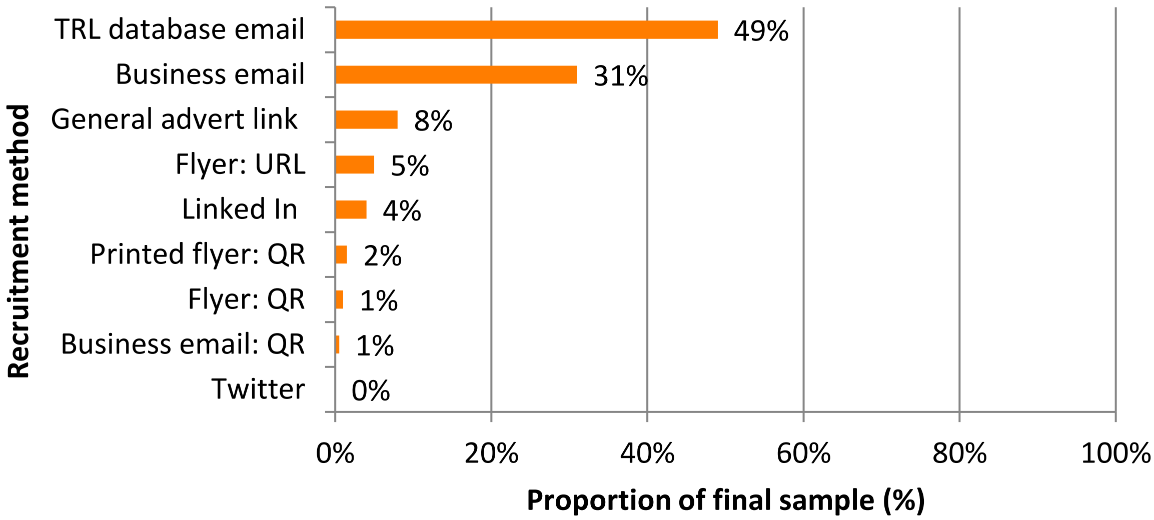

Figure 25: Proportion of final sample recruited via each approach

B.2.3 Hawthorne effects

The possibility of Hawthorne effects was examined by comparing participants' responses to the items on willingness to consider having a BEV or PHEV in the TP1 questionnaire with those given in the Interim 1 questionnaire, for those participants who experienced the ICEV first (Vehicle 1).

The number of participants who had the BEV, PHEV and ICEV as their first vehicle in the trial is shown in Table 20.

Table 20: Number of participants who had BEV, PHEV and ICE as Vehicle 1[28]

Vehicle 1	Frequency
BEV	90
PHEV	57
ICE	53
Total	**200**

One of the 53 participants who had the ICE vehicle first had missing TP1 data, and so statistical comparisons between TP1 and IQ1 were performed for 52 participants. The purpose of this comparison was to establish whether participation in the trial (as opposed to experience with a PiV specifically) was sufficient to cause a change in likelihood to purchase a BEV or PHEV. A 'difference score' was calculated for each participant by subtracting their response to TP1 (before experience with any vehicles) from their response to IQ1 (after experience with Vehicle 1). A positive difference score indicates participants reported higher likelihood to purchase in IQ1 compared with TP1; whereas a negative difference score

[28] As outlined in B.2.4, The trial was designed to achieve an even split across the possible vehicle orders. Because of participant drop-outs, no shows, or unfilled recruitment slots, the end result was a slightly imbalanced spread.

indicates a lower likelihood to purchase. The mean difference scores for the 52 participants who experienced the ICE vehicle first are shown in Figure 26.

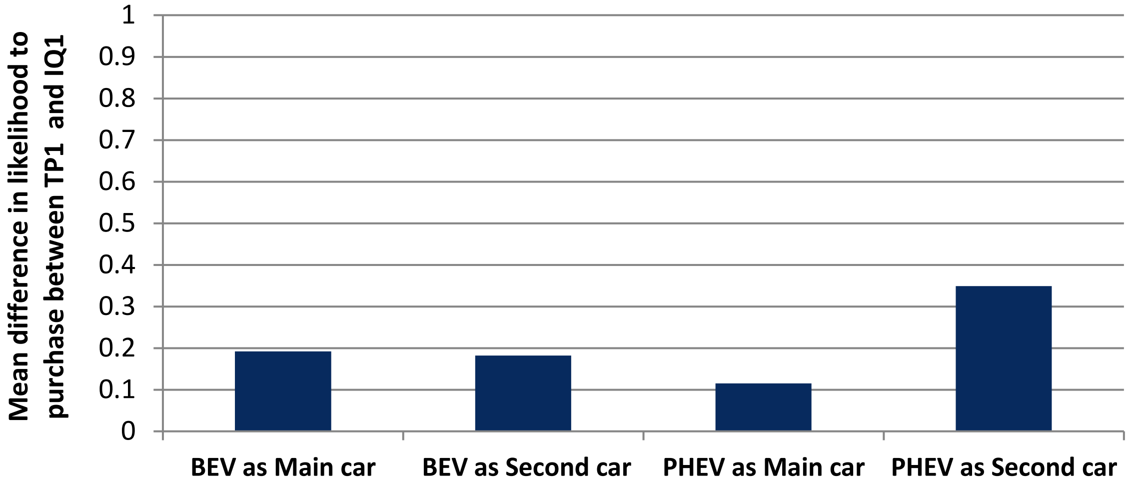

Figure 26: Mean difference scores showing change in likelihood to purchase BEV and PHEV between TP1 and IQ1 for 52 participants who experienced the ICE vehicle first

As shown in this figure, all mean difference scores were positive, but small. A one-sample t-test revealed that the difference scores for BEV as a main car (, BEV as a second car, and PHEV as a main car were not significantly different from zero. The difference scores for PHEV as a second car (M = 0.349, t = 2.412, p = 0.020) were found to be significantly different from zero, indicating a slight but significant increase in reported likelihood to purchase a PHEV as a second car following experience with the ICE vehicle.

Since these differences are observed in the group of participants who experienced the ICE first, the findings provide some indication that participation in the trial alone may have been sufficient to result in a small change in attitudes (that is, a Hawthorne effect), regardless of whether or not that participation included experience with a PiV.

B.2.4 Order effects

The block structure (see section A.5) used to run the trials also served the purpose of counterbalancing the order in which participants experienced each of the three types of vehicle. As participants were scheduled for handovers in each block, they were allocated to one of six vehicle orders, depending on when in the block participants took part in the trial.

As shown in Table 21, the number of participants who were allocated to each order was not perfectly balanced; this was due to logistical challenges associated with filling every block.

To check whether there was any systematic bias associated with order effects, the reported likelihood to purchase a BEV and PHEV in TP2 was compared between the six Order Groups.

Table 21: Order in which participants experienced each vehicle

Order Group	Vehicle 1	Vehicle 2	Vehicle 3	Number of participants
1	ICE	BEV	PHEV	29
2	PHEV	ICE	BEV	36
3	BEV	PHEV	ICE	47
4	ICE	PHEV	BEV	24
5	BEV	ICE	PHEV	43
6	PHEV	BEV	ICE	21
Total				**200**

A non-parametric independent samples Kruskal-Wallis test showed that there were no significant differences in the likelihood to purchase reported by participants between the six Order Groups: this provides evidence that there were no systematic biases resulting from order effects.

B.2.5 Impact of built-in satellite navigation systems

Both the ICEs and BEVs used for the trials had built-in satellite navigation systems as standard, however the PHEVs provided to participants did not include this feature. Statistical tests were run to investigate if this difference between the vehicles had an impact on the likelihood to purchase outcome measures collected in the TP2 survey. The tests investigated whether there were differences between the likelihood to purchase outcome measures for participants who rated a sat-nav as important and those who rated it as unimportant.

Overall, no differences in the reported likelihood to purchase were found when comparing the responses of participants who rated a sat-nav as important to those who rated it as unimportant. This suggests there was no impact on the participants' likelihood to purchase at the end of the trial related to the PHEV not having a built-in sat-nav system.

B.3 Segmentation

This section describes the detailed profiling of the 5 segments identified in the sample, structured according to different sections on the questionnaires (primarily PTQ and TP1, with some comparison of changes between TP1 and TP2) as well as additional characteristics such as their stated likelihood to adopt, current travel behaviour and various attitudes towards car owning and PiVs.

The procedure for assignment of participants to the ECCo segments was explained in section A.12.1. Five segments out of the 6 segments found in a previous study for DfT were replicated, with the exception being the Innovator segment which we did not expect to find given our sampling focus in this study on mainstream car buyers only. Their relative size and indicative labels can be seen in Figure 27. Three of the segments (Uninterested Rejecters, Cost-conscious Greens and Pragmatists) accounted for 94% of the sample, with the remaining two segments (Unmet Needs and Car-Loving Rejecters) only containing 5 and 6 participants in each. The small sample sizes of these latter two consumer segments were too small to allow meaningful comparisons between the groups, therefore, discussion of the results at the consumer segment level is limited to the Uninterested rejecters, Cost-conscious greens, and Pragmatists segments.

Segment	Count of participants
Uninterested Rejecters	38
Cost-conscious Greens	51
Pragmatists	100
Car-loving Rejecters	5
Unmet Needs	6
Total	**200**

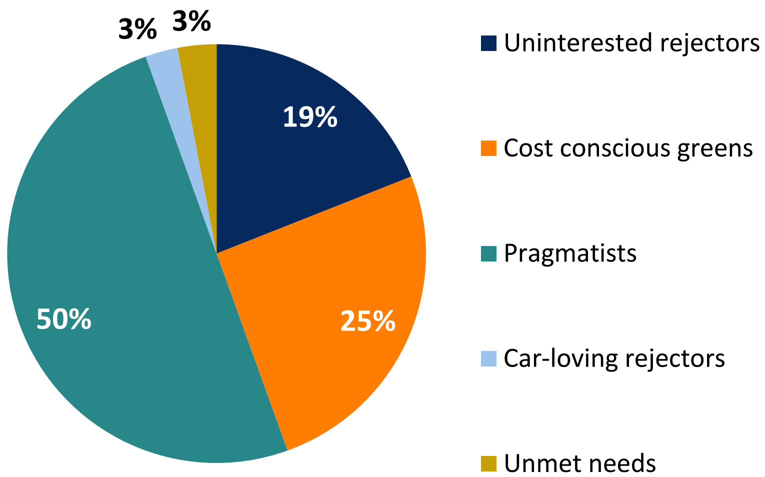

Figure 27: Participant segments

From the choice experiment, choice coefficients were derived for the whole sample as well as for each of the three main consumer segments. Since the Unmet Needs and Car-Loving Rejecters segments contained only six and five participants respectively, the sample sizes were too small to derive choice coefficients and they were not considered at the consumer segment level. Note that due to issues with answering the choice experiment, one Unmet Needs participant, one Cost-conscious Green, and two Pragmatists were excluded.

The relative shares of the consumer segments in the Consumer Uptake Trial sample differed from the sample of the previous consumer survey carried out in 2015 for DfT (from which the choice coefficients currently used in ECCo were derived) (Element Energy, 2015). The relative proportions of each consumer segment in the DfT survey sample are compared with the current trial in Figure 28.

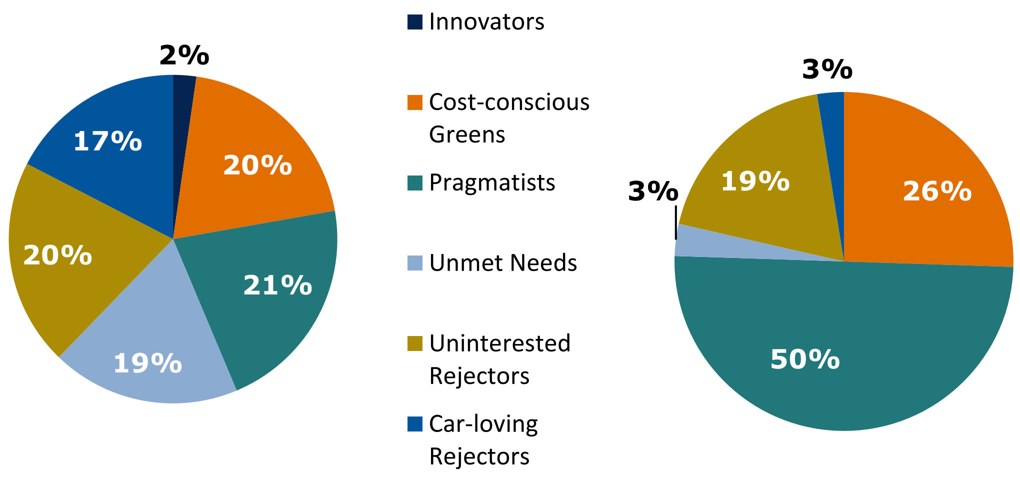

Figure 28: Consumer segment shares in choice experiment samples of the DfT survey (Element Energy, 2015) (left) and Consumer Uptake Trial (right)

The difference in segment proportions between the DfT survey sample and this sample are not surprising for several reasons. Firstly, the DfT survey was carried out on a nationwide representative sample, whereas the current sample was drawn from two specific geographical areas and recruited through specific routes (TRL database, social media) which by their nature will attract people with certain interest biases. Secondly, certain filtering criteria, such 'must have access to off-street parking at a location where a chargepoint could be installed safely' and 'must drive regularly (at least once every two or three days)' necessarily mean that the sample will be different to a more open and random sampling exercise. The parking requirement, for instance, is likely to explain the lower proportion of Unmet Needs in this study. The Pragmatists in this sample could also be described as 'Car Loving Pragmatists' as they have many characteristics which identify them as enthusiastic about cars. Given that, it is unsurprising that they are well represented in this sample as they responded to a trial about cars (albeit not initially knowing it would be about low carbon or plug-in cars). Finally, this data was collected almost four years after the data for the DfT study. This means that awareness and attitudes towards plug-in vehicles in the general populous is different (i.e. greater) between these two time points as is likely to mean that if the segments were replicated on a national sample that this would also result in different proportions being assigned to each segment. Indeed, it would be prudent to carry out the clustering analysis from scratch again with a large national sample to see whether different segments altogether would emerge given the different knowledge base, perceptions and social norms that now exist.

B.3.1 Profiling using the attitudes used to create the segments

It is useful to begin with an understanding of the relative contribution of the variables used to create the segments and what variables contribute to distinctions between the groups.

Table 22 shows the 25 variables used to assign participants to the ECCo segments. Out of the 25 variables, 16 differed significantly between all 5 groups, and 14 between the three largest (and therefore most robust) segments. This ranking provides some information about each variable's contribution to the separation of the segments. The differences between segments can be seen from their representative values such as mean values of the input variables from each cluster. Grey shading indicates that the differences between the segments on this variable were not statistically significant ($p < 0.05$). Where this is the case across all 5 segments, these variables have essentially not contributed to the segment assignments. Green shading indicates the highest values, and blue the lowest.

Especially noteworthy is the fact that differences in total mileage and income were not statistically significant different between the three main segments. The results hint that the two smaller segments, which are also the least enthusiastic about PiVs (based on stated likelihood scores), may have significantly higher income and mileage profiles.

Table 22: Variables included in the cluster analysis and their ranking in terms of importance in defining the cluster solution

	Mean scores						Statistics	
	Uninterested Rejecters	Cost-conscious Greens	Pragmatists	Car-loving Rejecters	Unmet Needs	Total	F	Sig.
My car says something about who I am[1]	2.30	2.31	3.56	3.80	3.33	3.01	26.571	*p* < 0.001
A car provides status and prestige[1]	2.14	2.25	3.33	3.60	3.83	2.85	20.274	p < 0.001
I like magazines / websites about new cars[1]	1.86	2.14	3.19	4.00	2.50	2.67	14.384	p < 0.001
Driving gives me a chance to express myself[1]	2.05	2.14	3.01	3.20	2.00	2.58	14.006	p < 0.001
I would prefer my car to be fuelled by something other than petrol or diesel[1]	3.24	4.12	3.59	2.20	3.50	3.62	13.048	p < 0.001
I am usually among the first to try new technology[1]	2.00	2.33	3.11	2.60	2.33	2.67	11.722	p < 0.001
BEVs are a good thing because they make us less dependent on oil[1]	3.73	4.45	4.00	3.00	4.33	4.05	11.450	p < 0.001
Being environmentally responsible is an important part of who I am[1]	2.92	3.90	3.39	2.40	3.83	3.42	11.371	p < 0.001
Reducing my car's environmental impact would make me feel good[1]	3.22	4.10	3.91	3.00	4.33	3.82	10.780	p < 0.001
Sometimes I feel under pressure to say that I am doing more to help the environment than I am[1]	2.49	2.24	2.94	2.20	2.83	2.65	7.031	p < 0.001
I would pay more for a car with lower running costs[1]	3.11	3.76	3.47	2.60	4.00	3.47	6.820	p < 0.001
Total mileage in past 12 months for the car you drive most often[2]	8507	8529	9582	14650	19167	9528	6.523	p < 0.001
I enjoy driving on my own[1]	3.78	3.53	4.13	4.00	3.67	3.89	5.619	p < 0.001
I am not the sort of person that looks to	3.08	2.86	2.29	2.80	2.83	2.61	5.518	p < 0.001

	Mean scores						Statistics	
	Uninterested Rejecters	Cost-conscious Greens	Pragmatists	Car-loving Rejecters	Unmet Needs	Total	F	Sig.
experience driving different cars[1]								
I like the idea of being able to 'refuel' at home rather than have to go to petrol stations[1]	3.95	4.47	4.11	3.80	4.17	4.17	5.055	0.001
Total household income from all sources before tax and other deductions[3]	4.31	5.09	5.04	7.00	7.00	5.04	4.596	0.001
65 + years	0.50	0.43	0.28	0.00	1.00	0.38	2.290	0.061
I don't like driving	1.70	1.84	1.51	1.40	2.00	1.64	2.154	0.076
I tend to stick to the same brand of car (e.g. Ford, Toyota, Nissan)	2.54	2.37	2.85	2.40	2.50	2.65	2.012	0.094
I couldn't manage without a car	3.86	4.06	4.19	4.80	4.67	4.13	1.868	0.118
17 years 29 years	0.29	0.41	0.47	1.00	0.50	0.44	1.274	0.282
The so called 'environmental crisis' has been greatly exaggerated	2.30	2.18	2.12	2.80	1.83	2.18	1.222	0.303
When I feel fuel prices are getting too high, I try and reduce the amount I drive	2.76	3.00	2.69	2.60	3.17	2.79	1.057	0.379
50years 64 years	0.66	0.75	0.54	0.40	1.00	0.63	.971	0.424
It's not worth me doing things to help the environment if others don't do the same	2.16	2.35	2.40	2.40	2.00	2.33	.617	0.651

Notes:: [1] Mean score on 5-point Likert scale from 1 (strongly disagree) – 5 (strongly agree); [2] Mean total miles travelled in the most driven car by segment members; [3] Mean score on 9-point household income scale starting at 1 (Up to £9,999 per year (£199 per week) per year up to 9 (£150,000 or more per year (£2,940 or more per week); Grey shading denotes no statistically significant difference between segments; Green shading indicates the highest values, and orange the lowest.

On the basis of these core participant-assignment variables, the three main segments can be characterised as follows:

Uninterested Rejecters (19% of sample)	*Attitudinally neutral about the environment, feeling moral obligation to reduce greenhouse gases but not seeing this as a priority. Do not particularly like cars or driving but recognise strong link between cars and status, and are interested in new technology. Tend to be young, 50/50 male/female. Average annual mileage, least frequent makers of journeys over 80km.*
Cost-conscious Greens (25% of sample)	*The most environmentally-conscious, and most likely to express concern about the environment and the need for energy security. Most likely to say they would pay more for lower running costs. They have an average enthusiasm for new technology. Average annual mileage, medium frequency of journeys over 80km.*
Pragmatists (50% of sample)	*Average interest in new technology and cars. They enjoy driving and somewhat agree that cars indicate status, but also have some pro-environmental motivations and value independence from oil. Average income, with an interest in reducing vehicle running costs. Highest annual mileage among the three segments, and the most frequent makers of journeys over 80km.*

Further detail about the differences between these three main segments is provided in the following sections. Note that only variables that demonstrate a statistically significant difference are included in the analysis.

B.3.2 Knowledge and awareness of PiVs

- → **A greater proportion of Pragmatists reported they were very or quite informed about BEVs and PHEVs than the other segments before the trial; Uninterested Rejecters were the least informed.**
- → **All three segments showed significant and substantial increases in self-reported knowledge of PiVs following experience in the trial.**
- → **The Uninterested Rejecters showed the greatest increase in self-reported knowledge of BEVs and PHEVs following experience with both types in the trial. .**

Figure 29 shows the proportion of participants in each consumer segments who indicated they felt ‘very’ or ‘quite’ informed about BEVs and PHEVS; these data are shown before and after experience with PiVs. The first thing to note is that the percentage of people saying they felt very or quite informed in TP1 was virtually identical between BEVs and PHEVs within each segment, but did differ significantly between segments ($\chi^2 = 31.96$, $p = 0.01$).

Secondly, the figure shows clearly that self-reported knowledge increased substantially in Time Point 2 following experience with the vehicles. The rate of knowledge increase was five times greater for the Uninterested Rejecters compared with the Pragmatists, with only 5% of the former initially saying they felt very/quite informed for both types of powertrain, rising to 50% for BEVs and 55% for PHEVs. This compares to a rise from 26% (BEVs) and 24% (PHEVs) to 62% (BEVs) and 58% (PHEVs) for the Pragmatists.

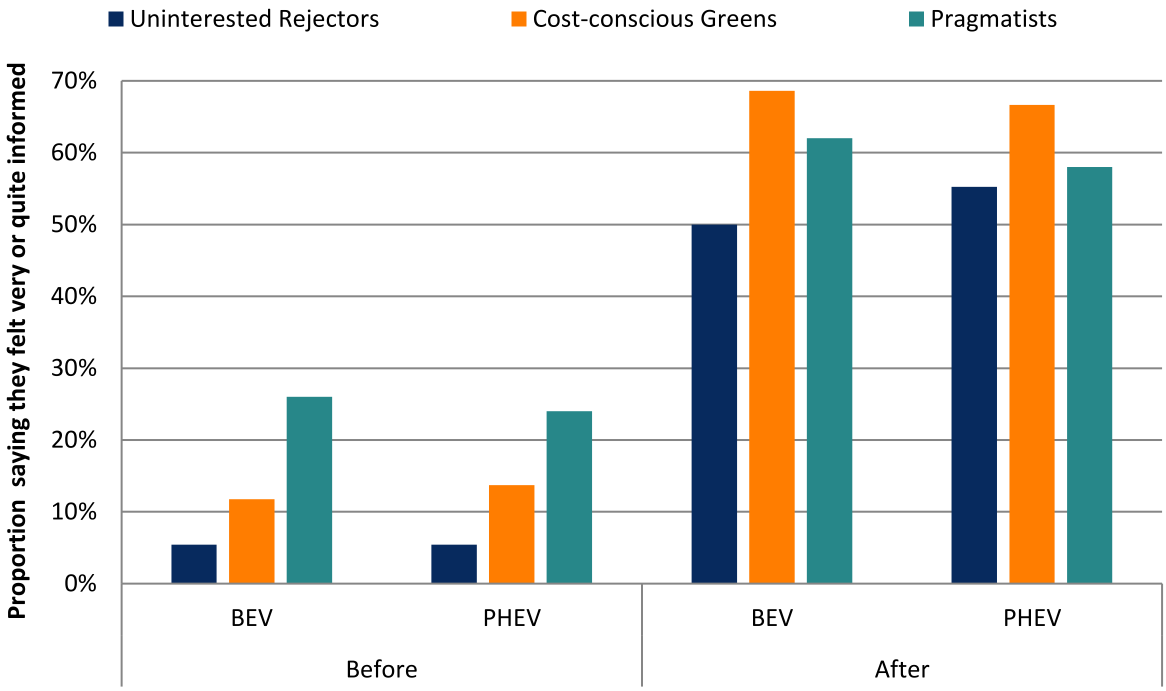

Figure 29: Proportion of participants who felt 'very or 'quite' informed about BEVs and PHEVs in TP1 and TP2 by consumer segment

Figure 30 shows how aware participants said they were about charge points at different types of destinations before and after the trial. They were asked to state a simple 'yes' or 'no' as to whether they were aware of any charge points at each type of location. The results must be treated with some caution as very few statistically significant differences were found between segments in either time points, or in the changes between time points for individual segments. Nevertheless, the consistently relatively low awareness of on-street parking is stark. Another observation is the fact that the greatest increases in awareness happened with respect to supermarket charging for all segments. Interestingly, Uninterested Rejecters claimed to be aware of more chargepoints at Supermarkets than other groups, and this increased significantly between time points. This is not the case for motorway service stations, although their awareness of these did increase in comparison to the other groups. It could be speculated that this group are more likely to notice these chargepoints at 'everyday' locations such as supermarkets as a result of not being as enthusiastic as other groups and perhaps noticing that they are taking up car parking spaces). The Uninterested Rejecters are also older and disproportionately female (see next section) which may explain these responses.

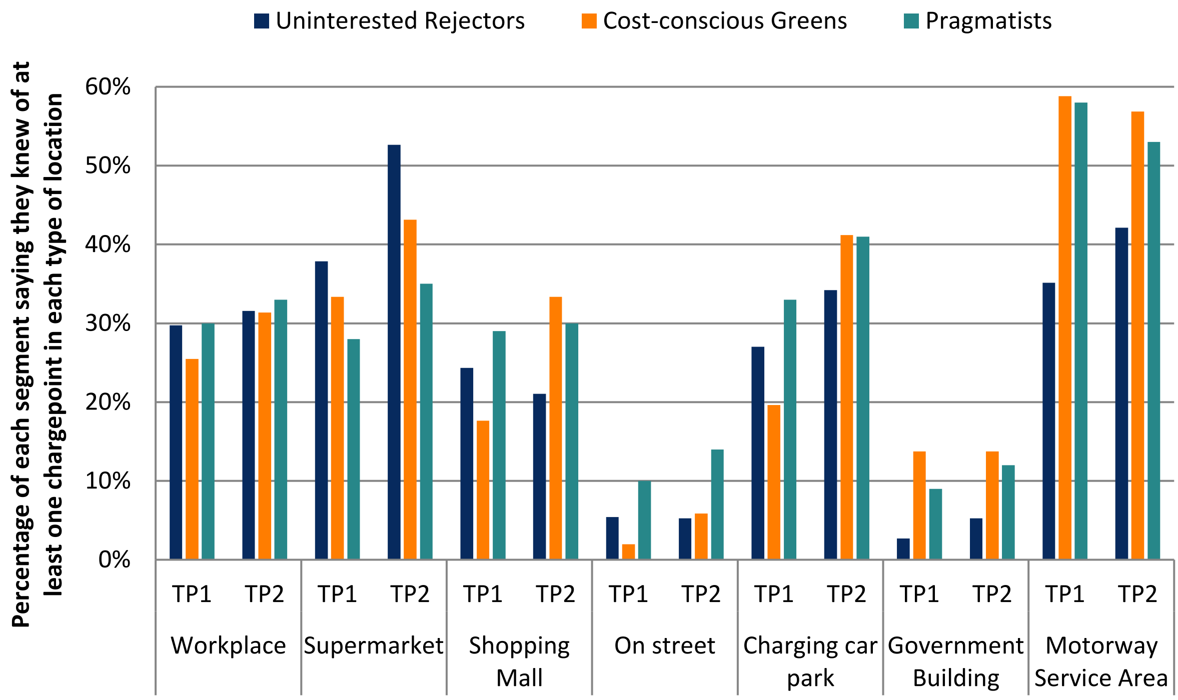

Figure 30: Awareness of charge points in different locations in TP1 and TP2 for each of the three main segments

B.3.3 Personal and household characteristics

All three of the main segments had similar income and home ownership profiles. There was also no difference in the geographical distribution of the segments between urban and rural locations. Some significant differences were identified however, these can be summarised as follows:

Uninterested Rejecters

Highest predominance in the oldest age groups and most likely to be female (63%). Smallest household size on average and least likely to have children.

Cost-conscious Greens

High likelihood of being aged 40 – 60 years. Equal gender balance. Largest household size on average, though presence of children is no greater than the Pragmatists.

Pragmatists

Youngest on average with almost a third of this group aged less than 34 years. High fraction of men (64%), and least likely to be married.

B.3.4 Car ownership

The average number of household cars does not vary significantly between segments for either private cars or company cars across the three main segments, nor does the average

age of the main car (F=0.334, *p* = 0.855). However, some characteristics of the household car fleet are worthy of note.

Figure 31 shows the proportion of the main household cars in each segment of each car type (car segment). Figure 32 shows the expected age of the next car when purchased. Both of these variables show some differences between the segments.

Uninterested Rejecters

Tend to own cars in the lower medium and possibly supermini car segments. Least likely to own just one car (30%) and least likely to be the sole decision maker (11%). Least likely (20%) to say they intend to buy their next car within the next two years, but more likely to say they will buy it brand new (24%) than the CCG segment.

Cost-conscious Greens

Most likely to own a car in the smallest car segments. This segment sits between the other two segments on almost all car-owing characteristics. It shows the least intention to buy a brand-new car (12%), the longest average driving licence holding.

Pragmatists

The majority have lower medium or upper medium cars, but Pragmatists were the segment with the most of the larger types of cars. Most likely to own one car (34%), new or relatively new, most likely to adopt using PCP, salary sacrifice or similar and to be the sole decision maker (26%). Most likely (45%) to say they will buy their next car within the next two years and to buy this as brand new (34%).

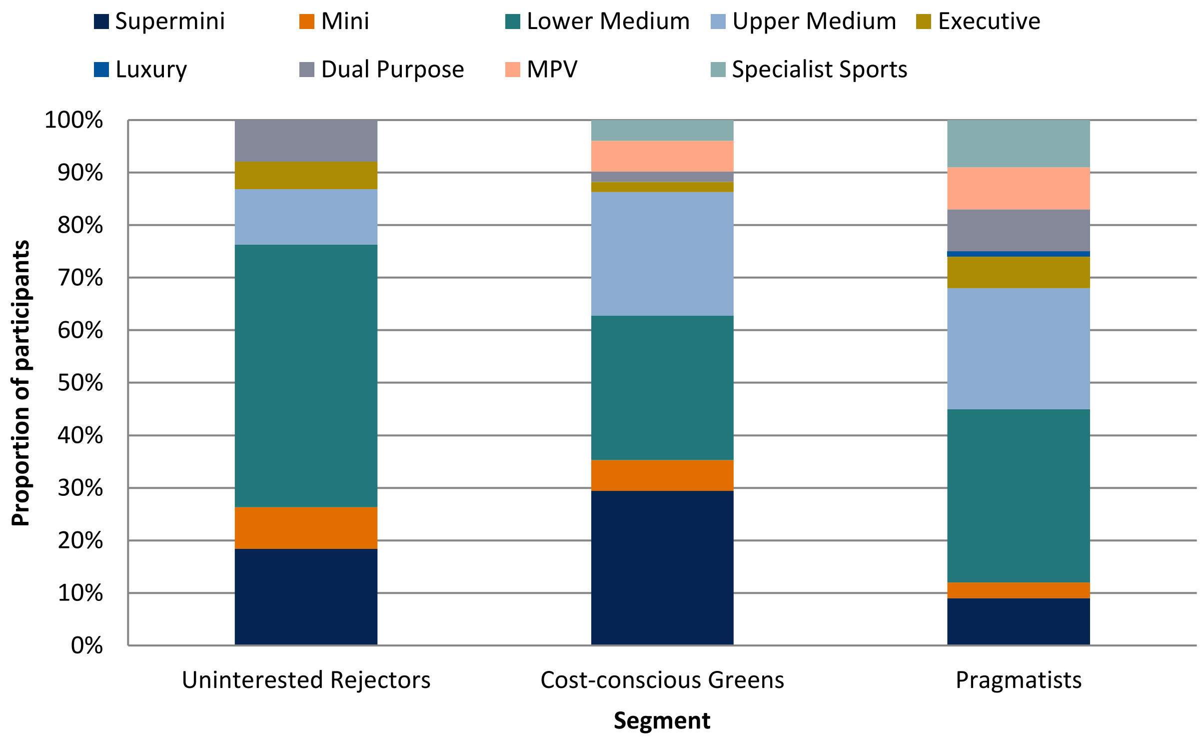

Figure 31: Proportion of main household cars in each car type by segment

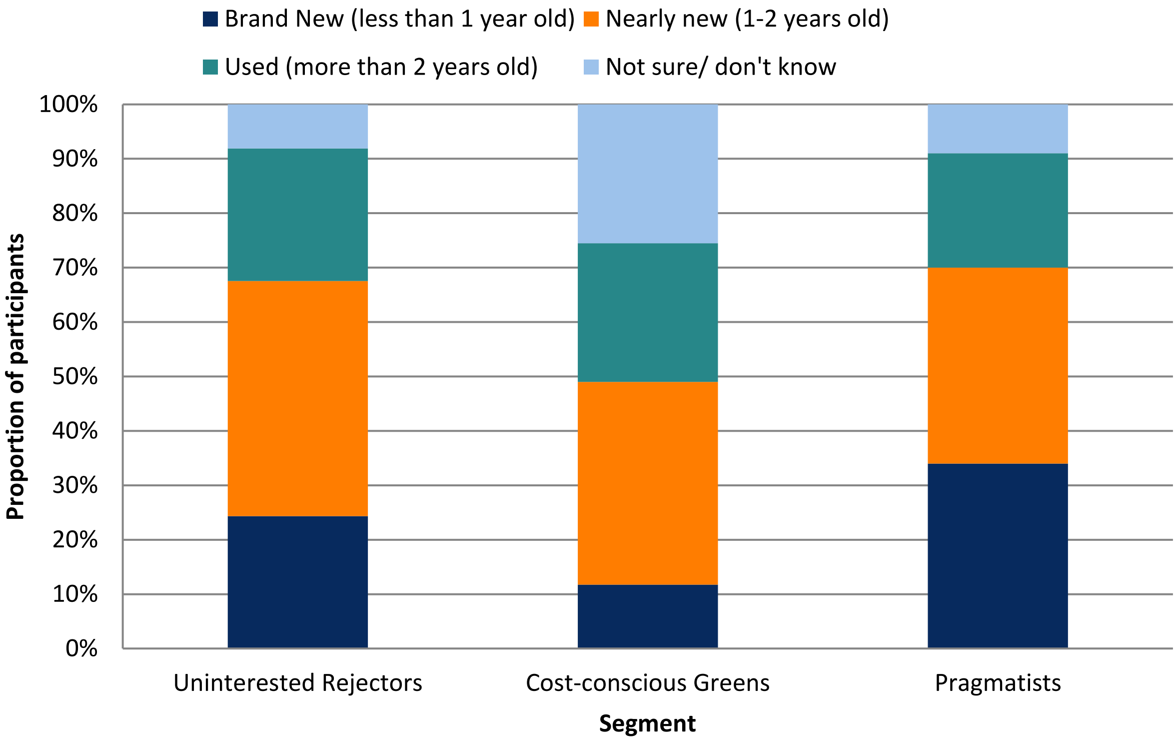

Figure 32: Expected age of next car when purchased by segment

B.3.5 Travel behaviour characteristics

Uninterested Rejecters

Around 70% of this segment say they do less than 10,000 miles by car per annum, with just under a quarter saying they do a trip of greater than 50 miles at least once a fortnight. On average, this group tends to do a greater proportion of miles in urban areas (55%) than the other three and are least likely to use on-demand services such as Uber.

Cost-conscious Greens

Just under 60% say they do less than 10,000 miles by car per annum, with just under a quarter saying they do a trip of greater than 50 miles at least once a fortnight. Claim to undertake roughly the same proportion of mileage in rural and urban areas.

Pragmatists

Around 50% say they do less than 10,000 miles per annum with just over 40% saying they do a trip of greater than 50 miles at least once a fortnight. Less mileage undertaken in urban than non-urban areas, with noticeably longer trips at weekends than the other two segments. Most likely to own a car of the largest car types. Most likely to cycle regularly and to use on-demand services such as Uber.

The segments did not differ significantly in terms of self-reported driving distances for commuting, average mileage on a weekday, or on the number of times a year in which trips over 80 miles are undertaken. However, there were some reported differences in terms of self-reported total miles[29] (

Figure 34; $\chi^2 = 78.68$, $p < 0.001$) and the number of times a trip greater than 50 miles is undertaken (Figure 33; $\chi^2 = 65.27$, $p < 0.001$).

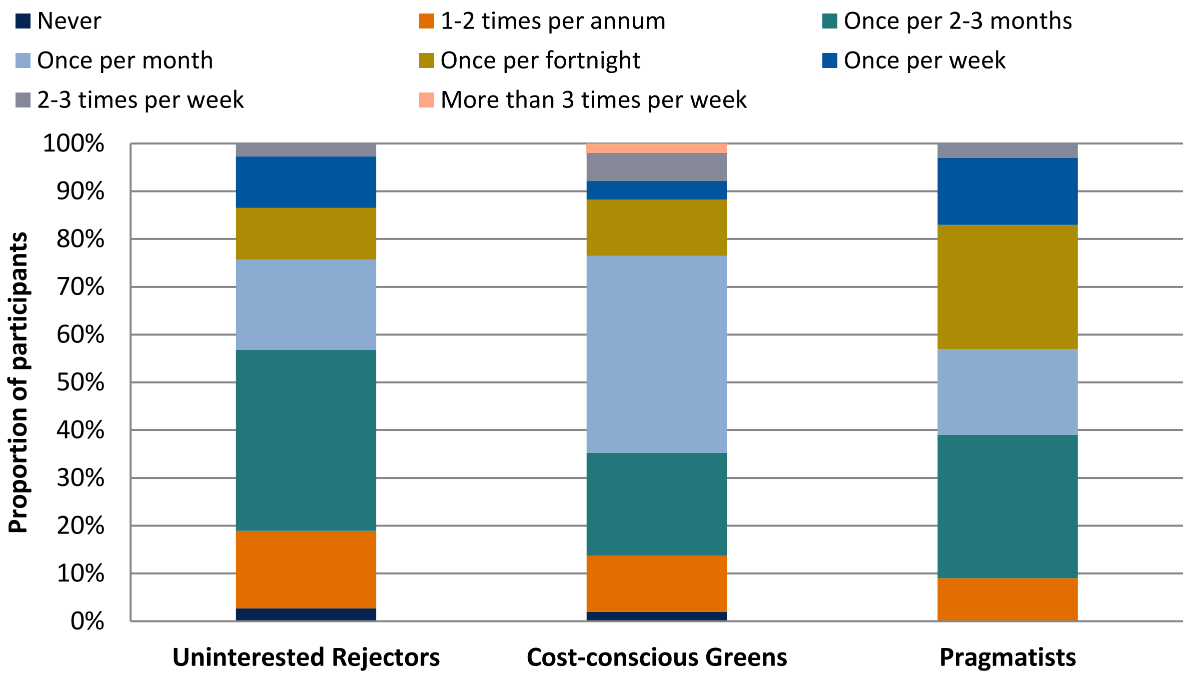

Figure 33: Number of times a trip of > 50 miles is undertaken by segment

[29] Note that there was not a significant difference when this was measured as an average value calculated for each participant in terms of the number of miles reported to travel in each of the cars in the household.

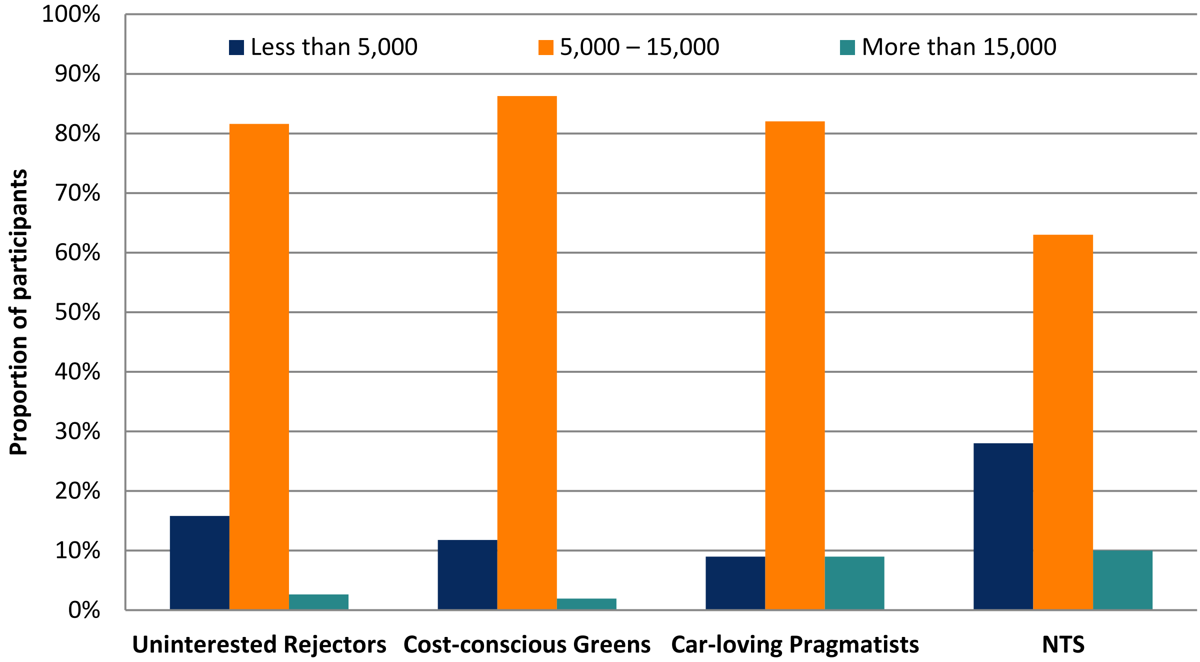

Figure 34: Total self-reported annual miles by segment compared to the NTS[30]

B.3.6 Symbolic and affective motivations towards car owning and driving

Uninterested Rejecters and Cost-conscious Greens

Neither of these segments believe that cars indicate status, and both are relatively disinterested in new technology, though both agree that they like driving. However, Uninterested Rejecters are the segment with the least pro-environmental motivations, while Cost-Conscious Greens have the highest pro-environmental motivations.

Pragmatists

Members of this segment tend to have an average interest in new technology and cars. They enjoy driving and somewhat agree that cars indicate status, but also have some pro-environmental motivations and value independence from oil.

Figure 35 and Figure 36 depict the strength of agreement (higher number) or disagreement (lower number) with each of the attitude statements related to car owning and driving. Only those statements which differ significantly between the three main segments have been included. These diagrams allow the areas of difference between segments to be seen at a glance. For instance, in Figure 36 we can see that the Pragmatists have quite a different attitudinal profile to the other two main segments, in that they are much more likely to believe their car defines them in some way. The other two segments are very similar to each other in their attitudes on these symbolic motivations of car ownership.

[30] Note that there was not a significant difference when this was measured as an average value calculated for each participant in terms of the number of miles reported to travel in each of the cars in the household.

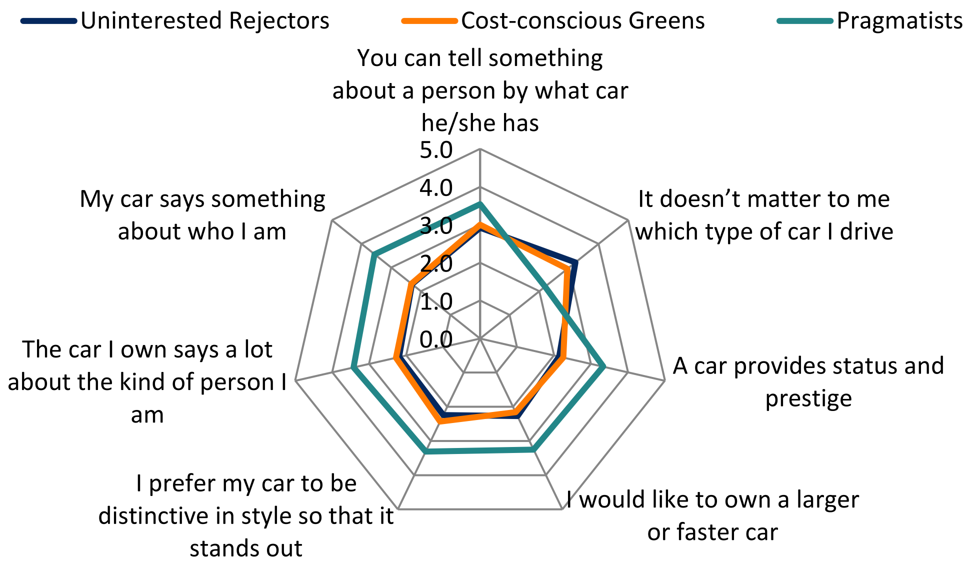

Figure 35: Average scores per segment on attitude statements relating to symbolic motives of car owning

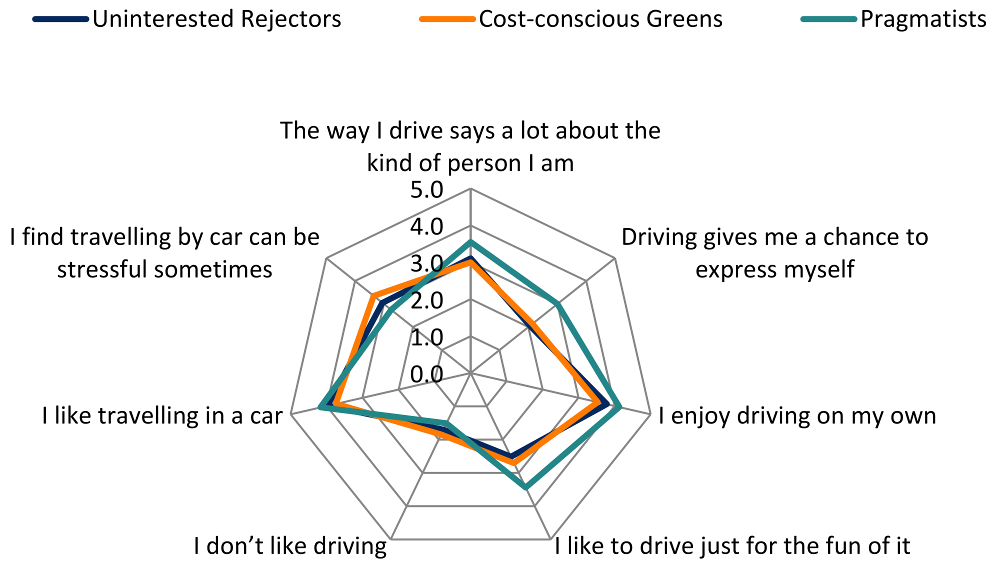

Figure 36: Average scores per segment on attitude statements relating to symbolic and affective motives of car driving

B.3.7 Technological Innovativeness

Uninterested Rejecters

This group appear to be the least engaged when searching for new cars and the least interested in new car technology and do not consider themselves to influence other people's opinions about cars.

Cost-conscious Greens

Similarly, unengaged as the Uninterested Rejecters but with a slighter greater tendency to regard themselves as influencing other people.

Pragmatists

This group tend to see themselves to an average or somewhat above average extent as open to new car technology, informing themselves about new cars and being an influencer of other people.

Figure 37 includes a set of attitude statements found to be important predictors of alternative fuelled vehicle uptake in previous research relating to how enthusiastic and open someone is to new vehicle technology and how far they see themselves as an informed 'authority' on cars in general (Schuitema, Anable, Kinnear, Stannard and Skippon, 2013; Morton, Anable, and Nelson, 2016).

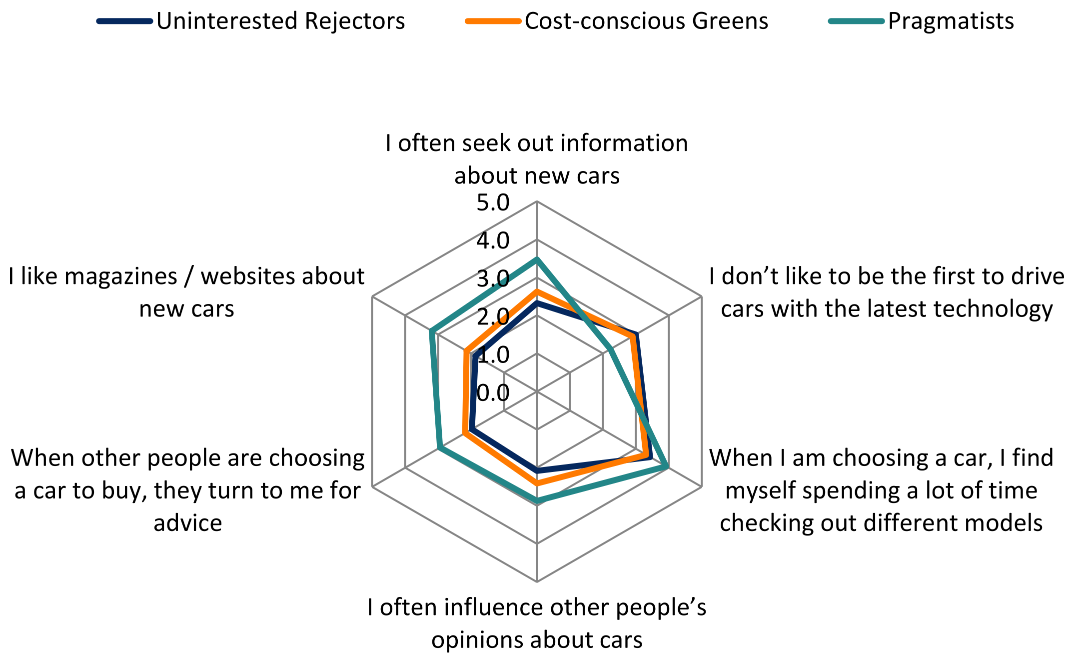

Figure 37: Average scores per segment on attitude statements relating to interest in new cars and new car technology

B.3.8 Environmental Attitudes

Uninterested Rejecters

This group has the lowest sense of responsibility for environmental issues and hence the concern for the least engaged with environmental motives such as paying more for lower fuel costs or reducing their car use.

Cost-conscious Greens

This group stands out for being motivated by environmental responsibility. Therefore, they also score most highly on wanting to increase their fuel economy and being prepared to pay a premium for this. They are also the most likely to say they would like to live without a car entirely.

Pragmatists

This group sits somewhere in the middle in terms of 'green' attitudes. They are marginally more likely to appreciate good fuel economy and environmental arguments than the Uninterested Rejecters.

Two sets of environmental attitudes were elicited. The first on general sense of individual responsibility and consciousness of environmental issues in general (Figure **38**), and second relating to car fuel economy and environmental impact (Figure 39). Whilst the differences between segments are small, only questions which demonstrated a statistically significant difference (at $p < 0.05$) between at least two segments have been included. Results suggest that environmental attitudes may be converging somewhat, although there is also a possibility that it represents a more motivated sample than a fully representative one.

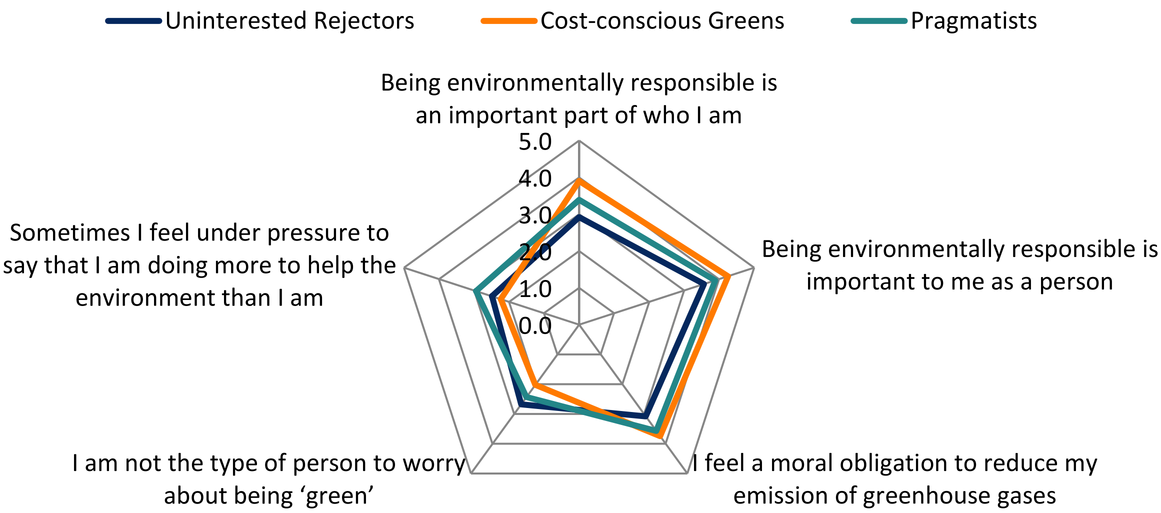

Figure 38: Average scores per segment on attitude statements relating to general sense of individual responsibility and consciousness of environmental issues in general

As can be seen in Figure 39, Cost-conscious Greens hold stronger views than the other segments on all environmental related car-ownership items. This includes preferring independence from oil, liking the idea of charging at home, reducing car use and paying more for a car with lower running costs. Uninterested Rejecters and Pragmatists meanwhile highlight that they are not as motivated by environmental factors when purchasing a car.

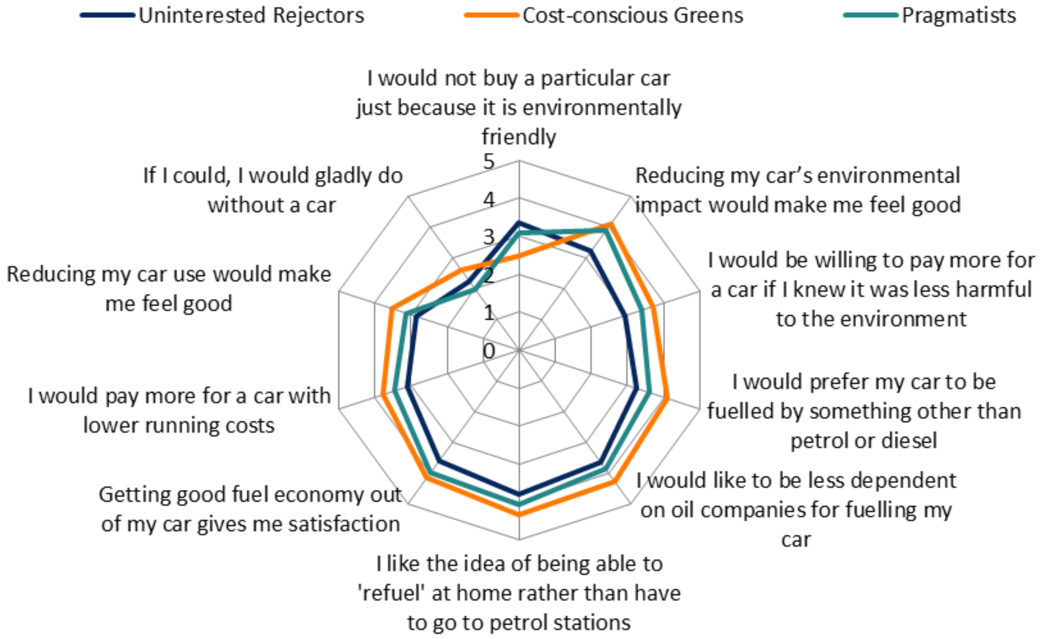

Figure 39: Average scores per segment on attitude statements relating to car fuel economy and environmental impact

B.3.9 General attitudes to BEVs and PHEVs

Uninterested Rejecters

This group is consistently more negative than the other two main segments about both powertrains, although it is no less worried about running out of charge with a PHEV than the other two, and has similar worries about not being able to adapt to charging as the Pragmatists.

Cost-conscious Greens

Once again, this group stands out for being the most positive about both types of vehicle technology. It has a significantly higher stated willingness to pay more for both powertrains, a stronger self-identity and overall a much more positive view of the charging regimes involved.

Pragmatists

This group has some mixed views in that these participants recognise a relatively high feel good factor for both types of car, are more likely to say they would be willing to pay more than the Uninterested Rejecters, but have some similar concerns about fit to self-identity and being able to adapt to charging.

This section highlights a few of the attitude factors which were asked separately with respect to a BEV and a PHEV. The figures below contrast the attitudes across these powertrains and across segments before the cars were experienced in the trial (i.e. data taken from TP1). Comparing attitudes on the powertrains, it is evident that both command similar attitudes with respect to 'feel good factor' ($F=5.80$, $p = 0.006$; Figure 40), self-identity with each type of car ($F=4.31$, $p = 0.015$; Figure 41), but also, perhaps more surprisingly, with respect to the perceived effort required to adapt to charging and how far this would put people off buying each one ($F=3.61$, $p = 0.029$; Figure 42). Indeed, a substantial proportion agreed or strongly agreed that they would worry about a PHEV running out of charge.

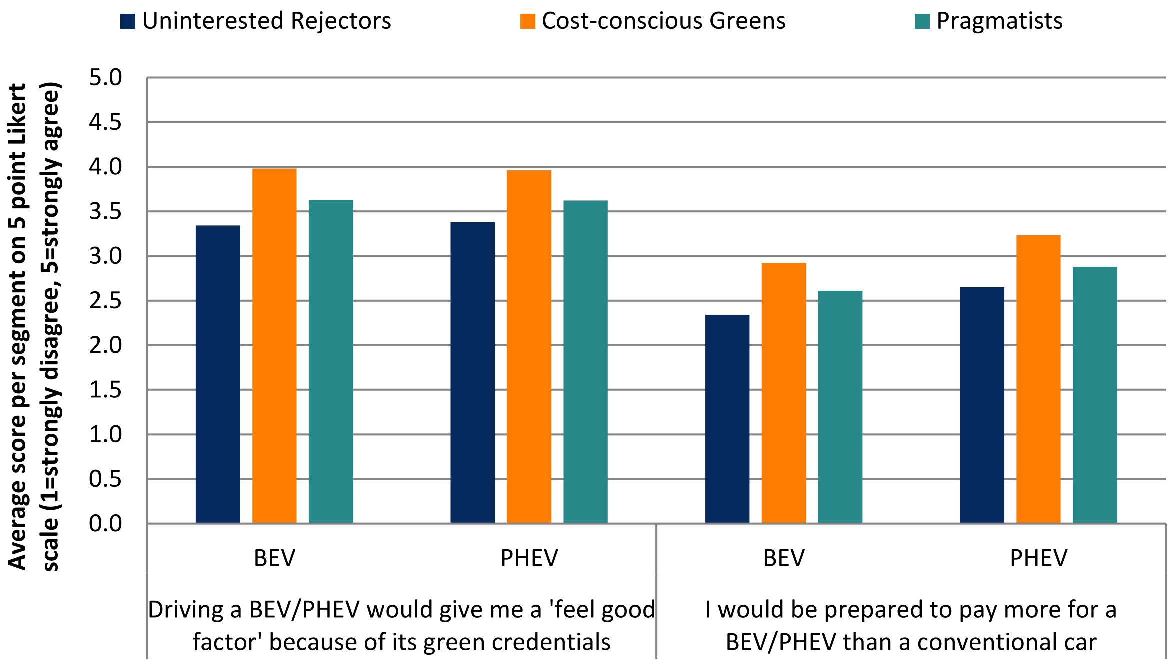

Figure 40: Average scores per segment on attitude statements relating to PiV 'feel good factor' and willingness to pay more

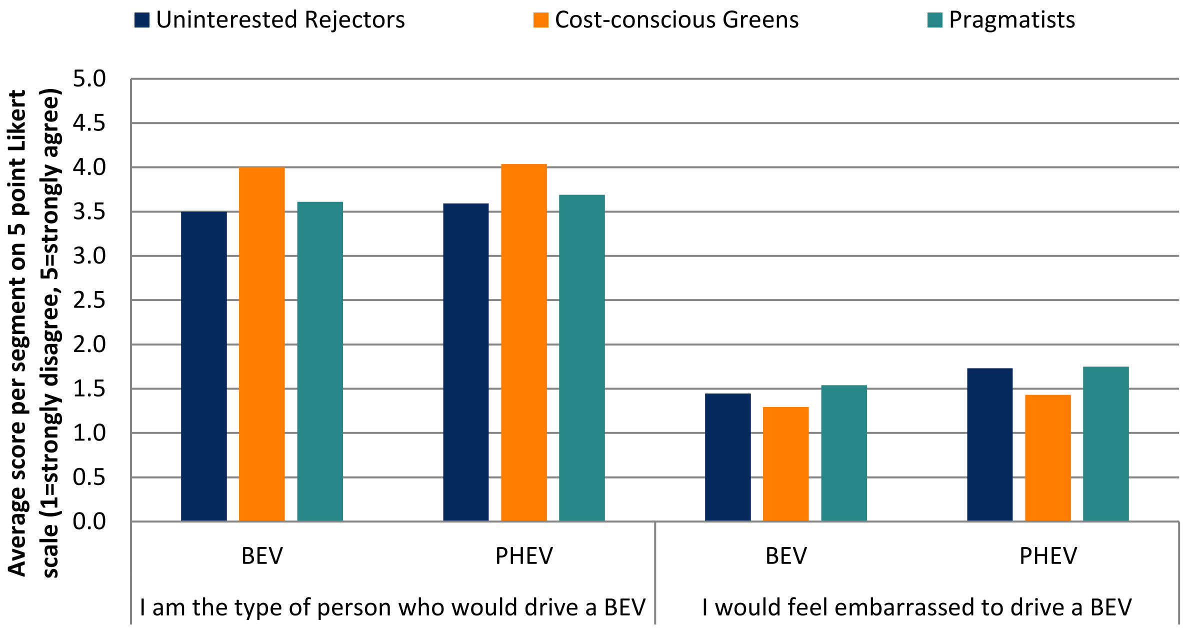

Figure 41: Average scores per segment on attitude statements relating to self-identity with a PiV and perceived embarrassment of driving one

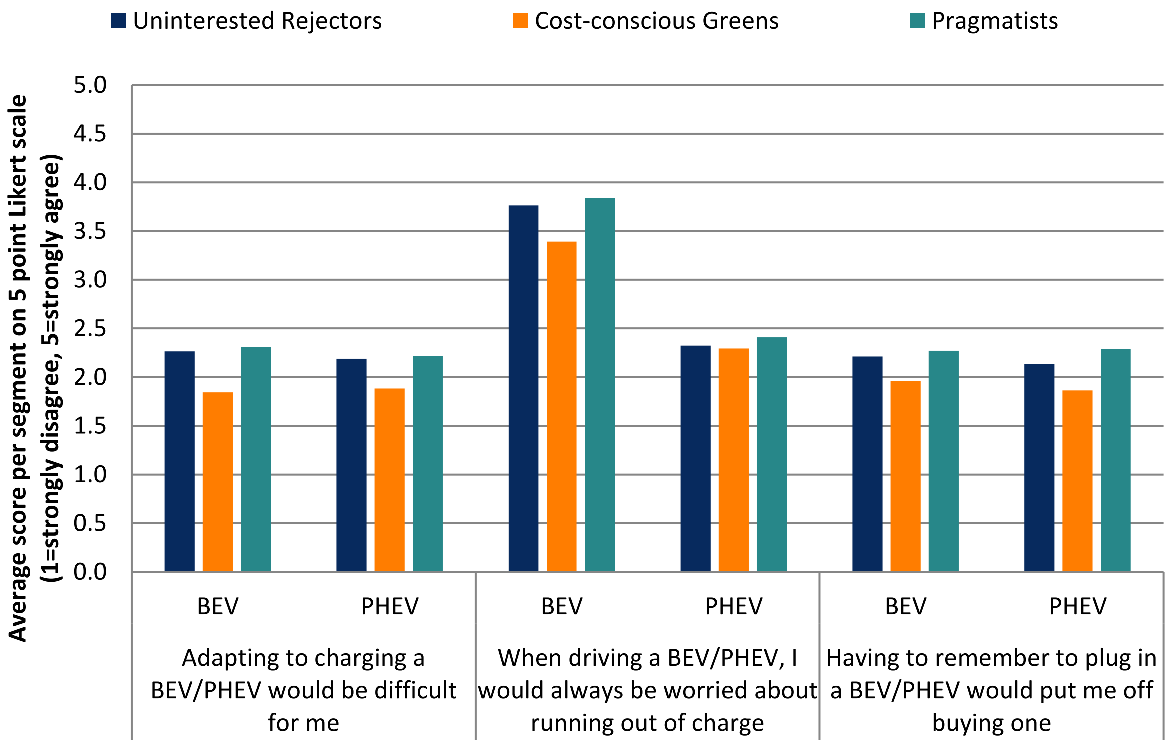

Figure 42: Average scores per segment on attitude statements relating to PiV charging a PiV

B.4 Core analyses

The core analyses were undertaken to address the research questions defined in Table 1.

B.4.1 Likelihood to purchase a BEV or PHEV

- → **Before experience with the BEV, PHEV and ICE vehicle, mainstream consumers reported they were least likely to purchase a BEV as their main car, but more likely to purchase a BEV as a second car or a PHEV as a main car.**
- → **The same pattern was observed after experience with the vehicles, however, the likelihood to purchase a BEV as a second car increased significantly.**
- → **The change in likelihood to purchase after experience differed between segments; on average Pragmatists showed an increased likelihood to purchase a PHEV whilst the other two segments showed decreased likelihood. Overall, Pragmatists reported higher likelihood to purchase a PHEV than Uninterested Rejecters, as main and second car.**

B.4.1.1 Before experience with plug-in vehicles (TP1)

Figure 43 presents participants' reported likelihood to purchase a BEV and PHEV as a main or second car in the next 5 years, before they gained experience with the vehicles in the trial (TP1 questionnaire).

A repeated measures non-parametric Friedman test revealed that likelihood to purchase (before experience with the vehicles) differed significantly between the four vehicle types (BEV-Main, BEV-Second, PHEV-Main and PHEV-Second) (χ^2 = 54.065, p < 0.001).

Non-parametric Wilcoxon signed ranks tests revealed that likelihood to purchase a BEV as a main car (*Mean* [*M*] = 2.593) was significantly lower than likelihood to purchase a BEV as a second car (M = 3.099, Z = -4.113, p < 0.001) and significantly lower than likelihood to purchase a PHEV as a main car (M = 3.261, Z = -7.199, p < 0.001). There were no significant differences in the reported likelihood to purchase a PHEV as a main car compared with a second car , or between the likelihood to purchase a BEV or PHEV as second car.

These findings show that, before experience with the three types of vehicle in the trial, mainstream consumer participants were more likely to purchase a PHEV than a BEV in the next 5 years (as a main or second car), and least likely to purchase a BEV as main car.

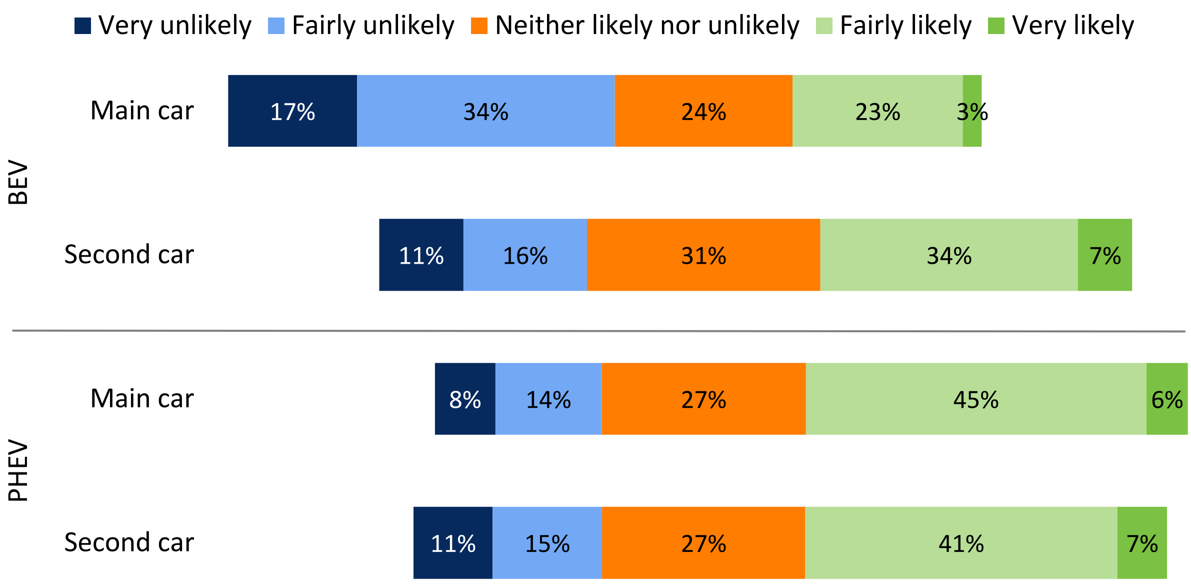

Figure 43: Proportion of participants likely or unlikely to choose a BEV/PHEV as a main or second car in the next 5 years before experience with vehicles (responses to TP1 questionnaire for global sample)[31]

The likelihood to purchase responses for each category of car are shown at the consumer segment level in Figure 44. A non-parametric Kruskal-Wallis test showed a significant effect of segment on likelihood to purchase a PHEV as a main (χ^2 = 6.210, p = 0.045), but no significant effect on likelihood to purchase a PHEV as a second car, a BEV as a main car, or a BEV as a second car.

Non-parametric Mann-Whitney U tests revealed a significantly higher likelihood to purchase a PHEV as a main car in the Pragmatist segment than the Uninterested Rejecter segment (Z = -2.795, p = 0.005). No other significant differences between segments were identified.

A repeated measures non-parametric Friedman test revealed there were significant differences in reported likelihood to purchase the different vehicle types for the Cost-conscious Greens (χ^2 = 12.643, p = 0.005), and Pragmatists (χ^2 = 31.312, p < 0.001) but marginal non-significance was found for the Uninterested Rejecters. This is likely due to the small sample size (n = 38) in that segment.

Non-parametric Wilcoxon signed ranks tests revealed that likelihood to purchase a BEV as a main car was significantly lower than likelihood to purchase a PHEV as a main car within all three consumer segments (Uninterested Rejecters; Z = -3.311, p = 0.001, Cost-conscious Greens; Z = -3.088, p = 0.002, Pragmatists; Z = -5.155, p < 0.001); thus mimicking the trend observed at the global sample level. For the Pragmatists, the likelihood to purchase a BEV as

[31] Note: For the questions on likelihood to purchase a BEV/PHEV as a second car, participants had the option to respond 'N/A' if a second car was not relevant to them. Thus, in this figure and throughout this report, the likelihood to purchase a BEV/PHEV as a second car represent the responses of 151 participants rather than the full 200 participant sample.

a main car was also significantly lower than a BEV as a second car (Z = -3.967, p < 0.001). No other significant differences were identified within the other segments.

These findings show that, before experience with the three types of vehicle in the trial, the trend observed at the global sample level for lowest likelihood to purchase a BEV as main car remains true within the three main segments. Figure 44 also suggests a trend of highest likelihood to purchase a PHEV as a main car in the Cost-conscious Greens segment; however, this was only found to differ significantly from likelihood to purchase a BEV as a main car (as detailed above).

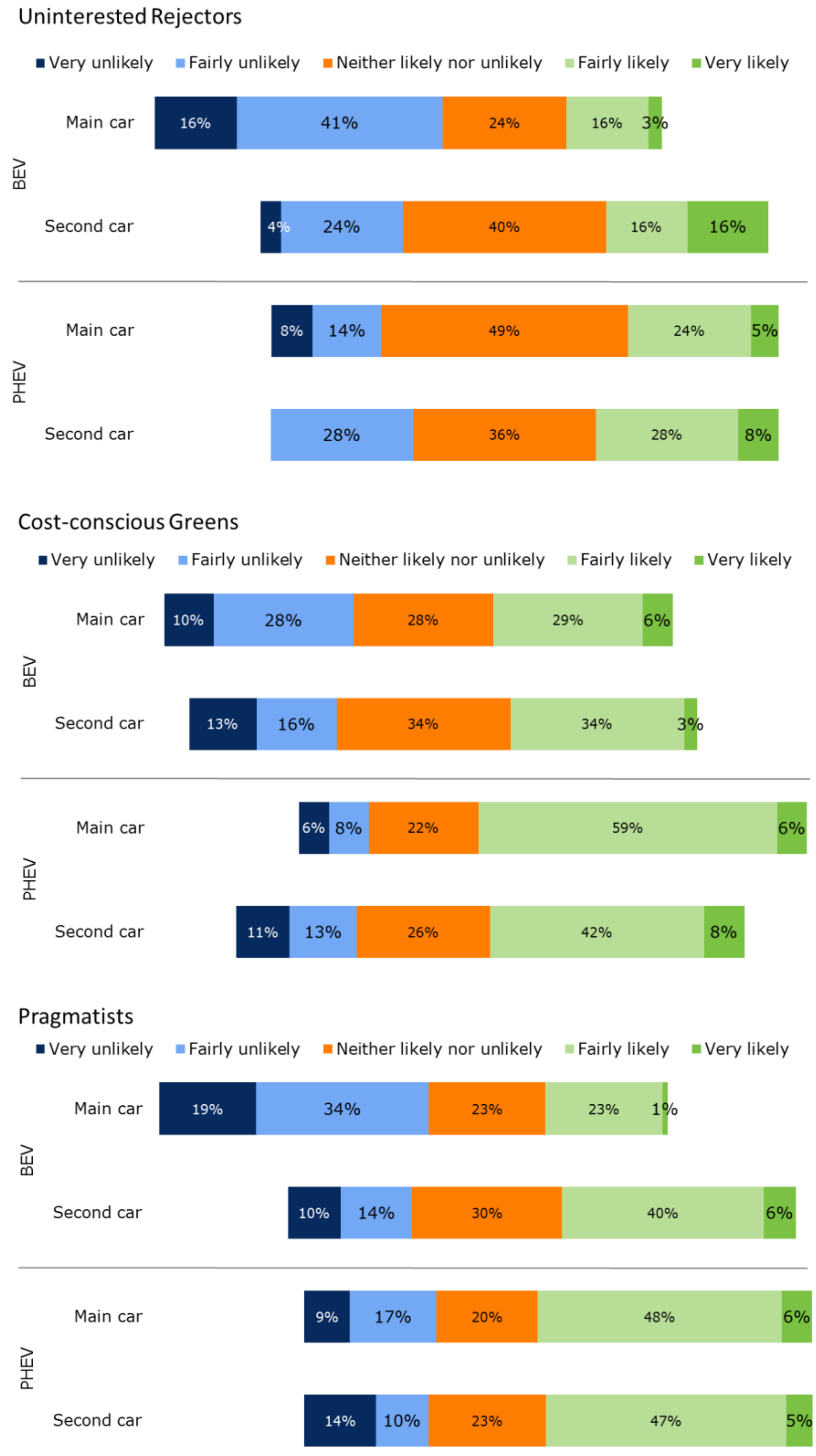

Figure 44: Proportion of participants likely or unlikely to purchase a BEV and PHEV as main and second car in the next 5 years after experience with the vehicles (responses to TP1 questionnaire split by consumer segment)

B.4.1.2 *After experience with plug-in vehicles (TP2)*

Following experience with all three vehicles, participants completed the TP2 questionnaire which included questions on likelihood to purchase a BEV and PHEV as a main and second vehicle in the next 5 years. The responses to these questionnaire items are summarised in Figure 45 below.

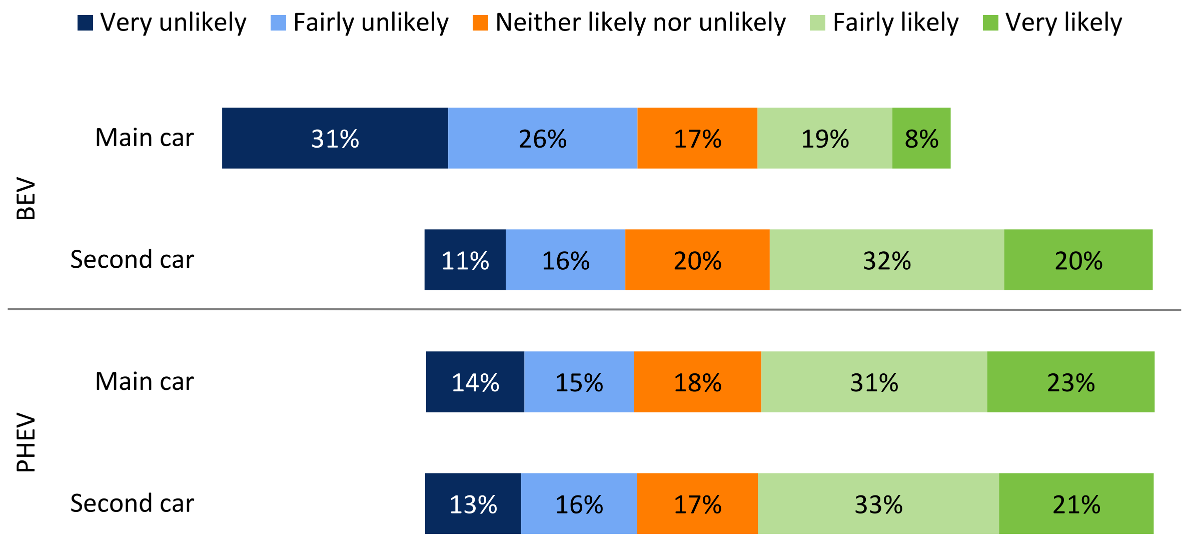

Figure 45: Proportion of participants likely or unlikely to purchase a BEV and PHEV as main and second car in the next 5 years after experience with the vehicles (responses to TP2 questionnaire)

A repeated measures non-parametric Friedman test revealed that likelihood to purchase differed significantly between the four vehicle types (BEV-Main, BEV-Second, PHEV-Main and PHEV-Second) ($\chi^2 = 70.644$, $p < 0.001$). Non-parametric Wilcoxon signed ranks tests revealed that likelihood to purchase a BEV as a main car ($M = 2.465$) was significantly lower than likelihood to purchase a BEV as a second car ($M = 3.342$, $Z = -5.790$, $p < 0.001$) and significantly lower than likelihood to purchase a PHEV as a main car ($M = 3.350$, $Z = -6.731$, $p < 0.001$).

There were no significant differences in the reported likelihood to purchase a PHEV as a main car ($M = 3.350$) compared with a second car ($M = 3.331$, $Z = -0.298$, $p = 0.766$), or between the likelihood to purchase a BEV or PHEV as second car ($Z = -0.080$, $p = 0.936$).

The likelihood to purchase responses for each category of car are shown at the consumer segment level in Figure 46. A non-parametric Kruskal-Wallis test showed a significant effect of segment on likelihood to purchase a PHEV as a main ($\chi^2 = 7.969$, $p = 0.019$) and second car ($\chi^2 = 6.536$, $p = 0.038$), but no significant effect on likelihood to purchase a BEV as a main or second car .

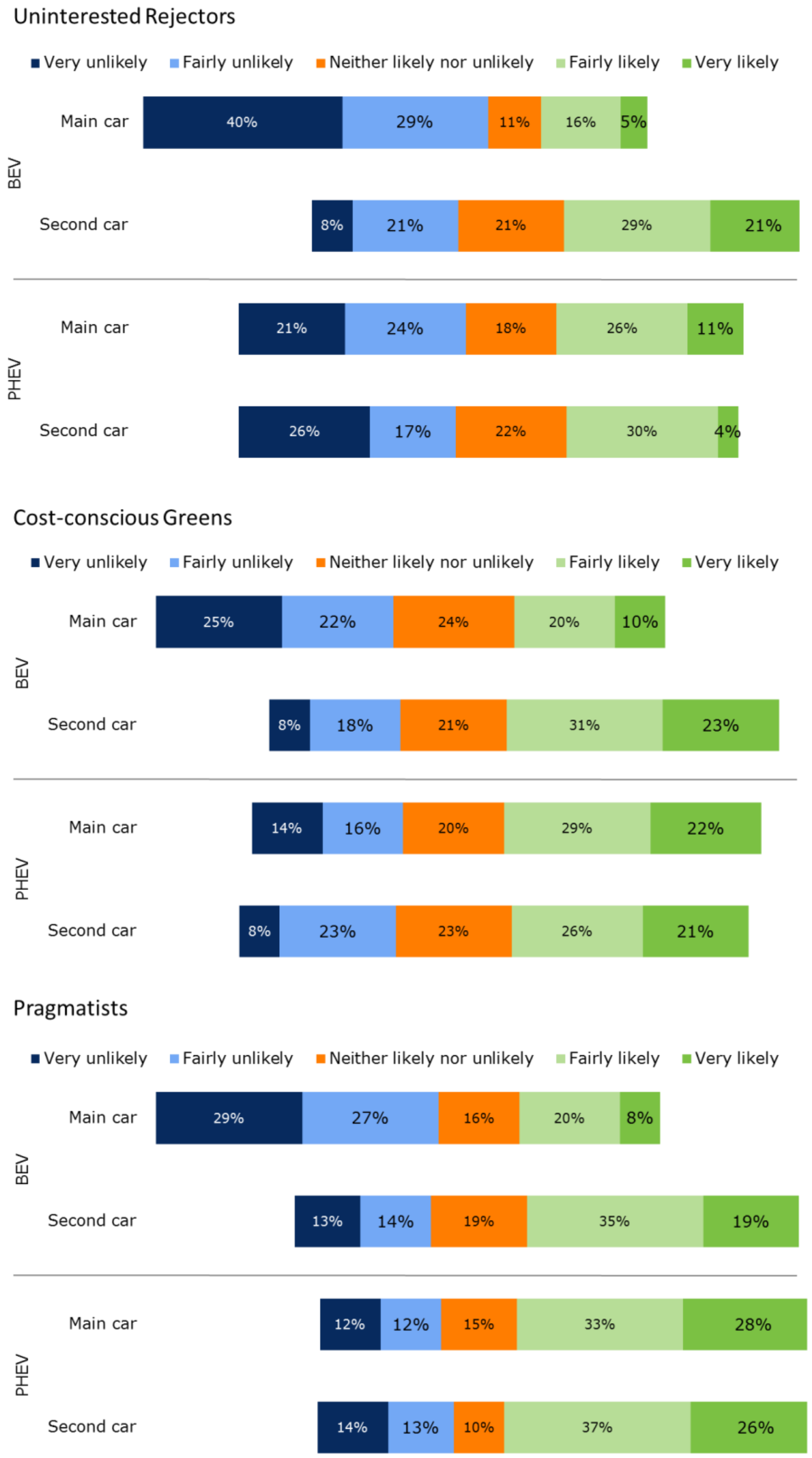

Figure 46: Proportion of participants likely or unlikely to purchase a BEV and PHEV as main and second car in the next 5 years after experience with the vehicles (responses to TP2 questionnaire split by consumer segment)

Non-parametric Mann-Whitney U tests revealed significantly higher likelihood to purchase a PHEV in the Pragmatist segment than the Uninterested Rejecter segment, for both main car

($Z = -2.795$, $p = 0.009$) and second car ($Z = -2.532$, $p = 0.011$). No other significant differences between segments were identified.

A repeated measures non-parametric Friedman test revealed there were significant differences in reported likelihood to purchase the different vehicle types for all three segments (Uninterested Rejecters; $\chi^2 = 14.908$, $p = 0.002$, Cost-conscious Greens; $\chi^2 = 13.155$, $p = 0.004$, Pragmatists; $\chi^2 = 45.035$, $p < 0.001$).

Non-parametric Wilcoxon signed ranks tests revealed that likelihood to purchase a BEV as a main car was significantly lower than likelihood to purchase a PHEV as a main car within all three consumer segments (Uninterested Rejecters; $Z = -2.263$, $p = 0.024$, Cost-conscious Greens; $Z = -2.812$, $p = 0.005$, Pragmatists; $Z = -5.172$, $p < 0.001$); again, confirming the trend observed at the global sample level, and that observed with the TP1 responses (section B.4.1.1). Likelihood to purchase a BEV as a main car was significantly lower than likelihood to purchase a BEV as a second car within all three consumer segments (Uninterested Rejecters; $Z = -3.226$, $p = 0.001$, Cost-conscious Greens; $Z = -2.377$, $p = 0.017$, Pragmatists; $Z = -3.967$, $p < 0.001$). For the Uninterested Rejecters, the likelihood to purchase a PHEV as a second car was also significantly lower than a BEV as a second car ($Z = -2.809$, $p = 0.005$). No other significant differences were identified within the other segments.

These findings show that, before experience with the three types of vehicle in the trial, the trend observed at the global sample level for lowest likelihood to purchase a BEV as main car remains true within the three main segments. The extent to which reported likelihood to purchase PiVs changed following experience in the trial is investigated in the following section.

B.4.1.3 Comparison before and after experience (TP1 vs. TP2)

Participants were asked to rate their likelihood to purchase a BEV and PHEV, as both a main car and a second car, in the Time Point 1 questionnaires (before experience with the vehicles) and in the Time Point 2 questionnaires (after experience with all three vehicles). The responses to these items are summarised in Figure 47.

Non-parametric Wilcoxon signed ranks tests were used to examine whether the differences in the likelihood to purchase a BEV and PHEV between TP1 and TP2 were significant. At the global sample level, the TP1 and TP2 responses for BEV as a main car , PHEV as a main car and PHEV as a second car were not significantly different; suggesting experience with the vehicles did not greatly influence the reported likelihood to purchase. Likelihood to purchase a BEV as a second car, however, was slightly but significantly higher after experience with the vehicles (TP2, $M = 3.342$) than before experience with the vehicles (TP1, $M = 3.099$, $Z = -2.607$, $p = 0.009$).

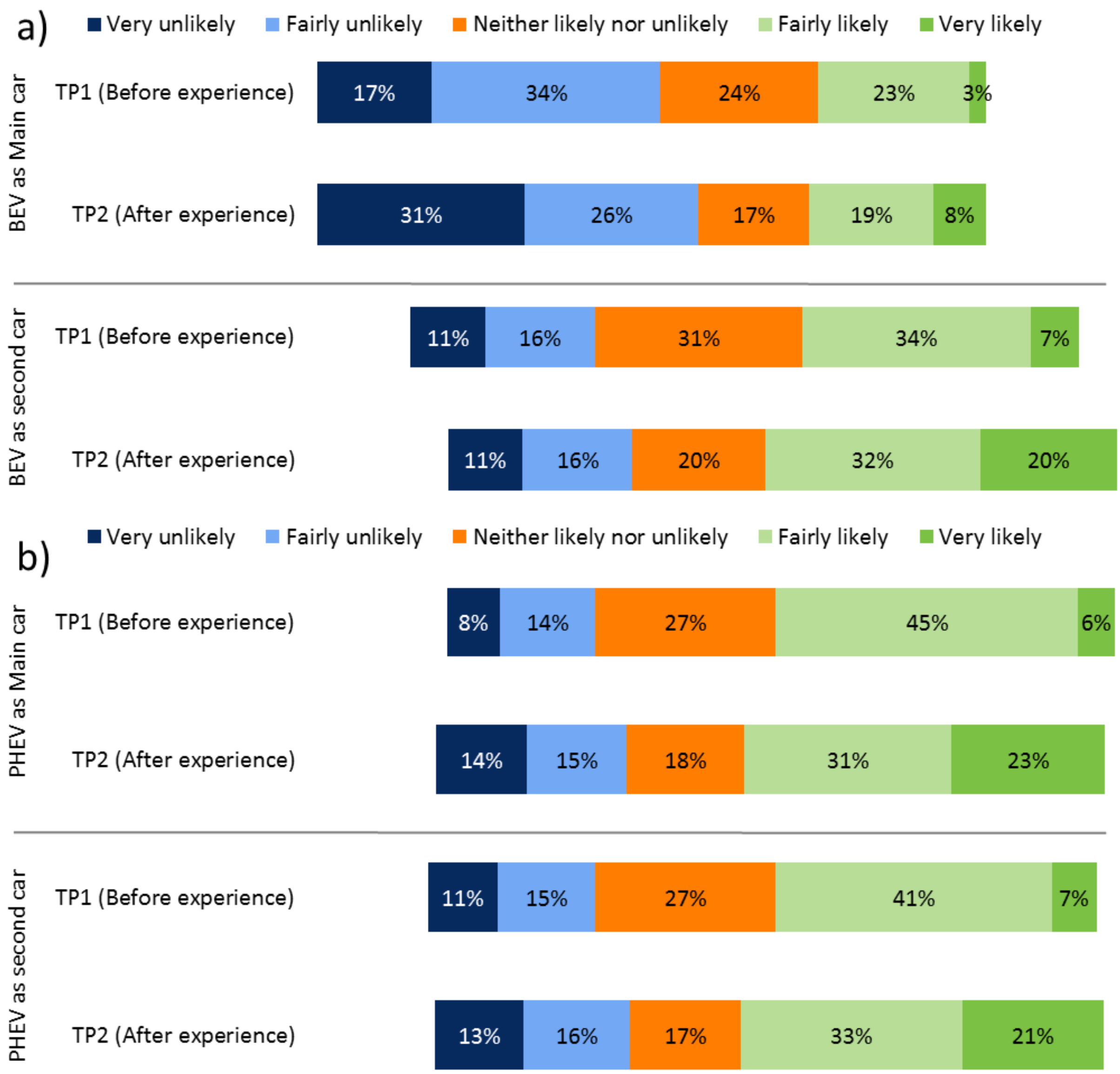

Figure 47: Proportion of participants likely or unlikely to purchase a) BEV and b) PHEV before (TP1) and after (TP2) experience with the vehicles

To examine this further, a ‘difference score’ was calculated for each participant by subtracting their response to TP1 (before experience with any vehicles) from their response to TP2 (after experience with all 3 vehicles). A positive difference score indicates participants reported higher likelihood to purchase in TP2 compared with TP1; whereas a negative difference score indicates a lower likelihood to purchase. The mean difference scores are shown in Figure 48.

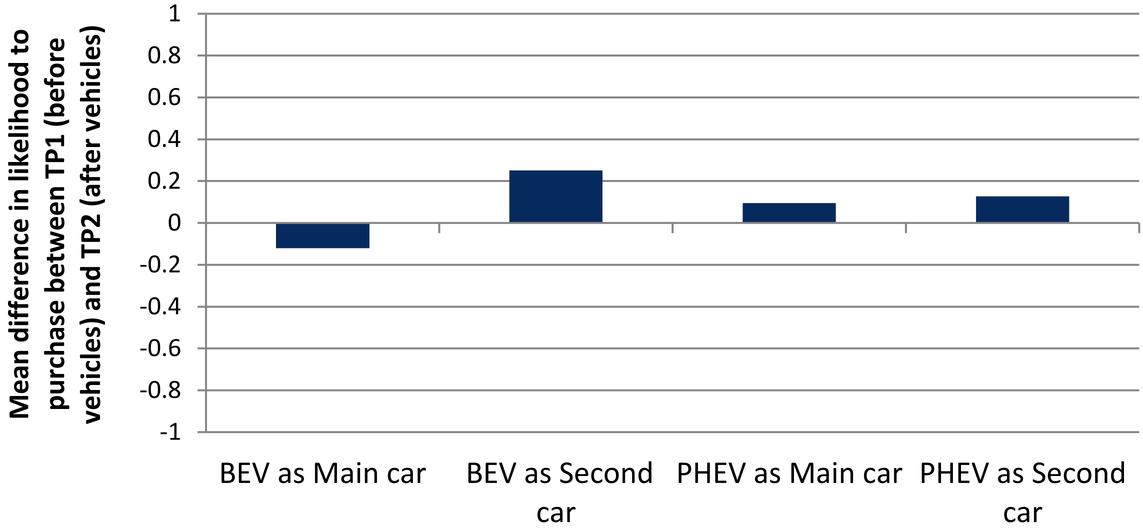

Figure 48: Mean difference scores showing change in likelihood to purchase BEV and PHEV between TP1 and TP2

A one-sample t-test revealed that the difference scores for BEV as a main car, PHEV as a main car, and PHEV as a second car were not significantly different from zero.

The difference scores for BEV as a second car, however, (M = 0.252, t = 2.432, p = 0.016) were found to be significantly different from zero, indicating a slight but significant increase in reported likelihood to purchase a BEV as a second car following experience with all three vehicles. Taken together these results suggest that experience with a BEV and PHEV significantly increased participants likelihood to purchase a BEV as a second car.

Figure 49 shows that the pattern of changes between TP1 and TP2 differed across segments.

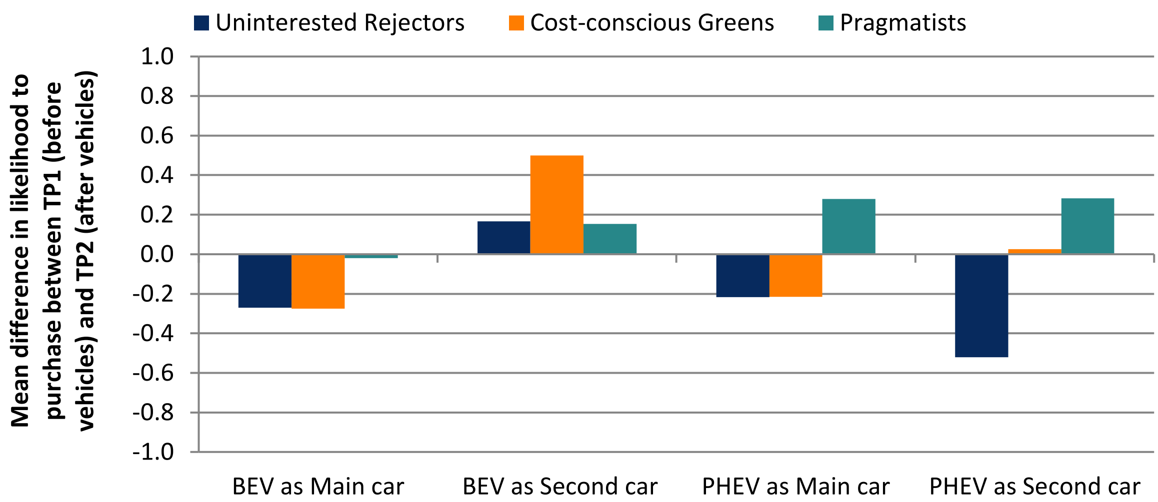

Figure 49: Mean difference scores showing change in likelihood to purchase BEV and PHEV between TP1 and TP2 by consumer segment

One-sample t-tests revealed that only some of the difference scores were significantly different from zero; Uninterested Rejecters (PHEV as a second car; t = -2.409, p = 0.025), Cost-conscious Greens (BEV as a second car (t = 2.353, p = 0.024) and Pragmatists (PHEV as a main car; t = 2.076, p = 0.041, PHEV as a second car; t = 2.086, p = 0.040).

No differences in mean scores between segments were identified for BEVs; all three segments showed negative mean difference scores for BEV as a main car (indicating decreases in likelihood to purchase) and positive mean difference scores for BEV as a second car (indicating increases in likelihood to purchase). Mean differences scores for PHEVs differed significantly between segments (main car; χ^2 = 6.751, p = 0.034, second car; χ^2 = 8.991, p = 0.011). The Pragmatists showed positive mean difference scores whilst the other two segments showed negative scores (see Figure 49).

Taken together these findings show evidence of substantial changes in participants' likelihood to purchase following experience with PiVs. Further evidence can be seen at the individual level; over 50% of the sample changed their viewpoint after experience in the trial (see Figure 50). Indeed, for each of the vehicle types (BEV and PHEV, main and second car) around 20% of the sample showed at least a two-point change in likelihood to purchase a PiV following experience in the trial. That is, their responses on the 5-point scale (1-Very unlikely, to 5-Very likely) shifted by 2 points or more. This suggests that experience with the vehicles strengthened the views of mainstream consumers considerably, either in a positive or negative direction. This demonstrates the importance of reducing psychological distance by providing real world experience with the vehicles in a controlled study design.

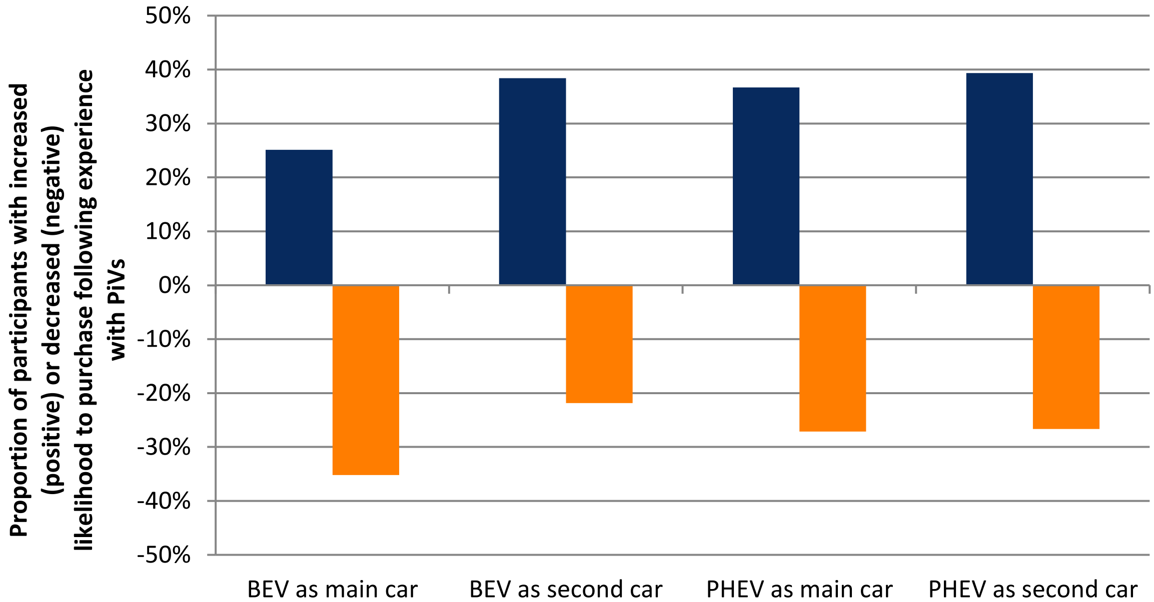

Figure 50: Proportion of participants whose likelihood to purchase a BEV and PHEV changed following experience with PiVs (positive changes indicate increased likelihood)

The finding has significant meaning for the vehicle industry in understanding the future market. It suggests that there is still room for attitudes and purchase intentions towards PiVs to be shaped within a large portion of the mainstream consumer market that remain undecided. It also suggests that attitudes will quickly polarise as the public gain experience following greater social diffusion of the technology.

B.4.2 How much does the potential All Electric Range (AER) of a BEV or PHEV influence willingness to consider adoption?

- **Willingness-to-Pay (WTP) for PHEV all-electric range was valued at £34 per km in increased vehicle purchase price.**
- **WTP for BEV range was non-linear; valued at £24 per km between 160-480 km, but only £7/km between 480-640 km.**
- **WTP for both BEV and PHEV range was higher than observed in the DfT 2015 survey, possibly reflective of the direct experience of both types of PiV gained by participants of the current trial.**
- **The average minimum BEV range accepted by participants was 200 miles (320 km) for a main car and 150 miles (240 km) for a second car.**
- **Cost-conscious Greens are more willing to consider a BEV with a lower range than the other segments, even as a main car. This was the case despite them making frequent long journeys, suggesting the influence of their pro-environmental motivations is a strong influence on their willingness to consider PiVs. For a PHEV, the average accepted minimum range was around 50 miles (80 km).**

B.4.2.1 Willingness-to-pay for AER

Figure 51 presents the WTP for PHEV all-electric range (AER) derived from the choice experiment. At the whole sample level, participants valued PHEV electric range at £34 per km. WTP was highest amongst Cost-conscious Greens, which may be because they recognise the environmental benefit of driving under electric power and greater potential for fuel cost savings with higher electric range.

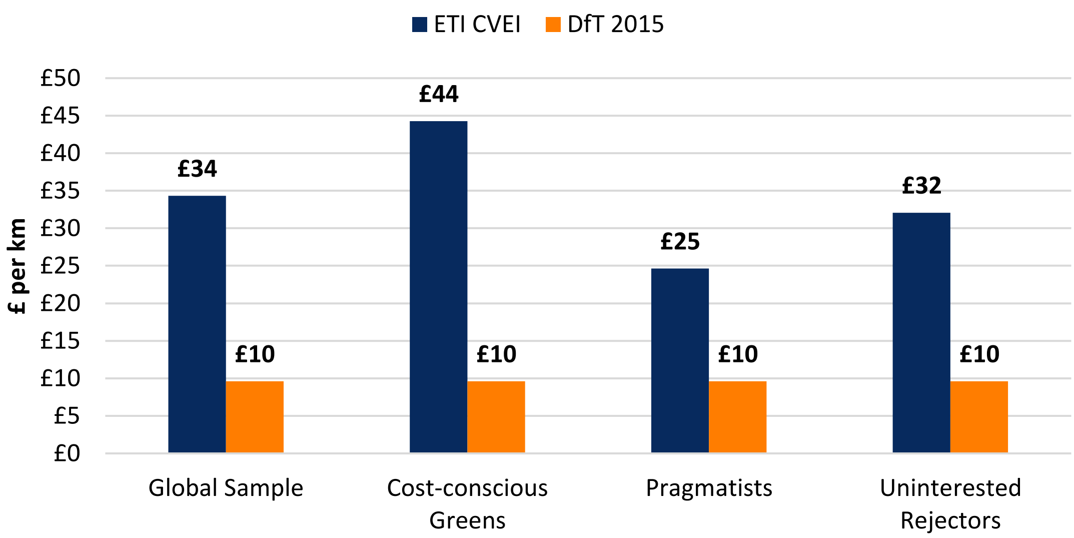

Figure 51: Willingness-to-pay (WTP) for PHEV electric range (£/km), derived from this choice experiment and compared with the DfT 2015 survey

WTP for electric range was measured between 10 and 60 miles (16 to 100 km) and it was expected that WTP for additional PHEV range would decrease at high ranges, as the marginal benefit in terms of greater share of electric mileage gets smaller. However, a statistically significant non-linear relationship between electric range and utility was not identified and general questionnaire responses suggested that PHEV AER greater than 60 miles would further increase the proportion of mainstream consumers willing to purchase a PHEV (see Figure 57). .

Figure 52 illustrates how PHEV electric range influences the consumer preference for PHEVs in a choice model. Since Cost-conscious Greens have the highest WTP for electric range, they are predicted to be most sensitive to a change, while Pragmatists are found to be the least sensitive. Note that this approach isolates the value of PHEV range excluding the impact on fuelling costs, as this is considered within the running cost attribute. In reality, increasing the range of a PHEV should also reduce running costs, since more driving could be done under electric power. Driving under electricity is generally cheaper than fuel, although this may not be the case if a company car driver is reimbursed for fuel and not electricity, or they charge using public charge point with expensive electricity rates. However, the choice experiment decouples the impact of PHEV range from running costs, and instead evaluates other factors such as the perceived environmental benefit of more electric range or reduction in trips to petrol stations. The value of a change in running costs is presented in section 0.

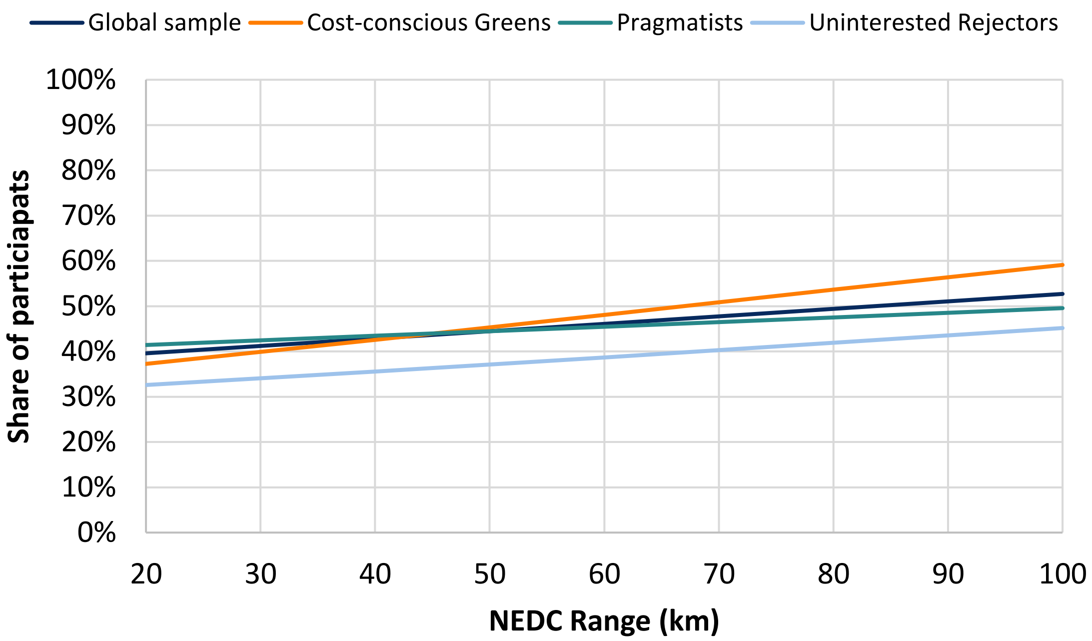

Figure 52: Share of participants predicted to choose the PHEV with different electric ranges and all other attributes set to their reference values

In general, WTP for PHEV range is significantly more for all consumer segments than was observed in the DfT 2015 survey (Element Energy, 2015). This may reflect the noticeable difference during driving in electric and petrol mode experienced by the participants, who are then more aware of the relationship between PiV range and the proportion of their driving they can carry out in electric mode, compared to the DfT respondents who had not experienced PHEVs as drivers. For this previous analysis, statistically significant WTP values for each consumer segment could not be derived, and instead the result for the whole sample was used for all consumer segments. Hence all consumers are shown to have the same WTP in Figure 51.

Figure 53 shows the WTP derived for BEVs. Unlike for PHEVs, a non-linear relationship could be observed, revealing that in general the WTP for additional range is lower at high range. For example, across the whole sample WTP for additional range between 160 km and 480 km was found to be £24/km, but this falls to only £7/km between 480 km and 640 km. A similar non-linearity was observed in Element Energy's 2011 choice experiment for the ETI (Element Energy, 2011), with WTP decreasing from £29/km between 160 km and 240 km to £4/km between 240 km and 320 km. The reason for this can be attributed to a fall in the marginal increase in convenience once a buyer perceives that a particular BEV range can meet all (or the vast majority) of their journey patterns.

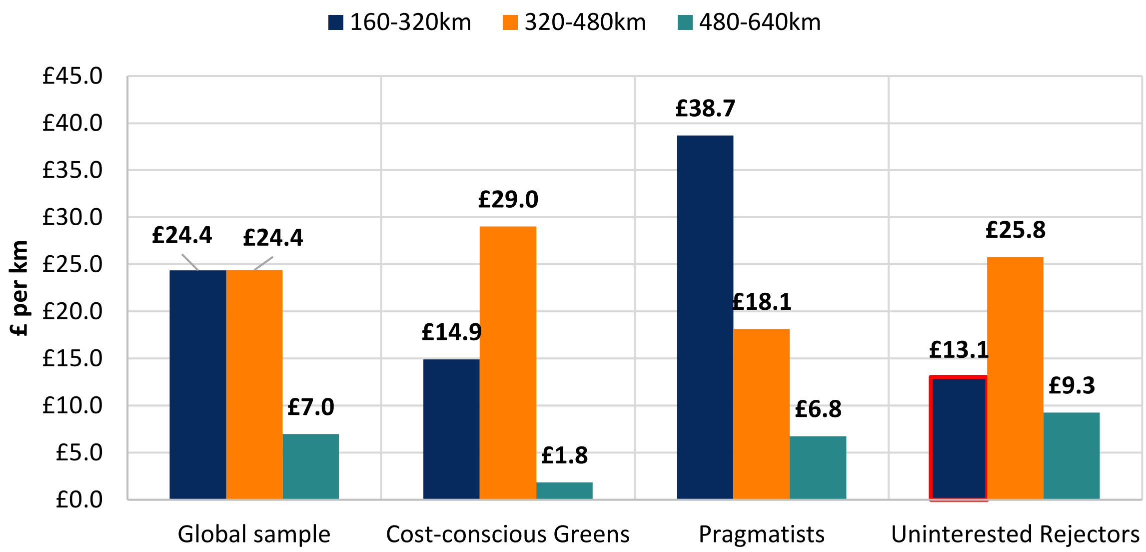

Figure 53: Willingness-to-pay for BEV range (£/km), derived from the Consumer Uptake Trial choice experiment. Red border means the result is not statistically significant

When looking at the individual consumer segments, however, only the Pragmatists show the expected trend of a gradual decrease in WTP as range increases. In contrast, both Cost-conscious Greens and Uninterested Rejecters show that WTP is lower between 160 km and 320 km compared with 320 km and 480 km. This may be because few participants consider a BEV when range is very low, and so a small increase in range from 160 km will not make them more likely to purchase a BEV. Range has to be increased considerably, to at least 320 km for example, for them to attribute significant utility to the BEV. This is illustrated in Figure 54, which presents how a change in BEV electric range affects the share of participants that are predicted to choose a BEV, with all other attributes set to their reference values. For Cost-conscious Greens and Uninterested Rejecters, the share choosing BEVs accelerates beyond 300km of range, before tailing off again at 500 km. Note that the coefficient derived for Uninterested Rejecters between ranges of 160 km and 320 km had a *p*-value of 0.14, and so is not considered statistically significant, but has been included in the prediction of participant share for completeness. The reasons for this difference in trend in WTP are unclear. Pragmatists report a marginally higher average annual mileage of approximately 9,700 miles, compared with 8,500 miles for both Cost-conscious Greens and Uninterested Rejecters. However, it would be expected that those with higher mileage would be less willing to consider a low range BEV. Furthermore, as shown in Figure 33, Cost-conscious Greens and Pragmatists drive trips >50 miles more frequently than Uninterested Rejecters, and so again this does not match the trend in WTP across the consumer segments. It may, therefore, be a reflection of the different process through which each of the consumer segments chooses their vehicle, and may also be related to affective differences towards PiVs in these groups.

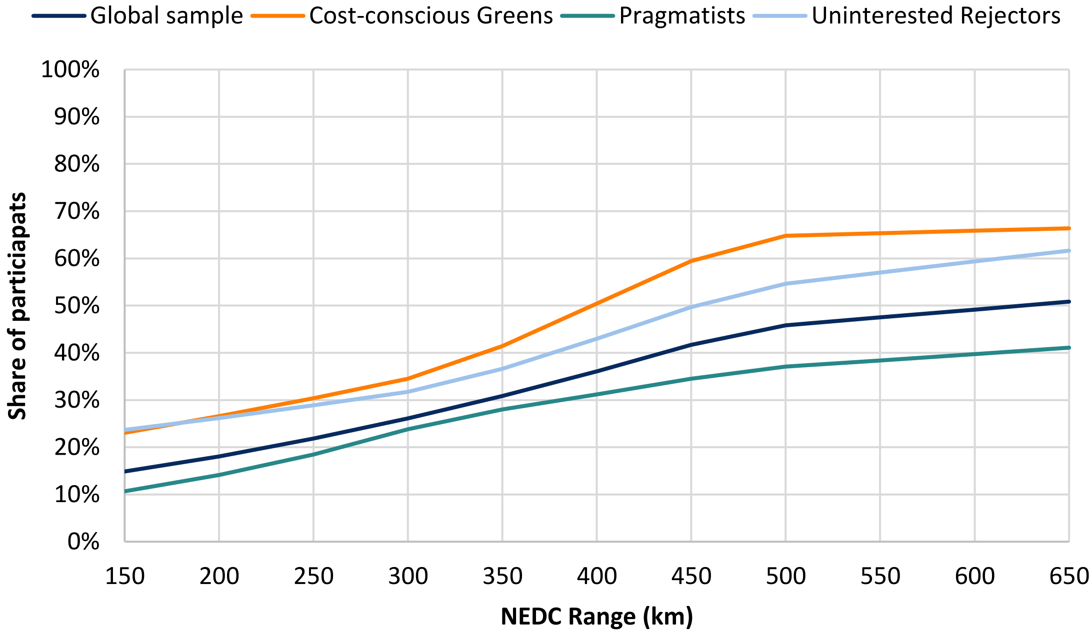

Figure 54: Share of participants predicted to choose the BEV with different electric ranges, with all other attributes set to their reference values

Figure 55 compares the WTP for BEV range from this study, averaged across the three range intervals, with that observed in the 2015 DfT survey (Element Energy, 2015). Note that the presence of a non-linear relationship was not explored in the previous study. In general, the participants in the Consumer Uptake Trial display a greater WTP for BEV range than in the DfT 2015 survey. It may be that now they have experienced driving a PiV, participants have become more aware of the restrictions imposed by limited range and so have a greater appetite for more range. Alternatively, or in addition, participants who have experienced a BEV may now be more willing to consider them as a viable option, and so would be less likely to simply reject them on the basis that their range is less than the ICE option. This will manifest itself as a higher WTP for range.

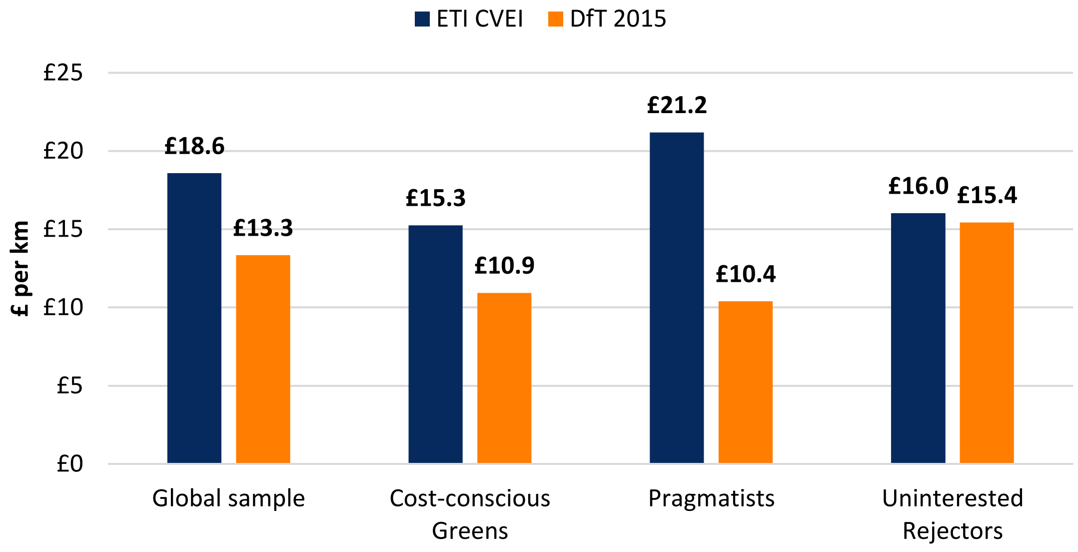

Figure 55: Average WTP for BEV electric range (£/km) between 160 km and 640 km, derived from this choice experiment and compared with the DfT 2015 survey

B.4.2.2 Impact of AER on likelihood to purchase

The impact of all-electric range (AER) on likelihood to purchase a BEV and PHEV was also assessed through additional items in the TP2 questionnaire. Participants were asked whether or not they would consider purchasing a BEV and PHEV as a main and second car for five alternative AER levels.

The proportion of participants who indicated [“Yes”] that they would purchase a BEV and PHEV with each level of AER is shown in Figure 56 and Figure 57, respectively.

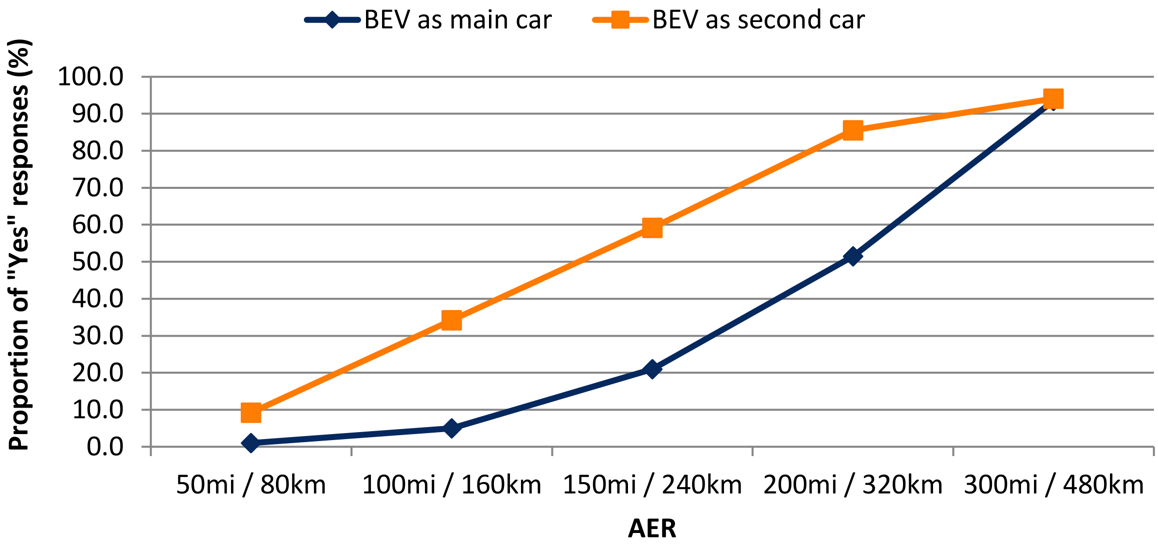

Figure 56: Proportion of participants who would purchase a BEV at each level of AER (responses to TP2 questionnaire)

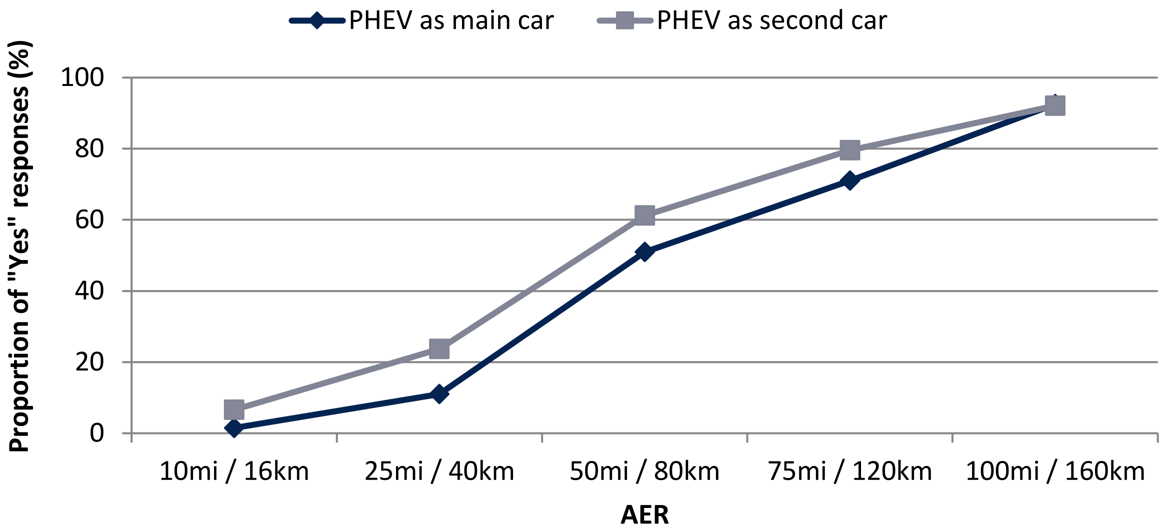

Figure 57: Proportion of participants who would purchase a PHEV at each level of AER (responses to TP2 questionnaire)

The minimum AER at which each participant indicated they would consider purchasing a BEV and PHEV was calculated; descriptive statistics for these values are shown in Table 23.

Table 23: Descriptive statistics showing minimum AER at which participants indicated they would purchase a BEV and PHEV

Descriptive statistics	BEV as main car	BEV as second car	PHEV as main car	PHEV as second car
Median	200	150	50	50
Mean	230	157	64	54
Std. Deviation	68	67	25	26

Non-parametric Wilcoxon signed ranks tests revealed there were significantly higher minimum acceptable AERs for a main car compared with a second car, for both the BEV (Z = -8.678, $p < 0.001$) and the PHEV (Z = -6.651, $p < 0.001$).

The mean minimum acceptable AERs for each segment are shown in Figure 58. A non-parametric independent samples Kruskal-Wallis test showed a significant effect of segment on minimum acceptable AER for a BEV, both as a main (χ^2 = 10.717, p = 0.005) and second car (χ^2 = 6.124, p = 0.047), but no significant effect for PHEVs.

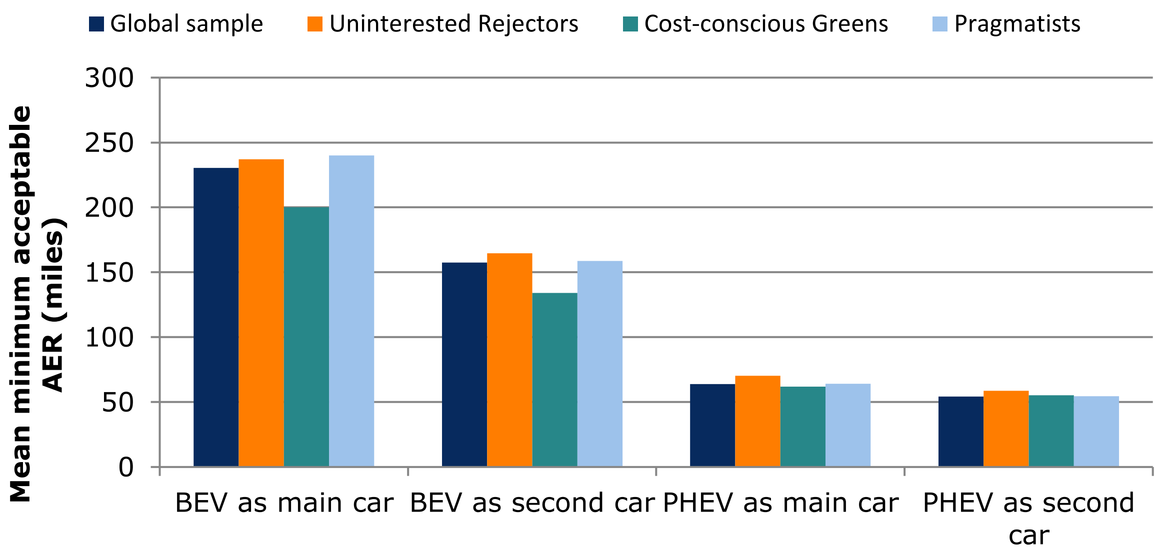

Figure 58: Mean minimum AER at which participants indicated they would purchase a BEV and PHEV, by segment

Non-parametric Mann-Whitney U tests showed the Cost-conscious Greens had significantly lower minimum acceptable AERs for BEVs than the Pragmatists (main car; $Z = -3.179$, $p = 0.001$, second car; $Z = -2.234$, $p = 0.025$) and the Uninterested Rejecters (main car; $Z = -2.296$, $p = 0.022$, second car; $Z = -1.990$, $p = 0.047$). No significant differences were found between the Uninterested Rejecters and Pragmatists.

B.4.2.3 Perceived importance of AER

The TP2 questionnaire also asked participants to rate how important range was when considering purchasing a BEV and PHEV using a scale from 1 (not at all important) to 5 (extremely important). The majority of participants reported that range was at least "Very important" when considering purchasing both a BEV (98.5%) and a PHEV (83%) (see Figure 59). A non-parametric repeated measures Wilcoxon signed ranks test showed that range was rated as significantly more important when considering purchasing a BEV ($M = 4.700$) compared with a PHEV ($M = 4.200$, $Z = -7.541$, $p < 0.001$).

Non-parametric Kruskal-Wallis tests revealed no significant differences in the ratings of importance between the consumer segments.

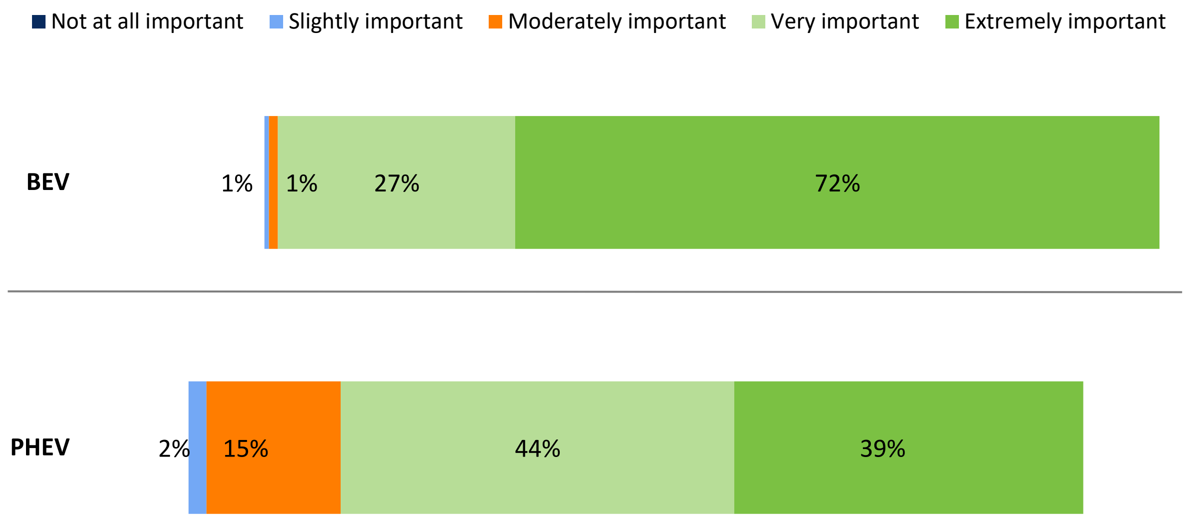

Figure 59: Proportion of participants by rating of importance of range when purchasing a BEV and PHEV (responses from 200 participants to TP2 questionnaire)

B.4.3 How much does the potential purchase price of a BEV or PHEV influence willingness to consider adoption?

- → **Purchase price was considered at least "Very important" by more than 85% of the sample and did not differ for BEVs and PHEVs.**
- → **Cost-Conscious Greens are the most sensitive to purchase price, and lose the greatest share of participants that would choose a BEV as price increases from £10,000 to £40,000.**
- → **Pragmatists are the least sensitive to price and lose the smallest share of participants as price increases.**

B.4.3.1 Purchase price choice coefficients

Figure 60 shows the choice coefficients for the purchase price attribute derived from the choice experiment. These can be interpreted as the change in utility for every £1 increase in car purchase price. Note that the coefficients are negative and so an increase in purchase price leads to a decrease in utility (i.e. greater 'disutility'). A larger coefficient signifies greater price sensitivity. Cost-conscious Greens have the largest coefficient and are the most sensitive to vehicle purchase price. Whilst the scale of the coefficients in this choice experiment and the DfT 2015 survey differs slightly, the same trend is observed between consumer segments.

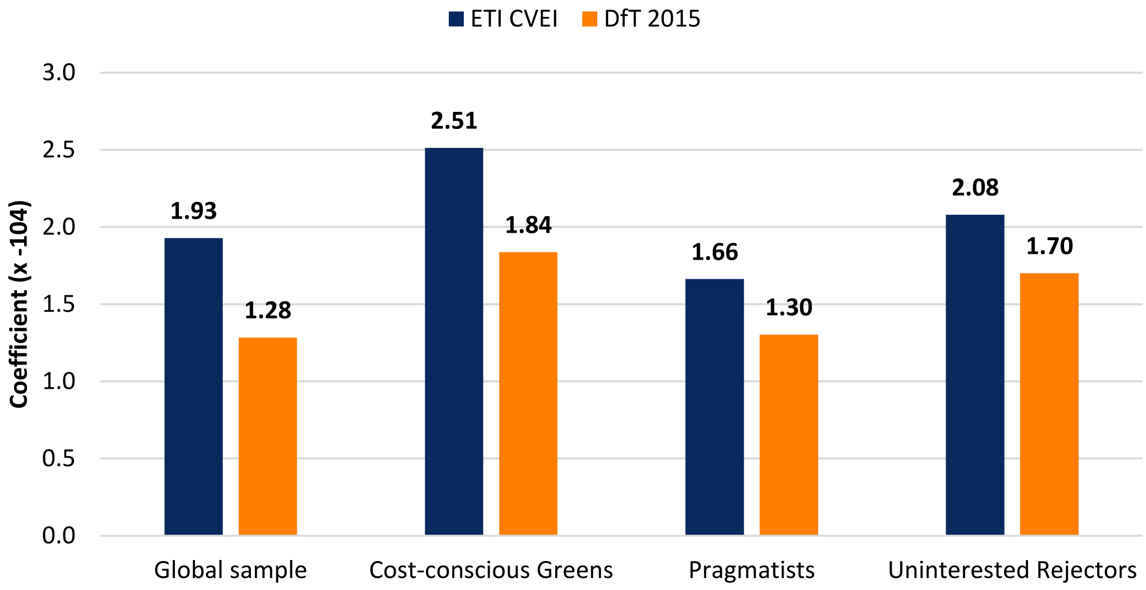

Figure 60: Purchase price choice coefficients derived from the ETI CVEI uptake choice experiment, and compared with the DfT 2015 survey results

Figure 61 demonstrates the sensitivity of each consumer type on purchase price, by showing how BEV purchase price affects the share of participants that would choose a BEV, as predicted by the choice model. Cost-Conscious Greens, who are most sensitive to purchase price, are found to show the strongest increase in participant share as BEV purchase price decreases. Conversely, Pragmatists are the least sensitive and decreasing BEV purchase price leads to a slower increase in participant share..

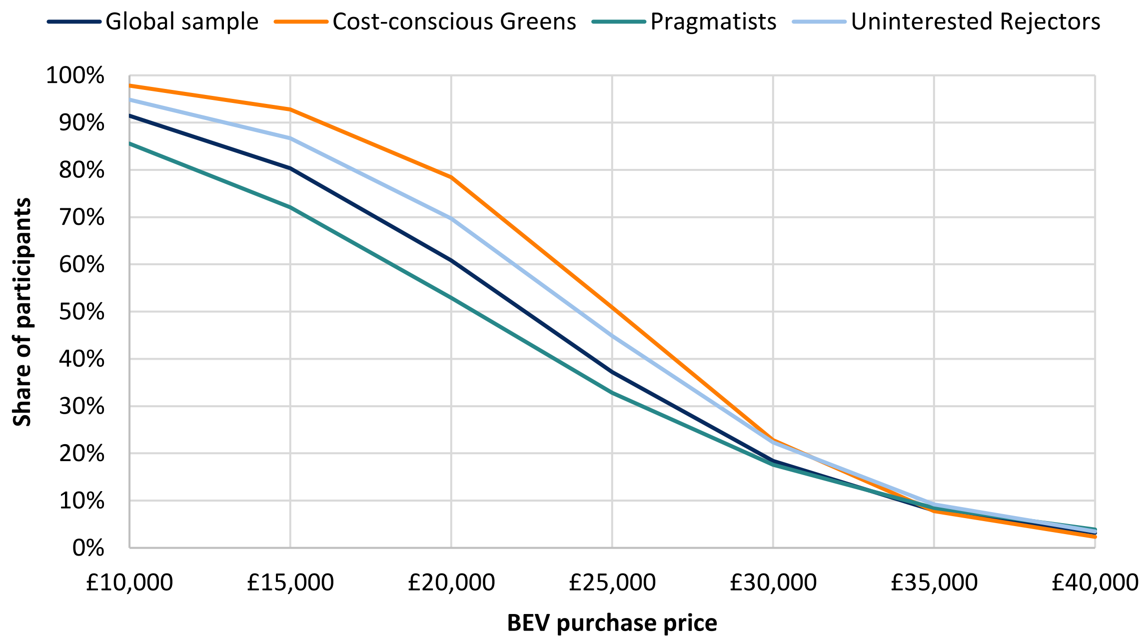

Figure 61: Share of participants predicted to choose the BEV alternative with different purchase prices (inclusive of VAT, grants, and taxes), with all other attributes set to their reference values

Note that under real-world purchasing conditions, price sensitivity would be expected to be higher, since participants usually display a greater willingness to spend hypothetical money in a choice experiment compared with actual money in a real car purchase (Train, 2003). To use coefficients derived from choice experiments to predict real world uptake, such as in ECCo, an intermediary step is necessary to calibrate the price sensitivity to observed elasticity's of demand. This is done by applying a scaling factor to all coefficients. Since the coefficients for purchase price and all other attributes are scaled equally, WTP values are unaffected.

B.4.3.2 Perceived importance of purchase price

Participants were asked to rate the importance of purchase price when considering purchasing a BEV and PHEV using a scale from 1 (not at all important) to 5 (very important). The majority of participants reported that purchase price was at least "Very important" when considering purchasing both a BEV (86%) and a PHEV (87%) (see Figure 62). A non-parametric repeated measures Wilcoxon signed ranks test showed that the rated importance of purchase price was not significantly different for both BEVs and PHEVs.

Non-parametric Kruskal-Wallis tests revealed no significant differences in the ratings of importance between the consumer segments.

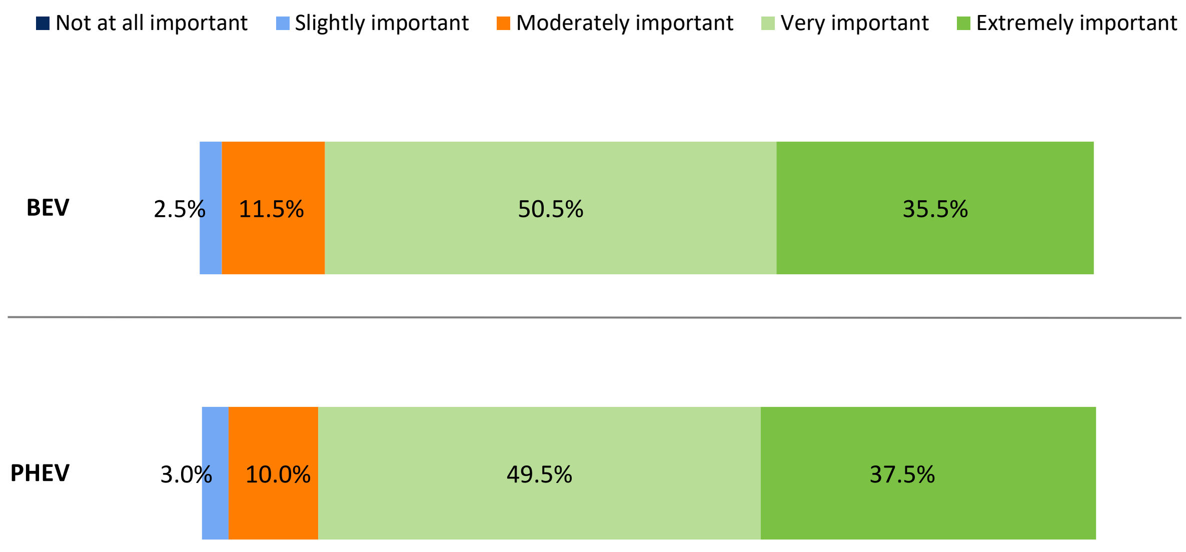

Figure 62: Proportion of participants by rating of importance of purchase price when purchasing a BEV and PHEV (responses from 200 participants to TP2 questionnaire)

B.4.4 How much does the potential running cost saving associated with using a BEV or PHEV influence willingness to consider adoption?

- → **More than 80% of the sample indicated running costs were at least "Very important" when considering purchasing a PiV, and perceived importance did not differ for BEVs and PHEVs.**
- → **A payback period of 4.7 years was identified; meaning consumers were willing to accept a higher upfront purchase price if the difference was re-paid through reduced running costs over 4.7 years**
- → **Despite being the most sensitive to purchase price, Cost-conscious Greens accepted the longest payback period (5.3 years)**

B.4.4.1 Willingness-to-pay for running cost savings

The choice experiment literature review undertaken during this project (see Deliverable D5.1) showed no consensus in how to present running costs in a choice experiment. In some cases it included fuel/electricity costs and other ownership costs separately, and in others only some of these components were used. For the choice experiment administered in this trial, a total running cost attribute was used, and defined for participants as including 'all on-going costs such as refuelling and/or recharging costs, servicing, insurance and road tax'.

Figure 63 shows the WTP for annual running cost savings, derived from the choice experiment. For the whole sample, a value of £4.7 for every £1/yr saving was observed. By way of example, this means if efficiency improvements increased vehicle purchase cost by £4.7 for every £1 saving in annual running costs, there would be no change on the share of participants choosing that vehicle. This is equivalent to accepting a payback period with reduced running costs of 4.7 years.

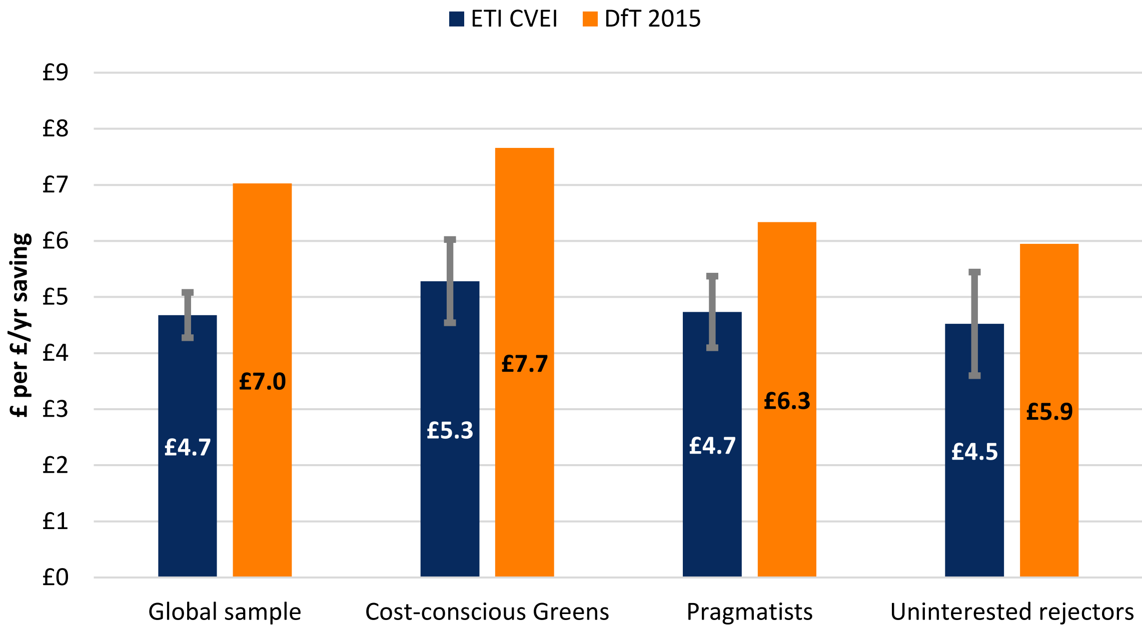

Figure 63: Willingness-to-pay for running cost savings (£ per £/year), derived from this choice experiment and the DfT 2015 survey. Error bars show 95% confidence intervals (±1.96 x standard error).

Despite being the most sensitive to purchase price, Cost-conscious Greens were found to accept a marginally longer payback period than the other consumer segments. Therefore, although they are least willing to accept an increase in purchase price, this is more likely to be tolerated if it also leads to cheaper running costs. However, a comparison of the confidence intervals for each result suggests that the behaviour of Cost-Conscious Greens may not be statistically different from the other consumer segments. Despite this, a similar trend in WTP for each consumer segment is observed in the choice coefficients from both this study and the DfT 2015 survey, however, WTP is found to be lower in this study. It was noted during the 2015 survey for DfT that the WTP for running costs of around £7 per year was higher than expected. The previous choice experiment for the ETI in 2011 (Element Energy, 2011) found an average WTP of £5 per year running cost saving, which is in line with this latest study. It was suggested in the previous study that because the survey for DfT took place in March 2015 when fuel prices were unusually low (e.g. average petrol price was £1.12/L[32]), participants may have been factoring in an expected rise. For example, they may have considered a £1 saving in March 2015 would have become more in future, and therefore showed greater WTP for it.

Figure 64 shows how running cost influences the share of participants that the choice model predicts would choose a BEV. The choice experiment was scaled on an individual basis based to ensure that the running costs tested fell into a realistic range for that participant. However, the resulting running cost coefficients have the same scale for all consumer segments. This demonstrates how as running cost decreases (going from right to left in the figure), the preference for BEVs rises fastest amongst Cost-conscious Greens. Although

[32] https://www.petrolprices.com/the-price-of-fuel/

Pragmatists were found to have a greater WTP for running cost savings than Uninterested Rejecters, in Figure 64 they appear less sensitive to a change in running costs. The reason for this is that, as shown in Figure 60, Pragmatists are less cost-sensitive than Uninterested Rejecters. Therefore, although a £1,000 saving in running costs is worth more to Pragmatists in terms of equivalent upfront cost (£4,700 vs. £4,500 for Uninterested Rejecters); upfront cost has less of an influence on their choice preference than for Uninterested Rejecters.

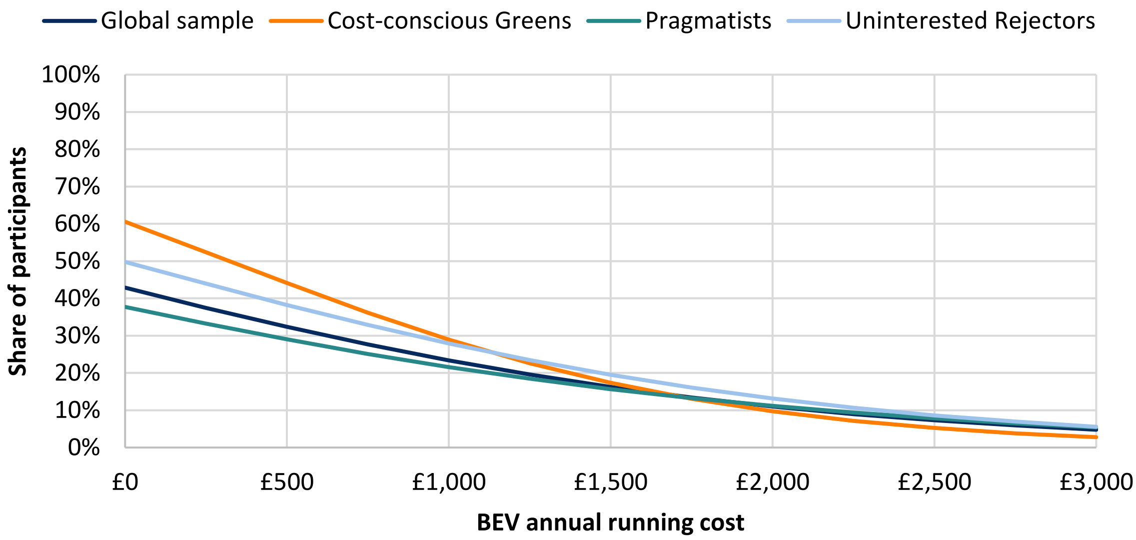

Figure 64: Share of participants predicted to choose the BEV with different annual running costs, with all other attributes set to their reference values

Figure 65 shows the share of participants predicted to choose the PHEV under different running costs. A similar pattern is observed as in Figure 64, where Cost-conscious Greens gain the largest share in participants choosing a PHEV as running cost decreases. Likewise, Pragmatists are the least sensitive to a change in running costs.

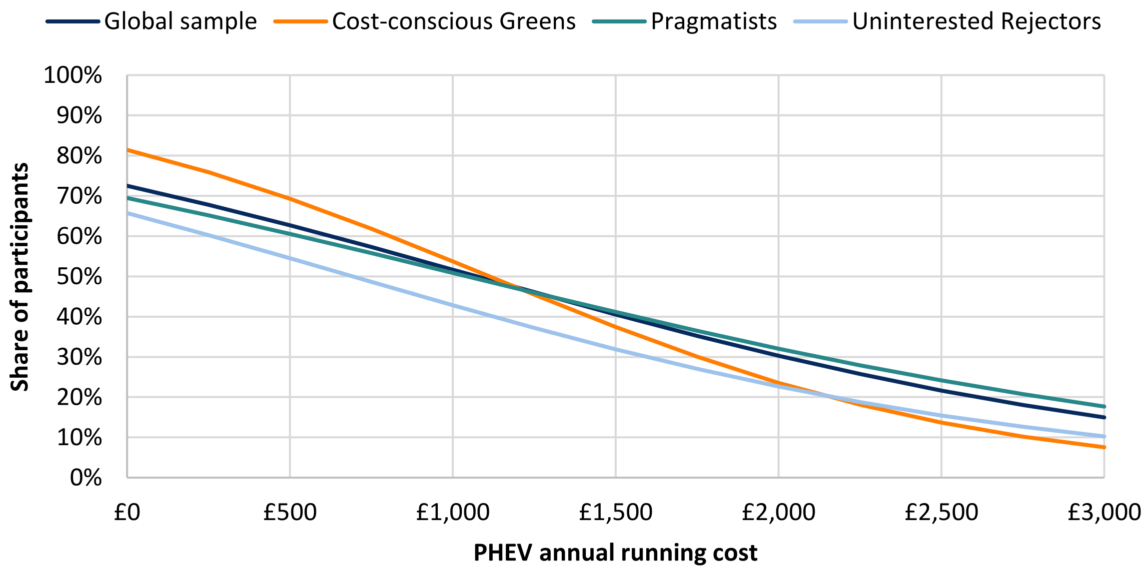

Figure 65: Share of participants predicted to choose the PHEV with different annual running costs, with all other attributes set to their reference values.

B.4.4.2 Perceived importance of running costs

Participants were asked to rate the importance of running costs when considering purchasing a BEV and PHEV using a scale from 1 (not at all important) to 5 (very important).

Unlike in the choice experiment, running costs were not explicitly defined for this question. As mentioned earlier, there is no consensus in the literature confirming how people interpret running costs. A limitation is that for this question, some participants may have perceived running costs to mean, for example, the cost of fuel or electricity, whilst others may have incorporated the costs associated with Vehicle Excise Duty, servicing, or insurance. Despite these limitations, however, since participants answered the question for both BEVs and PHEVs and they are likely to have maintained a consistent interpretation across the questions, the data can still be used to understand how perceived importance of running costs varies between the two vehicle types.

The pattern of responses to the questions was found to be almost identical between BEVs and PHEVs; the majority of participants reported that running costs were at least "Very important" when considering purchasing both a BEV (82%) and a PHEV (82%) (see Figure 66).

A non-parametric repeated measures Wilcoxon signed ranks test showed that the rated importance of running costs was not significantly different for BEVs and PHEVs. Non-parametric Kruskal-Wallis tests revealed no significant differences in the ratings of importance between the consumer segments.

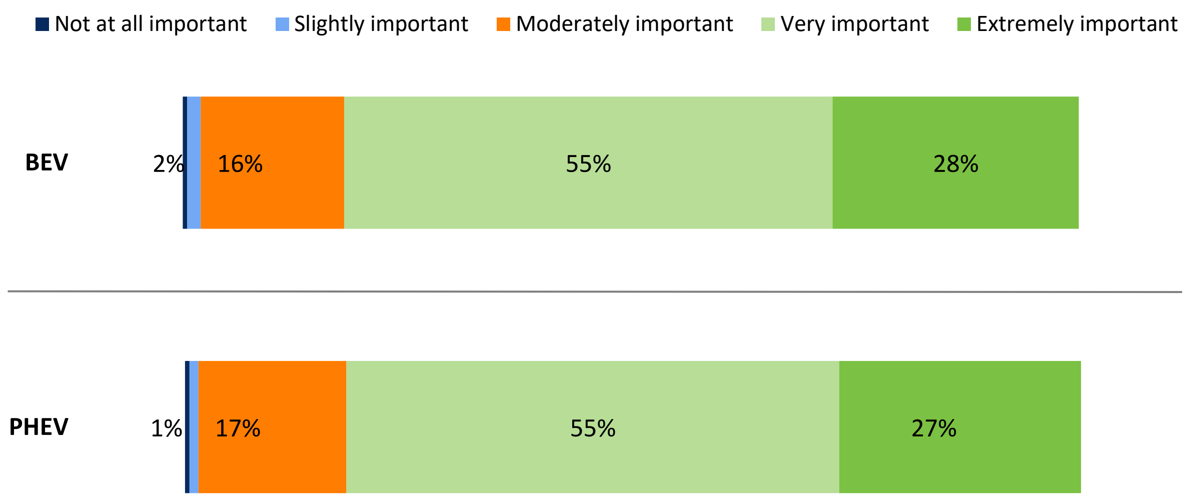

Figure 66: Proportion of participants by rating of importance of running costs when purchasing a BEV and PHEV (responses from 200 participants to TP2 questionnaire)

B.4.5 How much does the recharge time associated with a BEV or PHEV influence willingness to consider adoption?

- **On average, the maximum charge time (to deliver 100 miles of range) at which participants indicated they would consider a BEV was about 2 hours for a main car and 4 hours for a second car. For a PHEV, this was 4 and 6 hours, respectively.**
- **The 100 mile charge times accepted by the majority of mainstream consumers can be achieved using Mode 3 chargers (rated to 7.6kW) and exceeded using current DC rapid charge rates.**
- **In terms of rapid charging rate, participants valued increased charging rate at approximately £22 per kW between 50 kW and 150 kW, but only £6 per kW between 150 kW and 300 kW.**

B.4.5.1 Willingness-to-pay for rapid charging rate

Figure 67 shows the WTP for different rapid charging rates with a BEV, derived from the choice experiment. Note that as discussed in section A.9.2.1, rapid charging with PHEVs was not investigated. The charging rate is expressed in terms of miles added per minute of charging, and the WTP values are relative to a charging rate of 2.5 miles added per minute. For reference, this is approximately equivalent to 50 kW, which is the current charging speed offered by the majority of rapid charging points installed in the UK (further detail on charging rates can be seen in A.9.2.1). However, note that translating between miles added per minute and kW depends on the rate of electricity consumption (kWh/km) of the vehicle when driving, which itself depends on the vehicle specifications and driving conditions. The higher speed levels of 7.5 and 15 miles added per minute charging are approximately equivalent to 150 kW and 300 kW charging rates.

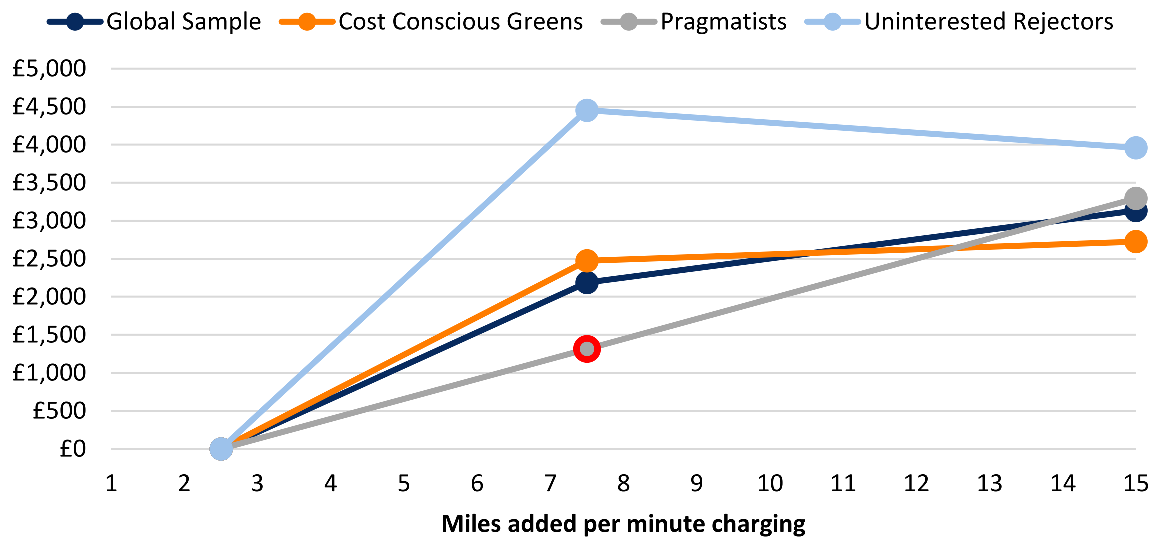

Figure 67: Willingness-to-pay for rapid charging rate of a BEV (in miles added per minute charging), relative to 2.5 miles added per minute charging (approx. 50 kW), derived from the ETI CVEI uptake choice experiment. Red border means the result is not statistically significant

There is a clear non-linearity in the WTP for rapid charging speed, with the marginal benefit in utility decreasing as the speed increases. Considering the whole sample, participants value increased charging rate at approximately £22/kW between 50 kW (~2.5 miles/minute) and 150 kW (~7.5 miles/minute), and approximately only £6/kW between 150 kW and 300 kW (~15 miles/minute). Presumably, once the speed is fast enough that the range needed to complete a journey (or make it to the next stop) can be added within the driver's typical dwell time during a trip rest stop (e.g. at a motorway service station), there is little further value in faster charging.

Cost-conscious Greens appear content with a charging rate of 7.5 miles/minute (150 kW), valuing the increase from 2.5 miles/minute (50 kW) at nearly £2,500, compared with only £250 to further increase it to 15 miles/minute (300 kW). This is illustrated in Figure 68, where the share of Cost-Conscious Greens that the choice model predicts would choose a BEV remains almost constant beyond 7.5 miles/minute (150 kW). Curiously, Uninterested Rejecters show a negative WTP to increase the charge rate from 7.5 miles/minute. However, this is likely more a reflection of their dissatisfaction with the base rate of 2.5 miles/minute, which results in a very high WTP to increase this to 7.5 miles/minute, but a negligible WTP to increase this further. In Figure 68 it is observed that Uninterested Rejecters show a relatively low BEV share similar to the Pragmatists at 2.5 miles/minute, but this rises to the level of Cost-Conscious Greens at 7.5 miles/minute. Pragmatists' WTP for additional charging speed appears to remain constant as charging speed increases, however, note that the value at 7.5 miles/minute is not statistically significant.

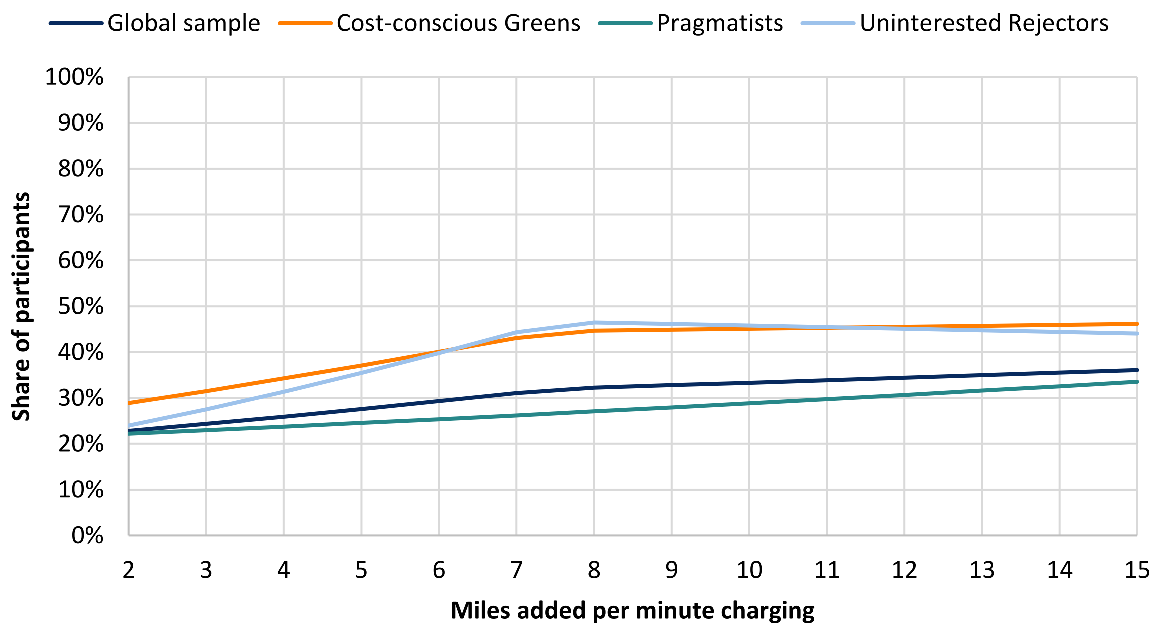

Figure 68: Share of participants predicted to choose the BEV with different rapid charging rates (miles per minute charging), with all other attributes set to their reference values

Figure 69 compares the WTP for rapid charging rate from this study, with those derived from the 2015 survey for DfT. Note that the DfT survey only included a charging speed up to 7.5 miles per minute. Whilst on a whole sample basis, both studies are in agreement, at a consumer segment level it can be seen that this is only because some consumers now show a much higher WTP, while others are much lower. Cost-conscious Greens placed very little value in faster rapid charging in the 2015 DfT survey (Element Energy, 2015), but after the Consumer Uptake Trial now behave more like the other consumer types. Uninterested Rejecters also now show a higher WTP, suggesting that experiencing a PiV has reinforced their perception that 50 kW rapid charging is not fast enough.

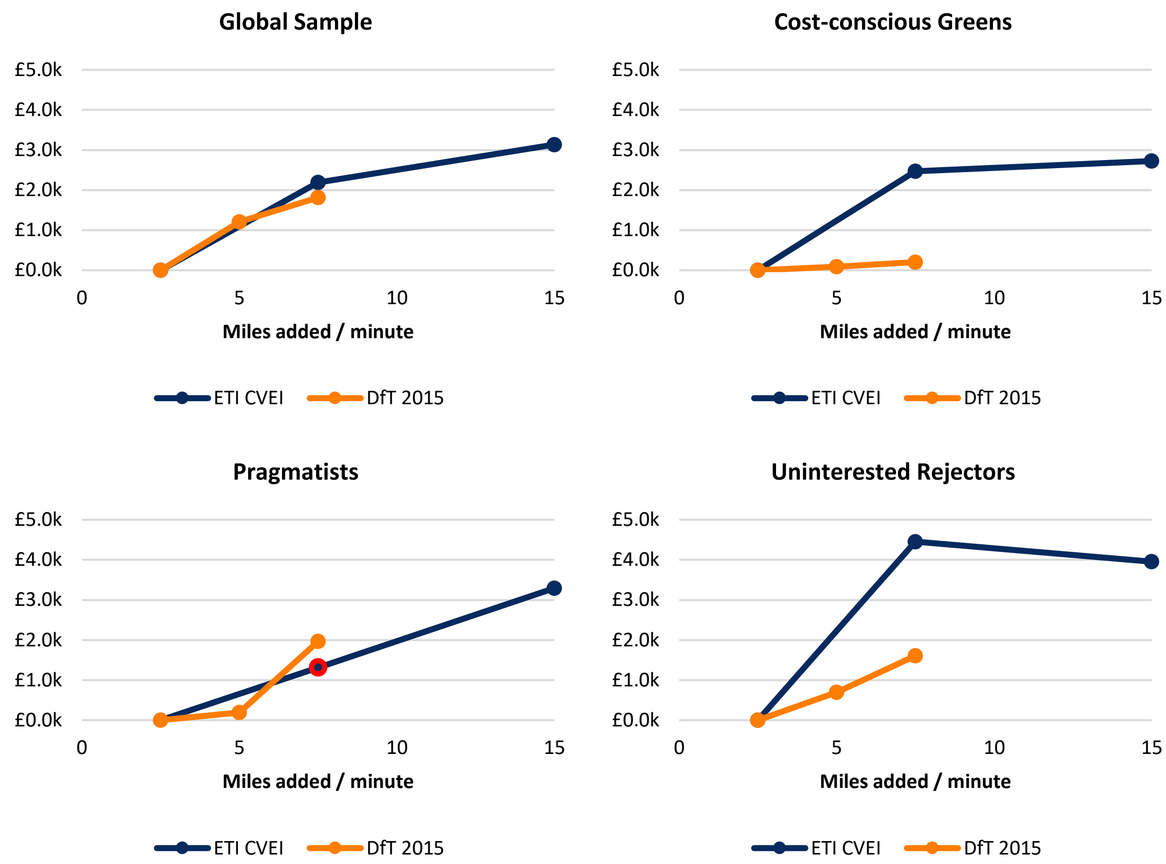

Figure 69: Comparison of willingness-to-pay for rapid charging speed relative to 2.5 miles added per minute charging, derived from this choice experiment and the DfT 2015 survey. Red border means the result is not statistically significant

B.4.5.2 Impact of recharge time on likelihood to purchase

The impact of charge time on likelihood to purchase a BEV and PHEV was also assessed through additional items in the TP2 questionnaire. Participants were asked whether or not they would consider purchasing a BEV and PHEV as main and second car for five alternative charge times varying between 8 hours and 1 hour of charging for 100 miles of range.

The proportion of participants who indicated [“Yes”] that they would purchase a BEV and PHEV with each charge time is shown in Figure 70 and Figure 71, respectively.

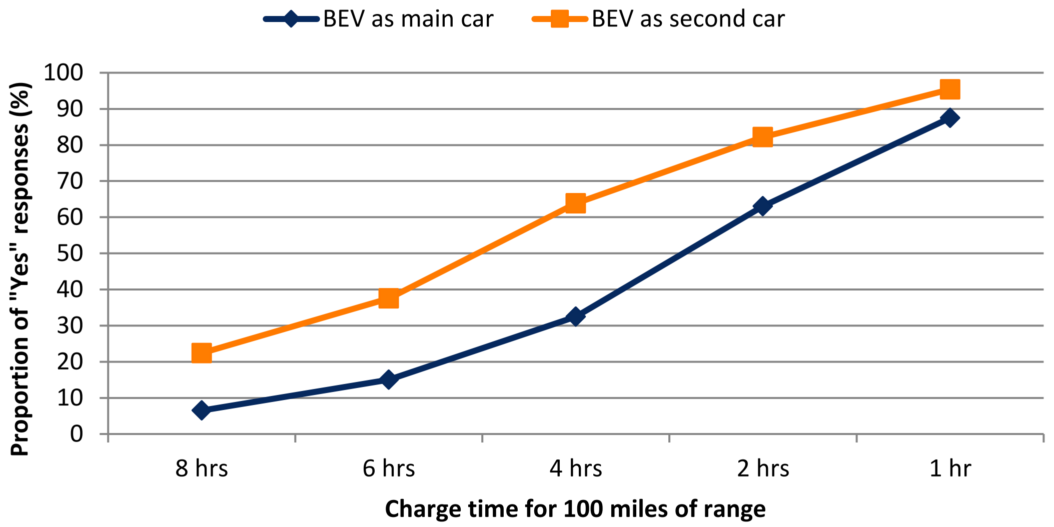

Figure 70: Proportion of participants who would purchase a BEV at each level of charge time (responses to TP2 questionnaire)

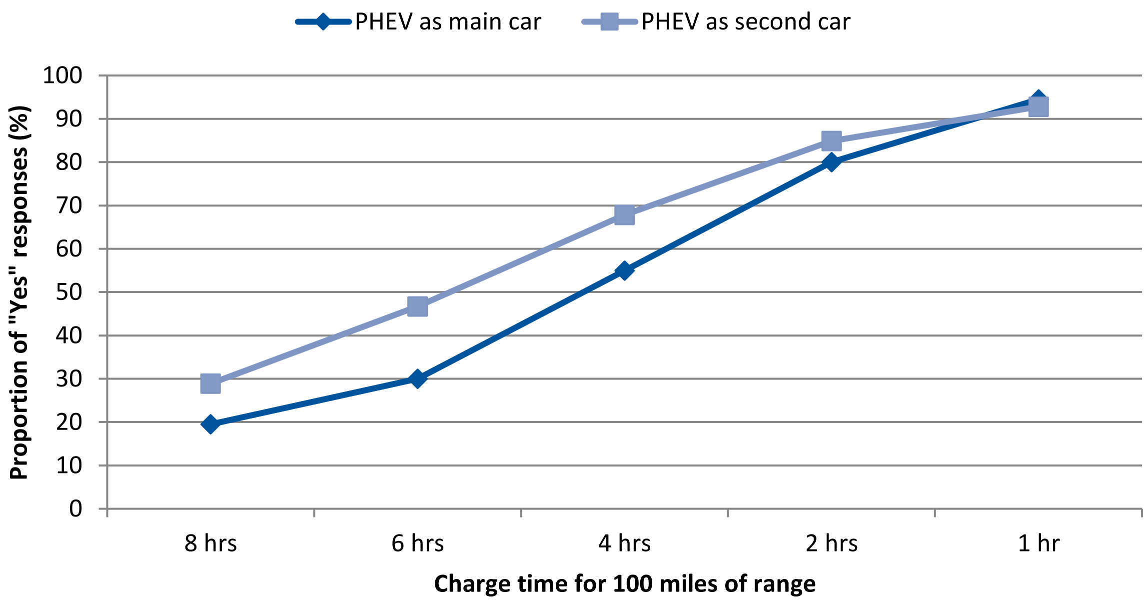

Figure 71: Proportion of participants who would purchase a PHEV at each level of charge time (responses to TP2 questionnaire)

The maximum charge time at which each participant indicated they would consider purchasing a BEV and PHEV was calculated; descriptive statistics for these values are shown in Table 24.

Table 24: Descriptive statistics showing maximum charge time (hours required for 100 miles of range) at which participants indicated they would purchase a BEV and PHEV

Descriptive statistics	BEV as main car	BEV as second car	PHEV as main car	PHEV as second car
Median	2	4	4	6
Mean	3	4	4	5
Std. Deviation	2	2	2	3

Non-parametric Wilcoxon signed ranks tests revealed there were significantly higher maximum acceptable charge times (for 100 miles of range) for a PHEV compared with a BEV (main car; $Z = -6.410$, $p < 0.001$, second car; $Z = -3.137$, $p = 0.002$), and for a second car compared with a main car, for both the BEV ($Z = -6.907$, $p < 0.001$) and the PHEV ($Z = -5.819$, $p < 0.001$).

A non-parametric independent samples Kruskal-Wallis test showed there was no significant effect of segment on maximum acceptable charge time for either a BEV or PHEV as a main or second car.

B.4.5.3 Perceived importance of recharge time

Participants were also asked to rate how important charge time was when considering purchasing a BEV and PHEV using a scale from 1 (not at all important) to 5 (very important). The majority of participants reported that charge time was at least “Very important” when considering purchasing both a BEV (91%) and a PHEV (75%) (see Figure 72).

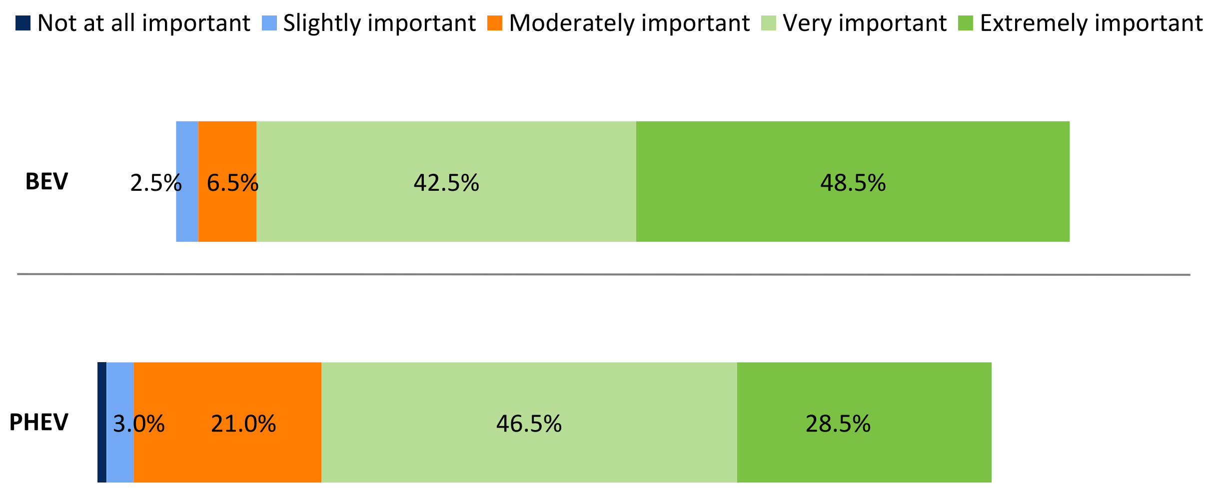

Figure 72: Proportion of participants by rating of importance of charge time when purchasing a BEV and PHEV (responses to TP2 questionnaire)

A non-parametric repeated measures Wilcoxon signed ranks test showed that charge time was rated as significantly more important when considering purchasing a BEV ($M = 4.370$) compared with a PHEV ($M = 3.985$, $Z = -6.827$, $p < 0.001$). Non-parametric Kruskal-Wallis tests revealed no significant differences in the ratings of importance between the consumer segments.

B.4.6 How much are personal characteristics (personality, innovativeness, liminality, self-congruity, driving style, demographic variables, etc.) predictive of willingness to consider adoption of a BEV or PHEV?

→ **Very few personal characteristics were related to the willingness to adopt a BEV or PHEV as a main or second car.**

→ **Different variables predicted the uptake of the different vehicle types.**

→ **For BEVs as a main car the predictors were interest in new technology scores and careful driving style scores; both in a positive direction.**

→ **For BEVs as a second car the predictors were gender and pro-environment identity scores with females and high scorers being more willing to adopt.**

→ **For PHEV as a main car, interest in new technology scores was the only predictor of willingness to adopt.**

→ **For PHEV as a second car, knowing people who are environmentally conscious and being more open to alterative transport mode predicted willingness to adopt.**

A number of variables from different surveys throughout the trial were used in to answer this research question (FS1, FS2, PTQ, TP1 and TP2 questionnaires). The relationship between the likelihood to purchase a PiV and a comprehensive list of personal characteristics were explored. This included age, gender, self-rated driving style, attitudes towards technology, attitudes towards the environment, and personality scores.

The aim of this research question was to see if any of these personal characteristics could predict the likelihood of someone purchasing a BEV or PHEV as a main or second car. This was investigated by creating four regression models to assess the extent to which the most important personal characteristics were predictive of willingness to adopt a BEV or PHEV as main or second car.

In order identify the personal characteristics that should be used in these models, the following analyses were needed:

- Creating the outcome variables (see section B.4.6.1)
- Analysis to reduce the number of survey items (see section B.4.6.1)
- Analysis to identify which personal characteristics were related to the willingness to adopt (see sections B.4.6.4 to B.4.6.7).

B.4.6.1 Creating the outcome variables

The intention to adopt a PHEV and BEV as a main and second car were measured on a five-point scale ranging from "very unlikely" to "very likely" with the single statement: "In the next 5 years, I would choose to have a BEV /PHEV as a main /second car". The question was repeated for BEV main and BEV second car, and PHEV main and PHEV second car. These four survey items were reduced into four dichotomous variables by grouping responses into two categories, likely or unlikely. The relatively small group of participants who responded "neither likely nor unlikely" were excluded from this analysis.

B.4.6.2 Predictor variable reduction

Personal characteristics were measured using a large number of survey items. In order for these to be included in the analysis, they were reduced using factor analysis to identify underlying factors, or, for those variables that form pre-existing scales, calculating the scale values (e.g. the 44 items used to characterise driving style form 8 scales).

Driving style

The Multi-dimensional Driving Style Inventory (MDSI; Taubman-Ben-Ari, Mikulincer & Gillath, 2004) was constructed to provide a conceptualisation of an individual's habitual driving style. "Style" is defined as the way the driver chooses to drive, or habitually drives and is thought to be influenced by attitudes and beliefs regarding driving, as well as by more general goals, including symbolic goals to signal aspects of identity. The MDSI characterises driving style using eight scales: Angry, Anxious, Cautious, Dissociative, Distress Reduction, High Velocity, Patient, and Risky. These eight scores were explored as potential predictors of the likelihood to purchase a PiV. These scores were normalized to the general population.

Personality

The Newcastle Personality Assessor (NPA) is a brief measure of personality. Five dimensions of personality (extraversion, neuroticism, conscientiousness, agreeableness and openness) were assessed by 12 items rated on five-point scales, with 1 being "very uncharacteristic" and 5 being "very characteristic". Scores for each personality dimension were formed by summing the scores from the relevant two or three items. Higher scores indicate a higher level of the personality trait. By measuring participants' own personality profiles it is possible to calculate a measure of self-congruity, which is the extent to which the symbolic meaning of a product (in this case, a BEV or PHEV) is congruent with personal identity. Both the personality scores and self-congruity scores were explored as part of this research question.

Attitudes to owning and driving a car

Car-authority identity was measured with statements from measures of consumer novelty seeking (Manning, Bearden & Madden, 1995) and opinion leadership (Flynn, Goldsmith & Eastman, 1996) in the Pre-trial questionnaire. These items asked the extent to which the participants agreed with statements such as "Driving gives me a chance to express myself" on a five-point Likert scale from "Strongly disagree" to "Strongly agree".

Factor analysis was conducted on these items and a four-factor solution was identified, explaining 52.4% of the total variance. The resulting factor structure is shown in Table 25**.**

Table 25: Attitudes to owning and driving a car factors[33]

	Factors			
	1	**2**	**3**	**4**
A car provides status and prestige	0.834			
My car says something about who I am	0.807			
You can tell something about a person by what car he/she has	0.696			
Driving gives me a chance to express myself	0.623			
It doesn't matter to me which type of car I drive	-0.599			
I would like to own a larger or faster car	0.499			
I couldn't manage without a car				
I don't like driving		0.859		
I like to drive just for the fun of it		-0.696		
I find driving can be stressful sometimes		0.684		
I enjoy driving on my own		-0.670		
If I could, I would gladly do without a car		0.435		
Getting good fuel economy out of my car gives me satisfaction			0.790	
I would pay more for a car with lower running costs			0.777	
When I feel fuel prices are getting too high, I try and reduce the amount I drive			0.447	
I tend to stick to the same brand of car (e.g. Ford, Toyota, Nissan)				0.835
I tend to buy the same type/ size of car (e.g. small car, family estate)				0.830

Extraction Method: Principal Component Analysis,
Rotation Method: Varimax with Kaiser Normalization,
Values <.4 have been suppressed

The four factor scores have been interpreted as follows:

- Factor 1: the level to which people believe that a person's car is related to their identity (low = not related, high = strongly related)
- Factor 2: the level to which people enjoy/dislike driving (high = dislike, low = enjoy)
- Factor 3: running costs (low = not important, high = very important)
- Factor 4: purchase loyalty (low = not loyal interest, high = very loyal)

Each of the factors were subject to a reliability analysis (using Cronbach's Alpha). Only the first two factors had strong enough reliability to be used in further analysis (alpha = .777

[33] The factor loadings in this table show how much each survey item contributes to the overall factor. Negative values show where the survey item has a negative relationship with the factor trend i.e. for the item "It doesn't matter to me which type of car I drive", high scores would relate to a low factor score and vice versa.

and .722 respectively). Factors 3 and 4 did not satisfy the criterion, hence the individual survey items that made up these factors were used in the subsequent analysis, rather than the factor score.

Attitudes to new technology

Attitudes to new technology were measured via a 16-item scale. The statements were developed on the basis of a literature review and qualitative data from interviews with mainstream consumers who had experienced a PiV (Graham-Rowe *et al*., 2012; Anable *et al*., 2011). Statements, such as “I generally know more than other people about new technology”, were answered on a five-point Likert-type scale ranging from “strongly disagree” to “strongly agree”.

A factor analysis was conducted on this set of items which found a two-factor solution; interest in new technology and car enthusiast. The two factors explain a total of 48.5% of the variance in the data and the factor structure is shown in Table 26. The reliability analysis found that each factor had a good level of internal consistency (alpha = .846 and .801 respectively).

Table 26: Attitudes to new technology factors

	Factors	
	1	**2**
I like to buy new and different technologies	0.840	
I am not the type of person that needs to be the first to have the newest technology	-0.670	
I generally know more than other people about new technology	0.663	
I am usually among the first to try new technology	0.799	
New technology excites me	0.830	
I often seek out information about new cars	0.450	0.663
I don’t like to be the first to drive cars with the latest technology	-0.652	
I tend to decide on what car to buy by relying on the opinions of friends who have already tried them		
When I am choosing a car, I find myself spending a lot of time checking out different models		0.540
Prior to buying a new car, I seldom consult my friends/ family		
I often influence other people’s opinions about cars		0.667
When other people are choosing a car to buy, they turn to me for advice		0.755
I like magazines / websites about new cars		0.787
I am not the sort of person that looks to experience driving different cars	-0.429	-0.432
I would prefer my car to be fuelled by something other than petrol or diesel	0.442	-0.410
I prefer my car to be distinctive in style so that it stands out		0.421

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Values <.4 have been suppressed

Symbolic meaning

Symbolic meaning was measured using the attribution-vignette method (Skippon, 2014; Skippon & Garwood, 2011). This is based on Miller's (2009) reproductive fitness indicator theory of product symbolism. For example, participants are asked to indicate on a five-point scale ranging from "doesn't fit the driver" to "fits the driver very well" how well a description (e.g. "Has a lot of fun") can be attributed to the driver of a BEV or a PHEV. Eighteen items like this measure participants' attributions of personal characteristics to an imagined typical user of a BEV or PHEV. Ten of the items were used to measure participants' attributions of the five-factor personality traits openness, conscientiousness, extraversion, agreeableness and neuroticism to an imagined typical user of a BEV or a PHEV. The remaining eight items measured participants' attributions of other mating-salient characteristics of an imagined typical user: status, gender, age, relationship investment (focus on long-term vs. casual relationships), and physical attractiveness. The data from these items were used to calculate a self-congruence score for both BEVs and PHEVs. This score ranges from 0 – 1 where a low score shows that a person sees themselves as a very different person to someone they see owning an EV, whereas a high score is given to someone who sees themselves as very similar to someone who they think would own an PiV.

Attitudes to the environment

Thirty-five items were included in Pre-trial questionnaire to capture data on participants' attitudes towards the environment. This section of the survey was designed to measure attitudes to driving, travel and the environment by exploring the dynamic between car use, perceptions of travel choices and environmental impact. Attitudes were measured by participants responding to multiple statements to indicate their degree of agreement. Participants were asked to rate items (e.g. "I am actively trying to use my car less") on five-point Likert-type scale ranging from "strongly disagree" to "strongly agree". This set of items was based on those used by Anable (2005) in segmentation studies of adults' travel choices, and statements to measure pro-environmental identity, an expansion of those used by Whitmarsh and O'Neill (2010).

Again, a factor analysis was used to reduce the number of items down to a more succinct set of factors that can be used in the regression model. A 10-factor solution was identified (see Table 27) which explained 64.0% of the variance. Normally, a solution with fewer factors would be sought, but a thorough examination of these factors showed that reducing their numbers would limit the amount of variance explained, and that the factors were logical to interpret.

Table 27: Attitudes to the environment factors

	Factors									
	1	2	3	4	5	6	7	8	9	10
I feel a moral obligation to reduce my emission of greenhouse gases	.801									
Reducing my car's environmental impact would make me feel good	.766									
Being environmentally responsible is an important part of who I am	.751									
Being environmentally responsible is important to me as a person	.665									
The government should take more of a lead in protecting the environment, even if people don't like it	.567									
I would be willing to pay more for a car if I knew it was less harmful to the environment	.567									
Reducing my car's environmental impact would be good for society	.550									
I am not the type of person to worry about being 'green'	-.508									
It's not worth me doing things to help the environment if others don't do the same	-.408									
I would only travel by bus if I had no other choice		.743								
I like travelling by bus		-.742								
I am quite flexible about what types of transport I use		-.703								
When I am getting ready to go out, I usually don't think about how I am going to travel, I just get in my car		.641								
Environmental threats such as global warming have been over exaggerated			.794							
The so called 'environmental crisis' has been greatly exaggerated			.775							
What I do in life doesn't make any real difference to the environment			.712							
It is important to build more roads to reduce congestion										
I am not interested in reducing my car use				.703						
I am actively trying to use my car less				-.586						
Reducing my car use would make me feel good	.432			-.506						
I would not buy a particular car just because it is environmentally friendly	-.448			.458						

	Factors									
	1	2	3	4	5	6	7	8	9	10
People should be allowed to use their cars as much as they like, even if it causes damage to the environment										
For the sake of the environment, car users should pay higher taxes					.681					
I would be willing to pay higher taxes on car use if I knew that the revenue would be used to support public transport					.615					
People should be allowed to use their car as much as they like				.408	-.535					
The way I drive says a lot about the kind of person I am						.804				
The car I own says a lot about the kind of person I am						.803				
Sometimes I feel under pressure to say that I am doing more to help the environment than I am						.529				
I like travelling in a car							.674			
I find travelling by car can be stressful sometimes							-.637		-.452	
I would like to travel by car more often							.592			
It would be easy for me to reduce some of my car use								.856		
There are no practical alternatives to most of the car trips I make								-.806		
Most people I know do their bit for the environment these days									.753	
I am worried that the world is running out of oil										.830

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

Loadings <.4 have been suppressed

Cronbach's alpha tests found that only the first 5 factors were reliable (with alpha scores between .708 and .862). These can be interpreted in the following ways:

- Factor 1: green identity (a low score means a person does not think being 'green' is something they need to do or benefits society, a high score means a person believes being 'green' is a good thing and benefits society)
- Factor 2: bias towards cars (a low score means a person is flexible in their transport modes and doesn't show a particular preference towards cars, a high score means a person is highly biased towards cars and is unlikely to consider alternative options)
- Factor 3: belief in environmental threats (a person with a low score believes the environment is under threat but that people can do something about it, someone with a high score thinks that threats to the environment have been exaggerated and individuals have little impact on the environment)
- Factor 4: willingness to restrict car use (low scores show a person is willing to or is already trying reduce their car use for environmental reasons, high scores show a person does not believe they need or does not want to restrict their car use)
- Factor 5: level of support for taxes to be used for environmental transport solutions (low scores mean that a person does not think that taxes should be increased to support environmental transport solutions, someone with a high score would be willing to pay more and have taxes increased for this purpose).

B.4.6.3 Identifying suitable predictor variables

In order to identify the variables to be entered into each model, the correlations between the predictor variables (i.e. personality scores) and the outcome variables (i.e. willingness to adopt) were examined. This was done for two reasons:

1. Multicollinearity: If two predictors are very highly correlated, only one should be used (or the data should be combined in some way).
2. Finding relationships: Entering large numbers of variables into a predictive analysis (even if they all have a logical relationship with the outcome variable 'willingness to adopt') can lead to overfitting. This is where the model corresponds with the data too closely and is overly complex. An over fitted model would be able to very accurately make predictions of willingness to adopt using the current dataset but would typically be very poor at predicting using future data or data from a wider sample. This can also happen when a predicting variable is too similar (or highly correlated) to the outcome.

None of the correlations suggested that multicollinearity would be an issue in this analysis.

Variables that significantly correlated with each outcome are shown in Table 28.

Table 28: Personal characteristics correlations

Vehicle type	Variable	Correlation coefficient	P value
BEV as a main car	The ‘interest in new technology’ factor	.23	.003
	Age (of participant)	-.19	.014
	The ‘green’ identity’ factor	.17	.029
	Careful driving style	.17	.028
	Item “I tend to buy the same type/ size of car (e.g. small car, family estate)”	-.15	.049
BEV as a second car	Gender	.19	.032
	The ‘green’ identity factor	.24	.009
	The ‘belief in environmental threats’ factor	-.18	.047
	Item “Most people I know do their bit for the environment these days”	.18	.048
PHEV as a main car	The ’interest in new technology’ factor	.19	.016
PHEV as a second car	Item “Most people I know do their bit for the environment these days”	.30	.001
	The ‘bias towards car’ factor	-.20	.024
	Angry driving style	-.18	.041

The variables were used to predict the willingness to adopt a BEV or PHEV as a main or second car in four separate models[34].

B.4.6.4 Predicting willingness to purchase a BEV as a main car

Each item was entered into a forward stepwise logistic regression procedure in which the variables that best predict willingness to purchase a BEV as a main car are included one at a time, starting at the best, until the model is not improved by adding more variables).

The model was significant ($X^2(2) = 14.994$, $p = 0.001$) predicting at 68% accuracy overall.

[34] Although correlations are indicative of a potential predictive relationship, is not necessarily the case that the variables with the strongest correlations will be significant predictors.

Table 29: Predicting willingness to purchase a BEV as a main car – model accuracy

		Predicted		
		Not likely to buy	Likely to buy	Percentage accuracy
Observed	Not likely to buy	103	10	**91%**
	Likely to buy	44	9	**17%**
Overall accuracy				**68%**

The 'interest new technology' factor and careful driving style scale were the only variables that had a significant impact on the likelihood of purchasing a BEV as a main car (p = 0.001 and p = 0.033 respectively).

The more interested someone is in new technology the more likely they were to say they are likely to purchase a BEV as a main car in the next five years. This is shown in Figure 73. The mean factor score for those who said they were likely to buy a BEV as a main car was 0.39 compared to the mean for those who said they were not likely to buy a BEV which was -0.16.

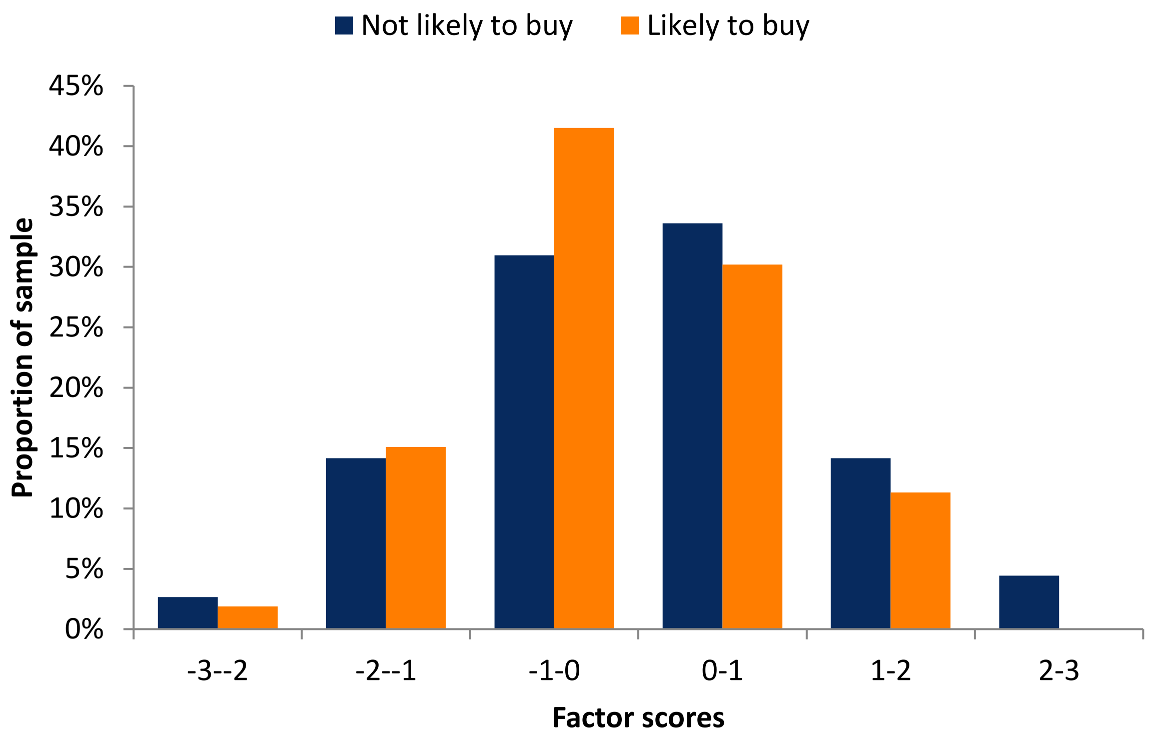

Figure 73: The interest in new technology factor scores (grouped) by likelihood to purchase a BEV as a main car

Higher scores on the careful driving scale were also related to an increased likelihood to buy a BEV as a main car (Figure 74). This may be related to careful drivers being able to get better range from a BEV through their use of acceleration and speed. However, further exploration of the raw data for this driving style (not normalised based on previous data) did not replicate this result. This suggests that this result should be interpreted with caution.

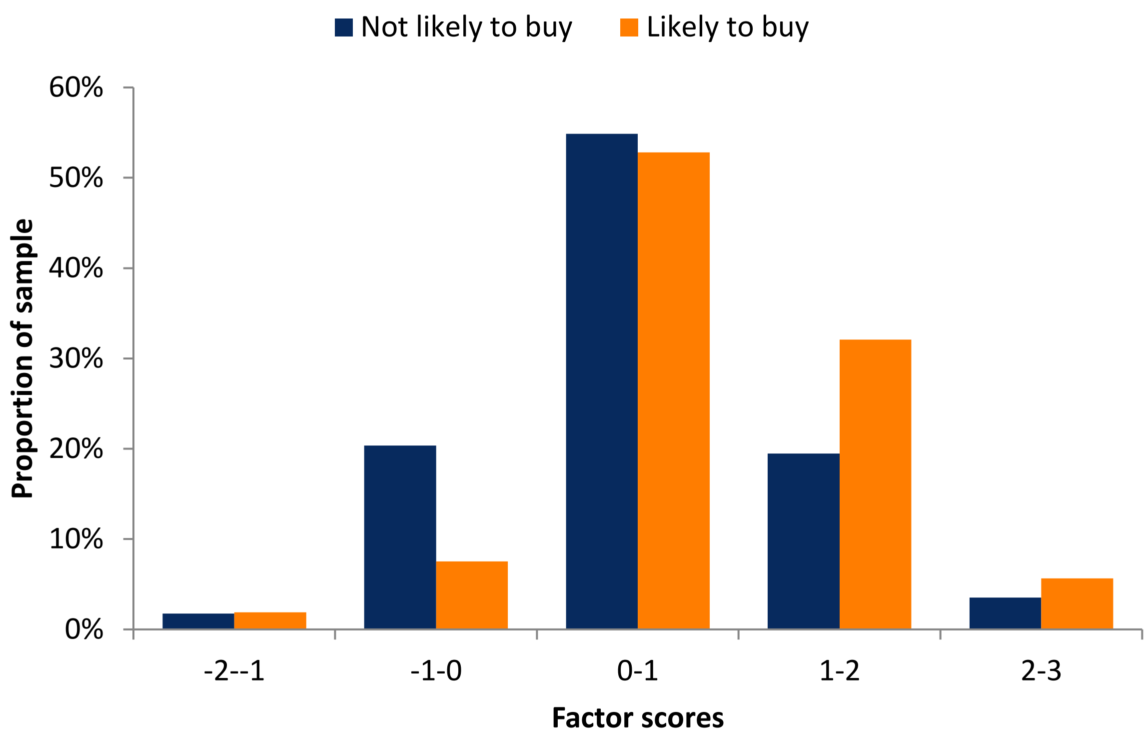

Figure 74: Careful driving style scores (grouped) by likelihood to purchase a BEV as a main car

B.4.6.5 *Predicting willingness to purchase a BEV as a second car*

Gender, the 'green identity' factor, and the 'belief in environmental threats' factor were significant predictors of the likelihood to purchase a BEV as a second car (p = 0.021, p = 0.008, and p = 0.047 respectively) and the model was significantly better than random ($X^2(2)$ = 16.284, p = 0.001) predicting at 68% accuracy.

Table 30: Predicting willingness to purchase a BEV as a second car – model accuracy

		Predicted		
		Not likely to buy	**Likely to buy**	**Percentage accuracy**
Observed	**Not likely to buy**	14	28	**33%**
	Likely to buy	11	69	**86%**
Overall accuracy				**68%**

Women were significantly more likely to say they were likely to buy a BEV as a second car in the next 5 years than men.

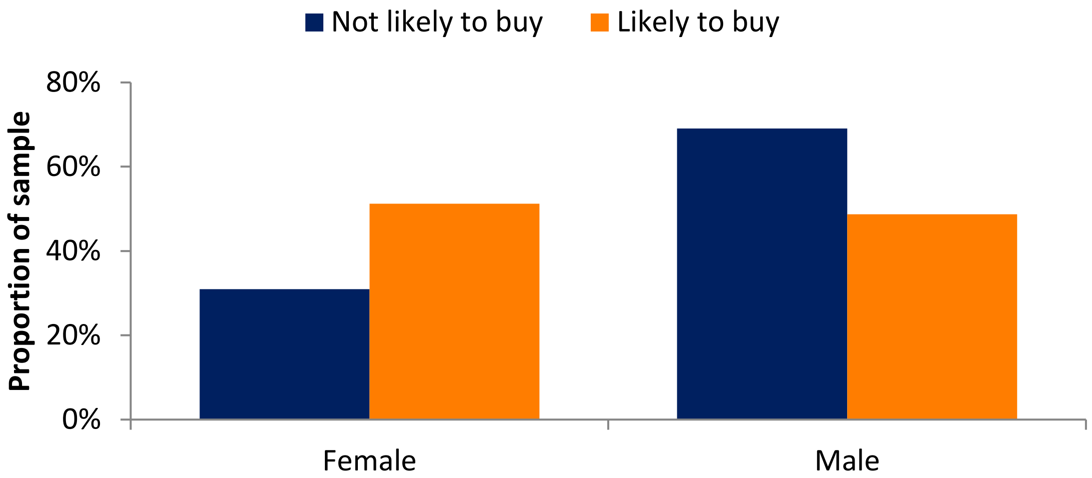

Figure 75: Likelihood to purchase a BEV as a second car by gender

Participants with higher 'green identity' factor scores were more likely to adopt a BEV as a second car, whereas participants with high scores on the 'belief in environmental threats' factor score were significantly less likely. In general, this suggests that people who are more environmentally aware are more likely to consider buying a BEV as a second car. These relationships are shown below in Figure 76 and Figure 77.

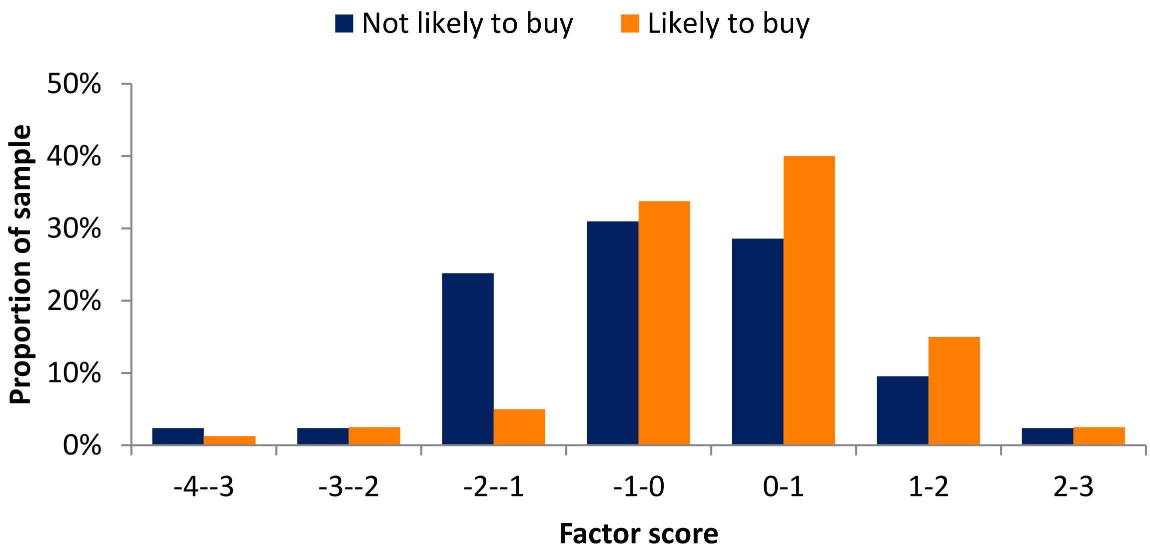

Figure 76: Likelihood to purchase a BEV as a second car by 'green identity' score

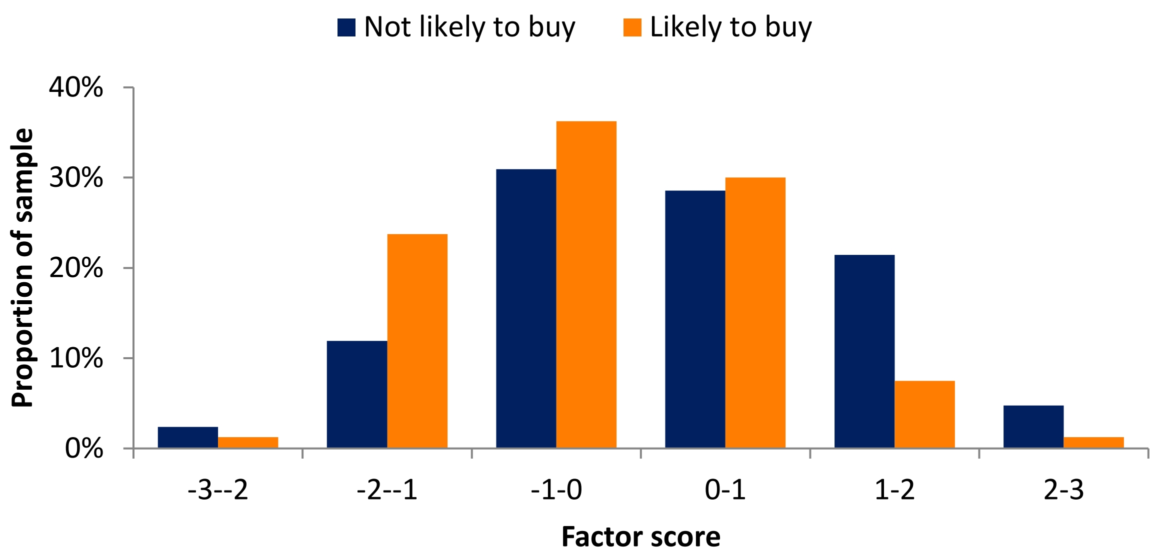

Figure 77: Likelihood to purchase a BEV as a second car by 'belief in environmental threats' scores

B.4.6.6 Predicting willingness to purchase a PHEV as a main car

Only the 'interest in new technology' factor was a significant predictor of the likelihood to buy a PHEV as a main car; participants that scored highly on this factor were more likely (p = 0.026). The model was significant ($X^2(1) = 5.203$, p = 0.23) and predicted with 68% accuracy.

Table 31: Predicting willingness to purchase a PHEV as a main car – model accuracy

		Predicted		
		Not likely to buy	**Likely to buy**	**Percentage accuracy**
Observed	**Not likely to buy**	103	10	**91%**
	Likely to buy	44	9	**17%**
Overall accuracy				**68%**

The relationship between the likelihood of buying a PHEV as a main car and self-rated interest in new technology is shown in Figure 78.

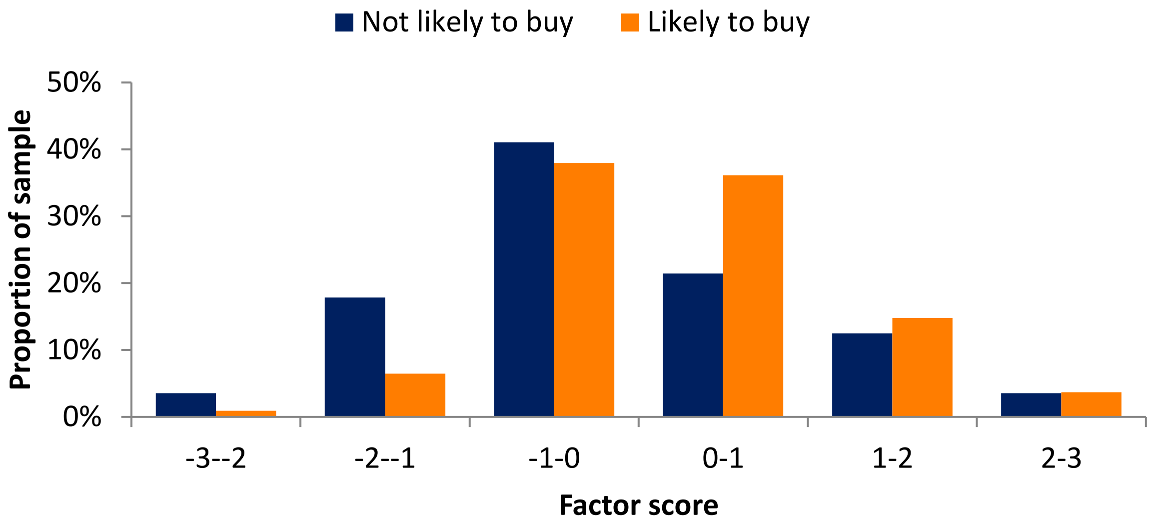

Figure 78: Likelihood to purchase a PHEV as a main car by 'interest in new technology' factor score

B.4.6.7 Predicting willingness to purchase a PHEV as a second car

Responses to the item "Most people I know do their bit for the environment these days" ($p = 0.001$) and the factor 'bias towards car' ($p = 0.019$) were both significant predictors of the likelihood to buy a PHEV as a second car and created a significant model ($X^2(2) = 22.729$, $p < 0.001$) predicting with 71% accuracy.

Table 32: Predicting willingness to purchase a PHEV as a second car – model accuracy

		Predicted		
		Not likely to buy	**Likely to buy**	**Percentage accuracy**
Observed	**Not likely to buy**	17	27	**39%**
	Likely to buy	9	73	**89%**
Overall accuracy				**71%**

Participants that more strongly agreed with the statement "Most people I know do their bit for the environment these days" were more likely to consider purchasing a PHEV as a second car in the next five years as shown in Figure 79.

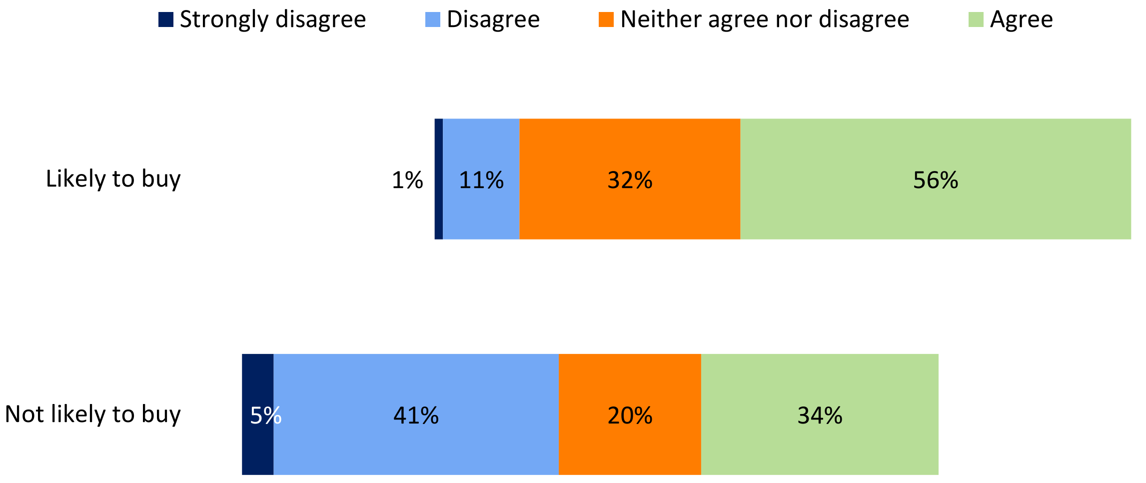

Figure 79: Proportion of participants who agreed or disagreed with statement "Most people I know do their bit for the environment these days" for those likely and not likely to purchase an PHEV as a second car

Participants that were more 'bias towards cars' were less likely to say that they were likely to buy a PHEV as a second car suggesting that people who are less flexible with their travel modes are less likely to consider buying a PHEV. This is shown in Figure 80.

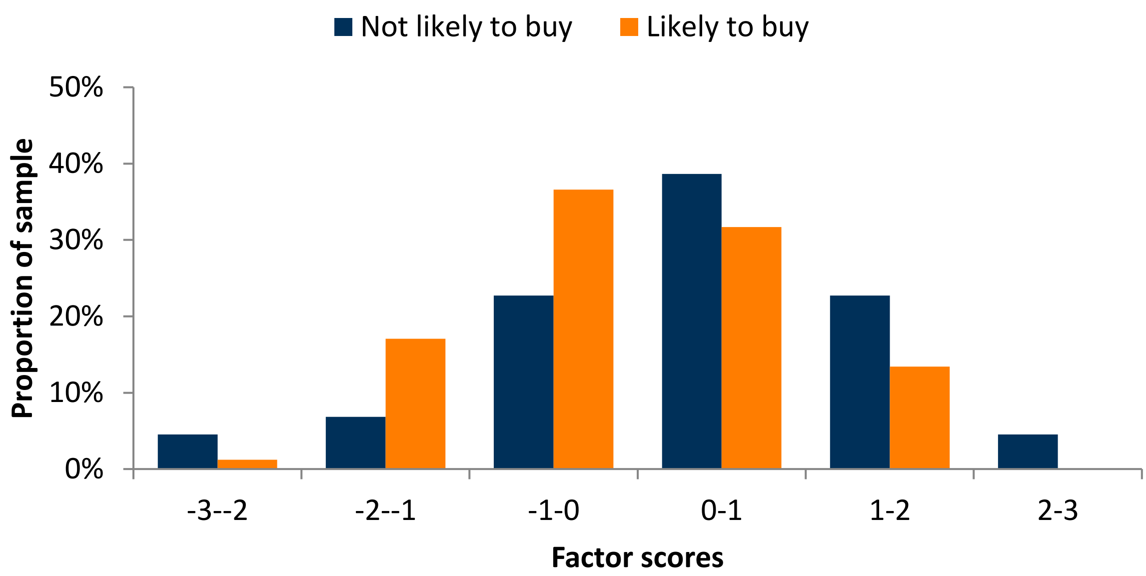

Figure 80: 'Bias towards cars' factor scores (grouped) by likelihood to purchase a PHEV as second car

B.4.7 How much are personal-situational variables (e.g. income, annual mileage) predictive of willingness to consider adoption of a BEV or PHEV?

→ **Very few personal-situational variables were related to the willingness to adopt a BEV or PHEV as second car and none predicted the willingness to adopt either a BEV or PHEV as a main car.**

→ **None of these variables consistently predicted the uptake of PiVs. Different variables predicted the uptake of the different vehicle types.**

→ **For PHEVs as a second car the only predicting variable was living situation with people living with their partner or family being more likely to adopt.**

This research question was also addressed using regression modelling to explore whether the willingness to consider having a BEV or PHEV (across the whole sample) could be predicted by personal-situational variables.

Personal-situational data from multiple surveys were used in this analysis. This included the following variables:

- Living arrangements
- Number cars in household
- Type of car owned (main car)
- Annual mileage
- Highest educational qualification
- Employment status
- Total household income
- Relationship status (married/single)
- Living arrangements (living with family/partner, with other tenets, or alone)
- House status (Home over, tenant, living with patents)
- Number of drivers in household (17 years and older)
- Number of private cars in household
- Number of company cars in household
- Age of main car when purchased
- Value of main car when purchased
- Typical weekly mileage (weekday)
- Typical weekly mileage (weekend)

B.4.7.1 Identifying suitable predictor variables

Correlations between the continuous variables (e.g. number of cars and weekly mileage variables) and the outcome variables (willingness to consider a BEV / PHEV, as main and second car) were used to identify which variables have a strong enough relationship with the outcomes to be used as predictors in the later models.

Most of the personal variables were categorical, such as employment or car type. The relationships between these and the outcome variables could not be explored through correlations as the answer options for these questions do not have a logical order. Instead, these variables were tested Chi-squared tests which look at the difference in frequencies across each variable category between groups.

None of the personal-situational variables collected as part of this trial had a clear relationship with the likelihood of buying a BEV as a main car in the next five years. This was the same for the likelihood of buying a PHEV as a main car.

However, weekend weekly mileage significantly correlated with the 'BEV second car' outcome variable (correlation coefficient = 0.226, $p = 0.012$). This was the only variable that had a clear relationship with the willingness to buy a BEV as a second car. Although unexpectedly, the relationship was positive, meaning that as weekend mileage increased, the likelihood of being in the group willingness to buy a BEV as a second car increased. The responses to the main car age question were also significantly[35] different between the group who said they were likely to buy a PHEV as a second car, and those who said they were not (correlation coefficient = 0.221, $p = 0.072$). As well as this, the responses to the living arrangement question were significantly different across the two 'PHEV second car' outcome variable groups ($\chi^2 = 6.13$, $p = 0.013$).

These variables were used in logistic regression models to test if they are able to significantly predict the willingness to adopt a BEV/PHEV as a second car.

The correlation between each personal variable was also used to identify any issues of multicollinearity. No issues were identified through this, hence no data reduction was needed on this set of variables.

B.4.7.2 Predicting willingness to purchase a BEV as a second car

The main car age and weekly mileage on weekend variables were entered into a forward step-wise regression model; however, neither of these variables was able to significantly predict the outcome variable, and a model that was significantly better than the random model could not be produced. These results suggest that personal-situational variables were not able to predict the willingness to adopt a BEV as a second car.

B.4.7.3 Predicting willingness to purchase a PHEV as a second car

The living arrangements variable was entered into a forward step-wise regression model and generated a model that was significantly better at predicting the outcome variables than the random model ($p = 0.016$) at 68% compared with 65%.

[35] Due to the lack of related factors, a relaxed significance *p* value was used for these correlations of 0.1; a 10% chance of finding a false positive result.

Table 33: Predicting willingness to purchase a PHEV as a second car – model accuracy

		Predicted		
		Not likely to buy	Likely to buy	Percentage accuracy
Observed	Not likely to buy	10	34	**22%**
	Likely to buy	6	76	**93%**
Overall accuracy				**68%**

The results showed that people who live with family or their partner are around 130% more likely to be willing to adopt a PHEV as a second car than those in other living situations such living alone or with other tenants. That pattern is shown in Figure 81. However, this result should be interpreted with caution as it may only reflect the small number of people who live alone or with tenants who own more than one car.

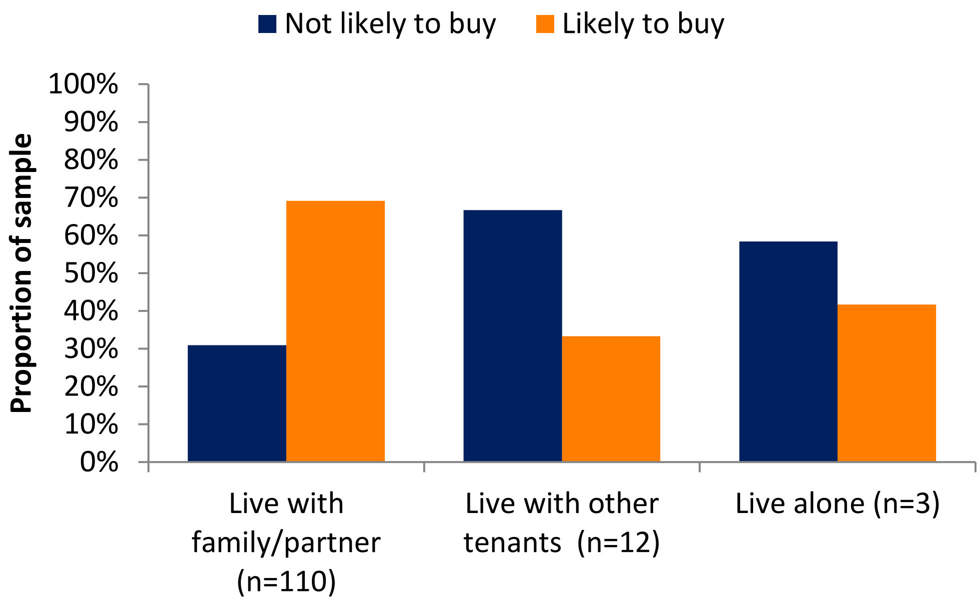

Figure 81: Living situation by likelihood to purchase a PHEV as a second car

B.4.8 What effect does varying the perceived level of access to public charging stations (e.g. density, type of location, type of charger) have on willingness to adopt BEVs or PHEVs?

- → **No significant WTP value for access to destination charging was identified for PHEVs, suggesting availability of public and workplace charging infrastructure does not significantly influence mainstream consumer decisions to purchase a PHEV.**
- → **For BEVs, availability of public charging was valued at £1,100 more than work place charging, and work place charging had less value when public charging was also available.**
- → **WTP for access to rapid (Mode 4) public charging for BEVs was £2,224; this represented a rapid public charging network with at least one available chargepoint positioned every 20 miles on motorways and major A-roads.**
- → **WTP values did not significantly change for increasing levels of rapid charger coverage beyond every 20 miles on motorways and major A-roads.**
- → **Cost-conscious Greens and Pragmatists valued access to rapid charging at approximately £2,500, and higher than Uninterested Rejecters.**

In the choice experiment, WTP for a BEV or PHEV with access to destination charging, was investigated for both charging at work and public car parks/spaces (referred to here as 'public charging').

For PHEVs, no statistically significant value for WTP for access to destination charging could be identified, even for the whole sample. The derived coefficients for access to each level of work and public charging were both positive and negative with no clear trend. This suggests that access to destination charging does not influence the decision to purchase a PHEV. Consequently, the destination charging attributes were not included in the PHEV utility equation. This differed from the 2015 survey for DfT (Element Energy, 2015a), where a set of statistically significant coefficients were derived, although this could only be done for the whole sample. Access to work charging was valued at £355, and access to public at £608. Access to both work & public was found to be very similar to public only, and so was assumed to be the same as public only in the model.

Figure 82 shows the WTP for a BEV with access to work, public and work, public charging, in addition to home charging. At the whole sample level, it can be seen that participants valued the availability of public charging £1,100 more than work place charging, and work place charging was valued less when public charging is also available. However, the coefficient derived for access to work charging was not statistically significant and may be highly dependent on whether the participants use their cars for commuting. Responses to this item may also have been affected by whether the participant envisaged having a place at work where they could feasibly charge. For those who did, the utility of workplace charging would be high, but for those who did not (e.g. they do not have a defined place of work) there may be no utility at all. Such nuances could be explored through more detailed qualitative analysis with consumers.

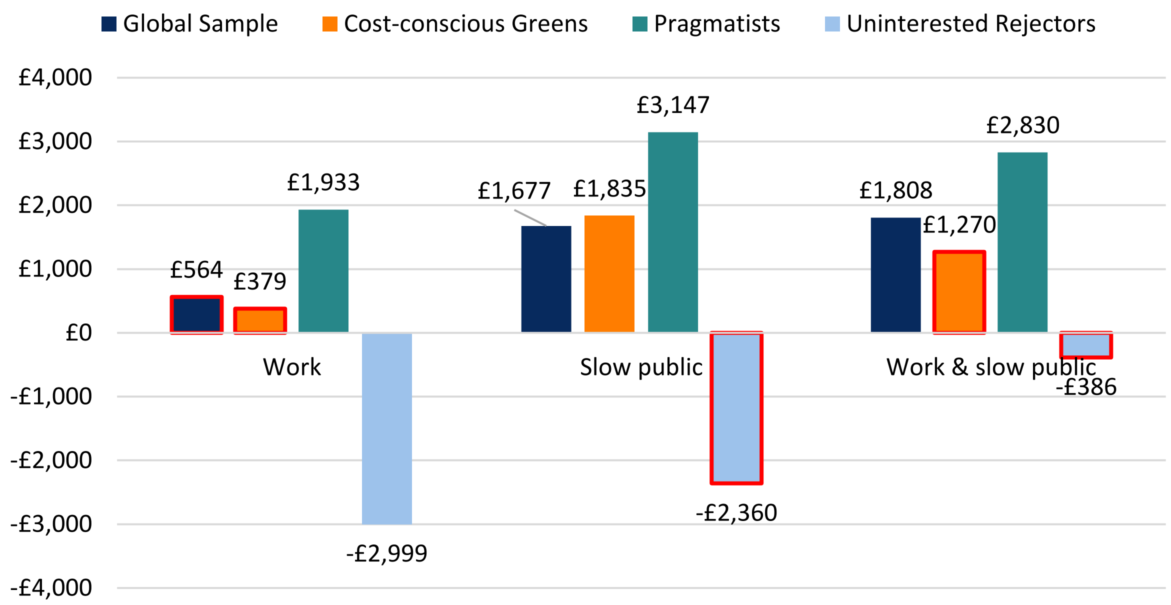

Figure 82: Willingness-to-pay for access to work and public destination charging with a BEV. Red border means the result is not statistically significant

However, at the consumer segment level the trends were less clear. All consumers shown had a similar share of participants who use their cars for commuting (Cost-conscious Greens = 68%, Pragmatists = 70%, Uninterested Rejecters = 65%) yet place very different value in the availability of work charging. Pragmatists showed a high WTP for a BEV with destination charging, valuing work charging at nearly £2,000 and public charging at over £3,100. However, their WTP for work & public charging together was seen to be less than public alone, although this is perhaps best interpreted as Pragmatists perceiving no further utility in having work charging if public charging is already available. However, this supposition would require additional qualitative follow-up work to confirm. A similar pattern was observed for Cost-conscious Greens, except that the overall magnitude of their WTP was lower and the coefficients for access to work charging and work & public charging were not statistically significant.

Uninterested Rejecters showed a very negative WTP for destination charging, despite it having the potential to reduce range anxiety and make driving a BEV more convenient. This means that installation of destination charging makes these consumers less likely to purchase a BEV. This is illustrated in Figure 83, where it is seen that the share of Uninterested Rejecters predicted to choose a BEV decreases from 32% to 20% when work charging is made available. The utility of destination charging access appeared to become less negative as coverage increased from work only, to public only and work & public, suggesting that these participants recognised the benefits of more charging access. However, the coefficient for public charging access was not significant and neither was that for work & public charging access. Therefore, it is not possible to infer a trend in WTP at different levels of charging access beyond it being highly negative. The reason for this result may be that Uninterested Rejecters, who are characterised by negative attitudes towards PiVs, were conflating the notion of having access to destination charging with the need to use it. Therefore, in the case where charging is available at their workplace, it may be they were interpreting this as needing to charge at work in addition to home, which adds to their perceived inconvenience of owning a BEV. Due to the lack of statistically significant coefficients for Uninterested Rejecters, it is not possible to infer whether this was also the case for public charging.

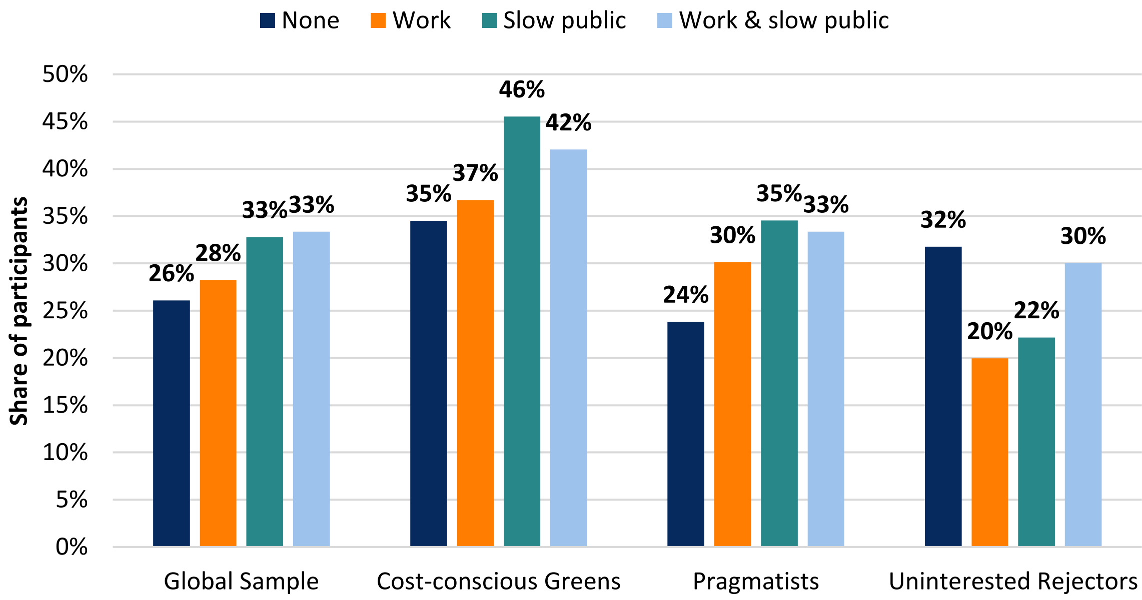

Figure 83: Share of participants predicted to choose the BEV with different levels of access to destination charging, with all other attributes set to their reference values. All levels include access to home charging

At the whole sample level, WTP for a BEV with access to public charging with a BEV from this choice experiment is found to be very similar to that which was derived from the 2015 survey for DfT (Element Energy, 2015). In this previous analysis, the value of access to both public and work charging was similar to public only and so WTP was assumed to be the same for both levels. Value of access to work charging was nearly twice as high in the DfT 2015 survey, despite the Consumer Uptake Trial sample containing a larger share of participants who use their cars for commuting (68% vs. 53%). This may reflect an overestimate of how often BEVs need to be charged by the DfT 2015 survey participants who collectively had very little real world experience of PiV ownership.

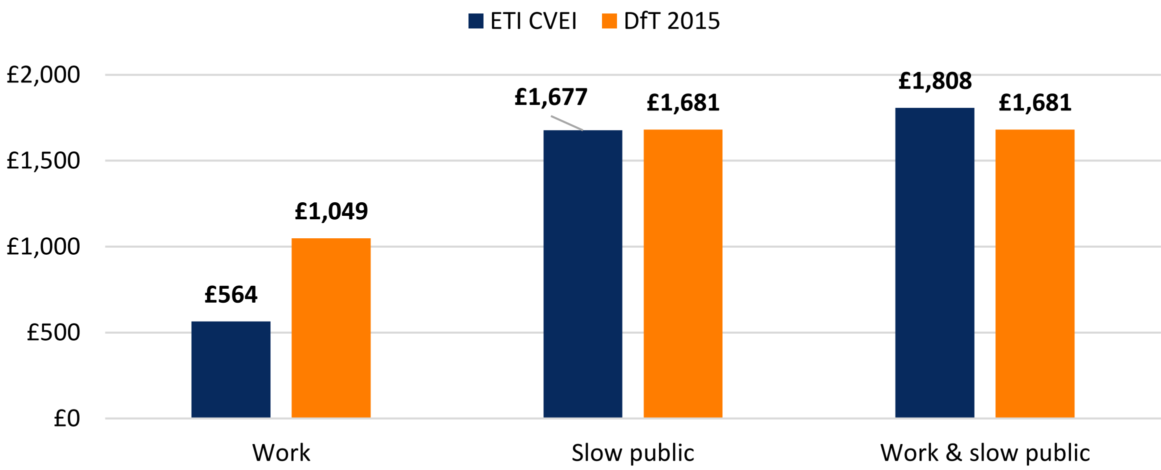

Figure 84: Comparison of willingness-to-pay for work and public charging access with a BEV from this choice experiment and the DfT 2015 survey (Element Energy, 2015)

Figure 85 shows the WTP for a BEV with access to rapid charging. Three levels of network coverage were tested:

1. Every 20 miles on motorways and major A-roads
2. Every 20 miles on motorways and all A-roads
3. Every 20 miles on motorways and all A roads, and at a similar frequency to petrol stations on all other road types

However, all levels showed very similar WTP values at the whole sample level, suggesting that participants perceived no further utility from increasing the coverage beyond every 20 miles on motorways and major A-roads. To reduce the number of attributes, and thus reduce the statistical burden on the model, the three levels were combined into a single attribute representing access to rapid chargepoints located at least every 20 miles on motorways and major A-roads. This had a negligible impact on the statistical significance of the whole model.

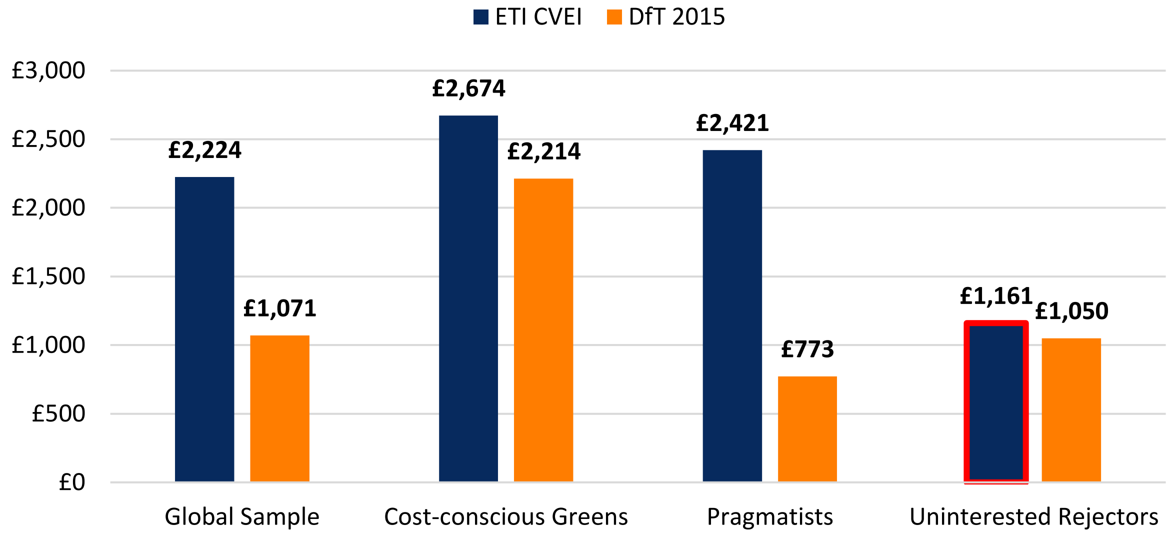

Figure 85: Willingness-to-pay for access to a rapid charging network with a coverage of at least every 20 miles on motorways and major A-roads. Red border means the result is not statistically significant

A similar finding was made in the previous survey for DfT (Element Energy, 2015), where it was concluded that participants perceived no additional value of increasing the rapid charging coverage from every 40 miles on motorways and major A-roads to every 20 miles on all motorways and A-roads. It was expected that participants would show WTP for increasing the coverage to a similar level as today's petrol stations, as this would serve both long-distance and local journeys. However, it appears that this is not the case.

It should be noted that all trial participants had access to home charging and so would likely only ever require rapid charging while on long journeys. Consequently, a chargepoint density of every 20 miles on motorways and major A-roads should be enough to allow them to complete any long-distance journey. Furthermore, use of rapid chargepoints in the trial was very low. Only eight participants were recorded as using one, and since the e-Golf has a fairly limited range on motorways of approximately 200 km, other participants perhaps did not consider a BEV as suitable for long distance driving. Consequently, experience of need for rapid charging was likely limited and so perhaps the value placed in greater coverage was low.

At the consumer segment level, Cost-conscious Greens and Pragmatists valued access to rapid charging at approximately £2,500. For Pragmatists this was significantly more than was observed in the 2015 survey for DfT and suggests that after experiencing use of BEV participants recognised a need for rapid charging. Uninterested Rejecters show a similar WTP as in the 2015 survey for DfT.

Figure 86 shows how access to a charging network affects the share of participants that the choice model predicts would choose a BEV under the reference attribute values. Note that when access is removed, the utility of the additional charging rate above 2.5 miles/minutes is also lost. Under the reference attribute values, this equates to 1.6 miles/minute of charging which is worth the following: Global sample = £701, Cost-conscious Greens = £792, Pragmatists = £420, Uninterested Rejecters = £1,426.

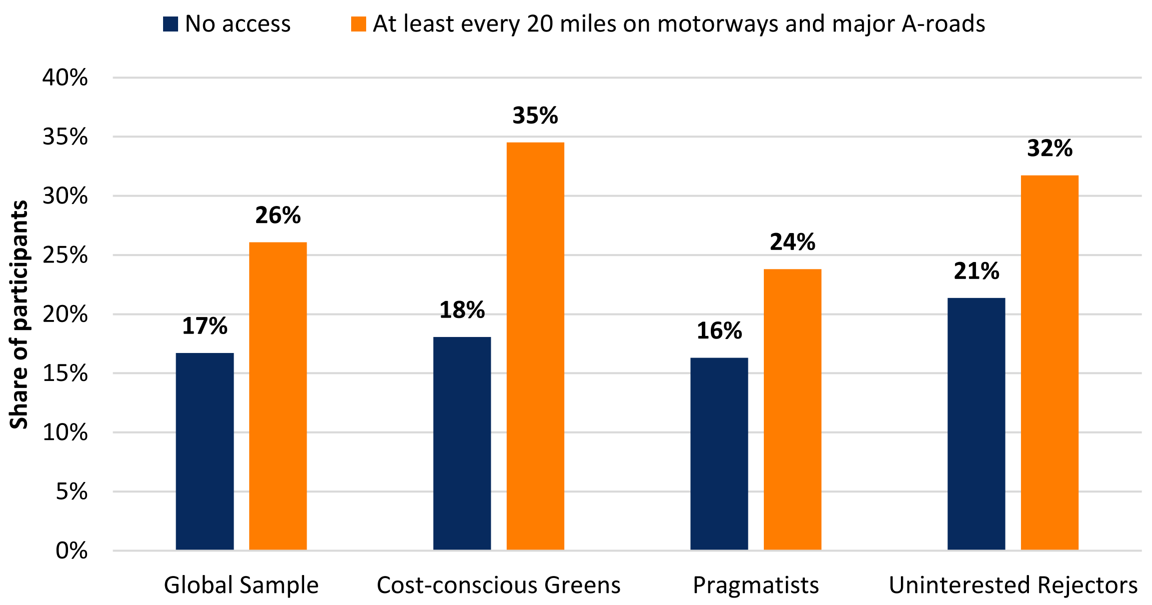

Figure 86: Share of participants predicted to choose the BEV with and without access to a rapid charging network, with all other attributes set to their reference values

Despite Cost-conscious Greens and Pragmatists showing a similar WTP for access to rapid charging, the impact on the share of participants predicted to choose a BEV was greater amongst the former. This is partly because Cost-conscious Greens valued the loss in charging rate more (£792 vs. £420), but primarily because the Cost-conscious Greens were more price sensitive (see section B.4.3.1). Therefore, if both consumer segments valued access to rapid charging at approximately £2,500 in equivalent upfront cost, this had a greater influence on the preferences of Cost-conscious Greens.

B.4.9 What effect does convenient access to public transport options for longer journeys have on willingness to consider adoption of a BEV?

→ **Convenient access to public transport was of low importance to most (over 60%) mainstream consumers when considering a BEV or PHEV.**

Participants were asked to rate the importance of convenient access to public transport when considering purchasing a BEV and PHEV using a scale from 1 (not at all important) to 5 (very important). The pattern of responses was similar between BEVs and PHEVs; the majority of participants reported that convenient access to public transport was either "Slightly important" or "Not at all important" when considering purchasing both a BEV (62%) and a PHEV (69%) (see Figure 87). A non-parametric repeated measures Wilcoxon signed rank test showed no significant difference in ratings of importance between BEV and PHEV.

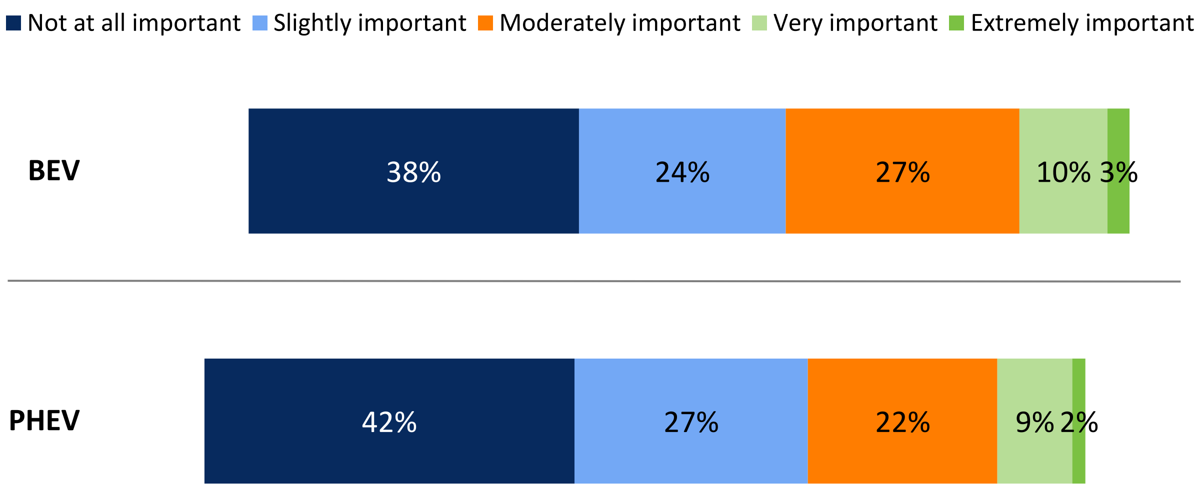

Figure 87: Proportion of participants by rating of importance of convenient access to public transport when considering a BEV and PHEV

The TP2 likelihood to purchase a BEV or PHEV responses were compared between participants who felt convenient access to public transport was important (those who responded 'slightly important' or higher) and participants who felt it was not important (those who responded 'not at all important'). Non-parametric Mann-Whitney U tests revealed no significant differences in the likelihood to purchase a BEV or PHEV (as main or second car) between these two groups. It is worth noting that perceptions of the importance of access to public transport generally are likely to vary according to where respondents live. In large conurbations such as London, for example, public transport is the primary means of travel for many people since a) there is a considerable choice and frequency of services is high, and b) travelling by private vehicle is often slower and less convenient. Individuals who live in conurbations may therefore place greater importance on having access to public transport than those who live in rural areas. Exploring these differences was not a focus for this study however, since the trial was constrained to recruiting participants from two specific locations in the UK (see section A.1).

B.4.10 What effect does the rate of depreciation of residual value have on willingness to consider adoption of a BEV or PHEV?

- → **Rate of deprecation had a negative relationship with likelihood to purchase a BEV and PHEV; as the expected value of a BEV/PHEV after 3 years decreases (i.e. as the rate of depreciation increases), the likelihood to purchase also decreases.**
- → **There was also a significant negative relationship between the rate at which a BEV and PHEV loses AER and likelihood to purchase; as the amount of range lost after 3 years increases, the likelihood to purchase decreases.**
- → **Large changes in likelihood to purchase indicated that participants considered loss of range to be a very important factor for purchase decisions.**

B.4.10.1 Impact of loss of residual value on likelihood to purchase

In the Time Point 2 questionnaire respondents were asked to indicate how likely or unlikely they would be to choose a BEV / PHEV in the next 5 years with varying levels of residual value depreciation. The level of depreciation was compared against a baseline for conventional cars; representing 40% residual value after 3 years assuming 10,000 miles per year. Responses to the questions relating to the likelihood to purchase a BEV according to rate of depreciation are summarised in Figure 88.

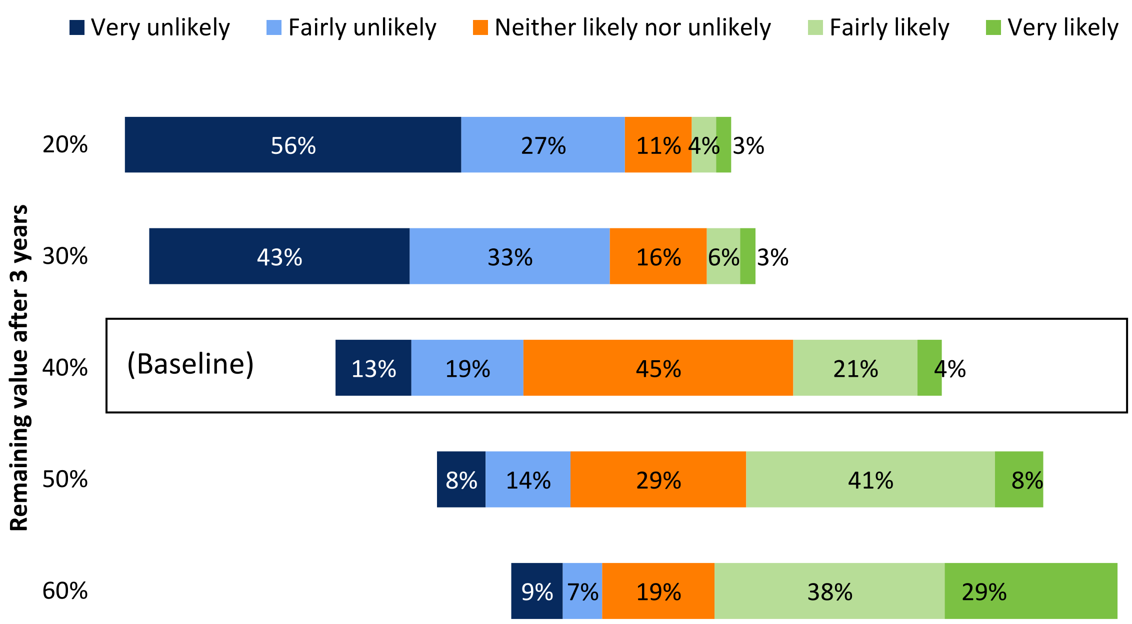

Figure 88: Proportion of participants likely or unlikely to purchase a BEV according to rate of depreciation. Equivalent ICE depreciation highlighted as baseline.

The data shows that, as expected, there is a negative relationship between the rate of depreciation and the likelihood to purchase a BEV. That is, as the remaining value of a BEV after 3 years decreases from 60% to 20% (i.e. as the rate of depreciation increases), the likelihood to purchase also decreases.

A non-parametric Friedman test revealed a significant effect of rate of depreciation on reported likelihood to purchase a BEV (χ^2 = 443.44, p < 0.001). Non-parametric Wilcoxon signed ranks test were used to examine differences in likelihood to purchase between each pair of depreciation rates (e.g. 20% vs. 30% remaining value after 3 years). Due to the number of comparisons, a Bonferroni correction was applied resulting in a significance (p) value of 0.005 (i.e. 0.05/10). Using this corrected p value, 9 out of the 10 comparisons, significant differences were identified (see Table 34). The exception was the test between the scenarios where the car would have 20% or 30% if its value remaining after 3 years. On the whole, the evidence suggests a significant effect of depreciation rate on likelihood to purchase a BEV.

Table 34: Wilcoxon signed ranks test results; differences in likelihood to purchase a BEV between pairs of depreciation rates

Comparison (loss of residual value after 3 years)	Z-score	p-value
20% vs. 30%	-2.177	0.01
20% vs. 40%	-10.333	<0.001
20% vs. 50%	-12.240	<0.001
20% vs. 60%	-13.305	<0.001
30% vs. 40%	-8.685	<0.001
30% vs. 50%	-11.019	<0.001
30% vs. 60%	-12.464	<0.001
40% vs. 50%	-4.178	<0.001
40% vs. 60%	-7.891	<0.001
50% vs. 60%	-4.402	<0.001

Responses to the questions relating to the likelihood to purchase a PHEV according to rate of depreciation are summarised in Figure 89.

The data show a similar negative relationship between the rate of depreciation and likelihood to purchase a PHEV as was seen with BEVs. As the expected rate of depreciation increases, the likelihood to purchase also decreases. A non-parametric Friedman test revealed a significant effect of rate of depreciation on reported likelihood to purchase a PHEV (χ^2 = 493.56, p < 0.001).

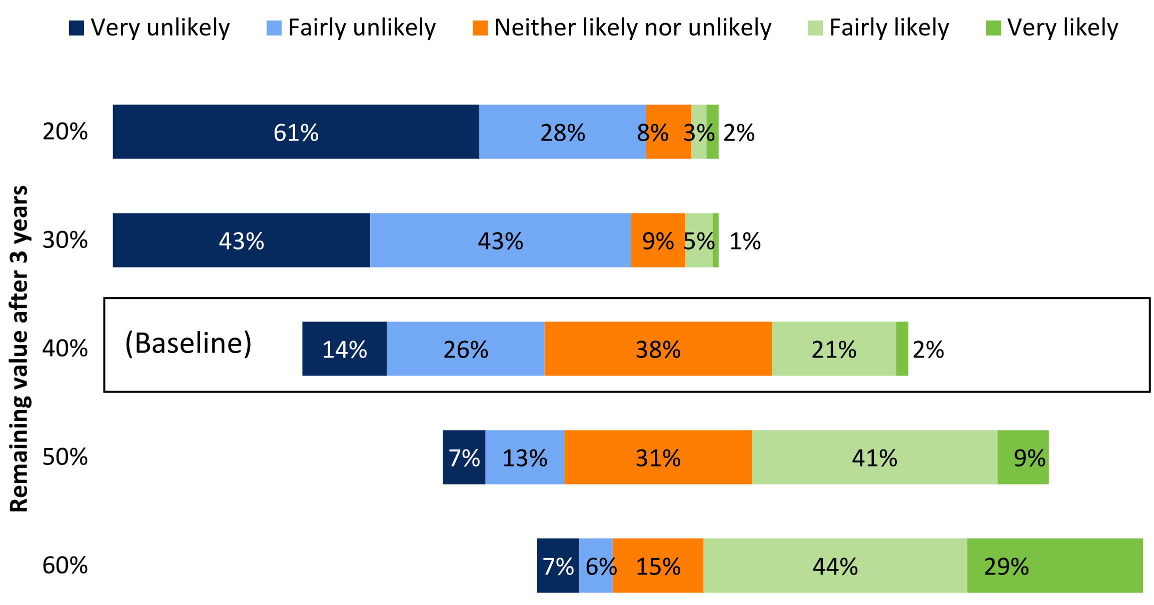

Figure 89: Proportion of participants likely or unlikely to purchase a PHEV according to rate of depreciation. Equivalent ICE depreciation highlighted as baseline.

As with the BEVs, non-parametric Wilcoxon signed ranks test were used to examine differences in likelihood to purchase between each pair of depreciation rates (e.g. 20% vs. 30% remaining value after 3 years), and a Bonferroni correction was applied. In each of the 10 comparisons, significant differences were identified (see Table 35), suggesting a significant effect of depreciation rate on likelihood to purchase a PHEV.

Table 35: Wilcoxon signed ranks test results; differences in likelihood to purchase a PHEV between pairs of depreciation rates

Comparison (loss of residual value after 3 years)	Z-score	p-value
20% vs. 30%	-3.000	0.001
20% vs. 40%	-10.692	<0.001
20% vs. 50%	-13.470	<0.001
20% vs. 60%	-14.499	<0.001
30% vs. 40%	-9.000	<0.001
30% vs. 50%	-12.536	<0.001
30% vs. 60%	-13.941	<0.001
40% vs. 50%	-5.705	<0.001
40% vs. 60%	-9.801	<0.001
50% vs. 60%	-5.355	<0.001

B.4.10.2 Impact of loss of range on likelihood to purchase

In addition to the rate of depreciation of residual value, the impact of loss of range over time on likelihood to purchase was also investigated from responses to the Time Point 2 questionnaire. Participants were asked to indicate their likelihood to purchase a BEV/PHEV for varying levels of loss of range after 3 years.

Responses to the questions relating to the likelihood to purchase a BEV according to rate of range loss are summarised in Figure 90.

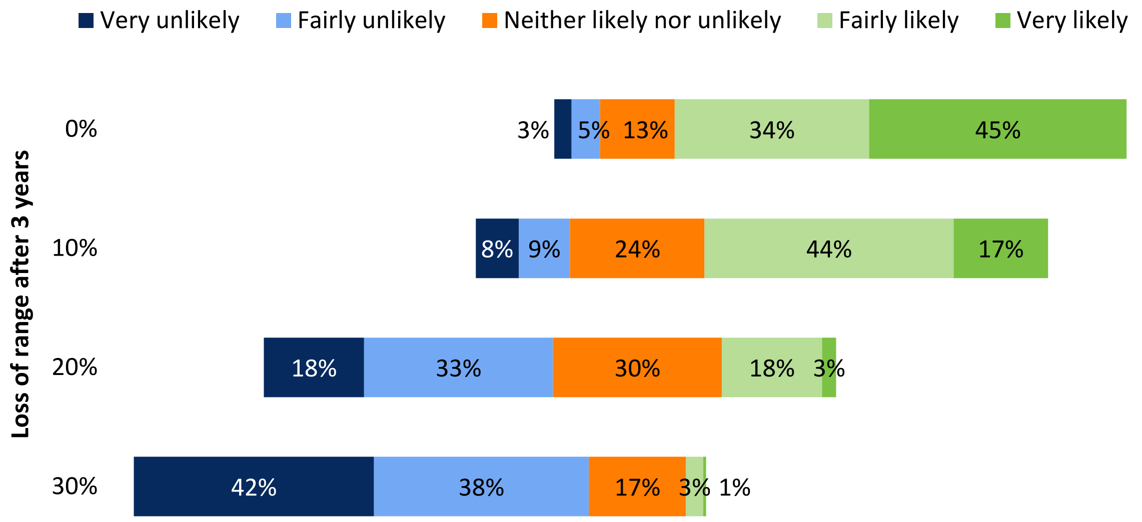

Figure 90: Proportion of participants likely or unlikely to purchase a BEV according to loss of range after 3 years

The data show a negative relationship between the rate of range loss of a BEV and reported likelihood to purchase a BEV. That is, as the amount of range lost after 3 years increases, the likelihood to purchase a BEV decreases. If the car lost none of its range, then 79% of participants would be fairly or very likely to purchase one. However, if the car lost 30% of its range after 3 years, only about 4% of participants would still be likely to purchase. This large change in percentage points indicates that participants considered this to be a very important factor in determining their likelihood to purchase a BEV.

A non-parametric Friedman test showed significant effects of loss of range on likelihood to purchase a BEV (χ^2 = 496.55, p < 0.001). Non-parametric Wilcoxon signed ranks tests were used to examine differences in likelihood to purchase between each pair of rates (e.g. 0% vs. 10% loss of range after 3 years). Due to the number of comparisons, a Bonferroni correction was applied. In each of the six comparisons significant differences were identified (Table 36).

Table 36: Wilcoxon signed ranks test results; differences in likelihood to purchase a BEV between pairs of loss of range

Comparison (loss of range after 3 years)	Z-score	p-value
0% vs. 10%	-5.945	<0.001
0% vs. 20%	-12.375	<0.001
0% vs. 30%	-15.269	<0.001
10% vs. 20%	-8.461	<0.001
10% vs. 30%	-13.008	<0.001
20% vs. 30%	-6.887	<0.001

Responses to the questions relating to the likelihood to purchase a PHEV according to rate of range loss are summarised in Figure 91.

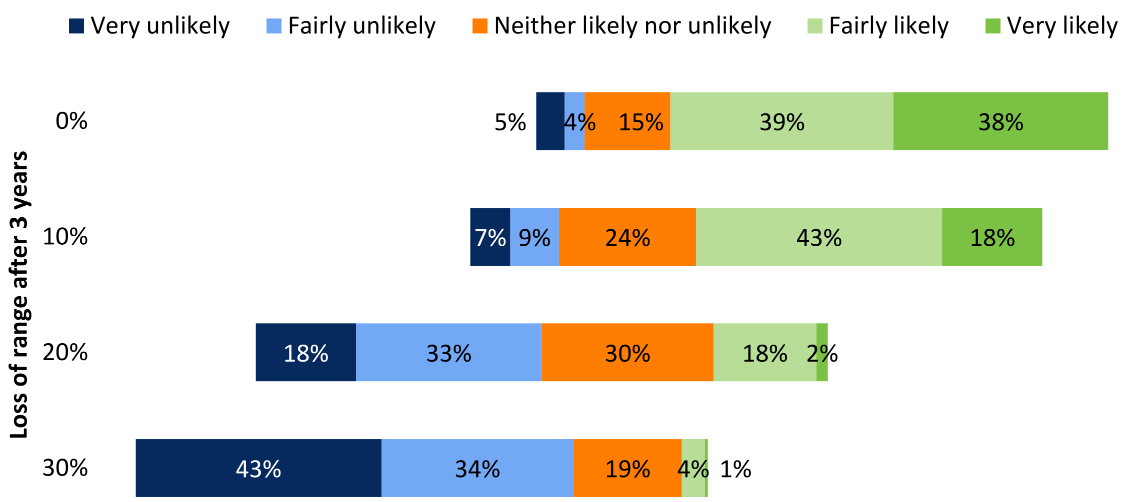

Figure 91: Proportion of participants likely or unlikely to purchase a PHEV according to loss of range after 3 years

The data shows a similar negative relationship between the rate of range loss of a PHEV and the reported likelihood to purchase as was seen with BEVs; as the amount of range lost after 3 years increases, likelihood to purchase a PHEV decreases.

A non-parametric Friedman test showed significant effects of loss of range on likelihood to purchase a PHEV ($\chi^2 = 437.63$, $p < 0.001$). Non-parametric Wilcoxon signed ranks tests were used to examine differences in likelihood to purchase between each pair of rates (e.g. 0% vs. 10% loss of range after 3 years). As with the BEV analysis, a Bonferroni correction was applied. In each of the six comparisons significant differences were identified (see Table 37).

Table 37: Wilcoxon signed ranks test results; differences in likelihood to purchase a PHEV between pairs of loss of range

Comparison	Z	p
0% vs. 10%	-4.480	<0.001
0% vs. 20%	-11.724	<0.001
0% vs. 30%	-14.620	<0.001
10% vs. 20%	-8.724	<0.001
10% vs. 30%	-12.930	<0.001
20% vs. 30%	-6.579	<0.001

B.4.10.3 Perceived importance of rate of depreciation

In the Time Point 2 questionnaire respondents were asked to indicate how important the rate of depreciation is when considering a BEV or PHEV. The percentage responses to these questions are presented in Figure 92.

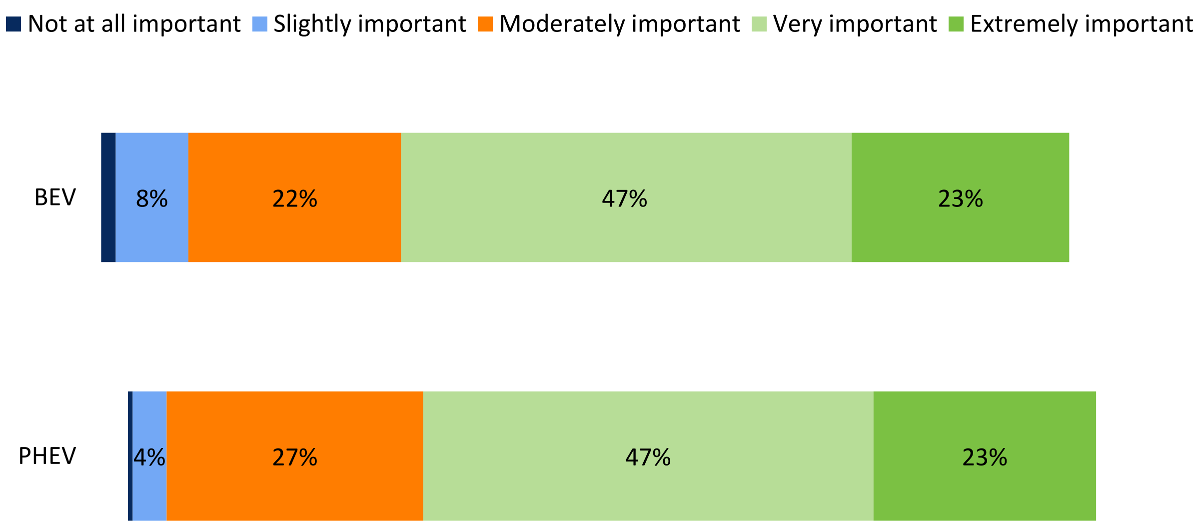

Figure 92: Proportion of participants by rating of importance of rate of depreciation when considering a BEV and PHEV

The data suggest that the rate of depreciation is an important factor for people when considering either a BEV or PHEV; in both cases, 70% of the total sample of participants considered it to be either ‘Very’ or ‘Extremely’ important.

There is a slight difference in the distribution of responses between people’s opinions about BEVs and PHEVs. A larger proportion of participants said that depreciation rate was either not at all or only slightly important when considering a BEV (9%) compared with a PHEV (4%). A non-parametric Wilcoxon signed ranks test showed that the importance of the rate of depreciation on likelihood to purchase did not significantly differ between BEVs and PHEVs.

B.4.11 What effect does access to additional ULEV benefits (e.g. access to bus lanes, free congestion charge, free parking) have on willingness to consider adoption of a BEV or PHEV?

- → **The range of ULEV benefits explored had varying impacts on likelihood to purchase a BEV and PHEV**
- → **Government grants towards the purchase price were perceived as the most beneficial by participants, resulting in significantly higher likelihood to purchase both a BEV and a PHEV compared with all other types of ULEV benefit.**
- → **The next three most influential benefits were exemption from car tax, access to free parking and provision of a free home chargepoint.**
- → **The least effective benefit was discounted access to public transport; which yielded the lowest likelihood to purchase responses.**

The Time Point 2 questionnaire was used to explore the influence of a number of ULEV benefits on participants' likelihood purchase a BEV or PHEV. In each case, the participant was asked to indicate how likely or unlikely they would be in the next 5 years to have a BEV or PHEV in their household, if a given ULEV benefit was available. The responses to these questions are summarised in Figure 93 for BEVs and Figure 94 for PHEVs.

The data show that the distribution of responses varied considerably between different ULEV benefits. For example, about 78% of participants would be either 'fairly' or 'very' likely to purchase a BEV if they received a government grant towards the purchase price, compared with only 28% of participants if they received discounted access to public transport.

A similar impact of ULEV benefits on likelihood to purchase a PHEV was observed; the government grant towards purchase price was the most effective (around 82% responses were 'fairly' or 'very' likely') and discounted access to public transport was the least effective (27% of responses were 'fairly' or 'very likely').

A non-parametric Friedman test showed that likelihood to purchase a BEV (χ^2 = 374.14, p < 0.001) and PHEV (χ^2 = 493.07, p < 0.001)) was significantly dependent on the type of ULEV benefit.

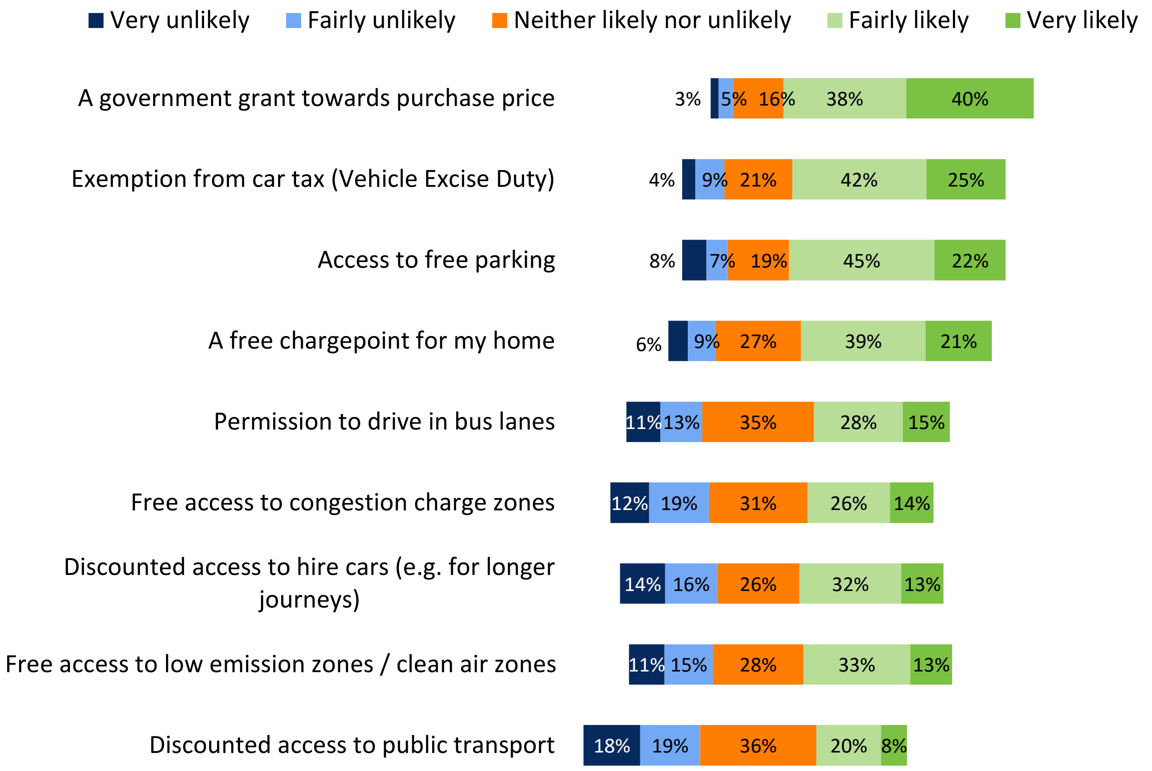

Figure 93: Impact of incentives on proportion of participants who would consider a BEV

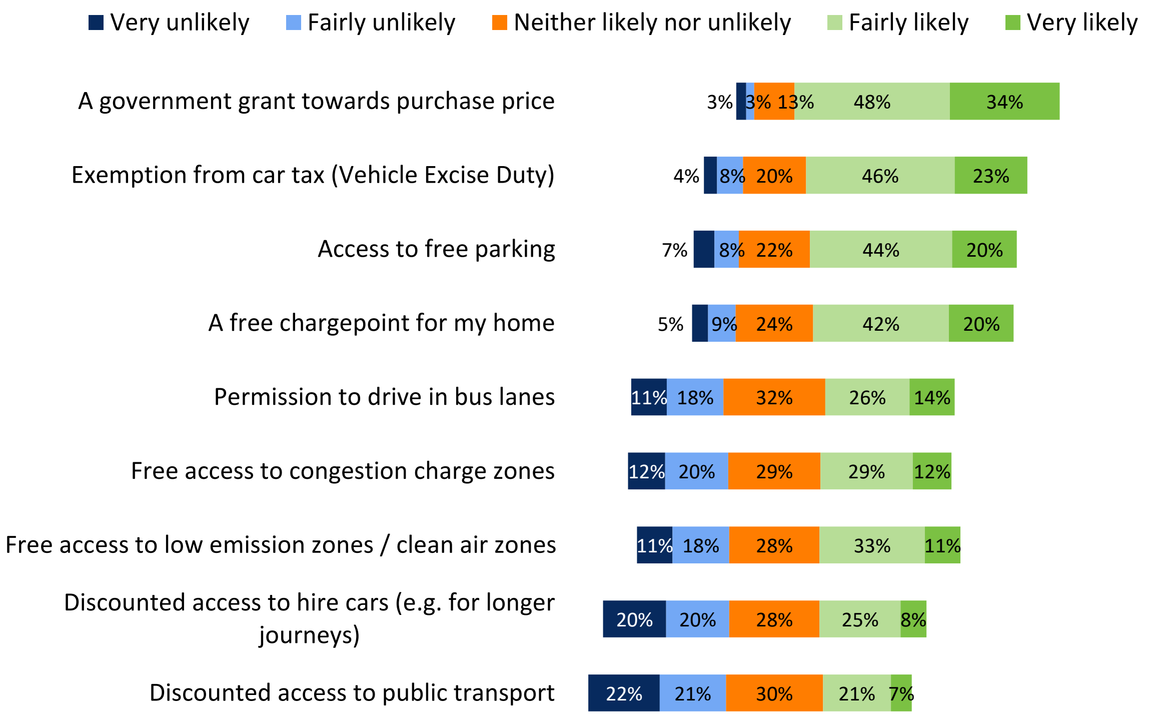

Figure 94: Impact of incentives on proportion of participants who would consider a PHEV

Mean likelihood to purchase responses for each benefit investigated are shown in Table 38.

Table 38: Mean likelihood to purchase given each type of ULEV benefit

Benefit	BEV	PHEV
Government grant	4.1	4.1
Car tax exemption	3.7	3.8
Free parking	3.7	3.6
Free home chargepoint	3.6	3.6
Low emission zones exemption	3.2	3.2
Access to bus lanes	3.2	3.1
Congestion charge zones exemption	3.1	3.1
Discounted hire cars	3.1	2.8
Discounted public transport	2.8	2.7

The results show that the government grant towards the purchase price is perceived as the most beneficial by participants, since this resulted in significantly higher likelihood to purchase both a BEV and a PHEV compared with all other types of ULEV benefit. The next three most influential benefits were exemption from car tax, access to free parking and provision of a free home chargepoint, which all resulted in significantly higher likelihood to purchase a BEV and a PHEV than the other benefits.

The order of importance of the ULEV benefits was similar across the three largest participant segments as shown in Table 39.

Table 39: Order of importance given to each ULEV benefit for the three largest segments

Order	Uninterested Rejecters	Cost-conscious Greens	Pragmatists
1	Government grant	Government grant	Government grant
2	Free parking	Car tax exemption	Free parking
3	Car tax exemption	Free parking	Car tax exemption
4	Free home chargepoint	Free home chargepoint	Free home chargepoint
5	Access to bus lanes	Low emission zones exemption	Discounted hire cars
6	Low emission zones exemption	Congestion charge zones exemption	Low emission zones exemption
7	Congestion charge zones exemption	Discounted hire cars	Access to bus lanes
8	Discounted hire cars	Access to bus lanes	Congestion charge zones exemption
9	Discounted public transport	Discounted public transport	Discounted public transport

The top four ULEV incentives and the least important benefit were the same for each group. Several differences in the order of importance did emerge with access to bus lanes being more important for Uninterested Rejecters than the other segments. This was similar to access to discounted hire cars for pragmatists.

As discussed in relation to the findings around access to public transport, the location where respondents live may influence their perceptions of the relative importance of ULEV benefits investigated here. While there was no significant difference in the geographical distribution of the segments between urban and rural locations, it should be noted that the trial was constrained to recruiting participants from two specific locations in the UK (see section A.1).

B.4.12 What other factors might compensate users for lack of long-range mobility sufficiently for them to consider adoption of a BEV?

- **The willingness to adopt a BEV as a main car was significantly predicted by vehicle factors, in particular it was predicted by electric range and having an alternative vehicle in the household. This suggests that owning an additional car may be able to compensate for lack of long-range mobility.**
- **The willingness to adopt a BEV as a second car was significantly predicted by the importance rating given to the time it takes to fully charge the vehicle. This suggests that improved charging speeds could compensate for lack of long-range mobility.**
- **Extending the research question, an exploration of the important vehicle factors with regards to willingness to adopt PHEVs was also conducted which found that the more important people rate the looks and performance of a vehicle, the more likely they are to consider a PHEV.**

The participants were asked at the end of the trial (as part of the Time Point 2 questionnaire) to rate the importance of a number of factors when considering purchasing a BEV or PHEV.

Figure 95 shows the results of these questions in order of importance. The order of importance and the distribution of responses for each of the factors were very similar between the different PiV types. Purchase price, electric range, and running costs were in the top four most important factors for both BEVs and PHEVs whereas brand and convenient access to public transport were in the bottom three for both BEVs and PHEVs. Access to an alternative vehicle in the household was the only factor that was considerably different in terms of its rank with participants rating it as a much more important factor for owning a BEV than a PHEV.

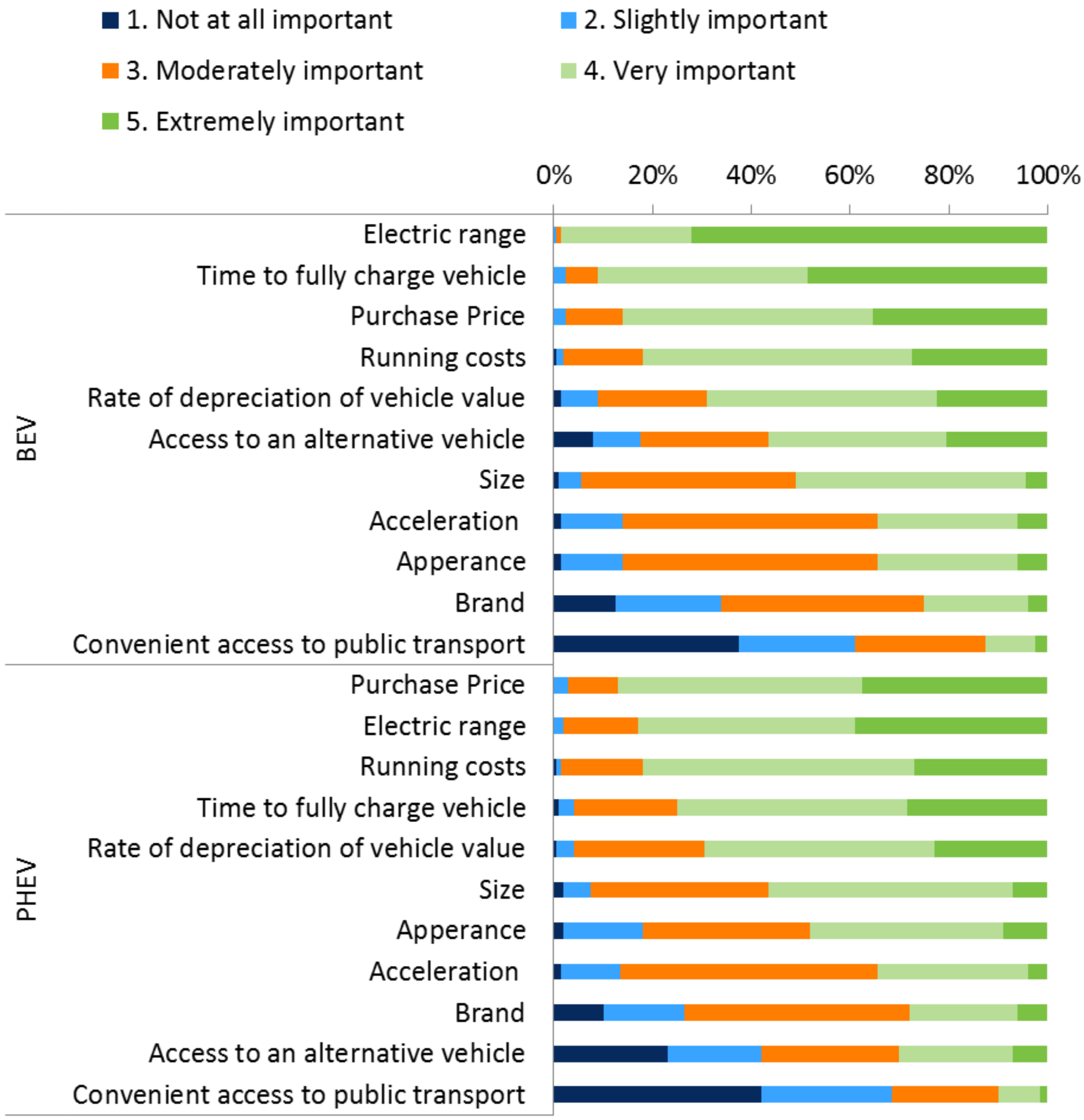

Figure 95: Proportion of participants by rating of importance of vehicle/transport factors for BEVs and PHEVs. The factors are shown in order of average rated importance.

B.4.12.1 BEV factor analysis

A factor analysis was conducted on these questions for BEVs and PHEVs separately to reduce the number of items. For the set of BEV survey questions, a four-factor solution was suggested which explained 62.8% of the variance in the data. As shown below in Table 40, each factor presented in a clear way and was easily interpreted.

Table 40: Vehicle/transport factor loadings for BEVs

	Factors			
	1	2	3	4
Appearance	0.870			
Brand	0.829			
Acceleration	0.677			
Size	0.520			
Purchase Price		0.765		
Running costs		0.735		
Rate of depreciation of vehicle value		0.680		
Electric range			0.866	
Time to fully charge vehicle			0.691	
Convenient access to public transport				0.816
Access to an alternative vehicle in your household				0.673

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Values <.4 have been suppressed

The factors can be described as follows:

- Factor 1 can be interpreted as the looks and performance of a vehicle, such as brand and size, as well as acceleration
- Factor 2 covers all of the finance related items and can be interpreted as the full cost of a vehicle over time including its re-sell value
- Factor 3 can be seen as the charging factor and groups the electric range and the time to charge items
- Factor 4 can be interpreted as access to alternative transport whether it is an alternative vehicle in the household or the use of public transport.

Each factor was tested for reliability (internal consistency) using the Cronbach Alpha test. The alpha value for Factor 1 met the criteria for acceptable internal consistency (0.74). However, the other factors had poor internal consistency (alpha values <.7). This suggests that only Factor 1 should be used in subsequent analysis and the raw questionnaire items from the other factors should be analysed individually.

B.4.12.2 PHEV vehicle/transport factor analysis

For the set of PHEV survey questions, a three factor solution was suggested which explained 59.3% of the variance in the data. As shown below in Table 41, each factor presented in a clear way and was easily interpreted. The factors were similar to those found for BEVs (in section B.4.12.1 above).

Table 41: PHEV vehicle/transport factor loadings

	Factors		
	1	2	3
Appearance	0.836		
Brand	0.832		
Acceleration	0.700		
Size	0.695		
Access to an alternative vehicle in your household		0.794	
Time to fully charge vehicle		0.736	
Electric range		0.642	
Convenient access to public transport		0.630	
Purchase Price			0.845
Running costs			0.766
Rate of depreciation of vehicle value		0.460	0.491

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Values <.4 have been supressed

Factors 1 and 3 can be interpreted the same as factors 1 and 2 for BEVs; looks and performance, and vehicle costs. For PHEVs, factor 2 can be understood as the convenience factor encompassing charging related items and alternative transport.

These factors were tested for reliability (internal consistency) using the Cronbach Alpha test. As with the BEV factors, only factor 1 met the required level of internal consistency (with alpha equal 0.78). The other factors had poor levels of reliability.

Factor 1, for both BEVs and PHEVs, and the remaining items from both were used to predict the participants willingness to purchase a BEV or PHEV as a main or second car (where appropriate) as part of a logistic regression analysis. The same outcome measures and analysis method used in section B.4.6 and B.4.7 were used on this data.

B.4.12.3 Predicting willingness to purchase a BEV as a main car

Each item was entered into a forward stepwise logistic regression model. This is where the model selects the best variables that predict willingness to purchase a BEV as a main car one at a time, starting at the best, until the model is not improved by adding more variables.

Due to the bias in the data where fewer people said they were likely to buy a BEV as a main car in the next five years than those who said they were not likely (32%[36] compared with 68%), the random model (i.e. the model before any predictor variables is added) predicted with a 68% accuracy.

[36] As with the previous analyses of this type (see section B.4.6), the participants who said they were neither likely nor unlikely to buy a BEV as a main car were excluded due to the small size of the group.

Electric range and access to an alternative vehicle in the household were the only two factors that were added to the model and therefore can be seen as the only factors included in the analysis that have a significant impact on the likelihood of purchasing this type of PiV ($p = 0.050$ and $p = 0.016$ respectively).

The higher a person rated the importance of the electric range, the less likely they were to say they were likely to buy a BEV as a main car in the next 5 years. Similarly, the greater the importance of having access to an alternative vehicle, the less likely they were to say they were likely to buy a BEV as a main car in the next 5 years.

With these predictors in the model, it was able to accurately predict if a participant was likely to buy a BEV as a main car at 77.2%. This is significantly more than the random model ($p < 0.001$).

Although nearly everyone said that the electric range of a BEV was either very or extremely important, people who said they were likely to buy a BEV as a main car were much less likely to think that electric range is extremely important than those who are not likely. This is shown in Figure 96.

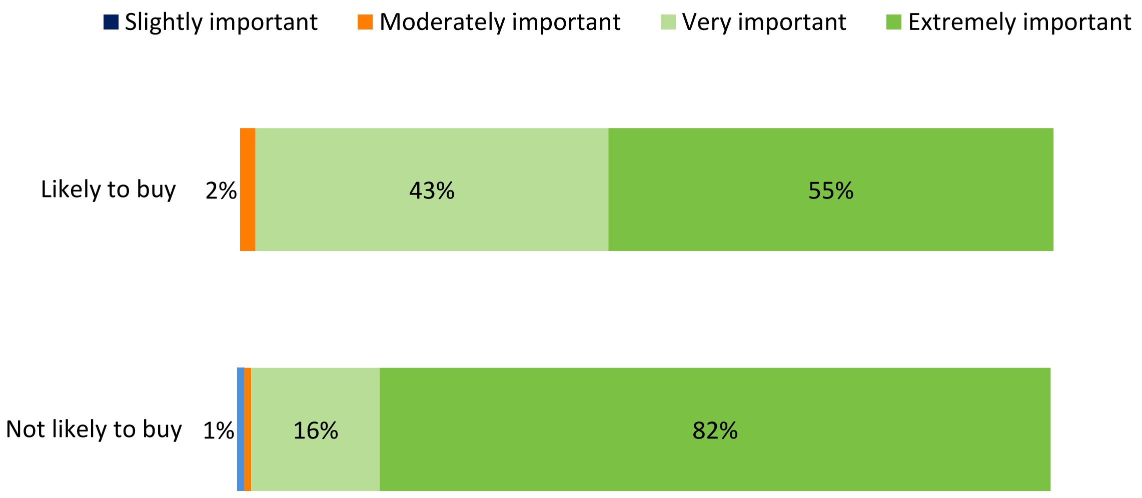

Figure 96: Proportion of participants by rating of importance of electric range for those likely and not likely to purchase a BEV as a main car

A much higher proportion of participants who said they were likely to purchase a BEV as a main car said that having access to an alternative vehicle was either not important, or only slightly important when compared to the group of participants who said they were not likely to purchase a BEV (Figure 97).

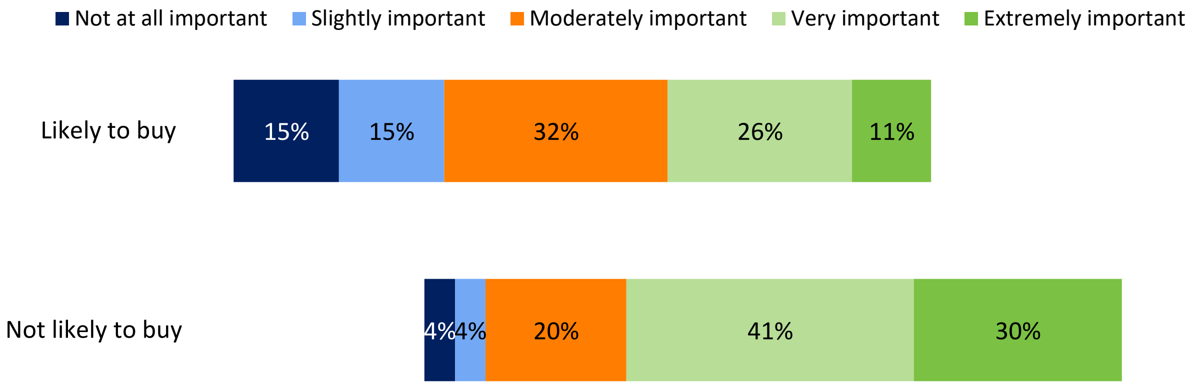

Figure 97: Proportion of participants by rating of importance rating of having access to an alternative vehicle in the household for those likely and not likely to purchase a BEV as a main car

B.4.12.4 Predicting willingness to purchase a BEV as a second car

The same analysis was conducted to predict the likelihood of purchasing a BEV as a second car[37]. The model was less accurate at predicting group membership than the model for purchasing a BEV as a main car (67.2% accuracy compared with 77.2% respectively), only 1.6% more than the random model. The time to full charge was the only important factor that came out of this model (p = 0.003). Rating the charge time as more important was generally related to being less likely to purchase a BEV as a second car. This is shown in Figure 98 where 69% of the 'not likely to buy group' said the time to full charge was 'extremely important' compared with only 34% of the 'likely to buy' group.

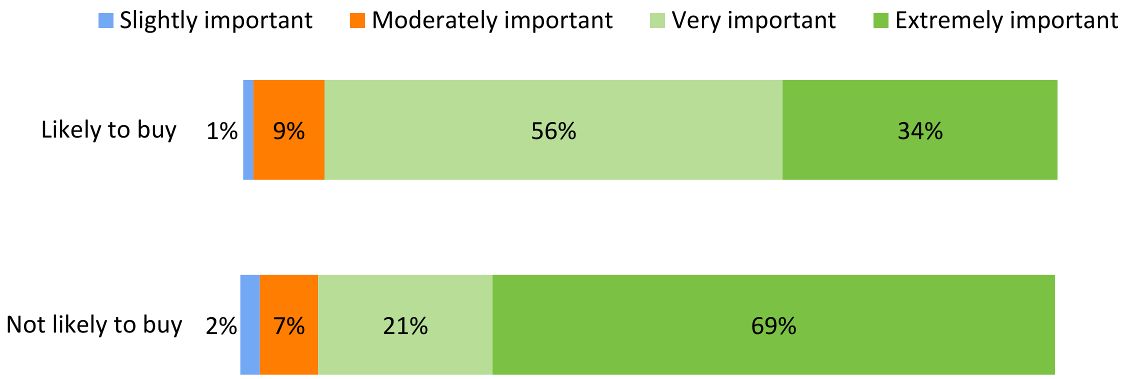

Figure 98: Proportion of participants by rating of importance of time to full charge for those likely and not likely to purchase a BEV as a second car

[37] The analysis was run on sample of participants who had a second car (71.5% of the total sample).

B.4.12.5 *Predicting willingness to purchase a PHEV as a main car*

When predicting the likelihood to buy a PHEV as a main car, the significantly predictive variable was the vehicle looks and performance factor (p = 0.032) which has a positive relationship with the outcome measure. Overall, the model was significant (p = 0.001) and predicted with 70.3% accuracy (around a 5% increase compared with the random model).

As shown in Figure 99, the importance of vehicle looks and performance factor scores are slightly skewed in a negative direction for those who said they were not likely to buy a PHEV as a main car whereas the scores are positively skewed for participants who said they were likely to buy a PHEV as a main car. These results suggest that people who place a higher amount of importance on a vehicles appearance and performance are more likely to consider buying a PHEV as a main car.

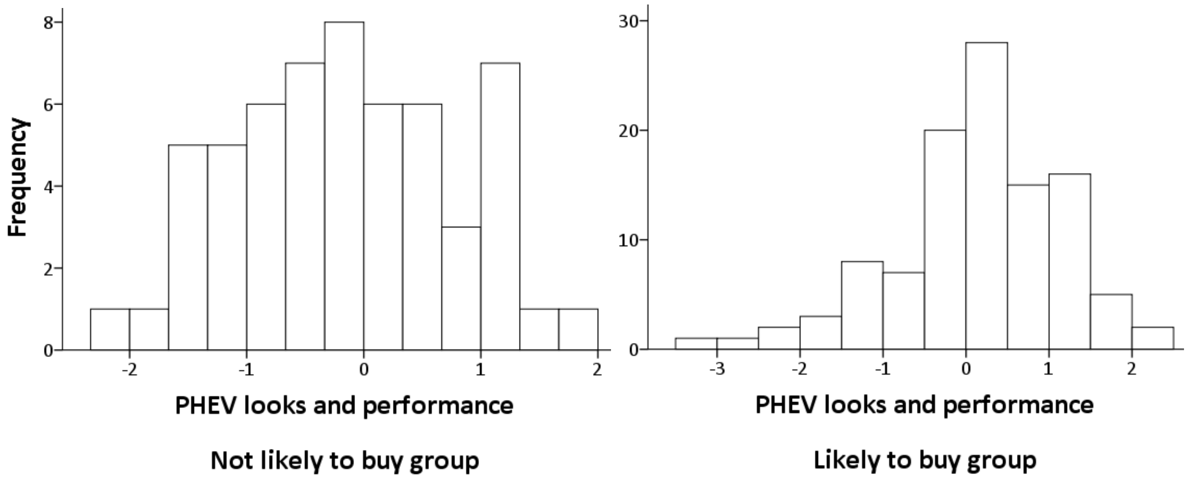

Figure 99: Importance of vehicle looks and performance factor scores by likelihood to buy a PHEV as a main car

B.4.12.6 *Predicting willingness to purchase a PHEV as a second car*

Overall, the vehicle features were able to produce a significant model (p = 0.021) to predict the willingness to adopt a PHEV as a second car. However, none of the variables alone were significant predictors.

B.4.13 *What effect does convenient access to a long-range vehicle (whether within the household or hired) for longer journeys have on willingness to consider adoption of a BEV?*

→ **Discounted access to a hire car resulted in higher likelihood to purchase a BEV compared with a PHEV**

→ **Nevertheless, discounted access to a hire car is not as important as other factors**

One of the ULEV benefits included in the analysis for Research Question 10 (see section B.4.11) was "Discounted access to a hire car (e.g. for longer journeys)". Participants were asked to indicate how likely they would be to purchase a BEV and PHEV if this benefit was provided to them. The responses to these items are presented in Figure 100.

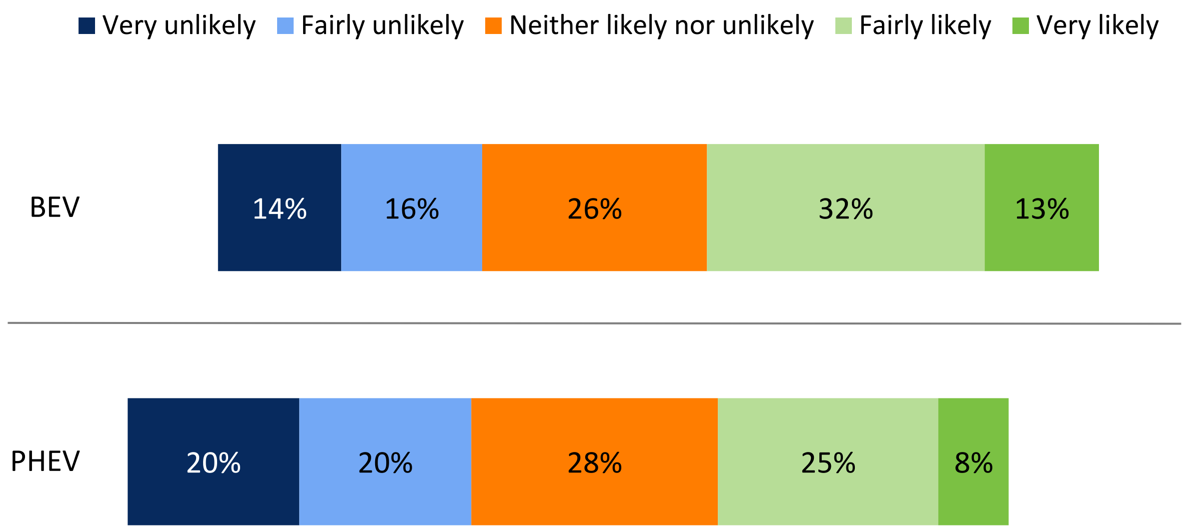

Figure 100: Proportion of participants likely or unlikely to purchase a BEV or PHEV if provided with discounted access to a hire car for longer journeys

The results show that access to hire cars was more important when considering a BEV compared with a PHEV: whilst 44.5% of participants would be 'fairly' or 'very likely' to purchase a BEV if they had discounted access to hire cars, only 33% had the same opinion with respect to PHEVs. A non-parametric Wilcoxon signed ranks test showed that this difference was statistically significant (Z =-2.263, p = 0.012), reflective of the longer range granted by a PHEV which can be refuelled (with petrol) quicker than is possible with a BEV.

Nevertheless, in the context of other factors (see section B.4.11), discounted access to a hire car is not considered important when compared to other factors.

B.5 Supplementary analyses

In addition to the core analysis conducted to answer the research questions, further areas of interest were explored. This section reports on the result of the supplementary analyses undertaken for specific areas of interest and associated secondary research questions. The areas of interest are:

- Comparisons between attitudes towards BEVs and PHEVs (after experience with both types of vehicle)
- Comparisons between travel patterns, vehicle usage and performance ratings for each of the three types of vehicle
- Relationship between vehicle use and likelihood to purchase

B.5.1 Comparisons between attitudes towards BEVs and PHEVs (after experience with both types of vehicle)

→ **In general, participants were more positive about the following attributes for BEVs compared with PHEVs: environmental benefits, independence from oil, being an exciting and good idea, lower running costs, and driving performance.**

→ **Participants were more positive about the following attributes for PHEVs compared with BEVs: driving enjoyment, purchase cost and depreciation, range and charging, safety of people outside the vehicle, and personal travel needs.**

→ **Most attitudes became significantly more positive over the course of the trial.**

→ **Some attitudes stayed stable; these were environmental attitudes, affective attitudes towards PHEVs, cost related attitudes, charging and range for BEVs, PHEV reliability, and travel needs related to PHEVs.**

→ **Very few attitudes became less positive between the start and end of the trial. Perceptions of the environmental benefits of PHEVs decreased over time (including their impact on independence from oil). There was an increase in the perception of BEV depreciation along with participants being more likely to say they were unlikely to have a BEV as their main car after the trial. Ratings of PHEV safety for passengers and people outside of the car were lower after the trial than at the start.**

→ **The choice experiment Alternative Specific Constants suggest that there is no inherent net negative bias towards PHEVs and BEVs, and on average participants are willing to pay £5,000 more for a BEV than an ICE with identical attributes. This £5,000 excludes the impact of any running cost difference since running costs were included as a separate attribute in the choice model.**

This analysis helps to answer a number of secondary research questions including;

- Do driver's attitudes to and perceptions of BEVs and PHEVs differ?
- Did driver's attitudes towards BEVs and PHEVs change over the course of the trial?

Responses to a number of attitude questions which were repeated in both TP1 and TP2 were used to answer these research questions, in addition to analysis of the Alternative

Specific Constants (ASC) from the choice experiment (see section B.5.1.6). These survey questions covered attitudes towards the following PiV related factors:

- Pro-environment
- Independence from oil
- Affective attributes
- Instrumental attributes
    - Cost
    - Performance
    - Range and charging
    - Reliability
    - Safety
    - Travel needs
- Symbolic attributes

In total this included 51 items per vehicle type. Initially, a factor analysis was used to reduce the number of items into a set of underlying factors. However, a consistent factor structure could not be identified across the vehicle types or over time. In addition, most of the factors identified had poor internal reliability and were non-intuitive to understand. Hence, the items were compared individually between TP1 and TP2, and also between BEV and PHEV for the TP2 responses using Wilcoxon tests. The attitude groups above have been used to more generally interpret the results of these comparisons. Only statistically significant results are reported.

B.5.1.1 Pro-environment

The results for comparing pro-environment attitudes for BEVs and PHEVs are shown in Table 42 as well as descriptive statistics for each vehicle type. The mean scores have been calculated from Likert scales where 1=Strongly disagree and 5=Strongly agree.

Table 42: Comparison of pro-environment attitudes for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	BEV	PHEV	Z score	p-value
BEVs/PHEVs are good for the environment	4.12	3.78	-5.50	<0.001
BEVs/PHEVs emit less carbon dioxide than conventional cars	4.42	3.84	-8.03	<0.001
BEVs/PHEVs offer environmental benefits	4.13	3.88	-5.04	<0.001
Driving a BEV/PHEV would give me a ‘feel good factor’ because of its green credentials	3.67	3.53	-2.16	0.031

Participants were more likely to agree that driving a BEV would give them a 'feel good factor' due to its green credential compared with a PHEV. They were also more strongly agreed that BEVs are good for the environment.

Although there were differences between how participants responded to these items for BEVs and PHEVs, for each vehicle type, there were few differences in responses over time, as shown in the following tables.

Table 43: Comparison of pro-environment attitudes for BEVs before and after the trial (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
BEVs emit less carbon dioxide than conventional cars	4.33	4.42	-1.97	0.048

For BEVs, the only change in participants' attitudes between the TP1 and TP2 surveys was for the item "BEVs emit less carbon dioxide than conventional cars" where they were more likely to agree with this statement after the trial.

Table 44: Comparison of pro-environment attitudes for PHEVs before and after the trial (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
PHEVs are good for the environment	3.91	3.78	-2.51	0.012
The environmental benefits of PHEVs have been over exaggerated	2.64	2.80	-2.54	0.011

Several attitudes towards PHEVs changed between TP1 and TP2. After the trial, participants generally had a lower level of agreement that PHEVs are good of the environment and were more likely to agree that the environmental benefits of PHEVs have been over exaggerated after the trial.

B.5.1.2 Independence from oil

The comparison for attitudes around independence from oil for BEVs and PHEVs are shown in Table 45 as well as descriptive statistics for each vehicle type.

Table 45: Comparison of attitudes on independence from oil for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**BEV**	**PHEV**	**Z score**	**p-value**
BEVs/PHEVs are a good thing because they make us less dependent on oil	3.93	3.63	-4.58	<0.001
I like the idea of being able to 'refuel' at home rather than have to go to petrol stations	4.07	3.91	-2.94	0.003
Not having to go to a petrol station to refuel would make me more likely to buy a BEV/PHEV	3.30	3.52	-3.10	0.002

BEVs were rated as being better in terms of independence from oil and on the benefit of being able to refuel at home rather than going to a petrol station than PHEVs. However, not having to re-fuel at a petrol station didn't appear to strongly drive likelihood to purchase a

BEV. For PHEVs, there is of course still a requirement to go to a petrol station, although possibly reducing the frequency of refuelling may have influenced the likelihood to purchase being rated more positively.

In a similar manner to the green identity items, none of the attitudes relating to independence from oil changed significantly over the course of the trial (i.e. between TP1 and TP2). This is likely to be due to independence from oil being a more general attitude and part of a stable personal characteristic. Experience with a BEV, therefore, did not enhance these views, nor dissuade established perspectives.

Table 46: Comparison of attitudes on independence from oil for PHEVs before and after the trial (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	TP1	TP2	Z score	p-value
PHEVs are a good thing because they make us less dependent on oil	3.83	3.63	-3.47	0.001
Not having to go to a petrol station to refuel would make me more likely to buy a PHEV	3.70	3.52	-2.66	0.008

Participants agreed that PHEVs are good as they are less oil dependent than conventional cars significantly less after the trial than before. They also agreed less that not having to refuel at a petrol station would make them more likely to buy a PHEV after the trial than compared with before.

B.5.1.3 Affective attributes

The comparison for attitudes towards affective attributes of BEVs and PHEVs are shown in Table 47 as well as descriptive statistics for each vehicle type.

Table 47: Comparison of attitudes towards affective attributes of BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	BEV	PHEV	Z score	p-value
BEVs/PHEVs are a current fad which will soon disappear	1.85	2.19	-4.73	<0.001
BEVs/PHEVs are a really good idea	4.19	3.90	-4.16	<0.001
BEVs/PHEVs are a very exciting new technology	4.11	3.79	-5.16	<0.001
BEVs/PHEVs are pleasant to drive	4.46	4.12	-6.39	<0.001
I would prefer to drive a conventional car than a BEV/PHEV	2.71	2.50	-2.77	0.006

The data suggest that while participants rate both BEVs and PHEVs as pleasant to drive, they prefer the experience of driving a BEV than a PHEV. Results identified that participants found BEVs more pleasant to drive and generally thought they are were a better idea and more exciting technology than PHEVs. Participants did not consider PiVs to be a temporary fad, with BEVs rated less of a fad than PHEVs. Comparison of BEVs or PHEVs to conventional vehicles suggested a slight preference for PiVs generally, with PHEVs rated more positively than BEVs

Table 48: Comparison of attitudes towards affective attribute of BEVs before and after the trial (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
BEVs are a current fad which will soon disappear	1.95	1.85	-2.04	0.041
BEVs are a really good idea	3.99	4.19	-3.58	<0.001
BEVs are a very exciting new technology	3.91	4.11	-3.61	<0.001
BEVs are pleasant to drive	3.42	4.46	-10.97	<0.001
I would prefer to drive a conventional car than a BEV	2.93	2.71	-3.22	0.001

As shown in Table 48 and Table 49 all of the attitudes towards BEVs became more positive over the course of the trial. The same was true for PHEVs where there was a decrease in the level of agreement to the item PHEVs are a current fad which will soon disappear.

Table 49: Comparison of attitudes towards affective attributes of PHEVs before and after the trial (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
PHEVs are a current fad which will soon disappear	2.22	2.19	-2.04	0.041

B.5.1.4 Instrumental attributes

Cost

The comparison of attitudes towards purchase and running costs for BEVs and PHEVs are shown in Table 50 as well as descriptive statistics for each vehicle type.

Table 50: Comparison of cost related attitudes for BEVs and PHEVs

(Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**BEV**	**PHEV**	**Z score**	**p-value**
BEVs/PHEVs are more expensive to buy than conventional cars	4.25	4.10	-3.48	<0.001
BEVs/PHEVs are more expensive to run than conventional cars	2.22	2.49	-3.83	<0.001
BEVs/PHEVs will hold its value better than a conventional car	2.84	3.05	-3.48	0.001
BEVs/PHEVs will lose value more quickly than a conventional car	3.14	2.97	-2.96	0.003
I would be prepared to pay more for a BEV/PHEV than a conventional car	2.66	2.80	-2.07	0.038

BEVs were seen as more expensive to buy and more likely to depreciate in value at a quicker rate than a conventional car compared with PHEVs. Participants were also more likely to agree that they would pay more for a PHEV than a BEV, potentially due to the added utility of a PHEV in addition to the green credentials. However, BEVs were generally seen as cheaper to run. The change in cost related attitudes for BEVs are shown in Table 51.

Table 51: Comparison of cost related attitudes for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
BEVs are more expensive to run than conventional cars	2.41	2.22	-2.79	0.005
BEVs will lose value more quickly than a conventional car	2.96	3.14	-2.69	0.007

BEV cost related attitudes that changed over time were related to the running costs and the vehicle depreciation. The perception of running costs compared to conventional vehicles decreased significantly over time, whereas attitudes towards vehicle value depreciation became less positive.

Unlike the results for BEVs, participants' attitudes towards the purchase and running costs of a PHEV did not change over the course of the trial. ***Performance***

The comparison of vehicle performance evaluations between BEVs and PHEVs are shown in Table 52 as well as descriptive statistics for each vehicle type.

Table 52: Comparison of performance evaluations for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**BEV**	**PHEV**	**Z score**	**p-value**
BEVs/PHEVs would be less responsive when accelerating than a conventional car	1.74	2.02	-4.10	<0.001
BEVs/PHEVs would be less smooth to drive when cruising	1.63	1.93	-5.26	<0.001
BEVs/PHEVs would be noisier when pulling away than a conventional car	1.34	1.88	-8.50	<0.001
BEVs/PHEVs would be quieter when cruising than a conventional car	4.33	3.51	-9.23	<0.001
BEVs/PHEVs would be smoother to drive when accelerating than a conventional car	4.19	3.55	-7.90	<0.001
BEVs/PHEVs would have better acceleration from 0-30mph compared with a conventional car	3.83	3.41	-6.29	<0.001

Participants generally rated BEVs as having better performance than PHEVs relative to a conventional car. This was particularly the case for the noise related performance measures and most of the acceleration measures.

The changes in BEV performance evaluations between TP1 and TP2 are shown in Table 53.

Table 53: Comparison of performance evaluations for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

Attitude	Mean scores		Statistical results	
	TP1	TP2	Z score	p-value
BEVs are similar to a conventional car in most respects	3.60	3.90	-4.49	<0.001
BEVs perform better than a conventional car	2.99	3.35	-4.97	<0.001
BEVs would be less comfortable than a conventional car	2.14	1.68	-6.11	<0.001
BEVs would be less responsive when accelerating than a conventional car	2.67	1.74	-8.70	<0.001
BEVs would be less smooth to drive when cruising	2.25	1.63	-8.09	<0.001
BEVs would be more powerful than a conventional car	2.70	3.18	-5.95	<0.001
BEVs would be noisier when pulling away than a conventional car	1.62	1.34	-5.41	<0.001
BEVs would be quieter when cruising than a conventional car	4.12	4.33	-3.66	<0.001
BEVs would be smoother to drive when accelerating than a conventional car	3.64	4.19	-7.29	<0.001
BEVs would have better acceleration from 0-30mph compared with a conventional car	3.34	3.83	-5.82	<0.001
BEVs would have worse acceleration from 30-50mph compared with a conventional car	2.79	2.09	-7.17	<0.001

In all of the performance measures included in the survey, participants rated BEVs as having better performance relative to conventional cars after they had experienced the vehicle than beforehand.

The changes in PHEV performance evaluations are shown in Table 54. Similar to the results for BEVs, the scores for performance became more positive across the board for PHEVs after the trial with most of these changes being significant. The measure that did not change significantly was cruising noise. This result is likely to be related to the PHEV running on the petrol engine having a comparable level of noise as the ICE. Participants in general were more likely to agree that PHEVs are similar to conventional cars after the trial than before.

Table 54: Comparison of performance evaluations for PHEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

Attitude	Mean scores		Statistical results	
	TP1	TP2	Z score	p-value
PHEVs are similar to a conventional car in most respects	3.73	3.96	-3.60	<0.001
PHEVs perform better than a conventional car	3.00	3.32	-4.73	<0.001
PHEVs would be less comfortable than a conventional car	2.12	1.75	-5.93	<0.001
PHEVs would be less responsive when accelerating than a conventional car	2.69	2.02	-8.43	<0.001
PHEVs would be less smooth to drive when cruising	2.37	1.93	-6.00	<0.001
PHEVs would be more powerful than a conventional car	2.83	3.12	-3.98	<0.001
PHEVs would be noisier when pulling away than a conventional car	2.17	1.88	-4.65	<0.001
PHEVs would be quieter when cruising than a conventional car	3.49	3.51	-0.40	0.693
PHEVs would be smoother to drive when accelerating than a conventional car	3.32	3.55	-3.35	0.001
PHEVs would have better acceleration from 0-30mph compared with a conventional car	3.08	3.41	-4.46	<0.001
PHEVs would have worse acceleration from 30-50mph compared with a conventional car	2.81	2.16	-8.26	<0.001

Range and charging

The comparison for attitudes around range and charging for BEVs and PHEVs are shown in Table 55, along with descriptive statistics for each vehicle type.

Table 55: Comparison of charging and range attitudes for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

Attitude	Mean scores		Statistical results	
	BEV	PHEV	Z score	p-value
Adapting to charging a BEV/PHEV would be difficult for me	2.19	1.87	-4.08	<0.001
Having to remember to plug in a BEV/PHEV would put me off buying one	2.16	1.98	-3.16	0.002
I would only consider a BEV/PHEV if I knew I had access to a rapid charging point (i.e. somewhere it would charge to 80% in around 30 minutes)	3.66	2.93	-7.39	<0.001
When driving a BEV/PHEV, I would always be worried about running out of charge	3.72	2.04	-10.712	<0.001

Participants were more likely to agree they would be put off a BEV than a PHEV due to charging and range related factors.

The only statistically significant change in attitude related to charging a BEV between TP1 and TP2 is shown in Table 56. Consideration of the challenge of adapting to charging a BEV became more positive following experience during the trial.

Table 56: Comparison of charging and range attitudes for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	TP1	TP2	Z score	p-value
Adapting to charging a BEV would be difficult for me	2.40	2.19	-2.44	0.015

The change in attitudes to PHEVs between TP1 and TP2 are shown in Table 57.

Table 57: Comparison of charging and range attitudes for PHEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	TP1	TP2	Z score	p-value
Adapting to charging a PHEV would be difficult for me	2.11	1.87	-3.01	0.003
Having to remember to plug in a PHEV would put me off buying one	2.15	1.98	-2.76	0.006
I would only consider a PHEV if I knew I had access to a rapid charging point (i.e. somewhere it would charge to 80% in around 30 minutes)	3.21	2.93	-3.19	0.001
When driving a PHEV, I would always be worried about running out of charge	2.37	2.04	-3.87	<0.001

Unlike the results for BEVs, these attitudes towards PHEVs all changed significantly between TP1 and TP2. In each case participants were more positive towards PHEVs regarding charging and range factors after the trial than before.

Reliability

Attitudes about vehicle reliability were compared between BEVs and PHEVs and the results are shown in Table 58 as well as descriptive statistics for each vehicle type.

Table 58: Comparison of reliability attitudes for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**BEV**	**PHEV**	**Z score**	**p-value**
BEVs/PHEVs are more complicated than a conventional car	2.48	3.38	-8.44	<0.001
BEVs/PHEVs would be more reliable than a conventional car	3.11	2.91	-3.08	0.002

Reliability scores were relatively comparable, with BEVs having a slightly better score than PHEV. However, PHEVs were seen as being more complex vehicles than BEVs. This may be related to be the vehicle having both electric and ICE capabilities.

As shown in Table 59, the general perceptions of BEV reliability compared to a conventional car significantly improved between TP1 and TP2.

Table 59: Comparison of reliability attitudes for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
BEVs are more complicated than a conventional car	2.74	2.48	-3.63	<0.001
BEVs are too new to be reliable	2.70	2.58	-2.19	0.029
The chances of breaking down in a BEV are higher than in a conventional car	2.86	2.71	-2.15	0.032

Unlike the BEV results, in general, the attitudes towards PHEV reliability did not significantly change after experience with the vehicles (see Table 60).

Table 60: Comparison of reliability attitudes for PHEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
PHEVs are too new to be reliable	2.63	2.52	-1.98	0.048

Safety

Attitudes about vehicle safety were compared between BEVs and PHEVs and the results are shown in Table 61 as well as descriptive statistics for each vehicle type.

Table 61: Comparison of safety attitudes for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**BEV**	**PHEV**	**Z score**	**p-value**
BEVs/PHEVs are a danger to people outside the car because of the lack of engine noise	3.21	2.80	-6.78	<0.001

There was a difference between the vehicle types for the danger to people outside of the vehicles where the level of agreement to the statement "BEVs/PHEVs are a danger to people outside the car because of the lack of engine noise" was significantly higher for BEVs than PHEVs.

Table 62 shows how safety attitudes towards BEVs changed between TP1 and TP2.

Table 62: Comparison of reliability attitudes for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
BEVs are a danger to people outside the car because of the lack of engine noise	3.44	3.21	-3.62	<0.001
BEVs are as safe for the driver and passengers as conventional cars	3.97	4.23	-4.63	<0.001

Participants were significantly more likely to give the BEV a safer rating at TP2 than at TP1 for both of the safety measures shown.

The results for how safety attitudes towards PHEVs changed between TP1 and TP2 are shown in Table 63.

Table 63: Comparison of reliability attitudes for PHEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
PHEVs are a danger to people outside the car because of the lack of engine noise	2.80	3.07	-3.62	<0.001
PHEVs are as safe for the driver and passengers as conventional cars	4.15	3.99	-2.58	0.010

The opposite results were observed for PHEVs, with participants' safety rating becoming more negative at TP2 than TP1.

Travel needs

Table 64: Comparison of travel needs attitudes for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	BEV	PHEV	Z score	p-value
A BEV/PHEV would suit my daily travel patterns	3.53	4.06	-4.99	<0.001
BEVs/PHEVs are impractical	2.67	1.97	-7.31	<0.001
BEVs/PHEVs are suitable for my lifestyle	3.37	3.93	-5.59	<0.001
Having a BEV/PHEV would mean I would have to plan journeys carefully	4.38	2.38	-11.45	<0.001
If I had a BEV/PHEV, it would be unlikely to be my main or only car	3.70	2.47	-8.79	<0.001

Participants' were significantly more likely to agree that PHEVs were able to meet their travel needs than BEVs.

The results for how these attitudes towards BEVs changed between TP1 and TP2 are shown in Table 65.

Table 65: Comparison of reliability attitudes for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	TP1	TP2	Z score	p-value
Having a BEV would mean I would have to plan journeys carefully	3.59	3.53	-2.28	0.023
If I had a BEV, it would be unlikely to be my main or only car	3.07	3.70	-6.51	<0.001

In general, this set of attitudes did not change over the course of the trial suggesting that experience of the BEV did not improve attitudes in this area. There was a significant increase between the level of agreement to the item "If I had a BEV, it would be unlikely to be my main or only car" in TP1 compared with TP2. This is in line with the result that more participants reported being likely to buy a BEV as a second car after the trial than before. Participants were also less likely to agree that owning a BEV would mean they would have to plan their journeys more carefully after the trial. These results together suggest that although little changed in whether or not participants' thought a BEV was suitable for their travel needs, there was an increase in interest in having a BEV as a second car.

The changes in travel needs attitudes for PHEVs between TP1 and TP2 are shown in Table 66.

Table 66: Comparison of reliability attitudes for PHEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**TP1**	**TP2**	**Z score**	**p-value**
PHEVs are impractical	2.17	1.97	-2.71	0.007
Having a PHEV would mean I would have to plan journeys carefully	2.82	2.38	-4.91	<0.001

For PHEVs, slightly difference results were found. Fewer people agreed that PHEVs are impractical and require more careful journey planning after the trial compared to before.

B.5.1.5 Symbolic attitudes

Table 67: Comparison of symbolic attitudes for BEVs and PHEVs (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	**BEV**	**PHEV**	**Z score**	**p-value**
I would feel embarrassed to drive a BEV/PHEV	1.45	1.54	-1.99	0.047
Many people I know would be attracted to owning a BEV/PHEV	3.16	3.44	-3.79	<0.001

The participants generally responded to the symbolic attitude items (i.e. how like someone who would own an EV is the participant) similarly for the BEV and PHEV although there were some significant differences. People agreed more that they would be embarrassed to have a PHEV than a BEV but were also more likely to agree that they knew people would be attracted to owning a PHEV. The former result may be impacted by some of the participants being very pro-BEV and anti-PHEV.

Table 68: Comparisons of symbolic attitudes for BEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	TP1	TP2	Z score	p-value
I am the type of person who would drive a BEV	3.50	3.70	-2.97	0.003
I would feel embarrassed to drive a BEV	1.74	1.45	-5.45	<0.001
I would feel proud of having a BEV outside my house	3.42	3.56	-2.29	0.022

Overall, the participants viewed themselves as being more like the type of person who could own a BEV after the trial than before; although not all items had a significant positive change, there were no significant differences that were negative.

Similar but fewer significant results were found for PHEVs shown in Table 69.

Table 69: Comparisons of symbolic attitudes for PHEVs between TP1 and TP2 (Scale: 1=Strongly disagree to 5=Strongly agree)

	Mean scores		Statistical results	
Attitude	TP1	TP2	Z score	p-value
I would feel embarrassed to drive a BEV	1.66	1.54	-2.49	0.013
I would feel proud of having a BEV outside my house	3.46	3.62	-2.56	0.011

B.5.1.6 Alternative Specific Constants (ASC)

While the choice experiment can provide a view on how participants value specific vehicle attributes, the results can also be used to investigate the underlying attitudes towards a particular powertrain technology through the Alternative Specific Constants (ASC). Recall the general equation for utility from section A.9.1:

$$U_i = \sum_{j=1}^{j=T} \beta_j x_{ij} + \varepsilon_i$$

The constant, ε_i, is represented by the ASCs for PHEVs and BEVs in the utility equations shown in A.9.1. Figure 101 shows the ASCs derived from the choice experiment:

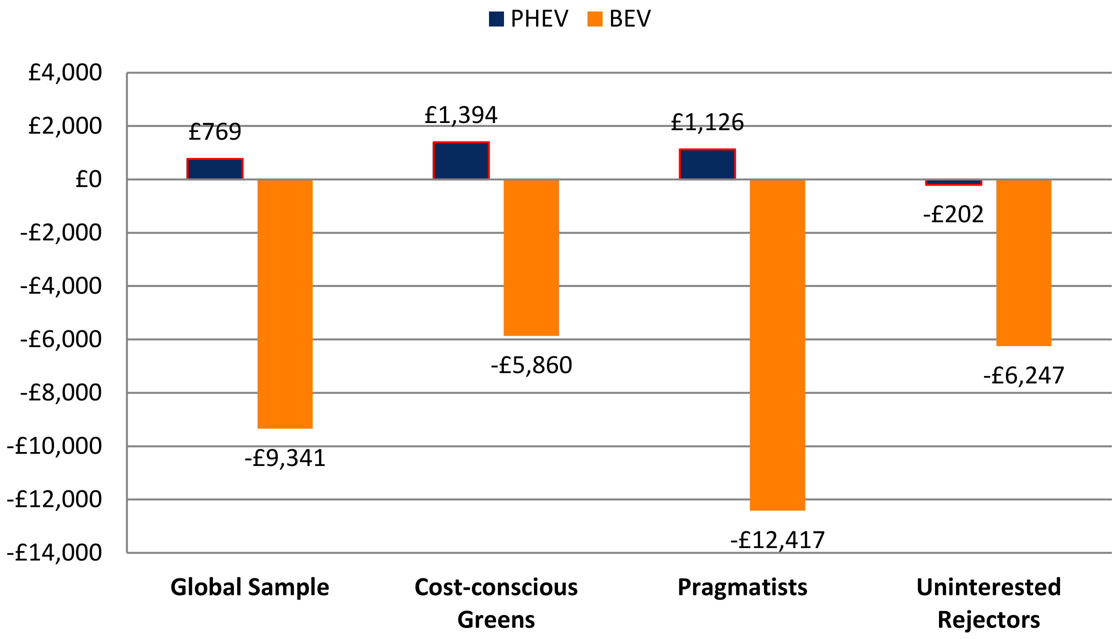

Figure 101: Alternative Specific Constants for BEVs and PHEVs derived from the choice experiment, expressed in terms of willingness-to-pay. Red border means the result is not statistically significant

At first glance it would appear that the ASCs signify a strong negative bias against BEVs equivalent to several thousand pounds of additional upfront cost, while PHEVs are favoured. However, before conclusions can be drawn from the ASCs it is necessary to understand exactly what they represent. In the utility equations ASCs serve two purposes:

1. To correct for the fact that each of the three alternatives have a different set of attributes. For example, consider the following simple set of utility equations describing an ICE and BEV:

$$U_{ICE} = \beta_{purchase\ price} \times Purchase\ Price_{ICE} + \beta_{running\ cost} \times Running\ Cost_{ICE}$$

$$U_{BEV} = \beta_{purchase\ price} \times Purchase\ Price_{BEV} + \beta_{running\ cost} \times Running\ Cost_{BEV} + \beta_{range} \times Range_{BEV} + ASC_{BEV}$$

   The utility of the BEV is dependent on its range while that of the ICE is not. Therefore, without ASC_{BEV}, and with identical purchase prices and running costs, the utility of the BEV will be larger than that of the ICE if its range is larger than zero. Therefore, the ASC must be negative to compensate for the range attribute not found in the ICE.

2. The ASC also accounts for the utility of the unobserved factors not explicitly investigated in the choice experiment. For example, this could be the perceived risk associated with purchasing a novel technology, or the reputational impact of driving a plug-in car. In the example above, this would be the difference in utility between an ICE and BEV with identical attributes.

An ASC of alternative, i, can therefore be expressed as the sum of its two component parts:

$$ASC_i = ASC_{i,correction} + ASC_{i,unobserved}$$

$ASC_{i,correction}$ corrects for the fact that not all attributes apply to all alternatives. $ASC_{i,unobserved}$ accounts for the unobserved factors not directly investigated in the choice experiment, for example the perceived risk associated with purchasing a novel technology. Derivation of both components can be demonstrated with the following example:

Consider a simple choice model between an ICE and a BEV alternative described by the following pair of utility equations:

$$U_{ICE} = \beta_{purchase\ price} \times Purchase\ Price_{ICE} + \beta_{running\ cost} \times Running\ Cost_{ICE}$$

$$U_{BEV} = \beta_{purchase\ price} \times Purchase\ Price_{BEV} + \beta_{running\ cost} \times Running\ Cost_{BEV} + \beta_{range} \times Range_{BEV} + ASC_{BEV}$$

If both the ICE and BEV are identical in respect of their observed attributes, then $ASC_{i,unobserved}$ can be isolated as the different in utility:

$$ASC_{BEV,unobserved} = U_{BEV} - U_{ICE}$$

Substituting in the utility equations yields:

$$\begin{aligned} ASC_{BEV,unobserved} &= \big(\beta_{purchase\ price} \times Purchase\ Price_{BEV} \\ &+ \beta_{running\ cost} \times Running\ Cost_{BEV} + \beta_{range} \times Range_{BEV} \\ &+ ASC_{BEV,correction} + ASC_{BEV,unobserved}\big) \\ &- \big(\beta_{purchase\ price} \times Purchase\ Price_{ICE} \\ &+ \beta_{running\ cost} \times Running\ Cost_{ICE}\big) \end{aligned}$$

And rearranging for $ASC_{BEV,correction}$:

$$\begin{aligned} ASC_{BEV,correction} &= \big(\beta_{purchase\ price} \times Purchase\ Price_{ICE} \\ &+ \beta_{running\ cost} \times Running\ Cost_{ICE}\big) \\ &- \big(\beta_{purchase\ price} \times Purchase\ Price_{BEV} \\ &+ \beta_{running\ cost} \times Running\ Cost_{BEV} + \beta_{range} \times Range_{BEV}\big) \end{aligned}$$

Since the observed attributes of the two powertrains are the same, the purchase price and running costs for both the BEV and ICE are equal. Consequently:

$$ASC_{BEV,correction} = \beta_{range} \times Range_{BEV}$$

In this case, $Range_{BEV}$ is the range that would make the BEV equivalent to the ICE.

The above example can be generalised to say that the $ASC_{i,correction}$ is the utility value of the attributes not considered for the base vehicle (e.g. the ICE) that would make that alternative equivalent to the base vehicle:

$$ASC_{i,correction} = -\sum_{k=1}^{k=M} \beta_k x'_{ik}$$

- j denotes the attributes of alternative i that are not included in the utility equations of all alternatives.
- x' denotes the values of these attributes which make all alternatives identical across their observed attributes.

For the utility equations derived for this study (see section A.12.5) that would be:

$ASC_{PHEV,correction} = -\beta_{range,PHEV} \times Range_{PHEV}$

$$
\begin{aligned}
ASC_{BEV,correction} \\
&= -[f(\beta_{range,BEV}, Range_{BEV}) \\
&+ \beta_{work\ charging,BEV} \times Charging\ Access_{work,BEV} \\
&+ \beta_{public\ charging,BEV} \times Charging\ Access_{public,BEV} \\
&+ \beta_{work\ \&\ public\ charging,BEV} \times Charging\ Access_{work\ \&\ public,BEV} \\
&+ \beta_{rapid\ charging,BEV} \times Charging\ Access_{rapid,BEV} \\
&+ f(\beta_{rapid\ rate,BEV}, Rapid\ Rate_{BEV})]
\end{aligned}
$$

Note that the utility of BEV range and rapid charging rate are expressed as functions because they are non-linear. The attribute values chosen to calculate $ASC_{PHEV,correction}$ and $ASC_{BEV,correction}$ are:

- PHEV range of 0 miles, since its range under fuel power was listed as the same as the ICE alternative in the choice experiment.
- BEV range of 400 miles, which was the range shown for the ICE alternative in the choice experiment.
- No access to work or public charging, since equivalent refuelling while parked at work or in public car parking spaces is not available to ICEs.
- Access to a rapid charging network with coverage the same as current petrol stations. Note that this has the same utility as a network with chargepoints every 20 miles on motorways and major A-roads (see section B.4.8).
- Rapid charging rate of 15 miles per minute charging (approximately 300kW). This is slower than ICE refuelling, but a faster rate was not tested in the choice experiment and the non-linearity identified suggests that the additional utility of even faster charging is small.

Once $ASC_{i,correction}$ has been estimated, $ASC_{i,unobserved}$ is calculated as:

$$ASC_{i,unobserved} = ASC_i - ASC_{i,correction}$$

Figure 102 shows a graphical example of how $ASC_{BEV,unobserved}$ is estimated for the whole sample. $ASC_{BEV,correction}$ is shown as the sum of the dark grey components, for which range is the strongest contributor.

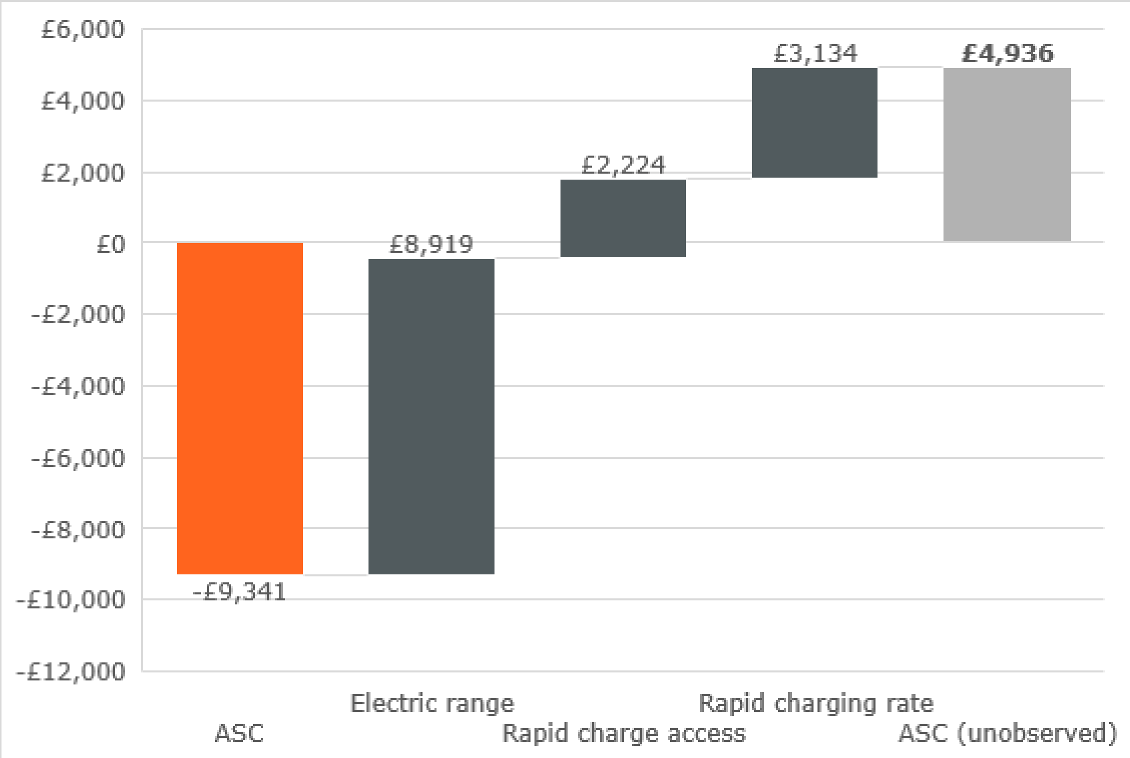

Figure 102: Example waterfall diagram illustrating the derivation of $ASC_{BEV,unobserved}$ for Global Sample, shown in terms of willingness-to-pay

The resulting estimates for the portion of the ASCs accounting for the unobserved factors is shown in Figure 103. This shows that for BEVs, the unobserved factors actually have a strong positive value for all consumer segments. This implies that there is no inherent net negative bias against battery electric technology, i.e. the positive factors strongly outweigh the negative. This is likely to be largely due to the value the participants place in the convenience of being able to charge at home, which offers a significant benefit over ICEs. Were this trial and choice experiment to be carried out with car owners who do not have access to home charging, it is probable that the value of the unobserved factors for BEVs would be lower.

For PHEVs, the value of the unobserved factors is considerably smaller than for BEVs, and none was statistically significant. This supports the hypothesis that the strong positive value for BEVs is largely due to the convenience of charging at home, since PHEVs must also be refuelled at petrol stations.

This analysis suggests that the underlying attitudes towards plug-in vehicle technology are generally positive, but it is important to consider all attributes as a whole, rather than just the unobserved factors, when assessing preferences for PiVs. While the average trial participant might be willing to pay nearly £5,000 more for a BEV compared to an identically specified ICE, it is unlikely that such a BEV would be made available in the short to medium term. By way of example, a medium sized car with a 400-mile range is estimated to need a battery size of ~80 kWh which would add significant cost to the vehicle and easily offsets the perceived £5,000 benefit of owning a BEV. Thus, the overall utility of the BEV may still be lower than that of the ICE. This is illustrated in Figure 104, which shows the total utility for a range of BEVs and PHEVs compared with their equivalent ICEs that are available today, calculated using the coefficients for the whole sample.

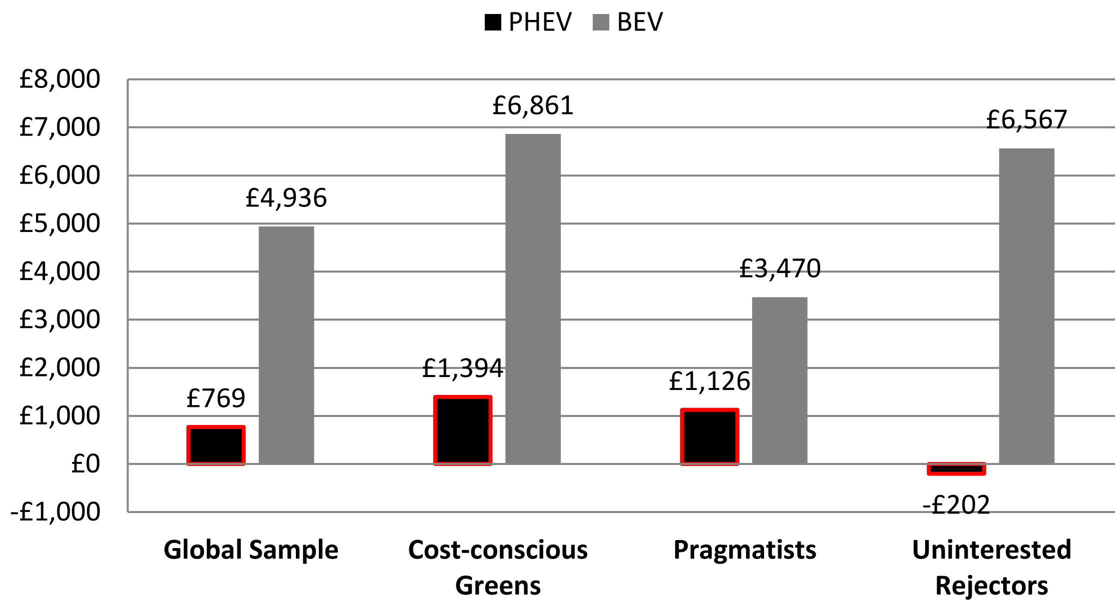

Figure 103: Estimate of $ASC_{i,unobserved}$ for BEVs and PHEVs from the choice experiment, expressed in terms of WTP (red border means the result is not statistically significant)

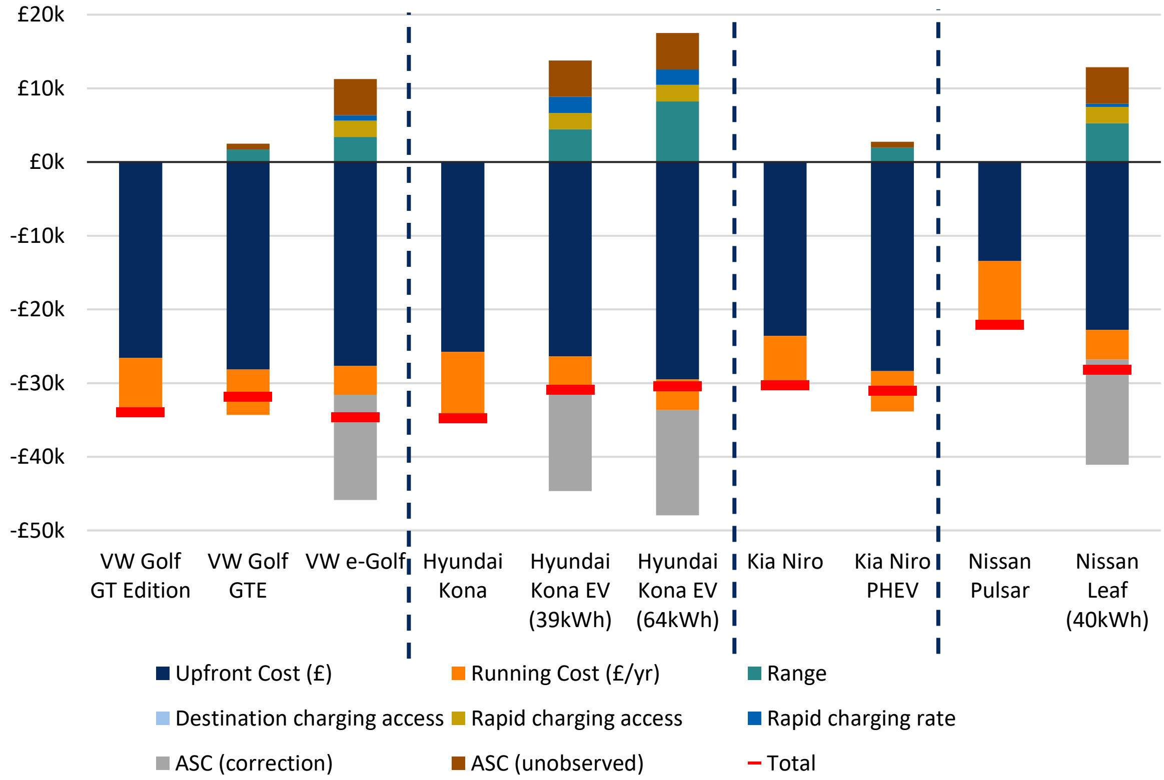

Figure 104: Total utility, expressed as WTP, for the Global Sample for a range of currently available ICE, PHEV and BEV models

In each case the red line denotes total utility, and those that are less negative are considered most valuable (they have the lowest disutility). A comparison of the 39kWh and

64kWh Hyundai Kona EV variants illustrates the trade-off between vehicle purchase price and its other attributes. The 64kWh model has an NEDC range of 339 miles, compared with 214 miles in the 39kWh base model. Despite this, the 64kWh version shows virtually no improvement in utility because it is also £3,000 more expensive. This result also suggests that Hyundai judge that their customers value this additional range at a similar level as has been derived in this study.

The different powertrains in Figure 104 show similar utility, but it is worth noting that these figures include the Government's Plug-in Car Grant which is worth £4,500 for BEVs and £2,500 for PHEVs, and exclude the cost of a home chargepoint. Furthermore, for each vehicle an ICE with a comparable trim level was selected, which in all cases other than the Nissan Leaf was a premium trim. Selling only premium trim variants of plug-in vehicles allows manufacturers to raise profit margins to help cover the higher underlying vehicle cost. The Nissan Leaf demonstrates that when this strategy is not followed then ICE utility is currently significantly greater.

In future, as battery costs decrease, and higher ranges and faster charging rates are made available, PiV utility is expected to increase. Assuming that improvement occurs at a faster rate than that of ICEs, and can compensate for future subsidy reductions (e.g. the removal of the plug-in car grant), the present utility gap between PiVs and ICEs should close. For buyers with access to home charging at least, the sum of the utility from the observed attributes (including $ASC_{BEV,correction}$) for BEVs only needs to be within £5,000 of an equivalent ICE to be competitive.

B.5.2 Comparisons between travel patterns, vehicle usage and performance ratings for each of the three types of vehicle

- → **On average participants made significantly shorter journeys in the BEV than the PHEV**
- → **Mean SOC at the start and end of journeys was higher in the BEV than PHEV**
- → **PHEVs were charged more frequently at home than the BEVs, but mean SOC at start and end of charges was higher in the BEVs.**
- → **Statistically significant differences in driving style metrics were observed between the vehicle types, but the magnitude of the differences was negligible.**
- → **In general, BEVs were rated as more highly performing than PHEVs, and PHEVs were higher performing than ICEs, with the exception of the 'sportiness' rating which was higher for the PHEV and ICE than the BEV.**
- → **Participants rated their charging experiences positively in terms of convenience, safety, and ease of use, with no significant differences between vehicle type.**

B.5.2.1 Travel behaviour and vehicle usage

Using the telematics data, the travel behaviours of participants were compared between the PHEV, BEV and ICE vehicle. For this purpose, composite metrics were generated by aggregating across all journeys per participant and per vehicle, allowing comparison of these composite metrics between vehicle types across the sample. Descriptive statistics for these comparisons are shown in Table 70.

Table 70: Comparison of travel behaviour metrics by vehicle type

Travel pattern	Mean scores			Statistical results	
	BEV	PHEV	ICE	Test value	p-value
Total number of trips	18.81	18.88	18.23	2.45	0.294
Mean trip distance (mi)	7.41	8.45	8.02	6.07	0.048*
Mean trip duration (mins)	17.34	18.20	17.62	4.47	0.107
Mean SOC start of journey (%)	79.78	59.36	-	-10.98	< 0.001*
Mean SOC end of journey (%)	73.41	45.18	-	-2.69	0.007*
Total number of home charge events	3.10	4.45	-	-2.57	0.01*
Total number of public charge events	2.94	2.74	-	-.34	0.731
Mean SOC start of charge (%)	61.59	30.99	-	-10.98	< 0.001*
Mean SOC end of charge (%)	90.87	86.72	-	-2.69	0.007*

In general, the trips made in all three vehicles were similar with the only significant difference being the average trip distance, with participants making shorter journeys in the BEV than in the PHEV (the differences in journey length between the ICE and the two PiVs were small and not significant).

There was a significant difference between most of the charging patterns for the BEV and PHEV. This was as expected due to the different battery sizes and vehicle capabilities of the two vehicles. Participants generally started their journeys with more charge in their BEVs than the PHEVs and also ended their journeys with more change. This was also true for the charging events. Participants tended to charge the PHEV more frequently at home than the BEV; but there was no difference observed between the number of public charge events.

B.5.2.2 Driving style

The following aggregated driving style metrics were generated by calculating the mean values across all journeys per participant and per vehicle:

- Mean % hard acceleration
- Mean % hard braking
- Mean speed (mph)
- Mean maximum speed (mph)

Parametric repeated measures ANOVAs (and post-hoc repeated measures t-tests) were used to identify significant differences in these metrics between the three vehicles; the results of these analyses are summarised in Table 71.

Table 71: Effects of vehicle type on driving style metrics

Metric	Mean values BEV	PHEV	ICE	Significant results from statistical tests
Mean % hard acceleration	16.9%	15.3%	16.3%	Significant main effect (*F* = 12.291, $p < 0.001$) Significantly lower mean % hard acceleration in PHEV compared with BEV (*t* = -4.908, p <0.001) and ICE (*t* = -3.402, $p < 0.001$)
Mean % hard braking	17.7%	18.1%	20.1%	Significant main effect (*F* = -26.534, p <0.001) Significantly higher mean % hard braking in ICE compared with BEV (*t* = -6.554, p <0.001) and PHEV (*t* = -6.106, p <0.001)
Mean speed (mph)	19.95	20.72	20.42	Significant main effect (*F* = -3.228, $p = 0.045$) Significantly higher mean speed in PHEV compared with BEV (*t* =2.964, $p = 0.003$)
Mean maximum speed (mph)	48.14	48.81	47.99	No significant main effect (*F* = 1.726, $p = 0.179$)

As summarised in the table above, statistical analysis revealed some significant differences in the aggregated driving style metrics between the BEV, PHEV and ICE vehicle; however the magnitude of these differences was consistently small. For example, the amount of hard acceleration was significantly lower in the PHEV than the other vehicles, but the largest difference in mean values was only about 1.6%. Likewise there was only a mean difference of just over 2% in the amount of hard braking, and a mean difference of less than 1 mph in terms of mean speed. No significant differences were identified in the mean maximum speeds observed between vehicle types. These findings suggest that, when aggregated at the participant level, driving style observed in the 4-day trial period did not greatly differ between the three types of vehicle.

Self-reported driving style was measured using the Multidimensional Driving Style Inventory (MDSI; Taubman-Ben-Ari, Mikulincer & Gillath, 2004). The MDSI characterises driving style using eight scales: Angry, Anxious, Cautious, Dissociative, Distress Reduction, High Velocity, Patient, and Risky. These can be condensed down into four 'global styles' as shown in Table 72 (Taubman-Ben-Ari & Skvirsky, 2016).

Table 72: MDSI Global Driving Styles

Global style	Inputs (mean values calculated across scores)
Reckless and careless	"Risky" and "high velocity" scores
Anxious	"Dissociative", "Stress reduction" and "Anxious" scores
Angry and hostile	"Angry" score
Patient and careful	"Patient" and "Careful" scores

To examine the extent to which self-reported driving style aligned with actual behaviour observed in the vehicles, correlation analysis was performed between the four global driving style metrics defined above and the driving style metrics obtained from vehicle telematics (Mean % hard acceleration, Mean % hard braking, Mean speed, and Mean maximum speed).Results of this analysis are shown in Table 73.

Table 73: Results from correlation analysis between self-reported driving style (MDSI) and observed driving style metrics (telematics)

Self-reported driving style scores (MDSI)		Aggregated driving style metrics from telematics data											
		BEV - Mean Speed (MPH)	BEV - Max Speed (MPH)	BEV – % Hard Acc	BEV – % Hard Braking	ICE - Mean Speed (MPH)	ICE - Max Speed (MPH)	ICE – % Hard Acc	ICE – % Hard Braking	PHEV - Mean Speed (MPH)	PHEV – Max Speed (MPH)	PHEV – % Hard Acc	PHEV - % Hard Braking
Reckless and careless	Pearson Correlation	0.198**	0.224**	0.168*	0.084	0.071	0.176*	0.082	0.069	0.191**	.214**	-0.006	0.002
	P-value	0.005	0.002	0.019	0.244	0.316	0.013	0.248	0.336	0.007	0.003	0.931	0.976
Anxious	Pearson Correlation	-0.086	-0.177*	-0.185**	-0.152*	-0.050	-0.115	-.241**	-.209**	-0.036	-0.168*	-0.290**	-0.209**
	P-value	0.231	0.013	0.009	0.034	0.484	0.106	0.001	0.003	0.619	0.018	0.000	0.003
Angry and hostile	Pearson Correlation	0.109	0.085	0.158*	0.087	0.022	0.073	0.140*	0.121	0.087	0.100	0.052	0.023
	P-value	0.130	0.237	0.028	0.227	0.761	0.304	0.049	0.089	0.224	0.162	0.471	0.751
Patient and careful	Pearson Correlation	-0.167*	-0.142*	-0.200**	-0.171*	-0.054	-0.106	-0.120	-0.106	-0.133	-.178*	-0.146*	-0.130
	P-value	0.020	0.048	0.005	0.017	0.446	0.135	0.091	0.136	0.062	0.012	0.040	0.069
****. Correlation is significant at the 0.01 level**													
***. Correlation is significant at the 0.05 level**													

In general, the driving style related metrics collected from vehicle telematics show good agreement with the self-reported driving style scores calculated from the MDSI. With the exception of the ICE, the 'Reckless and careless' driving style score was significantly positively correlated with both mean and maximum speed variables, showing a higher score was associated with higher driving speeds, as would be expected from a reckless and careless driving style. Patient and careful driving style scores, on the other hand, were generally significantly negatively correlated with mean and maximum speed, showing, as would be expected, that patient and careful drivers tend to drive at slower speeds. Angry and hostile driving scores showed the fewest significant correlations, but the proportion of hard acceleration in the BEV and ICE showed a positive correlation implying that these types of drivers engaged in more aggressive acceleration. Conversely, the proportion of hard acceleration and hard braking was negatively correlated with Anxious driving style scores; confirming the expectation that these types of drivers are more cautious and engage in more gentle acceleration and braking manoeuvres.

B.5.2.3 Vehicle performance ratings

On the return of each vehicle, the participants were asked to rate the performance of the vehicle experienced. Each participant was asked to rate each of the following performance measures for each vehicle type:

- Acceleration 0-20 mph
- Acceleration 30-50 mph
- Acceleration 50-70 mph
- Responsiveness
- Cruising noise
- Stationary noise
- Sportiness[38]
- Smoothness
- Power
- Safety
- Comfort
- Enjoyment
- Performance

These items cover those aspects of performance identified by Skippon (2014) as the ways in which drivers construe vehicle performance. Top speed was not included because the top speed of all vehicles in the trial substantially exceeds the UK national speed limit, so asking

[38] Sportiness refers to a character of engine noise, low pitched growl rather than high pitched whine (Skippon, 2014).

drivers to evaluate it would not be ethical. Smoothness of gear changes was not included as it is not relevant for the trial PiVs.

Participants were asked to rate each of these performance measures using a Borg CR-10 Category-Ratio 12-point scale ranging from 0-10 (the scale is non-linear and includes 0.5 as a response option). This scale is claimed (Borg, 1998, p39) "to be able to describe a psychophysical stimulus-response function over a wide range of stimulus intensities with a mathematical function that as accurately as possible reflects the genuine growth of the sensory perception", i.e. it is intended to reflect the form of mental "scales" of perceived stimulus intensity better than, say, Likert-type ordinal scales. The scale has a non-linear, positively accelerating growth function for perceived intensity, with verbal anchors ranging from "no (stimulus) at all" up to "extremely high" (the maximum the participant has ever experienced). The CR-10 scale also includes a final category, "maximal (stimulus)".

The ratings for each vehicle type were compared using Friedman repeated measures tests (as each variable did not have a normal distribution) and the results are shown in Table 74.

All comparisons were significant so Wilcoxon tests were used to compare each pair of results to see for example, if BEVs had significantly better ratings for safety than PHEVs.

All of these comparisons were significant (with $p < 0.001$) with the exception of:

- PHEV and BEV for acceleration from 50-70 mph ($p = 0.150$)
- PHEV and ICE for sportiness ($p = 0.340$)
- BEV and ICE for safety ($p = 0.182$)
- BEV and PHEV for safety ($p = 0.129$)
- BEV and PHEV for comfort ($p = 0.719$)
- BEV and PHEV for enjoyment ($p = 0.926$)
- BEV and PHEV for comfort ($p = 0.719$)
- BEV and PHEV for performance ($p = 0.383$)

Table 74: Vehicle performance comparison results

Performance measure	Mean score			Chi-squared value	p value
	BEV	PHEV	ICE		
Acceleration 0-20	9.21	8.40	7.02	119.09	< 0.001
Acceleration 30-50	8.67	8.16	6.97	119.57	< 0.001
Acceleration 50-70	8.17	7.95	7.09	58.40	< 0.001
Responsiveness	9.21	8.44	6.97	108.98	< 0.001
Cruising noise	3.49	4.23	4.95	97.44	< 0.001
Stationary noise	2.45	2.90	3.69	111.82	< 0.001
Sportiness	3.05	5.69	5.45	138.10	< 0.001
Smoothness	9.64	8.88	8.08	81.21	< 0.001
Power	8.81	8.49	7.30	86.15	< 0.001
Safety	9.29	9.51	9.09	10.49	0.005

Comfort	9.38	9.32	8.74	24.09	< 0.001
Enjoyment	9.02	9.01	7.59	54.40	< 0.001
Performance	9.20	9.04	7.86	61.54	< 0.001

In general, BEVs were rated as being better on these measures than PHEVs, and PHEVs better than ICEs. For the noise measures (cruising and stationary), the results are in the opposite direction. This result is likely to be due to participants misinterpreting the questions and rating 'noise level' instead of 'noise performance'. Another measure with a different relationship between the vehicle types was sportiness. Both PHEV and ICE were rated as significantly better than the BEV. The only significant difference for safety was between the PHEV and ICE where the PHEV had a significantly higher rating than the ICE.

The results for the three largest segments were also compared for each of the performance measures. The only significant differences between the segments were for the following performance measures:

- PHEV acceleration from 0-20 mph (Z = 9.19, p = 0.010)
- PHEV driving smoothness (Z = 8.06, p = 0.018)
- PHEV responsiveness (Z = 7.34, p = 0.026)

Post-hoc tests showed that Uninterested Rejecters gave significantly lower ratings for acceleration from 0-20 mph than Pragmatists (Z = -2.64, p = 0.008) and Cost-conscious Greens (Z = -2.48, p = 0.013). A similar result was seen for the ratings of PHEV respondents with Uninterested Rejecters giving significantly lower ratings than Cost-conscious Greens and Pragmatists (Z = -2.73, p = 0.006; Z = -1.99, p = 0.047). However, for driving smoothness, Uninterested Rejecters only had significantly lower rating than Cost-conscious Greens (Z = -3.01, p = 0.002).

This result suggested that potentially Pragmatists and Cost-conscious Greens ratings were impacted by the driving modes they were choosing to use and were using the PHEV in the electric mode more often than Uninterested Rejecters. This hypothesis was tested using the telematics data for the mean percentage of each journey completed using the electric battery. However, there were no significant differences between the segments to support this theory. The results were also compared between the group of participants who said they were likely to consider buying a BEV or PHEV as a main or second car (see Table 75 for significant differences). The enjoyment rating and overall performance rating were consistently significantly higher for people who would consider purchasing a PiV.

Table 75: Vehicle performance comparison results – Willingness to adopt

Comparison	Performance measure	Mean score: Not likely to buy	Mean score: Likely to buy	Z score	p value
BEV (main car)	Acceleration 0-20	9.26	9.94	-2.17	0.030
	Responsiveness	9.29	10.06	-2.70	0.007
	Comfort	9.39	10.29	-3.00	0.003
	Enjoyment	8.75	10.49	-4.43	0.001
	Performance	9.19	10.17	-3.36	0.001
BEV (second car)	Enjoyment	8.56	9.84	-2.69	0.010
	Performance	9.02	9.84	-2.27	0.023
PHEV (main car)	Power	8.11	8.80	-2.71	0.007
	Enjoyment	8.05	9.54	-3.54	< 0.001
	Performance	8.22	9.43	-3.41	0.001
PHEV (second car)	Enjoyment	8.18	9.53	-2.27	0.024
	Performance	8.35	9.41	-1.98	0.048

B.5.2.4 *Home and public charging experience*

Following experience with each PiV, participants were asked about their experience with charging the vehicle at home and at public places (in the Interim questionnaires). Less than 5% of participants reported that they forgot to charge their vehicle during the trial.

The reported number of charges undertaken by participants during the trial is shown in Table 76. The average number of home and public charge events recorded via vehicle telematics was 3.1 and 2.9 for the BEV, and 4.5 and 2.7 for the PHEV, respectively (see section B.5.2.1).

Table 76: Proportion of participants by number and type of reported charges undertaken during the trial

Number of charges	BEV			PHEV		
	Home	**Work, family or friends**	**Other location**	**Home**	**Work, family or friends**	**Other location**
0	<1%	31%	<1%	<1%	32%	<1%
1	55%	5%	55%	6%	4%	6%
2	17%	56%	17%	64%	5%	64%
3	14%	3%	14%	13%	55%	13%
4	10%	3%	10%	11%	4%	11%
5+	4%	1%	4%	6%	1%	6%

Ratings of convenience, safety and ease of use were gathered using 10-point scales ranging from 1 (very inconvenient / very difficult / very unsafe) to 10 (very convenient / very easy / very safe). As can be seen by the mean scores in Table 77, in general, participants rated their charging experiences positively in terms of convenience, safety, and ease of use. There were no significant differences in ratings between the BEV and PHEV ($p > 0.05$).

Table 77: Mean ratings of convenience, safety and ease of use when charging at home and at public chargepoints (1=low rating, 10= high rating)

Measure	Mean ratings	
	BEV	PHEV
Convenience of charging at home	7.2	7.5
Convenience of charging in public	6.7	7.6
Safety of plugging in vehicle at home	9.0	9.1
Safety of unplugging vehicle at home	9.0	9.0
Safety of plugging in at public charge point	8.5	8.7
Safety of unplugging at public charge point	8.7	8.7
Ease of plugging in vehicle at home	8.8	8.9
Ease of unplugging vehicle at home	8.8	8.9
Ease of plugging in at public charge point	8.0	8.1
Ease of unplugging at public charge point	8.4	8.5

B.5.3 Relationship between vehicle use and likelihood to purchase

→ **There were very few significant and strong correlational relationships suggesting no robust predictive relationship between aggregated vehicle use data for each participant and their reported likelihood to purchase.**

The relationship between vehicle use and reported likelihood to purchase a BEV or PHEV was investigated to examine whether the regression models detailed in section B.4.6 and B.4.7 could be supplemented by additional predictor variables related to vehicle usage patterns. Aggregated metrics were generated by calculating the mean values from variables across all journeys per participant and per vehicle. The variables are shown in Table 78.

Table 78: Journey and charge variables used to calculate aggregated metrics per participant and per vehicle

Journey variables	Charge variables
Mean speed (mph)	Number of charge events
Maximum speed (mph)	Charge Start Time (hh:mm)
Fuel consumption (mpg)	Charge duration (mins)
Electricity consumption (kWh)	Maximum charge duration (mins)
EV Fraction	SOC at charge start (%)
Journey distance (mi)	SOC at charge end (%)
Total distance for all journeys (mi)	Distance from home during charge (km)
Journey duration (mins)	Maximum distance from home during charge (km)
Total duration for all journeys (mins)	
SOC at journey start (%)	
SOC at journey end (%)	
% Hard acceleration	
% Hard braking	

Spearman correlation coefficients were calculated between each of the metrics listed in Table 78 and the four outcome variables related to likelihood to purchase a BEV or PHEV as a main and second car. Only four statistically significant correlations were identified; these are shown in Table 79.

Table 79: Statistically significant results from correlation analyses between aggregated telematics variables and likelihood to purchase variables

Variables	Correlation coefficient	p-value
Total trip duration (PHEV) + Likelihood to purchase PHEV as second car	0.173	0.035
Mean SOC at journey start (PHEV) + Likelihood to purchase BEV as main car	0.158	0.026
Mean SOC at journey start (PHEV) + Likelihood to purchase BEV as main car	0.165	0.020
Mean charge start time (BEV) + Likelihood to purchase PHEV as main car	0.143	0.046

As can be seen from these results, all correlation coefficients were significant but small, suggesting only weak relationships between the pairs of variables identified. Further, three of the four significant correlations were between one PHEV-related variable and one BEV-related variable, reducing the likelihood that the correlation represents a meaningful relationship between journey patterns and consumers' purchasing intentions.

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