Uptake of Ultra Low Emission Vehicles in the UK

A Rapid Evidence Assessment for the Department for Transport

August 2015

Office for Low Emission Vehicles

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Acronyms used in report

AFV	Alternative Fuel Vehicle
BEV	Battery Electric Vehicle
DC	Direct Current
DfT	Department for Transport
EV	Electric Vehicle
HOV	High Occupancy Vehicle
ICE	Internal Combustion Engine
NTS	National Travel Survey
OLEV	Office of Low Emission Vehicles
PHEV	Plug-in Hybrid Electric Vehicle
PiCG	Plug-in Car Grant
PiP	Plugged-in Places
SMMT	Society of Motor Manufacturers and Traders
TCO	Total Cost of Ownership
ULEV	Ultra Low Emission Vehicle

The terms “Electric Vehicle” and “EV” are used in this report to refer generically to both BEVs and PHEVs in instances where no distinction is being made between the two.

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Executive Summary

Introduction

- This report presents the findings from a rapid evidence assessment undertaken to review recent research on the uptake of ultra low emission vehicles (ULEVs) relevant to the UK.
- The Government aspires that by 2040 every new car in the UK will be a ULEV and is facilitating this through a range of measures including financial support to help consumers meet the upfront purchase costs of ULEVs, through the Plug-in Car Grant, and investment in a national charge point network.
- The objectives of the rapid evidence assessment were to review recent UK and international evidence in the following areas:
  - the characteristics of current and future ULEV owners
  - how ULEVs are being used and experienced
  - the impact of public incentives and other key motivators and barriers to uptake of ULEVs
  - current and future infrastructure provision for ULEVs
- The methodology followed Government Social Research guidance on the conduct of rapid evidence assessments. 295 UK and international evidence sources were initially identified and assessed, then 45 of these were reviewed and analysed in detail.
- Overall, there are still significant gaps and limitations in the evidence base on ULEVs but also some new sources of evidence from countries with more developed ULEV markets, and opportunities for future research.

The ULEV market in the UK

- The ULEV market in the UK has recently undergone a significant expansion, and in the last quarter of 2014 and first quarter of 2015 they represented over 1% of new car sales for the first time.
- PHEVs currently account for around two-thirds of ULEVs being sold in the UK, and BEVs a third.
- ULEVs represented a similar proportion of new car sales in the UK in 2014 as they did in the US, France and Germany, while California (3.2%) and Norway (17.8%) had two of the largest EV market shares globally.

Current and future ULEV owners

- Most private EV owners are currently middle-aged, male, well-educated, affluent, and live in urban areas with households containing two or more cars and with the ability to charge at home.
- Looking ahead to the next 3-5 years, and based on insights from more developed EV markets, the basic socio-demographic profile of EV owners in the UK is not likely to change significantly.
- The evidence suggests more people in this same demographic are going to start buying EVs, and some people with similar demographics are likely to start buying them too.
- Identifying specific segments of future EV owners, who can be characterised in terms of their attitudes as well as their demographics, is more challenging and no evidence identified in this rapid

evidence assessment provides an off-the-shelf model.

- Based on the available evidence there are likely to distinct segments of future EV purchasers in the UK, all sharing similar demographics, but characterised by either strong pro-environmental attitudes, the desire to save money on fuel costs or an active interest in new technology.

- Most fleet EV owners are currently private sector businesses, working in a range of industries, with fewer than 500 employees and a small-medium sized fleet.

- The identity of fleet EV purchasers in the next 3-5 years is uncertain, and there is little evidence on which to base future projections. Many organisations appear to have initially bought one or a small number of EVs in order to assess their suitability for their wider fleet.

- Private sector businesses are expected to continue to represent the bulk of future EV fleet owners but further research is needed into: the extent to which an initial EV purchase is leading on to large-scale purchasing; and the potential for more organisations with larger fleets to start buying EVs.

Usage and experiences of ULEVs

- EVs are typically being used as the "main car" in private owner's household, relied on for the majority of day-to-day journeys to work, education and other local destinations. Other cars in the household are typically being used for infrequent, longer journeys.

- Despite early predictions that EVs would only be driven for low mileages, recent research in the UK and other countries indicates privately owned EVs are being driven for comparable mileages to ICE cars.

- Private owners charge their EVs primarily overnight at home and currently have a strong preference for doing this rather than using public or workplace charging.

- Most private owners are satisfied with their EV and positive about buying another in the future. This appears to be underpinned by EVs' performance, comfort, low fuel costs, and the ease and convenience of home charging.

- Range is still the greatest perceived downside of EVs for private owners, but this needs to be seen in the context of the overall high levels of satisfaction with the EV ownership experience.

- Evidence on how EVs are being used by fleet purchasers is more limited but what there is suggests they are being regularly used, driven for high mileages and, when being used as a pool car, charged mainly at the workplace.

- Fleet purchasers are generally positive about the experience of using EVs but, for some, EVs aren't seen to offer the flexibility necessary to meet their needs and not all may be willing to proactively change their operations in order to incorporate them.

Impacts of public incentives

- Separating out and accurately quantifying the impact of public incentives is not currently possible, and is always likely to prove challenging.

- Private and fleet EV owners in the UK indicate the PiCG was important in reducing the upfront costs of EVs, and in the case of some fleet owners, the additional benefits they can qualify for has been an active motivation for them to buy an EV.

- International comparisons suggest a positive relationship between financial incentives and EV uptake but there are confounding examples (of countries with high incentives but low EV uptake) to this.
- Other factors, notably measures which accrue ongoing benefits to EV owners during ownership have been found to mediate the relationship between financial incentives and EV uptake.
- Features of financial incentives themselves (other than how big they are) can also play significant roles in mediating their impact on EV uptake, including when incentives are introduced, levels of incentives for different types of EV and different types of purchaser, and whether incentives extend to leasing EVs.
- The evidence also suggests that a package of well-designed financial incentives plus non-financial incentives (and possibly also investment in public charging) may be the most effective means of increasing EV uptake.
- There is insufficient evidence to date to draw any firm conclusions about the impacts of reducing or withdrawing incentives on EV uptake. The one precedent for this in the Netherlands suggests that withdrawing incentives when an EV market is still in the early stages of developing and price differentials between EVs and ICEs are still significant is highly likely to have a negative effect on this development.

Other key motivations and barriers

- The most important factors that private and fleet car buyers take into consideration when choosing a new car are costs – both purchase price and running costs – as well as size, style, reliability, comfort, engine power, design and safety.
- Private EV owners most commonly cite the following motivations for buying an EV: saving money on fuel costs; environmental factors; and interest in new technology.
- The most commonly cited barriers to private car buyers buying an EV in the future are: range concerns; purchase price; and a lack of knowledge about/familiarity with EVs.
- The most commonly cited motivations for buying an EV for fleet purchasers are: financial factors; and environmental factors (linked to CSR).
- The most commonly cited barriers to fleet purchasers are largely the same as those for private car buyers: range concerns; purchase price; and a lack of knowledge about/familiarity with EVs.

Current and planned infrastructure provision

- Public charging provision is seen to have two overlapping but different roles: meeting the needs of existing owners and addressing the concerns of potential future EV owners about buying an EV.
- Existing EV owners rely mostly on home and workplace charging but consistently report a desire for more extensive – and fast – public charging to enable them to undertake longer journeys.
- The evidence also suggests that additional public charging infrastructure can help to address the range concerns of potential future EV owners and increase EV uptake.
- Current public charging provision in the UK is comparable, even favourable in certain respects, to provision in countries with more developed EV markets.
- But additional evidence is needed in order to address key questions about how much more public

infrastructure will be needed in the future in the UK and where this new infrastructure should be in order to maximise its impact.

Implications and priorities for future research

- More up-to-date evidence is needed on the characteristics, behaviours and attitudes of current EV owners in the UK. In order to keep pace with the rapid development of the market and inform future policy making aimed at supporting the growth of the EV market in the UK, evidence on EV owners should ideally be collected on a continuous or semi-regular basis.

- Representing fleet owners and users should be a priority for future research in order to address the many existing gaps in the evidence on their characteristics, attitudes and usage of EVs. This would help to assess the effectiveness of incentives and other policy measures targeted at fleet owners and inform their future design.

- Additional research is needed to understand the differences between BEVs and PHEVs - in terms of who buys them, how they are used and experienced - in order to help to inform future infrastructure provision.

- Other priorities and opportunities for future research include:
    - research to better characterise different segments of current EV owners
    - collecting additional insight into the role of diffusion in the uptake of EVs
    - research into the nature and extent of longer-term EV ownership issues, such as battery life, maintenance and resale value
    - choice experiments or local trials to test how new car buyers would respond to different packages of financial and non-financial incentives
    - further analysis of charge point utilisation rates in different types of geographical setting

1 Introduction

- This report presents the findings from a rapid evidence assessment undertaken to review recent research on the uptake of ultra low emission vehicles (ULEVs) in the UK.
- The Government aspires that by 2040 every new car in the UK will be a ULEV and is facilitating this through a range of measures including financial support to help consumers meet the upfront purchase costs of ULEVs, through the Plug-in Car Grant, and investment in the creation of a national charge point network.
- The objectives of the rapid evidence assessment were to review recent UK and international evidence in the following areas:
  - the characteristics of current and future ULEV owners
  - how ULEVs are being used and experienced
  - the impact of public incentives and other key motivators and barriers to uptake of ULEVs
  - current and future infrastructure provision for ULEVs
- The methodology followed Government Social Research guidance on the conduct of rapid evidence assessments. 295 UK and international evidence sources were initially identified and assessed, then 45 of these were reviewed and analysed in detail.
- Overall, there are still significant gaps and limitations in the evidence base on ULEVs but also some new sources of evidence from countries with more developed ULEV markets, and opportunities for future research.

1.1 Background and Aims

This report presents the findings from a rapid evidence assessment undertaken to review recent research on the uptake of ultra low emission vehicles (ULEVs) in the UK. The Government aspires that by 2040, every new car in the UK will be ULEV. In July 2013, £500m funding was allocated to support the uptake of ULEVs from 2015 to 2020. Current support to facilitate this includes:

- **The Plug-in Car Grant.** This was introduced in 2011 to reduce the up-front cost of ULEVs by providing a 25% grant towards the cost of new plug-in cars, up to a maximum of £5,000. From 1st April 2015, the grant was raised to cover up to 35% of the vehicle's recommended retail price, meaning buyers of cheaper EVs can still qualify for the maximum of £5,000[1].
- **The Electric Vehicle Homecharge scheme.** This was introduced in 2013 (initially as the Domestic Chargepoint Grant) to enable ULEV owners to receive a grant towards the installation of a domestic charge point. Owners can currently receive a 75% grant of up to £700 towards these costs.
- **The Go Ultra Low consumer campaign.** This was introduced in 2014 to promote ULEVs and provide an online one-stop-shop for information about owning and running them, the makes and models

[1] The criteria for the plug-in car grant were also updated from 1st April 2015. ULEVs must now meet criteria in one of the following categories: 1. CO2 emissions of less than 50g/km and a zero emission range of at least 70 miles; 2. CO2 emissions of less than 50g/km and a zero emission range between 10 to 69 miles; 3. CO2 emissions of 50-75g/km and a zero emission range of at least 20 miles.

available and the locations of public charge points. It is being delivered in partnership by the Government and ULEV manufacturers.

The Government has also previously supported the installation of public charging infrastructure through the **Plugged-in Places scheme**, 2011-2014, and recently committed a further £32m towards the installation of national rapid charge point network between 2015 and 2020. Further details of Government support can be found here: www.gov.uk/government/publications/ultra-low-emission-vehicles-in-the-uk-measures-to-support-use-and-development-2015-to-2020

The purpose of this rapid evidence assessment was to identify, review and report the findings from recent evidence on the uptake of ULEVs in the UK and other comparable car markets, with the ultimate objective of informing the design and delivery of future Government support. The specific research questions the rapid evidence assessment sought to address were:

- **What are the characteristics of current and future ULEV owners?**
- **How do current owners experience and use ULEVs?**
- **What is the impact of public incentives on ULEV markets?**
- **What are other key motivators and barriers and to what extent do they influence purchase behaviour?**
- **To what extent is current and planned infrastructure provision sufficient to support the use of ULEVs?**

An additional overarching objective was to identify key gaps in the existing evidence-base and suggest priorities for future research in this area by Government and others.

1.2 Scope

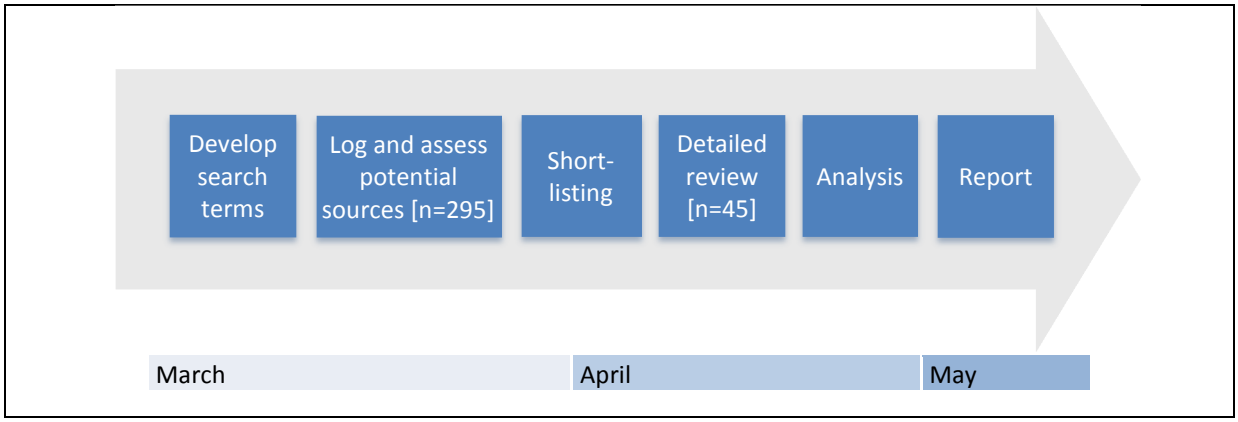
The evidence base on ULEVs is extensive (at least in terms of quantity) and rapid evidence assessments, by definition, are not intended to systematically review all available evidence on a given subject. In order to focus the rapid evidence assessment on evidence most able to provide new insights, only sources published in 2011 or later were considered. Evidence on PHEVs and BEVs was included but evidence on other alternatively fuelled vehicles was excluded. Evidence on electric vans, lorries and other heavy goods vehicles was deemed to be out of scope. Evidence on both private and business/fleet purchasers was deemed to be in-scope.

1.3 Methodology

The rapid evidence assessment was undertaken by researchers at Brook Lyndhurst with input from academic staff at the Centre for Transport Studies (Aberdeen University) and the Centre for Transport and Society (University of the West of England). The methodology followed Government Social Research guidance on the conduct of rapid evidence assessments[2], with some tailoring to reflect the specific requirements of the research. Search terms were developed and used to identify potential evidence sources, using commercial and academic search engines, and additional potential sources were identified by members of the research team, academic staff and DfT. This generated a long-list of 295 sources which were logged and assessed in terms of their relevance to the research questions and methodological strength. A shortlist of 39 sources was then agreed with DfT, and six further sources were subsequently identified and added during the later phases.

[2] http://www.civilservice.gov.uk/networks/gsr/resources-and-guidance/rapid-evidence-assessment

Figure 1. Rapid Evidence Assessment phases

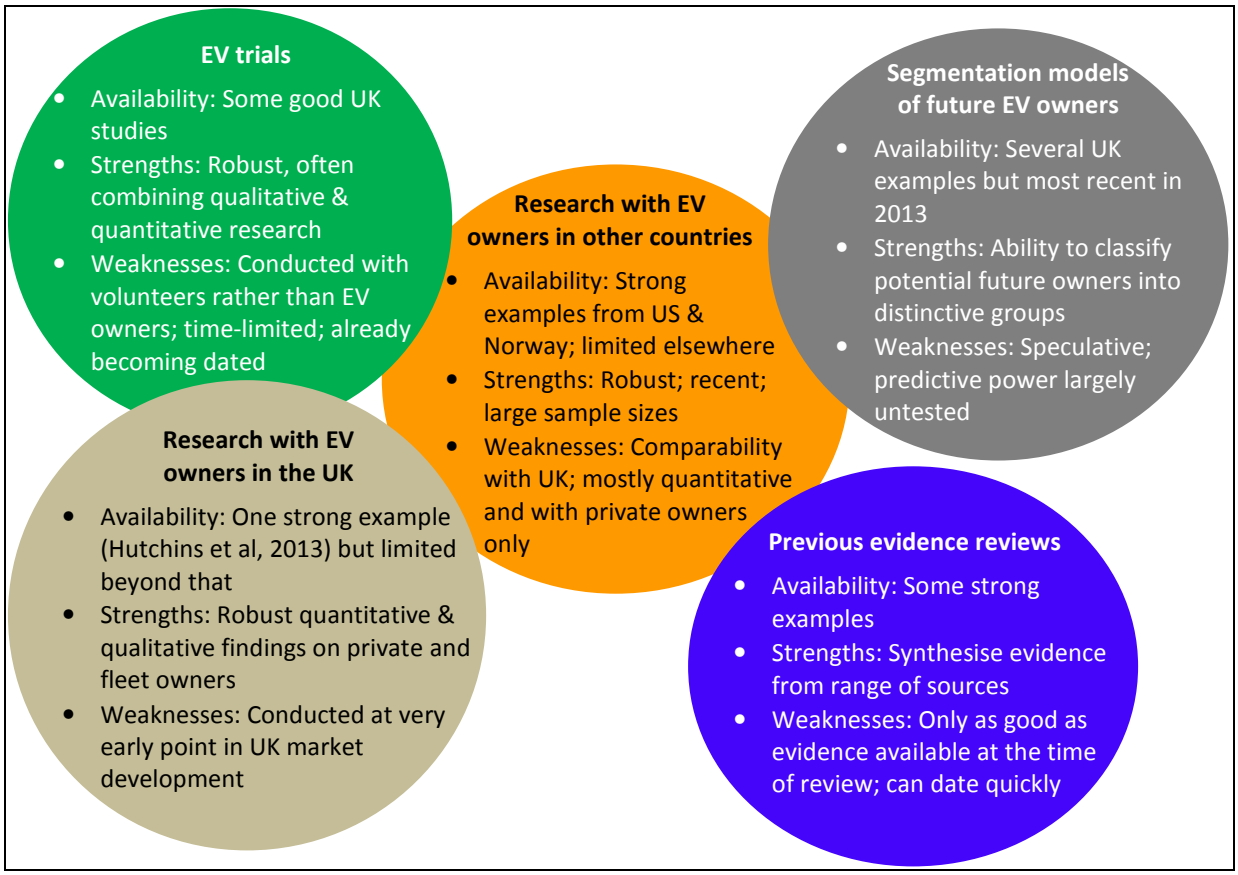


Shortlisted sources were reviewed in detail, and relevant findings summarised in an analytical database. The analysis and report phases combined individual analysis by members of the research team with an initial internal analytical workshop and a further workshop with OLEV and DfT to discuss the findings.

1.4 Evidence coverage and quality

Different types of evidence were reviewed in the rapid evidence assessment, each with variable levels of availability and certain strengths and weaknesses, summarised below.

Figure 2. Types of evidence sources reviewed



Overall, there are some significant gaps and limitations in the current evidence base, not least because of the challenges of carrying out research into what is a rapidly changing and evolving phenomena. In a recent

systematic evidence review concerning the UK EV market (Anable et al, 2014) the following observations were made by the authors:

- "Altogether the literature is not sufficient to provide an overall understanding of consumer wants, needs and perceptions"
- "Attempts to segment customers with respect to EV uptake have largely been restricted to the crude early adopter/early majority model"
- "There is very little evidence regarding the decision making processes of public and private fleet buyers"
- "Evidence on the role of policy interventions is fragmented"
- "There is little consensus in the literature on either the potential efficacy of fiscal instruments to incentivise the uptake of EVs, or their most effective design."

This rapid evidence assessment encountered similar limitations, particularly with respect to the shortfall of evidence on fleet owners and users, the speculative nature of research to segment future EV owners, and the difficulties of delineating the impact of financial and non-financial policy interventions. There is also a real lack of insight into how attitudes, usage, and the impact of policy interventions compares between BEVs and PHEVs. However, some new sources and opportunities for future research were also identified, in the form of evidence from EV owners in some countries with more developed markets and the increasing availability of charge point data in the UK and elsewhere. These challenges and opportunities are returned to in the final chapter of the report.

1.5 Structure of report

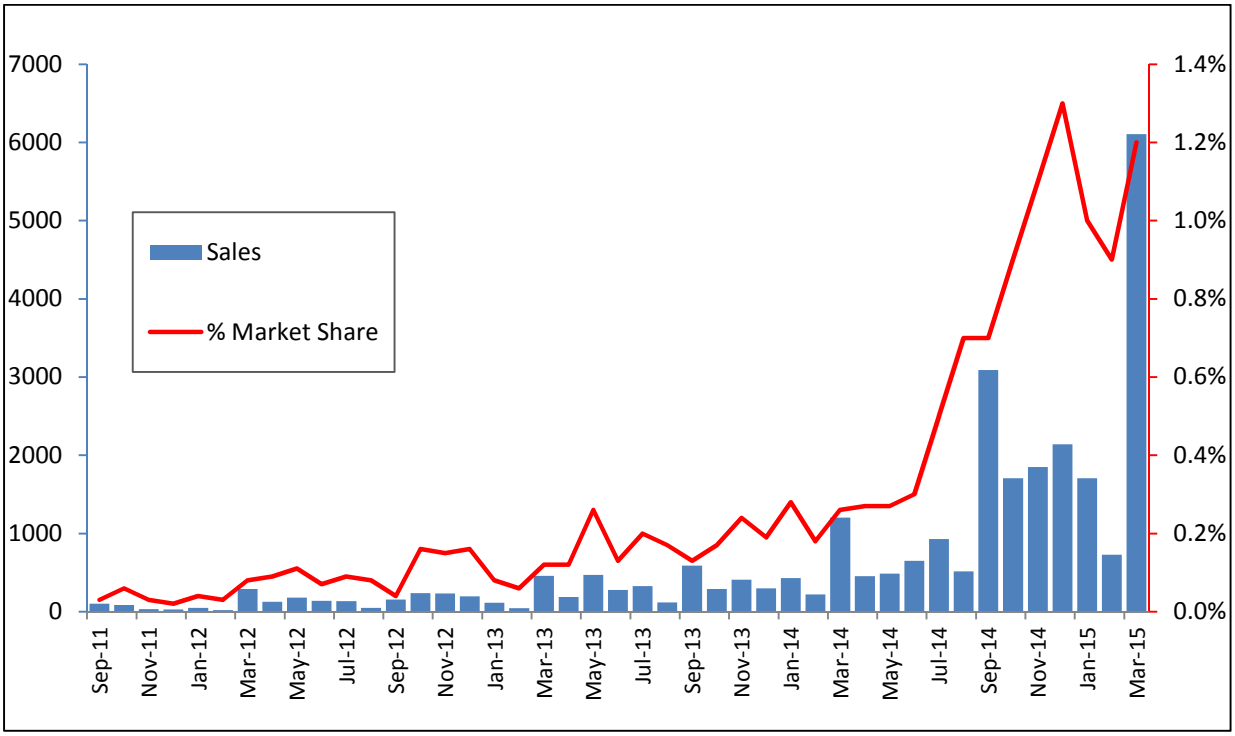
The next chapter provides a brief contextual overview of the current ULEV market in the UK and how it compares to markets in the other selected countries. Chapters three to seven then present evidence for each of the research questions listed in section 1.1. Chapter eight discusses what conclusions can be drawn from the preceding evidence and opportunities for future research to add to the existing evidence base.

2 The ULEV market in the UK

- The ULEV market in the UK has recently undergone a significant expansion, and in the last quarter of 2014 and first quarter of 2015 they represented over 1% of new car sales for the first time.
- PHEVs currently account for around two-thirds of ULEVs being sold in the UK, and BEVs a third.
- ULEVs represented a similar proportion of new car sales in the UK in 2014 as they did in the US, France and Germany, while California (3.2%) and Norway (17.8%) had two of the largest EV market shares globally.

The EV market in the UK has recently undergone a significant expansion, both in terms of the number of EVs being sold and the proportion of all new car sales they now represent. Prior to the fourth quarter of 2014 EVs had a market share of around 0.3% but there was a spike in EV sales in this quarter and based on sales in January, February and March 2015 EVs had a market share of over 1% of new car sales.

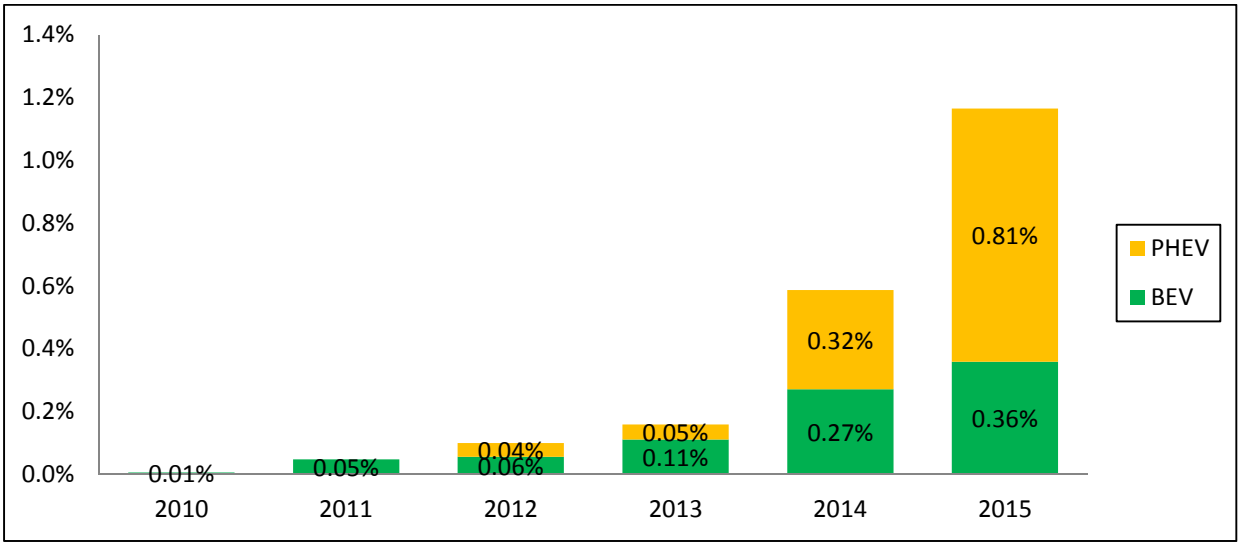
Figure 3. Sales and Market Share of ULEVs in the UK over time



source: SMMT 2011-2015

The majority of EVs sold in the UK up to 2014 were BEVs, which is likely to partly reflect the later emergence of PHEVs onto the market. In 2014, BEVs and PHEVs had a roughly equal share of sales. In January, February and March 2015, BEVs have accounted for a quarter of EV sales and PHEVs three-quarters.

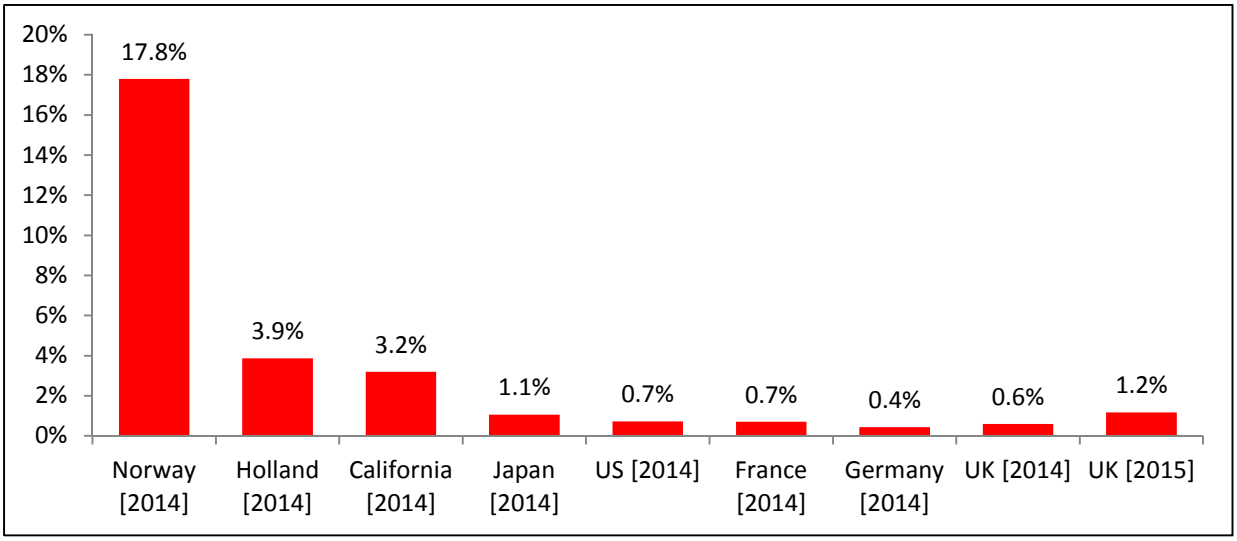
Figure 4. Market Share of BEVs and PHEVs in the UK over time



source: SMMT 2010-2015

In 2014, the UK EV market share was comparable to that in the US, France and Germany. Although the recent growth in EV sales means that the UK may have edged ahead in 2015 (equivalent EV sales in the first three months of 2015 could not be found for all these countries) it is still some way behind the most advanced EV markets globally.

Figure 5. Market share of ULEVs in the UK and other selected countries (2014/15)



sources: various

Norway, the Netherlands and the US state of California had the largest EV market share in 2014. Robust research with sample sizes of over 1,000 current EV owners has also been carried out in Norway and California in recent years[3]. Comparing evidence from these markets with the UK is challenging because of the various cultural, political and structural differences that are likely to have mediated EV uptake in each.

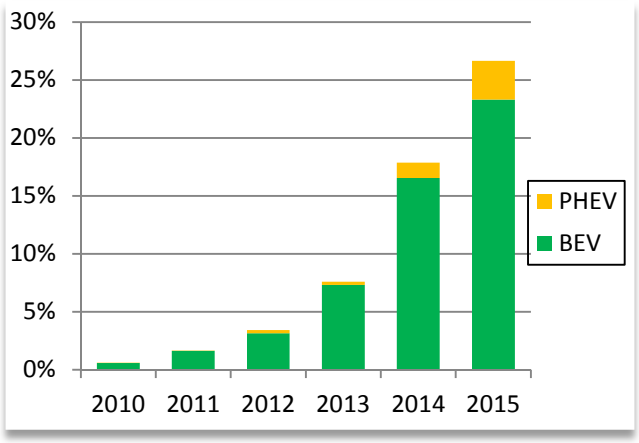
[3] Equivalent research in the Netherlands was not identified in this rapid evidence assessment.

However they do offer potential insights into how the EV market in the UK may develop over the next few years, and how EVs are being used and experienced by large numbers of current owners. On that basis, evidence from Norwegian and Californian sources is drawn and highlighted at various points in this report. In order to enable readers to make their own assessment as to the relevance of this evidence to the UK EV market, brief descriptions of the EV market in each are provided below.

Norway

- Small car market [144,000 new car sales in 2014]
- 2% EV market share in 2011; 18% in 2014
- Mostly BEVs
- Financial incentives: VAT, registration tax and toll road exemption; reduced annual vehicle licence fee
- Non-financial incentives: bus lane access and free parking
- 8,803 public charging points

Figure 6. Market share of EVs in Norway over time

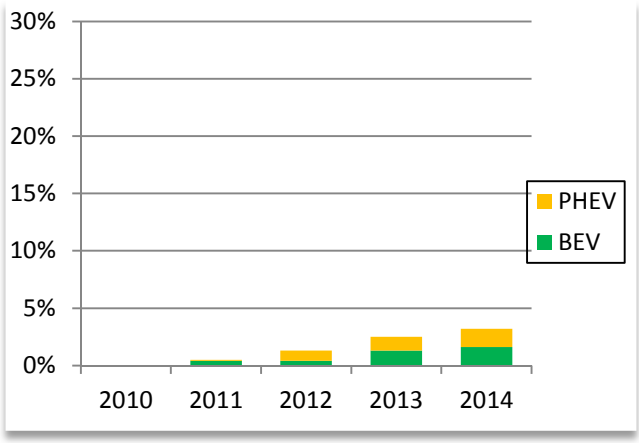


source: Grønn Bil, 2015

California

- Large car market [1 million new car sales in 2014]
- 1% EV market share in 2011; 3% in 2014
- Equal split of BEVs and PHEVs
- Financial incentives: $7,500 federal and $2,500 state rebate
- Non-financial incentives: High Occupancy Vehicle (HOV) lane access
- Regulations that require car manufactures sell a set number of EVs each year
- 6,702 public charging points

Figure 7. Market share of EVs in California over time



source: California Auto Outlook, 2015

The following chapters in the report include some more detailed information about the characteristics of EV owners in Norway and California and the provision of incentives and public charging infrastructure in each.

3 Current and future ULEV owners

- Most private EV owners are currently middle-aged, male, well-educated, affluent, and live in urban areas with households containing two or more cars and with the ability to charge at home.
- Looking ahead to the next 3-5 years, and based on insights from more developed EV markets, the basic socio-demographic profile of EV owners in the UK is not likely to change significantly.
- The evidence suggests more people in this same demographic are going to start buying EVs, and some people with similar demographics are likely to start buying them too.
- Identifying specific segments of future EV owners, who can be characterised in terms of their attitudes as well as their demographics, is more challenging and no evidence identified in this rapid evidence assessment provides an off-the-shelf model.
- Based on the available evidence there are likely to distinct segments of future EV purchasers in the UK, all sharing similar demographics, but characterised by either strong pro-environmental attitudes, the desire to save money on fuel costs or an active interest in new technology.
- Most fleet EV owners are currently private sector businesses, working in a range of industries, with fewer than 500 employees, and a small-medium sized fleet.
- The identity of fleet EV purchasers in the next 3-5 years is uncertain, and there is little evidence on which to base future projections. Many organisations appear to have initially bought one or a small number of EVs in order to assess their suitability for their wider fleet.
- Private sector businesses are expected to continue to represent the bulk of future EV fleet owners but further research is needed into: the extent to which an initial EV purchase is leading on to large-scale purchasing; and the potential for more organisations with larger fleets to start buying EVs.

This chapter presents evidence on the characteristics of current and future ULEV owners, broken down into private owners and business/fleet owners. In terms of future owners, the focus was on who these may be in the next 3-5 years rather than in 10, 20 or 30 years' time.

3.1 Private owners

3.1.1. Socio-demographic characteristics of current EV owners

The single most definitive source of evidence on the characteristics of EV owners in the UK is research with PiCG recipients undertaken for DfT in 2013. Although the research was undertaken at an early point in the development of the EV market in the UK (only 0.16% of new cars sales in 2013 were EVs) and had a modest sample size (n=192), the findings are the richest of any data source relating to UK EV owners and are drawn on extensively in this section, alongside evidence from research with EV owners in other comparator countries. No more recent research with UK EV owners was identified in this rapid evidence assessment. The following table summarises relevant evidence from the PiCG research and international sources.

Figure 8. Socio-demographic characteristics of current EV owners

Characteristic	UK Evidence (Hutchins et al, 2013)	Other Evidence (various)
Age	7% age 21-39 23% age 40-49 29% age 50-59 23% age 60-69 17% age 70+ 1% N/A	75% of EV owners in California are aged 35-64 (Center for Sustainable Energy, 2015). 82% of EV owners in Norway are aged 35-66 and their average age is 47. (Figenbaum et al, 2014)
Gender	89% male 11% female	The majority of EV owners in the Netherlands, Norway and California are male (Velthuis, 2012, 2014; Figenbaum et al, 2014; Center for Sustainable Energy, 2015)
Income	This was not asked in the survey, but 72% of respondents were identified as being in the DfT segment "Educated suburban families". The majority of this segment has an annual income of £35,000+ and for over a quarter it is £60,000+.[4]	75% of EV owners in California have an annual household income of over $100,000[5] (Center for Sustainable Energy, 2015). 81% of EV owners in Norway have an annual household income of over 600,000 kroner[6] (Figenbaum et al, 2014).
Education	69% had degree or diploma	89% of current EV owners in California (Center for Sustainable Energy, 2015) have a degree or equivalent, as do 79% of current EV owners in Norway (Figenbaum et al, 2014).
Social grade	34% A (upper middle class) 32% B (middle class) 25% C1 (lower middle class)	Early adopters of EVs in the Netherlands have higher social status, and have a greater degree of upward social mobility. (Velthuis, 2012)
Location	17% urban – London 46% urban – other 18% town and fringe 11% hamlet/village/other	90% of EV owners in Norway live in a big city, city, or densely populated area. (Figenbaum et al, 2014)
(Pre-EV) mileage	This was not asked in the survey but 72% of respondents were identified as being in the DfT segment "Educated suburban families". This segment has a relatively high annual mileage – 30% between 5,000-8,999 miles and 47% over 9,000 miles.[7]	N/A
Cars in household	80% 2 or more cars 20% 1 car	94% of EV owners in California have 1 or more ICE cars in their household in addition to their EV (Center for Sustainable Energy, 2013)
Ability to charge at home	97% of respondents said they had charged EV at home, suggesting almost all had the ability to charge at home.	Most EV owners in the Netherlands and Norway have the ability to charge at home. (Velthuis, 2012; Figenbaum and Kolbenstvedt, 2013)

[4] Thornton et al, 2011.
[5] Equivalent to approximately £65,500 at 2015 exchange rates.
[6] Equivalent to approximately £57,800 at 2015 exchange rates.
[7] Ibid.

The evidence presented above illustrates that current EV owners can be fairly clearly defined in terms of their socio-demographics. In the UK and elsewhere they are generally middle-aged, male, well-educated, affluent, and live in urban areas with households containing two or more cars and with the ability to charge at home. However, many new car buyers in the UK also share these characteristics – particularly in terms of age, gender, income and household circumstances. For example, data from a national survey for DfT (Thornton et al, 2011) found that the majority of new car owners were also:

- aged between 40-69 years old (55%)
- in social grades AB or C1 (70%)
- had degree or diploma (56%)
- had an annual household income of £35,000-59,999 (24%) or £60,000+ (30%)
- lived in an "urban – other" (57%) or "urban – London" (12%) location
- had 2 or more cars in their household (55%)

Despite their overall similarity, this data does suggest that EV owners are even more heavily concentrated in the 40-69 age group than new car buyers in general, and even more likely to have a high social grade, have a degree or diploma, and live in a multi-car household. Evidence was not identified in this rapid evidence assessment to enable a direct comparison of the household income of EV owners and new car owners in the UK. However, their higher social grade is indicative of higher household incomes, and comparisons between EV owners and car buyers in the US (for example by Tal et al, 2013) support this.

In addition, various authors (Morton, 2013; Anable et al, 2014; Element Energy et al, 2013) have suggested that there are also other, more attitudinal, characteristics that differentiate EV owners from this wider population of new car buyers.

3.1.2. Attitudinal characteristics of current EV owners

Evidence on the attitudinal characteristics of current EV owners comes again from the UK PiCG research and from EV owners in other countries where this type of research has also been undertaken. The following table summarises the relevant evidence from these sources.

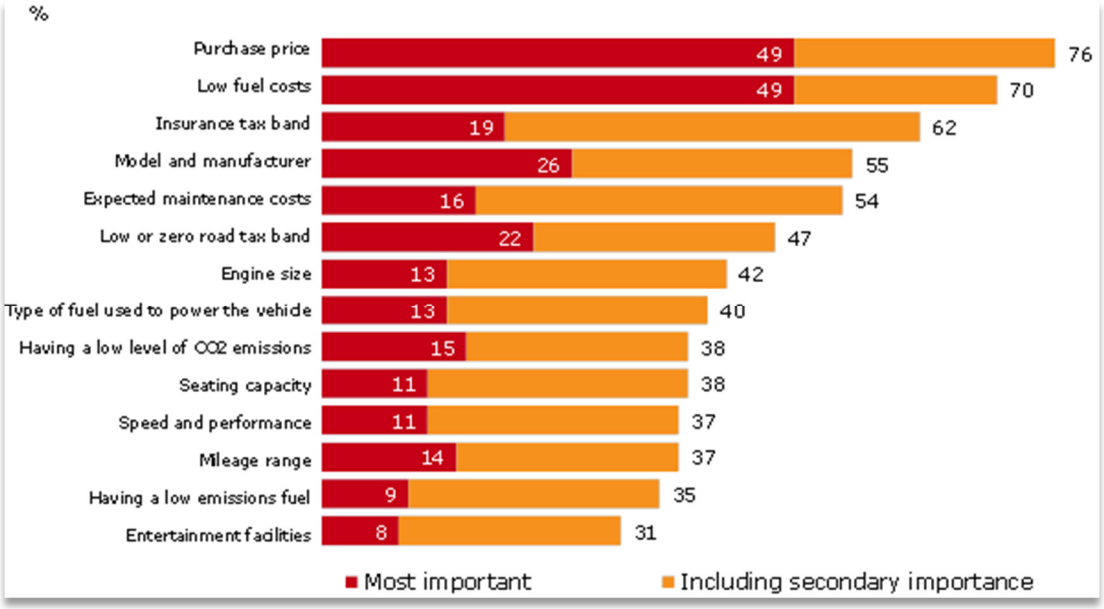
Figure 9. Attitudinal characteristics of current EV owners

Characteristic	UK Evidence (Hutchins et al, 2013)	Other Evidence (various)
Desire to save money on fuel costs	58% of the EV owners cited "save fuel money" as a reason for choosing an EV rather than an ICE.	37% of EV owners in California said "saving money on fuel costs" was their primary motivation for buying an EV – making it the most frequently cited motivation (Center for Sustainable Energy, 2015) 47% of EV owners in Norway cited "lower operating costs" as being a very significant factor in their decision to buy one. 34% also said it had a large significance and 15% some significance. (Figenbaum et al, 2014)
Pro-Environmental Attitudes	Over 40% of the EV owners cited "the environment" as a reason why they had chosen to buy an EV rather than an ICE. 17% also cited "climate change/CO2", and 9% "pollution/air quality". In addition, 72% of the EV owners were also identified as being in	22% of EV owners in California said "reducing environmental impacts" was their primary motivation for buying an EV – making it the second most cited motivation (Center for Sustainable Energy, 2015) It has also previously been reported that 32% of EV owners in California have solar panels on their home and another 16% are planning to install them. (Center for Sustainable Energy, 2014)

	the DfT segment "Educated suburban families". This segment is by far the most likely to believe that climate change is already impacting on the UK and expressed a greater willingness to change their behaviour than any other segment[8].	33% of EV owners in Norway cited "EVs are environmentally friendly" as being a very significant factor in their decision to buy one. 15% of EV owners in Norway are members of an environmental organisation, and overall: "EV owners emerge as more environmentally friendly than cross-section samples from the population" (Figenbaum et al, 2014)
Interest in new technology	28% of the EV owners cited a "desire to be involved in new/fun innovative technology" as a reason why they had chosen to buy an EV rather than an ICE.	5% of EV owners in California said "a desire for newest technology" was their primary motivation for buying an EV – making it the fifth most cited motivation (Center for Sustainable Energy, 2015) 21% of EV owners in Norway cited "I am interested in new technology" as being a very significant factor in their decision to buy one. 27% also said it had a large significance and 26% some significance. (Figenbaum, 2014)

In terms of how these compare to new car buyers in general, evidence from a number of surveys suggest some similarity but also some points of difference. For example, a recent survey of people intending to buy a new car in the next 2 years found that, while low fuel costs do feature as a key consideration, environmental considerations ("having a low level of CO2 emissions" and "having a low emissions fuel") were cited by smaller proportions of respondents. Interest in new technology does not feature at all, although this may partly reflect the fact that it is not routinely included as a response option in surveys of this type[9].

Figure 10. Importance of different characteristics in choice of car amongst new car buyers



Source: TNS-BMRB (2014)

[8] Thornton et al, 2011.

[9] Anable et al (2014) reviewed five previous surveys of car buyer priorities when purchasing a new car. Four of the surveys prompted respondents with response options but did not include "interest in new technology" or similar as a response option. The other survey (Lane and Banks, 2010) was based on unprompted spontaneous answers by respondents. "Interest in new technology" did not feature amongst the 19 most frequently given answers reported, although "features/gadgets" was the 15th most frequently given answer.

These findings are fairly consistent across a number of surveys (see chapter 7 for more detail) and indicate that EV owners are somewhat distinct from new car buyers in terms of their strong pro-environmental attitudes and/or their active interest in new technology.

In additional to the attitudinal factors highlighted above, some authors have suggested that the symbolic meanings attached to cars are a further characteristic that differentiate EV owners from other new car buyers. The evidence to support this is more speculative. It is primarily based on attitudinal surveys of car buyers who don't currently own EVs but are asked about their likelihood of buying one in the future. Such surveys are typically undertaken to predict the characteristics of future EV owners, and as such are discussed in more detail in the next section. However, in summary, key findings from this type of research are that some car buyers attach strong symbolic meanings to cars (e.g. as an expression of personality and status) while others see them in more functional terms. Anable et al (2011) indicate that initial EV purchasers may be those who attach strong symbolic meanings to cars but importantly also envisage that an EV would project a positive image of themselves to others. In addition, Anable et al (2014) suggests that some EV buyers may be motivated by "the belief that such a purchase would vividly demonstrate commitment to a cleaner environment". Research with current EV owners in the UK and elsewhere has not explored these characteristics.

Overall, the evidence presented above strongly indicates that current EV owners not only have certain socio-demographic characteristics but are also likely to be motivated to save money on fuel costs, hold pro-environmental attitudes and/or be interested in new technology. This helps to differentiate them more clearly from the wider population of new car buyers. Equally, the evidence does not show that all current EV owners hold all these attitudes in equal measure. The implication is that there are likely to be subgroups within current EV owners - some primarily characterised by one attitude and others by another. EV owners may also be further differentiated in terms of the symbolic meaning they attach to their car but ultimately further research is needed to test this and develop a more fine-grained understanding of the characteristics of different subgroups or segments of current EV owners. This represents a significant evidence gap, returned to in the final chapter of this report.

3.1.3. Future EV owners

Evidence on the characteristics of future UK EV owners is, by definition, speculative. Two main types have been identified and reviewed in this REA:

Evidence on the characteristics of EV owners in more developed EV markets than the UK

As highlighted in chapter 2, California and Norway are currently two of the most developed EV markets in the world. In 2014 over 3% of new car sales in California were EVs and in Norway this was 18%. Data has been collected on EV owners at different points in the development of each market, which allows for some comparison of their characteristics over time. Although this data is confined to a small number of basic socio-demographics it provides some insight into the extent to which future EV owners in the UK may differ from or resemble current EV owners as the UK market expands. The main caveats to this are associated with the difficulties of comparing the UK with California and Norway noted in chapter 2, and also the fact that external influences on the expansion of the EV market in UK (in the next few years) may be different to those experienced in California and Norway as their market expanded over the last few years.

In terms of **California**, between 2012 and 2014 its EV market expanded from 1% to 3.2%. New EV owners in each year were surveyed by the Center for Sustainable Energy. Findings from these surveys are summarised below:

Figure 11. Characteristics of new EV owners in California 2012-2014

	Age	Gender	Education	Annual Household Income
2012	9% age 18-34 80% age 35-64 12% age 65+	81% Male 19% Female	90% degree or equivalent	17% $0-$99,999 61% $100,000-$249,999 22% $250,000+
2014	12% age 18-34 75% age 35-64 13% age 65+	74% Male 26% Female	87% degree or equivalent	25% $0-$99,999 54% $100,000-$249,999 21% $250,000+

Source: Center for Sustainable Energy, 2015

These findings illustrate some changes to the profile of people buying EVs in California over time. People below the age of 34, women, people without a degree or equivalent, and people a lower income all represented a large proportion of new EV owners in 2014 than in 2012. However, the scale of these changes is relatively small, suggesting a gradual widening of EV ownership rather than a radical shift from one demographic group to another.

In terms of **Norway**, between 2012 and 2014 its EV market expanded from around 3% to 18%. Surveys of EV owners were conducted in both years – but it is important to note that these were not surveys of 'new' EV owners. Those surveyed may have bought their EV some years previously. This provides a less precise comparison than the California data and is likely to underplay any changes in new EV owner characteristics over time. Findings from these surveys are summarised below:

Figure 12. Characteristics of EV owners in Norway 2012-2014

	Age	Gender	Education	Annual Household Income	Cars in household
2012	n/a age 18-35 71% age 36-55 n/a age 56+	76% Male 24% Female	81% degree or equivalent	82% 600,000 Kroner+	91% 2+ cars 9% 1 car
2014	14% age 18-34 63% age 35-54 24% age 55+	76% Male 24% Female	79% degree or equivalent	81% 600,000 Kroner+	75% 2+ cars 25% 1 car

Source: Figenbaum and Kolbenstvedt, 2013; Figenbaum et al, 2014; Haugneland, 2014

These findings illustrate some changes to the profile of people buying EVs in Norway over time but in most cases these are of a smaller scale than apparent in California, which may partly reflect the less precise comparisons possible. However, one pronounced change is the increase in single-car households from 9% in 2012 to 25% in 2014. Additional findings in Figenbaum et al (2014) suggest these "EV-only" households are on average younger and more likely to be single than other EV owners in Norway but in other respects share the same broad demographics. Despite the emergence of this new apparent subgroup of EV owners, the archetypal Norwegian EV owner still conforms to the same broad demographic as previously:

"The typical Norwegian EV user is a family father with high education and high income. He recently bought a Nissan LEAF as one of two cars in the household. He lives in one of the bigger cities in Norway." (Haugneland, 2014)

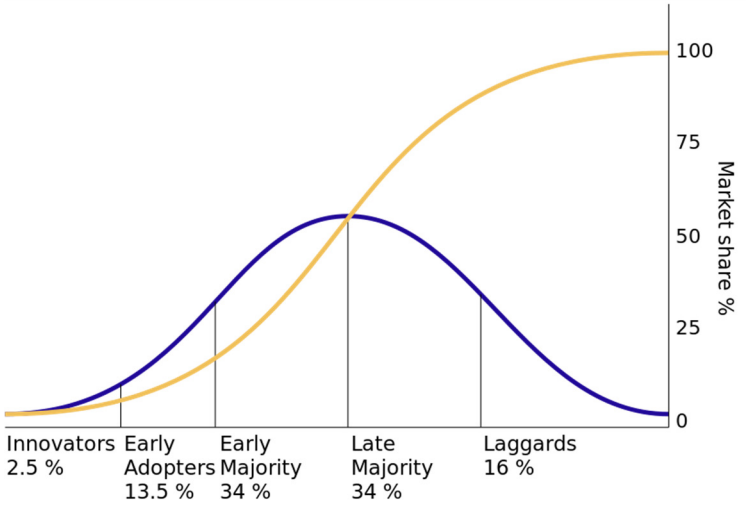
There is also some additional evidence of how EV uptake has "diffused" within social networks (which tend to share the same demographics) in these more developed markets. In Norway, 36% of EV owners report having friends and family who also own an EV and 38% report having family and friends considering buying

one. (Figenbaum et al, 2014). 32% of EV owners in California said they received information from family and friends before buying an EV and over half rated this as extremely or very important (Center for Sustainable Energy, 2015). Further evidence on the role of peer influences in the diffusion of EV uptake is presented in chapter 6 of this report.

Overall, the findings from California and Norway indicate the socio-demographic profile of future EV owners in the UK is not likely to differ greatly to current EV owners. More people in this same demographic are going to start buying EVs, and some people with similar demographics (e.g. slightly younger and/or slightly lower income) are likely to start buying them too.

Segmentation models of future EV owners in the UK

Segmentation models are typically based on surveys asking members of the general public how likely or how much they are willing to pay to buy an EV in the future. The results from this and from other survey questions about the characteristics of respondents are analysed to identify distinct segments in the population. Their main potential limitation is their reliance on responses to hypothetical questions about buying an EV as a predictor of actual future car purchasing behaviour. Various studies have highlighted the pitfalls of this in other spheres, and the rapidly changing nature of EV technology, infrastructure and other factors adds an additional challenge to its use in this sphere. Most segmentation models to date concerning EVs have also been heavily informed by Rogers' model of diffusion of new technologies:



Innovators are the young risk-takers, with a high education, good finances. Their risk tolerance allows them to try new technologies, which may eventually fail.

Early Adopters come directly after early users. They also have better finances, education and status, and are younger than those who adopt at a later date. They are somewhat more cautious than the innovators.

Source: Rogers, 1962

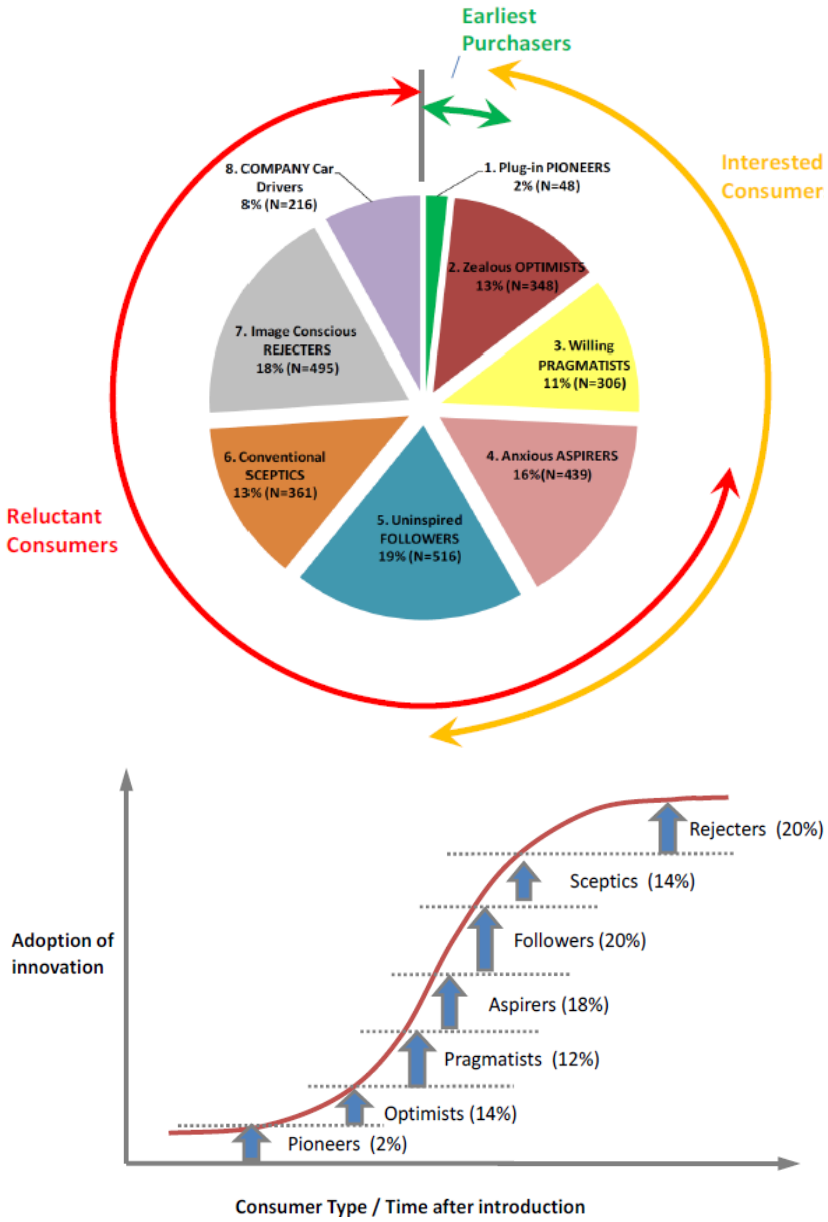
The implication of Rogers' model (and the segmentation models informed by it) is that the initial EV uptake in the UK now should primarily be by young, rich innovators. The evidence presented in the preceding section suggests this has not been the case, and that these models may not be fully equipped to explain the diverse and complex nature of the emerging EV market in the UK. Current UK EV owners do have high incomes but most are not young, and only some appear to have been motivated to buy an EV by an active interest in new technology.

Despite these limitations, segmentation models are of potential value because of their ability to combine socio-demographic and attitudinal factors to identify distinct, nuanced, subgroups in the wider population of new car buyers. Seven segmentation models were identified in this REA and findings from the two most recent and insightful models are presented below[10].

[10] Sources for the other five models: Shell (2004) *Consumer Acceptance of New Fuel and Vehicle Technologies*; Anable (2005) *'Complacent Car Addicts' or 'Aspiring Environmentalists'? Identifying travel behaviour segments*

- **Anable et al (2011)** Segmentation model based on a large quantitative survey of UK buyers of new or nearly new cars in the UK (n=2,729) conducted in 2010. Segmentation was based on the willingness to pay for an EV of respondents and other, primarily attitudinal, characteristics. Selected findings:

Figure 13. Selected findings from Anable et al (2011)



Plug-in PIONEERS
"It's about time, why wouldn't you?"
- Typically male, younger, very high income
- Buy new, relatively expensive cars, high mileage
- Image conscious; would be proud to own EV
- Willing to pay for environmental benefits

Zealous OPTIMISTS
"Yes please. It would save me how much fuel?"
- Typically male, older, high income
- Buy small cars with low fuel consumption, above average mileage
- High willingness to pay for fuel economy
- Belief BEV would fit social identity

Willing PRAGMATISTS
"Yes please, but make it a plug-in hybrid for now"
- Typically male, older, high income, high number of retired
- Buy medium/large cars, with average MpG, medium mileage
- Motivated more by "functional" than "symbolic" factors
- High willingness to pay for fuel economy but not environment

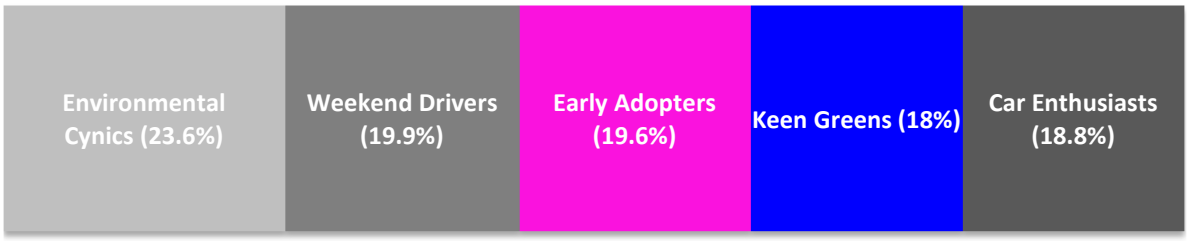
The model suggests that initial EV uptake in the UK will be by a small group of pioneers followed by two older segments motivated by a combination of fuel economy and environmental attitudes. All three segments have a high income and are typically male but have some differences in terms of car buying preferences and attitudes to cars in general. The findings about the current characteristics of EV owners in the UK presented previously suggest that, in reality, members of each of these segments have started buying EVs. Although the implicit assumption in the model that Optimists and Pragmatists

using attitude theory; GLA (2009) *London's Electric Vehicle Infrastructure Strategy*; Girard (2010) *Turning London Electric;* Borthwick and Carreno (2012) *Persuading Scottish drivers to buy low emission cars: The potential role of green taxation measures*.

will only enter the market after Pioneers have done so may not hold true, the segments themselves are still potential valid and valuable in classifying current and near-future EV owners.

- **Morton (2013)** Segmentation of car buyers based on a survey in Newcastle and Dundee (n=552) which included different measures of innovativeness and emotional responses to EVs as factors in the analysis. Two segments, Early Adopters and Keen Greens, were identified as having a similar likelihood of buying an EV in the future. Selected findings:

Figure 14. Selected findings from Morton (2013)



EARLY ADOPTERS
- Display high EV preferences
- Hold low levels of innovativeness
- Are concerned about the environmental implications of cars
- Hold positive attitudes about the functional capabilities of EVs
- Average age: 59 years old
- 64% had a degree or professional qualification
- 58% had a household income of over £30,000 p.a.
- 57% working; 43% retired

KEEN GREENS
- Display high EV preferences
- Hold higher levels of innovativeness
- Are likely to associate EVs with positive emotions
- Are also motivated by biospheric life principles
- Average age: 53 years old
- 72% had a degree or professional qualification
- 70% had a household income of over £30,000 p.a.
- 68% working; 29% retired

A limitation of this model is that the two segments of interest are quite large, and as a consequence don't provide a very precise target audience which, for example, potential future policy interventions could be directed at. However, it is valuable in illustrating that potential future EV owners with similar demographics may have different attitudes motivating them to buy an EV - the Early Adopters segment being primarily motivated by environmental factors and the Keen Greens by a combination of both environmental factors and interest in new technology. Despite these differences, both segments expressed a similar likelihood of buying an EV in the future, which fits with the findings on current EV owners better than other models predicated on initial uptake by a single segment of "Innovators".

Overall this evidence, and recent reviews on the subject (e.g. Anable et al, 2014), all point towards there being distinct segments of future EV purchasers in the UK, all sharing similar demographics, but characterised by either strong pro-environmental attitudes, the desire to save money on fuel costs or interest in new technology.

3.2 Fleet owners

The evidence-base on the characteristics of current and future fleet EV owners is considerably smaller than that for private owners, despite them so far representing the majority of initial EV purchasers in the UK. There is also little evidence on the characteristics of fleet EV owners in other countries that can be drawn on here[11].

3.2.1. Organisational characteristics of current fleet EV owners

What evidence there is comes primarily from the research with PiCG recipients undertaken in 2013 plus a small amount of evidence from other sources. This is summarised below.

Figure 15. Organisational characteristics of current EV owners

Characteristics	UK Evidence (Hutchins et al, 2013)	Other Evidence (various)
Sector	88% private sector 9% public sector 2% charity/not for profit 1% don't know	Recent survey by Intelligent Car Leasing (cited in Business Green, 2015) suggested under half (40%) of local authorities in England and Scotland had purchased an EV. In 2014, 89% of fleet EV purchasers in California were private sector, 11% public sector and 3% charity/not for profit. (Center for Sustainable Energy, 2015)
Industry	25% classified themselves as being retailers or shops, followed by manufacturing (12%) and several other activities cited by 5% of the sample or less. 32% said they were involved in 'other' business activities.	N/A
Number of employees[12]	2% None/sole trader 49% 1-49 26% 50-500 23% 501+	UK survey by GE Capital (2011) (cited in Anable et al, 2015) which reported that 18% of organisations with a fleet of 500+ vehicles operate EVs of some type as compared to only 2-3% for fleets with fewer than 500 vehicles.
Intended usage of EV	72% for use by employees of organisation. 12% for leasing to other organisations. 43%[13] for display in a dealership.	N/A

The evidence above suggests current EV fleet owners are predominantly private sector businesses working in a range of industries, with less than 500 employees, who have bought an EV for use by their employees. The one area of disagreement in the evidence is over the size of the organisations currently buying EVs. The GE Capital survey findings (and some early projections of EV uptake by fleet purchasers – see section 3.2.2) suggest a higher uptake by large organisations with large fleets than was found in the research with PiCG recipients. No more recent evidence was found in the REA on the size of organisations currently owning EVs in the UK or elsewhere.

[11] In Norway, fleet purchasers currently account for around 19% of EV owners and in California 3%. The Netherlands has historically had a higher proportion of EV fleet purchasers (Velthuis, 2012) more comparable with the UK but no evidence was found in this REA on the characteristics of EV fleet owners in the Netherlands.

[12] Dealerships were excluded from the analysis of responses to this question.

[13] These total over 100% because some EVs were being used for more than one of these purposes.

3.2.2. Other characteristics of current fleet EV owners

Evidence on the motivations of organisations that have bought an EV provides some insight into their other characteristics, albeit not sufficient to clearly differentiate them from fleet purchasers more generally.

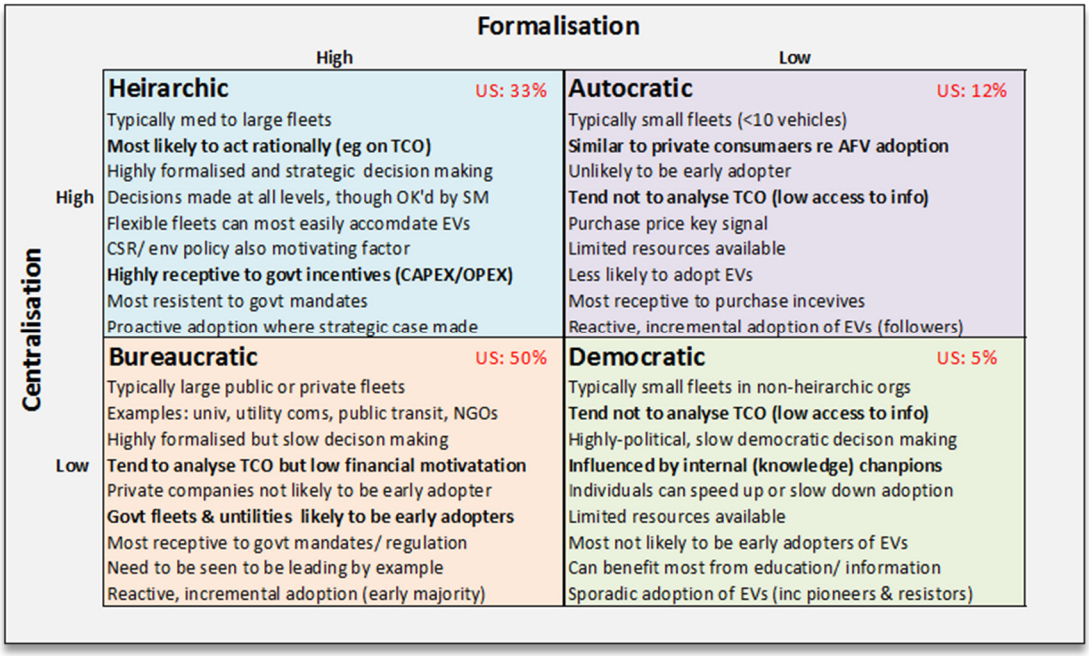
Figure 16. Other characteristics of current fleet EV owners

Characteristic	UK Evidence (Hutchins et al, 2013)
Sensitivity to total costs of ownership	The two most frequently cited motivations for buying an EV were "save fuel money" (43%) and "tax benefits/incentives" (26%).
Pro-environmental attitudes and/or policies	The third most cited motivation was "Environment/CSR" (26%) and the fourth was "climate change/CO2" (23%).

3.2.3. Future fleet EV owners

Evidence on the characteristics of future fleet EV owners is very limited, and much of what there is appears to be out of step with initial uptake in the UK. The only two sources identified in this REA were Velthuis, 2012 and Nesbitt and Sperling, 2001 (which is cited extensively in Anable et al, 2015). The former predicted that early fleet adopters in the Netherlands were likely to be large companies with focus on Corporate Social Responsibility (CSR), utility and energy companies, taxi operators and delivery services. The latter undertook a more sophisticated analysis of fleet purchasers in the US and classified them according to a number of organisational characteristics – see below.

Figure 17. Classification of organisation types and their likelihood of buying an EV (US)



Source: Nesbitt and Sperling, 2001 (cited in Anable et al, 2015)

The authors suggest that organisations operating larger fleets are most likely to consider new vehicle types (including EVs) if they can be classified as 'hierarchic', as typified by large private sector corporations. These organisations tend to be highly motivated by TCO considerations and CSR policy, and view potential risks as

opportunities. While more 'bureaucratic' organisations, as are found in the public sector, aspire to adopt new technologies, aim to lead by example but tend to be risk averse, have overly complex decision making processes, and have less access to investment capital. As such they are not expected to be EV early adopters.

The findings on the characteristics of current fleet EV owners in the UK suggest initial uptake has primarily been by private sector businesses, many of which are sensitive to TCO and CSR policy. It is a reasonable assumption that future fleet EV purchasers in the UK are also likely to share these characteristics. The main disconnect is between the predicted and actual size of the organisations buying EVs. Large organisations with large fleets do not so far appear to account for the majority of EV purchasers and there is insufficient evidence to make any assumptions about whether they will or won't in the future.

One further insight from the evidence reviewed in this REA is that many initial fleet purchasers appear to have bought an EV in order to evaluate whether it would be viable to invest more in EVs at a later stage. This was a finding in the research with PiCG recipients in which 18% spontaneously gave this as a reason for buying an EV (Hutchins et al, 2013). More recently the survey by Intelligent Car Leasing (cited in Business Green, 2015) found most local authorities in England and Scotland with an EV in their fleet had only bought one or two so far: *"….the figures show 57 councils have just one EV while just 12 operate more than nine."* A key evidence gap, which could potentially be addressed by analysis of data on more recent fleet PiCG recipients, is the extent to which the purchase of one EV is being followed by further purchases by the same organisation.

Overall the evidence presented above suggests that the identity of future fleet EV purchasers is uncertain. The majority are likely to be private sector businesses that are sensitive to TCO and/or have overtly pro-environmental policies. However, the size of these organisations, and the extent to which an initial EV purchase will lead on to larger-scale adoption in a business's fleet, is currently a significant evidence gap.

4 Usage and experience of ULEVs

- EVs are typically being used as the "main car" in private owner households, relied on for the majority of day-to-day journeys to work, education and other local destinations. Other cars in the household are typically being used for infrequent, longer journeys.
- Despite early predictions that EVs would only be driven for low mileages, recent research in the UK and other countries indicates privately owned EVs are being driven for comparable mileages to ICE cars.
- Private owners charge their EVs primarily overnight at home and currently have a strong preference for doing this rather than using public or workplace charging.
- Most private owners are satisfied with their EV and positive about buying another in the future. This appears to be underpinned by EVs' performance, comfort, low fuel costs, and the ease and convenience of home charging.
- Range is still the greatest perceived downside of EVs for private owners, but this needs to be seen in the context of the overall high levels of satisfaction with the EV ownership experience.
- Evidence on how EVs are being used by fleet purchasers is more limited but what there is suggests they are being regularly used, driven for high mileages and, when being used as a pool car, charged mainly at the workplace.
- Fleet purchasers are generally positive about the experience of using EVs but, for some, EVs aren't seen to offer the flexibility necessary to meet their needs and not all may be willing to proactively change their operations in order to incorporate them.

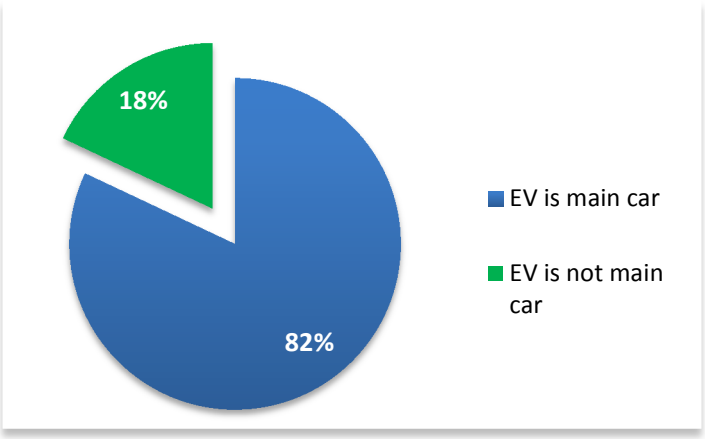
This chapter presents evidence on how EVs are being used and experienced by private owners and organisations. Evidence comes from two main sources: trials of EVs; and research with current EV owners and users. In areas where both types of evidence are available, emphasis has been given to the latter as it generally provides a more recent, real-world understanding of usage and experience.

4.1 Private Owners and Users

4.1.1. How much EVs are being used

Evidence from current owners in the UK and other countries shows EVs are typically being used as the "main car" in the owner's household, relied upon for the majority or all car journeys. In Hutchins et al, 2013, the EV was reported to be the only car in 20% of private owners' households and amongst private owners with more than one car in the household, most described the EV as the main car.

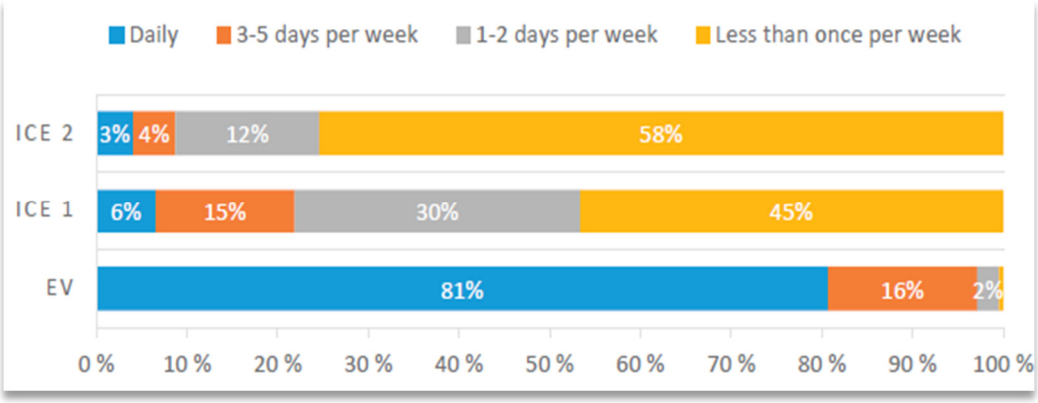
Figure 18. Status of EV in multi-car households (UK)



Source: Hutchins et al, 2013

In recent surveys in Norway, EVs have been reported to be the only car in 25% of households (Haugneland, 2014) and to be used much more than other cars in multi-car households (Figenbaum et al, 2014).

Figure 19. Frequency of EV use in multi-car households (Norway)



Source: Figenbaum et al, 2014

The proportion of California households relying solely on an EV (Center for Sustainable Energy, 2013) is lower than in the UK or Norway but the high mileages reported for EVs in the US (see section 4.1.3) suggest they are being relied upon for the majority of car journeys in multi-car households. Rolim et al (2014) also found that owners in Portugal used their EV as a replacement for their conventional everyday vehicle, even though most still owned at least one ICE.

Evidence from the UK shows some variations between PHEV and BEV owners. First, 29% of PHEV owners said they had no other cars in the household compared to 17% of BEV owners. Second, a higher proportion of PHEV owners in multi-car households described it as their main car than did BEV owners (Hutchins et al, 2013).

4.1.2. Types of journey EVs are being used for

Various evidence sources have reported that EVs are being used to commute to work and education, go shopping, run errands, visit friends, and to get to and from local leisure facilities. These are typically regular journeys that owners undertake several times a week, over relatively short distances (Tal et al, 2013) and

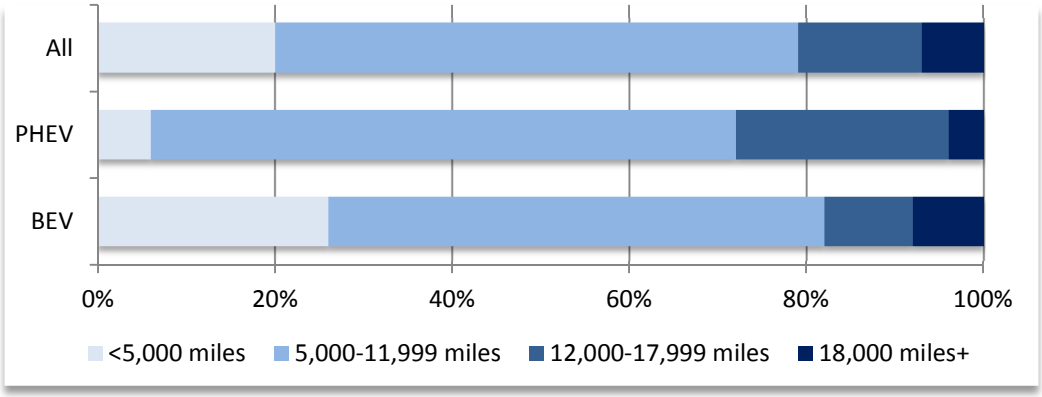
travelling mainly on residential, urban and inter-urban roads (Rolim, 2014), including A-roads in the UK. EVs are being used much less frequently for longer journeys (e.g. for holidays and business trips) and journeys involving motorway travel. Overall, 27% of EV owners in Hutchins et al (2013) had not used their EV on a motorway at all. This was higher for BEVs (31%) than PHEV owners (16%).

4.1.3. How far EVs are being driven

Older evidence from EV owners and findings from EV trials in the UK have generally suggested that EVs were being driven for notably lower mileages than ICE cars. For example, Anable et al (2014) cited previous research by Element Energy (2009) which concluded that "EV owners typically have lower mileages than the population overall" and Carroll et al (2013) reported lower than average daily and weekly mileages amongst private trial participants.

However, more recent research with current EV owners in the UK indicates EVs are being driven for comparable mileages to ICE cars. This evidence is based on self-reporting by EV owners, likely to be prone to human error and/or bias, but similar findings from EV owners in other countries give some confidence in these findings. Overall, Hutchins et al (2013) found that where an EV was being used as the main car in the household (as it was in most households) the average annual mileage was approximately 8,850 miles. This was compared to the estimated national average for all cars (based on 2010 National Travel Survey data) of 8,430 miles. The average annual mileage reported by PHEV owners was higher than BEV owners, with over a quarter (28%) saying this was 12,000 miles or more, compared to 18% of BEV owners.

Figure 20. Annual reported mileage of EVs in UK



Source: Hutchins et al, 2013

The reported mileage of EVs in the US is lower than the average for all passenger vehicles but only by 6% in the case of PHEVs. On average, BEV owners were estimated to have an annual mileage of 11,500 km and PHEVs an annual mileage of 15,900 km. This compared to the average annual mileage for passenger vehicles in the US of approximately 17,000 km (ECOtality, 2013a). In Norway, Figenbaum et al (2014) conclude on the basis of survey and in-car mileage data that "the annual driving length for EVs with the latest technology is about the same as for new ICE vehicles."

4.1.4. Where and when EVs are charged

Evidence from various sources has found that private owners charge their EV mainly at home, on a daily basis, and generally overnight (Azadfar et al, 2015; Element Energy et al, 2013; Pierre, 2011; Anable, 2014; Hutchins et al, 2013; ECOtality, 2013a; Rolim et al, 2014). This is also fairly consistent between the UK and other countries. In Hutchins et al (2013) 95% of private EV owners reported charging at home daily or weekly compared to 26% who reported charging at work daily or weekly and 12% who reported using

public charging daily or weekly. In the US, ECOtality (2013a) found that 80% of charging events by BEV owners were at home and 20% "away from home", compared to 86% and 14% respectively for PHEV owners. In Norway, 97% of EV owners charge at home daily or weekly compared to 51% at work and 20% using public charging (Figenbaum et al, 2014).

There is also general agreement in the evidence base that this charging behaviour is primarily being driven by EV owner preferences, convenience and habit rather than the availability or cost of public charging infrastructure (see for example, Anable et al, 2014 and Azadfar et al, 2015). As discussed more in section 4.1.6, private owners generally like charging at home and find it relatively easy to do so. No significant differences in charging behaviour were found in Hutchins et al (2013) between the charging behaviours of private owners living in PiP and non-PiPs areas.

PHEV and BEV owners in the UK and elsewhere have been found to have similar charging behaviours. Both charge mostly at home but PHEV owners charge more frequently on average the BEV owners. For example, in the US, BEV owners have been reported to 1.1 charging events a day compared to PHEV owners who average 1.5 charging events a day while the average distance driven between charges was comparable at approximately 28 miles for both (ECOtality, 2013a).

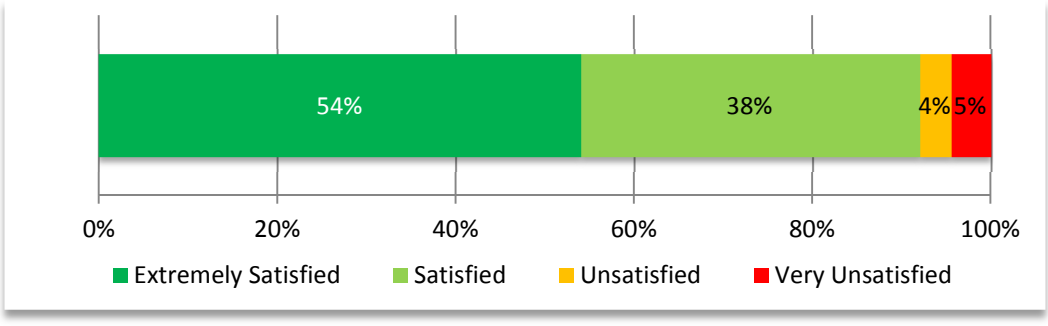
No evidence was found in this REA which suggested that current PHEV owners under-use or ignore the electric capacity of their vehicle. In a recent systematic evidence review, Anable et al, 2014 concluded that most owners run their PHEVs on electricity as much as possible, and this is supported by US findings that suggest PHEV users run their vehicle on electrical power for 72.5% of the time (ECOtality, 2013a).

4.1.5. Overall experiences of owning and using EVs

Evidence from current owners in the UK and elsewhere suggests high levels of satisfaction with their EV. In the UK, 91% of trial participants said they would recommend EVs to others on the basis of their experiences of driving one (Carroll et al, 2013). Owners in Hutchins et al (2013) gave "generally a positive response" when asked whether they would consider buying another EV in future and most had no immediate plans to sell their current EV.

In the US, 92% of EV owners in California said they were satisfied with their EV in a 2013 survey.

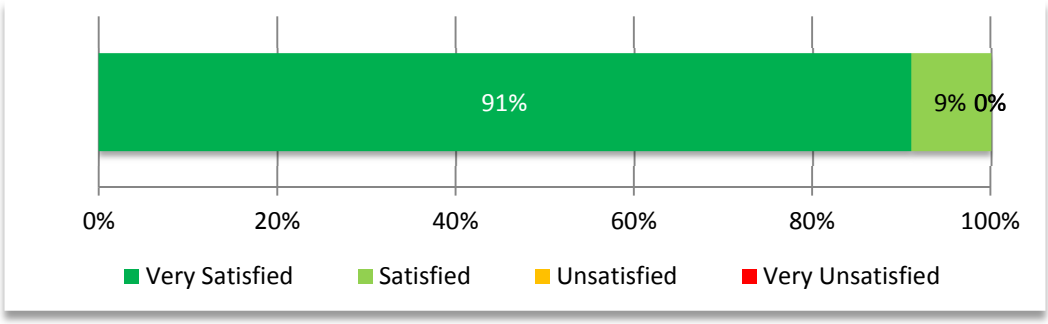
Figure 21. Satisfaction with EV in California



Source: Center for Sustainable Energy, 2014

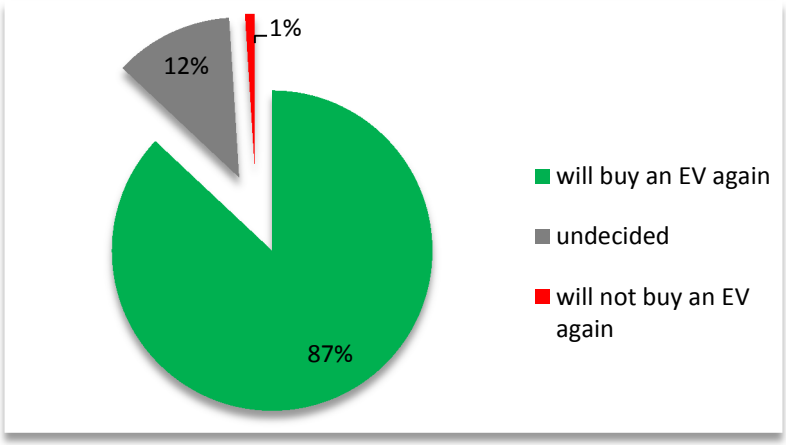
In Norway, reported levels of satisfaction amongst EV owners, and their likelihood to buy another EV in the future, were both also very high in recent surveys.

Figure 22. Satisfaction with EV in Norway



Source: Haugneland, 2014

Figure 23. Future intentions of EV owners in Norway



Source: Figenbaum et al, 2014

The findings above compare favourably to those of a 2012 survey in Norway which found that 60% of EV owners intended to buy another EV in the future (Figenbaum and Kolbenstvedt, 2013).

4.1.6. Experiences of different aspects of owning and using EVs

The table below summarises evidence on different aspects of owning and using EVs, much of which has been reported at length in other recent reviews (see Anable et al, 2014 and Element Energy, 2013 in particular).

Figure 24. Experiences of different aspects of owning and using EVs

Aspects	Evidence
Performance and Driving Experience	EV trials and research with private owners have reported consistently positive findings with regard to the performance and overall driving experience of EVs. A third of UK trial participants reported that the EV they tried was better to drive than their normal car (Burgess et al, 2013) and more generally EVs were seen as fun to drive, smooth, and rated very highly on their acceleration performance (Carroll et al, 2013). Trials in France and Germany also reported that participants found EVs fun, pleasant and smooth to drive (Pierre et al, 2011; Bühler et al, 2014). Several of the UK EV owners in Hutchins et al, 2013 reported that their EV had "exceeded their

	pre-purchase expectations in terms of the performance offered" and were "impressed by the responsiveness and handling of the vehicle". In California, 80% of owners said they were extremely satisfied with the performance of their EV and 14% said they were satisfied (Center for Sustainable Energy, 2014). In Norway, 70% of owners rate the acceleration of their EV as an advantage, making it the second most cited advantage of owning and using an EV. This was over 90% amongst Tesla owners and still a respectable 66% amongst Nissan Leaf owners (Figenbaum et al, 2014).
Comfort	Similar to the above, trial participants and EV owners have also consistently reported finding EVs comfortable to drive – primarily because of their smoothness and quietness in comparison to ICEs. See: Pierre et al, 2011; Velthius, 2012; Carroll et al, 2013, Hutchins et al, 2013; Bühler et al, 2014.
Fuel costs	EV owners and trial participants have reported saving money on fuel costs, and cited this as an advantage of owning an EV over an ICE – even if it doesn't necessarily translate into lower total costs of ownership. Bühler et al, 2014 and Bunce et al, 2014 present trial evidence to this effect and Hutchins et al, 2013 reported that EV owners "tended to be very aware of the amount that using an EV had saved them, and described the cost savings they had made." Although the authors caution that not all future EV owners may be minded to carry out these types of calculations, Anable et al (2014) makes the point that this may not matter, it is the general sense of saving money which makes EVs seem advantageous over ICEs.
Home charging	EV trial participants have consistently reported that the experience of charging at home is easier and more convenient than refuelling an ICE at a petrol station. Bunce et al, 2014 cites research in Germany where 71% of trail participants expressed a preference for charging at home over petrol stations and there are additional qualitative findings to support this from other research – see: Velthuis, 2012; Hutchins et al, 2013; and Bühler et al, 2014.
Flexibility	Evidence on the perceived flexibility of EVs is mixed, although it suggests this is seen as less of a disadvantage over time and may even confer some advantages. Some of the more negative findings on this aspect of EVs comes from trial participants who, it could be hypothesised, may have lacked the same willingness to adapt as individuals who have chosen to buy an EV and/or had limited time during the trial to adapt. For example, Carroll et al (2013) reported that initially trial participants "expected an EV to fit their life immediately and did not wish to alter their lifestyle to accommodate it". In addition, Morton (2013) cites findings from Graham-Rowe et al (2012) based on a 1 week EV trial, in which participants "raise(d) concerns regarding the capability of EVs…this translated into reduced levels of pleasure participants received from driving." Evidence from participants in longer trials and from EV owners is considerably more positive. Pierre et al (2011), Velthuis (2012), Carroll et al (2013) and Hutchins et al (2013) all report that drivers adapt their driving behaviour over time (e.g. planning journey routes in advance, not accelerating/breaking unnecessarily, minimising motorway travel). They generally form a more favourable view of their flexibility as a consequence – albeit not to the point that they are considered to offer the same flexibility as an ICE. Hutchins et al (2013) also suggests some EV owners saw these changes as a positive because it meant they were now driving more efficiently and economically.
Range	Range is still the greatest perceived downside of EVs, and although anxiety may diminish with experience, dissatisfaction with existing range and the desire for more may not. Trials and research with owners have consistently found that users can undertake most of their

	day-to-day travel quite easily in an EV, and just relying on home charging. However, users also consistently report a desire to be able to undertake all their journeys, including more occasional longer ones, in their EV, ideally without needing to charge away from home (Anable et al, 2014). Over time, owners adapt to maximise the range of their EV and become more confident in using more of the battery capacity between charges, but there are also other factors that have been reported to exacerbate dissatisfaction with range. Respondents in Hutchins et al (2013) were frequently disappointed at the difference between the advertised range and the actual range, reported reduced range in cold weather and seemingly inaccurate in-car readings of battery charge levels. Range in cold weather is also a particularly salient concern in Norway, cited as a problem by 60% of survey respondents, and overall 81% said the range of their EV was worse than they had expected it to be (Figenbaum et al, 2014). In California, 60% of EV owners said they were satisfied with its range - 7% extremely satisfied, 53% satisfied, 30% unsatisfied and 10% very unsatisfied (Center for Sustainable Energy, 2014). Previous UK trial findings suggest that on average people would consider a range of 60 miles "adequate" for an EV but that an "ideal" range of 206 miles would be necessary to enable them to meet all their travel needs (Carroll et al, 2013). What's generally lacking in the evidence is insight into how experiences and perceptions of range compare between BEVs and PHEVs. The only evidence identified in this REA addressing this was in California. On average Nissan Leaf (a BEV) owners in the survey said they wanted to have an electrical range of 200 miles compared to the actual electrical range of 78 miles. For Chevrolet Volt (a PHEV) owners these figures were 100 miles and 38 miles respectively. (Center for Sustainable Energy, 2014).
Public charging	Evidence suggests that satisfaction with public charging provision is generally low in the UK and other countries. This evidence is discussed in chapter 7 but it can be noted here that this apparent dissatisfaction partly explains the strong current preference amongst EV owners for charging at home and their desire for EVs to have longer ranges – see above.
Battery life, Maintenance and Resale value	Battery life, maintenance and resale value have been cited as potential disadvantages of EVs but there is very little evidence to date on the experiences of EV owners of these issues. The extent to which concerns about these issues are acting as a barrier to the uptake of EVs is discussed in chapter 6. The lack of experiential evidence to date may reflect the fact these are issues likely to only emerge over an extended period of ownership, and that most research to date has been with trial participants and owners relatively early on in their ownership of an EV. For example, even in Norway the second-hand EV market has recently been described as "very limited" (Figenbaum et al, 2014). The fact they generally aren't emerging as key concerns in research with EV owners could be interpreted as a positive, but ultimately more research is needed. What evidence there is suggests at least that resale value is currently being perceived as a disadvantage by some EV owners. Figenbaum et al (2014) found that 56% of owners in Norway cited uncertainty over the resale value of their EV as a disadvantage. Only range-related issues and uncertainty over the continuation of incentives were cited as disadvantages by a higher proportion of respondents.

Overall, the evidence presented above illustrates that most current owners are satisfied with their EVs. This appears to be underpinned by the performance and driving experience of EVs, perceived savings on fuel costs, and the ease and convenience of home charging. Range remains the key disadvantage being experienced by EVs owners, but this needs to be seen in the context of the overall high levels of satisfaction with the EV ownership experience. EV owners' experiences of battery life, vehicle maintenance and resale value currently represent a significant evidence gap, particularly given their potential importance in the evolution of current and future (i.e. second hand) EV markets.

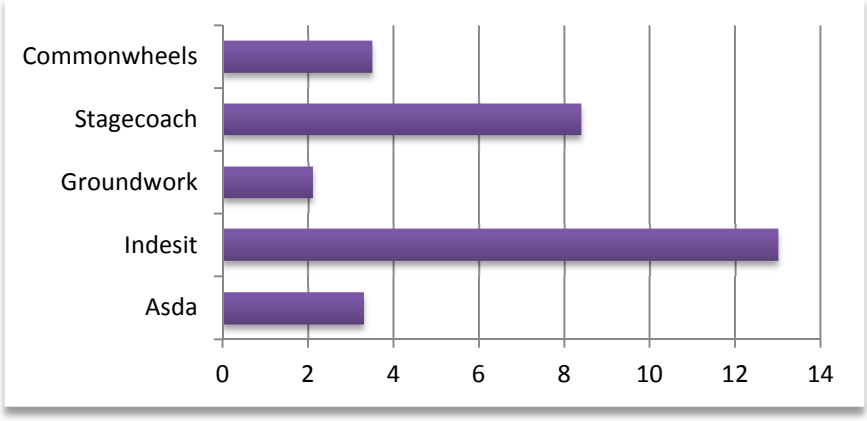
4.2 Fleet Owners and Users

4.2.1. How much EVs are being used

The majority (73%) of the organisations in Hutchins et al (2013) that bought an EV for use by their employees reported that it was being used on a daily basis, and in nearly all cases (94%) it was being used at least once a week. No further findings were reported as to how this compared between EVs being used as pool cars and company cars but trial data does suggest that EVs may be driven more frequently (at least in terms of the number of journeys undertaken) when they are being used as a pool car. Robinson et al (2013) report that EVs being used as pool cars undertook 520 journeys during the trial period compared to 476 journeys by EVs being used as a company car.

There is other evidence to suggest that levels of usage of EVs may vary quite widely – both between different employees within an organisation and between different types of organisation. For example, Hutchins et al (2013) report that concerns were expressed by employees about BEV range in 61% of organisations, with employees avoiding making journeys in a BEV in 73% of organisations. No findings for employee attitudes to PHEVs were reported. The implications of this are that some employees may be using EVs quite frequently within organisations that have bought one but others possibly less so or not at all. Most organisations in the research also had ICE cars in their fleet. Previous trial research (Carroll, 2011) also found quite different frequencies of use between the small sample of organisations involved.

Figure 25. Average number of journeys by EV per day during trial



Source: Carroll, 2011

Further research would be needed to be able to understand the extent to which these trial findings are being replicated amongst different types of organisations that have bought an EV.

4.2.2. Types of journey EVs are being used for

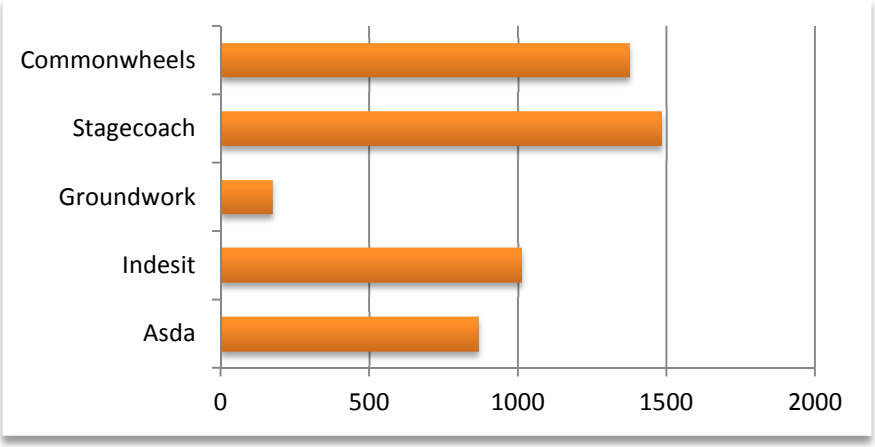
Hutchins et al (2013) report that EVs were primarily being used by employees in organisations for "business trips, visiting customers or suppliers, delivering goods, escorting people". This was not differentiated by EVs being used as pool or company cars, but the findings are consistent with those from trials, in which EVs have mainly been employed as pool cars (Carroll, 2011). As with private EV owners, it has been reported that these are typically regular journeys, over relatively short distances and travelling on residential, urban and inter-urban roads. For example, Rolim et al (2014) reports that "In fleets, all drivers use the EV for short trips (0–15 km) and occasionally some drivers use it for medium length trips (16–40km). These trips are mainly within an urban context". Evidence on differences in the types of journeys being undertaken by EVs being used as pool cars or company cars is more limited, but Robinson et al (2013) report evidence from trials that the average trip length for the former was 7.6 km and 10.6 km for the latter.

4.2.3. How far EVs are being driven

Hutchins et al (2013) report that EVs owned by organisations have higher mileages that privately owned EVs, although EVs being used solely as pool cars were excluded from this analysis, and no findings for pool car mileage were reported. Findings from trials indicate that EVs used as company cars are likely to have higher mileages than those used as pool cars. Robinson et al (2013) reported that the average mileage of EVs used as company cars during the trial was 4,924 km compared to 3,971 km for those used as pool cars. Research with a small sample of fleet owners in Sweden (Wikström et al, 2014) reported similar findings.

Trial evidence (see below) also suggests that, as with frequency of use, there may be wide variations in the mileages of EVs in different organisations. The reasons for these variations are not directly accounted for but several factors (including the different types of journey the EV was being used for, the location of the organisations and their proximity to key destinations, and the attitudes of their staff) appeared to have influenced the mileage of the EVs during the trial.

Figure 26. Total kilometres travelled by EV during trial



Source: Carroll, 2011

Again, further research would be needed to be able to understand the extent to which these trial findings are being replicated amongst different types of organisations that have bought an EV, and the factors that determine this. Another key evidence gap is how the reported mileages for EVs being used as a pool and company cars compare to the mileages of ICEs being used as pool and company cars. No direct comparisons were identified in this rapid evidence assessment.

4.2.4. Where and when EVs are charged

Evidence on the charging behaviours of fleet EV users is particularly limited, and confined mainly to trial findings. Hutchins et al (2013) report that two-thirds of the organisations owning an EV had one or more charge points installed, and that the majority of these were standard charge points rather than fast or rapid ones, but no findings were reported on usage of these charge points. The trial findings indicate that EVs used by organisations are charged with a similar frequency as EVs used by private individuals (3.7 times a week compared to 3.3 times a week). Employees using an EV as a pool car used workplace charge points to charge their EV mainly during the daytime, and straight after they have used it to ensure it was charged for the next user. Trial findings on employees using EVs as a company car are less clear-cut, but appear to show they charged their EV at home during the evening and/or at their workplace during the daytime if there were workplace chargers installed (Burgess et al, 2013; Carroll et al, 2013; Robinson et al, 2013).

4.2.5. Overall experiences of owning and using EVs

As well as private EV owners, organisational EV owners in Hutchins et al (2013) were reported to give "generally a positive response" when asked whether they would consider buying another EV in future and most had no immediate plans to sell their current EV. Positive findings have also been reported from trials with fleet users in the UK and some research in other countries. Carroll (2011) reported that "feedback was mainly positive and staff appeared eager to make EVs a permanent addition to the company" and that "68% of fleet managers said that involvement in the trial had accelerated their company's interest in EVs". In addition, the majority of fleet EV users in a Swedish trial said they would like to see more EVs in their company fleets (Wikström et al, 2014).

However, the evidence also points to some caveats and limitations in the extent to which organisations may be willing to embrace EVs themselves or recommend them to others. For example, Carroll (2011) reported that a quarter (25%) of organisations "reported that they were not willing to modify their fleet operations to incorporate EVs". Rolim et al (2014) reported that "fleet drivers would advise the deployment of EVs in other companies, but state that the types of trips and services should be taken into consideration". The authors also suggest that if organisations are going to buy EVs they "must develop operational plans that take into account which aspects of the EV will work for their specific fleet". These findings appear to reflect concerns about range, charging times and, linked to this, the extent to which EVs are being seen to offer the flexibility necessary to meet the needs of different types of organisations.

4.2.6. Experiences of different aspects of owning and using EVs

The table below summarises evidence on different aspects of owning and using EVs from the perspective of fleet owners and users. For most aspects the findings are very similar to those reported for private EV owners and users reported earlier in this chapter, particularly in terms of performance and driving experience, comfort, and public charging. Some differences are apparent though with respect to flexibility, range and experience of charging at work as opposed to charging at home.

Figure 27. Experiences of different aspects of owning and using EVs

Aspects	Evidence
Performance and Driving Experience	Hutchins et al (2013) report that fleet users were just as positive about the performance and driving experience of EVs as private users were. Carroll (2011) reported that on average fleet participants in trials "rated the performance aspects of EVs as marginally better than a conventional vehicle".
Comfort	Hutchins and Delmonte (2012), in research with fleet managers, report that the quietness and comfort of EVs was seen as a potential advantage for employees.
Fuel costs	Despite the widely cited focus of fleet purchasers on TCO and the fact that a significant proportion of organisations who have bought an EV say were motivated to do this by a desire to save money on fuel costs (see chapter 6) no evidence was found in this rapid evidence assessment on how fleet owners or users actively experience this after the point of purchase.
Workplace charging	What limited evidence there is on this suggests that fleet owners and users' experiences of charging EVs at work are mixed, and overall less positive when compared to private owners' experiences of charging at home. Carroll et al (2013) reported that "corporate managers pointed to much faster charging times as being essential in order to gain maximum use of EVs in a multi-driver fleet" and that they "did not show the very high levels of preference for charging

	compared to refuelling at petrol stations. This may be a function of having to charge following each trip…and not being able to receive personal financial compensation for driving an EV as they would an ICE." It was also reported in Carroll (2011) that "19% of users considered that charging the EV disrupted their normal working patterns".
Flexibility	The evidence suggests that EVs may be deemed to offer insufficient flexibility to meet the needs of some organisations. Carroll (2011) reported that some of the case study organisations were able to incorporate EVs into their fleet and use them to meet most or all of their travel needs. Others (notably Indesit and Stagecoach) reported that, because of a combination of the length and frequency of journeys they needed to undertake, plus the limited range of EVs and long charge times required, EVs weren't able to offer them the flexibility they needed.
Range	Fleet owners and users cite this as the main disadvantage of EVs (Hutchins et al, 2013; Rolim et al, 2014; Carroll et al, 2013; Wikström et al, 2014). As with private users, there is evidence that fleet users adapt aspects of their driving behaviour in response to the range limitations of EVs over time. However, this process of adaptation may take somewhat longer (Carroll et al, 2013) and, as noted above, for some organisations no amount of adaptation may be sufficient for an EV to be seen to offer the range and flexibility they require. However, it is worth reiterating here one of the main limitations of much of the evidence this is based on: these trials were primarily conducted with BEVs. The fleet user experience of PHEVs is currently a significant evidence gap.
Public charging	As with private owners, fleet owners and users were reported to have been generally dissatisfied with public charging infrastructure by Hutchins et al (2013) at the time of the research.
Battery life, Maintenance and Resale value	Little evidence was identified on these aspects from the perspective of fleet EV owners and users – again somewhat surprising given their documented focus on TCO. Hutchins et al (2013) noted that "concerns over residual value seemed to be more important for organisational respondents than private purchasers" but, in terms of actual experiences of these issues, no evidence was identified.

Overall, the evidence presented above is not sufficient to provide a complete understanding of how EVs are being experienced by fleet users. What evidence there is suggests that the balance of pros and cons may be slightly less favourable for fleet users than it is for private users, but also that there is likely to be wide variation in this respect across different types of organisation. For some, EVs are able to meet all their transport needs and offer some advantages over ICEs in terms of performance, driving experience, comfort and (it is assumed) low fuel costs. For others, EVs may not be able to meet their needs for undertaking long and/or very frequent journeys, and may be unwilling to make adjustments to their fleet operations to accommodate this.

5 Impacts of public incentives

- Separating out and accurately quantifying the impact of public incentives is not currently possible, and is always likely to prove challenging.
- Private and fleet EV owners in the UK indicate the PiCG was important in reducing the upfront costs of EVs and, in the case of some fleet owners, the additional benefits for which they can qualify has been an active motivation for them to buy an EV.
- International comparisons suggest a positive relationship between financial incentives and EV uptake, but there are confounding examples (of countries with high incentives but low EV uptake) to this.
- Other factors, notably measures that accrue EV owners ongoing financial and non-financial benefits during ownership, have been found to mediate the relationship between financial incentives and EV uptake.
- Features of financial incentives themselves (other than how big they are) can also play significant roles in mediating their impact on EV uptake, including when incentives are introduced, levels of incentives for different types of EV and different types of purchaser, and whether incentives extend to leasing EVs.
- The evidence also suggests that a package of well-designed financial incentives plus non-financial incentives (and possibly also investment in public charging) may be the most effective means of increasing EV uptake.
- There is insufficient evidence to date to draw any firm conclusions about the impacts of reducing or withdrawing incentives on EV uptake. The one precedent for this in the Netherlands suggests that withdrawing incentives when an EV market is still in the early stages of developing and price differentials between EVs and ICEs are still significant is highly likely to have a negative effect on this development.

This chapter presents evidence on the impact of public incentives on the uptake of EVs. Several UK and international sources were identified in this rapid evidence assessment that have attempted to address this issue, but ultimately none provide definitive answers to key questions such as: 'what impact have incentives had so far on increasing uptake and in EVs?' and 'what impact can they have in increasing uptake in the future?' However, despite the lack of definitive answers, some tentative conclusions about the impacts of incentives can still be drawn from the evidence.

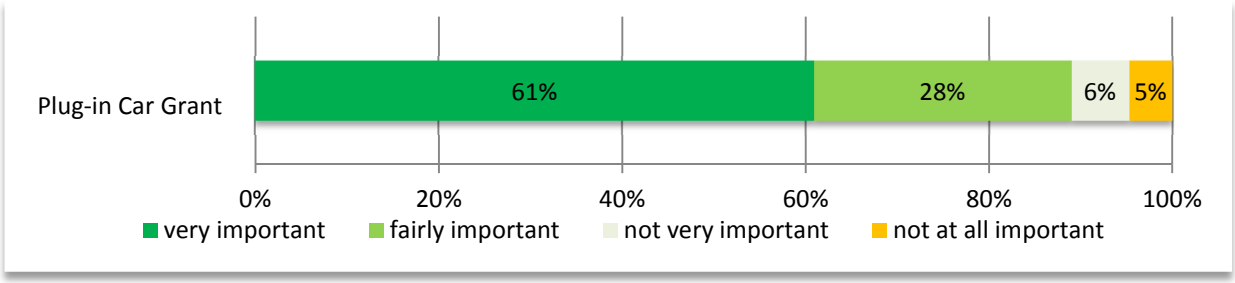
This chapter is structured around the two main forms this evidence comes in: findings from research with consumers on the impact of incentives; and comparative analysis of incentives and EV uptake in different countries. In discussing each of these, selected findings are presented and the subsequent conclusions that can be drawn from them then considered.

5.1 Evidence from research with consumers on the impact of incentives

In the research for DfT with PiCG recipients in 2013, 84% of private respondents stated that they had been aware of the PiCG when they first considered buying an EV. Less than 5% spontaneously cited the PiCG as a reason for buying an EV but in the qualitative element of the research: "many respondents explained that

they would not have been in a position to purchase their EV had they not been eligible for the Grant" (Hutchins et al, 2013). When prompted, nearly 90% also stated that the PiCG had been very or fairly important in their decision to buy an EV.

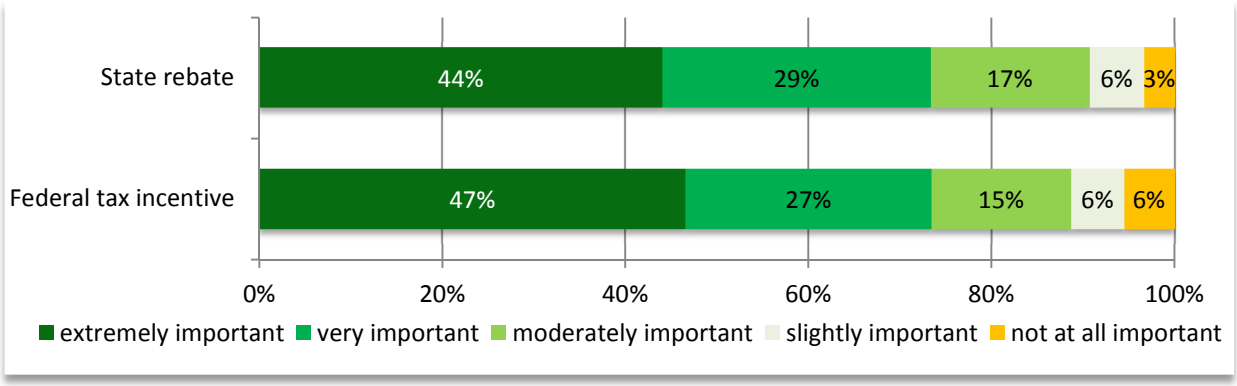
Figure 28. Importance of PiCG in decision to buy an EV for private owners (UK)



Source: Hutchins et al, 2013

There are similar findings from EV owners in California, when asked about the importance of the federal tax incentive of up to $7,500 and the state rebate of up to $2,500 in their ability to acquire an EV.

Figure 29. Importance of incentives in ability to acquire an EV for private owners (California)



Source: Center for Sustainable Energy, 2015

In terms of business EV owners, 90% of respondents in the DfT research stated that their organisation was aware of the PiCG when it first considered buying an EV. Less than 5% spontaneously cited the PiCG as a reason for buying an EV but 27% did spontaneously cite "tax benefits and incentives[14]" – making it the second most frequently cited reason. When prompted, 88% also stated that the PiCG had been very or fairly important in their decision to buy an EV (Hutchins et al, 2013).

These findings are useful in demonstrating that incentives do appear to be something most EV owners are conscious of when making the decision to buy an EV. In the case of private purchase they appear to have played an important role in reducing the existing price premium EVs have in comparison to ICE, and making it easier for them to be able to afford to buy one. Element Energy et al (2013) also conclude that "purchase incentives are essential to bridge the significant price gap (between EV and conventional vehicles)…and will be required well into the 2020s if EV sales are to increase." For business purchasers, this evidence also suggests that the combination of the PiCG and the additional tax benefits they can qualify for is not just helping but actively motivating some to buy EVs. This is consistent with research that has highlighted that business purchasers are more sensitive to TCO than private purchasers (Anable et al, 2014), although

[14]The tax benefits EV owners can currently qualify for are detailed in: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315604/factsheet-tax-implications.pdf

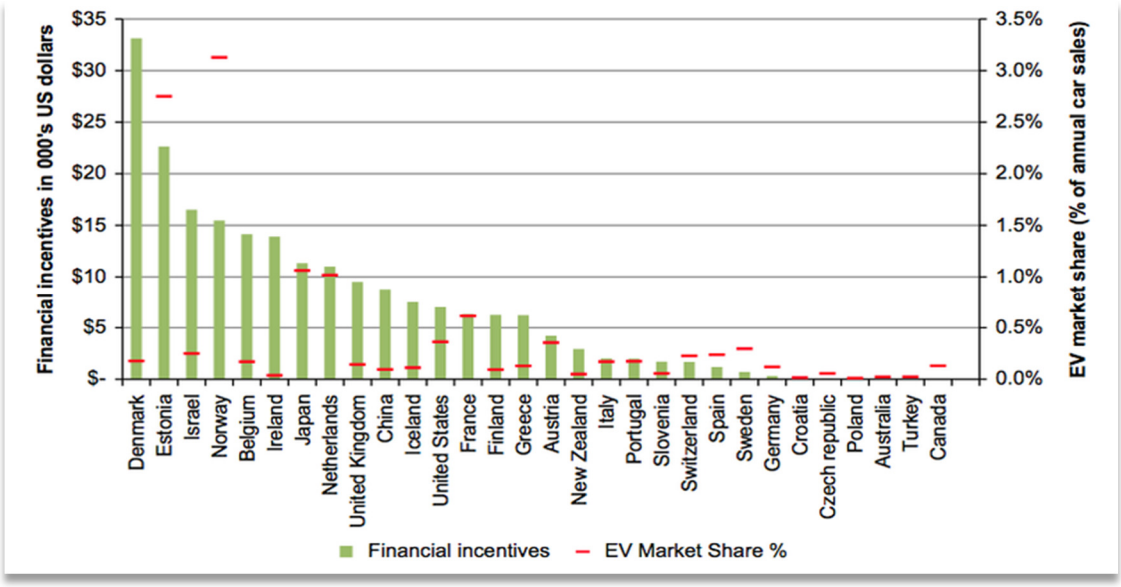
looked at another way, it may also partly be a reflection of the fact they can simply receive more financially by way of incentives than private purchasers currently can[15].

The key limitations of this evidence are that it relies heavily on statements made by research respondents who have already directly benefitted from these incentives, typically made sometime after they have been through the decision-making process of buying their EV. Research (Anable et al, 2014) has highlighted the complexity of this decision-making process, and the tendency of private purchasers to over or understate the importance of certain factors (e.g. fuel efficiency) before or after the event. Evidence of this type also provides little by way of counter-factual evidence – i.e. what EV uptake would have been if the incentives had not been introduced – or insight into what EV uptake would have been (or will be in the future) if the incentives were bigger, smaller or offered in different forms.

5.2 Evidence from international comparisons of incentives and EV uptake

The limitations highlighted above have led some researchers to attempt to quantify the impact of incentives by analysing and comparing levels of EV uptake in different countries (or in different states, in the case of some US studies). The findings from this have been quite mixed. For example, in a recent review Vergis and Chen (2014) highlight that "some studies…suggest that subsidies are correlated with HEV sales, while others find no relation with HEV purchase". In studies where a relationship has been found between incentives and EV uptake this has generally come with a number of caveats about the strength of this relationship and the confidence that can be placed in the findings. For example, on the basis of the analysis of 2012 data on incentives and EV sales Sierzchula et al (2014) reached the following conclusions: "…while this study does show that financial incentives are positively correlated to national EV market shares, it is definitely not evidence of a causal relationship and should be treated with prudence."

Figure 30. Financial incentives by country and corresponding EV market share for 2012



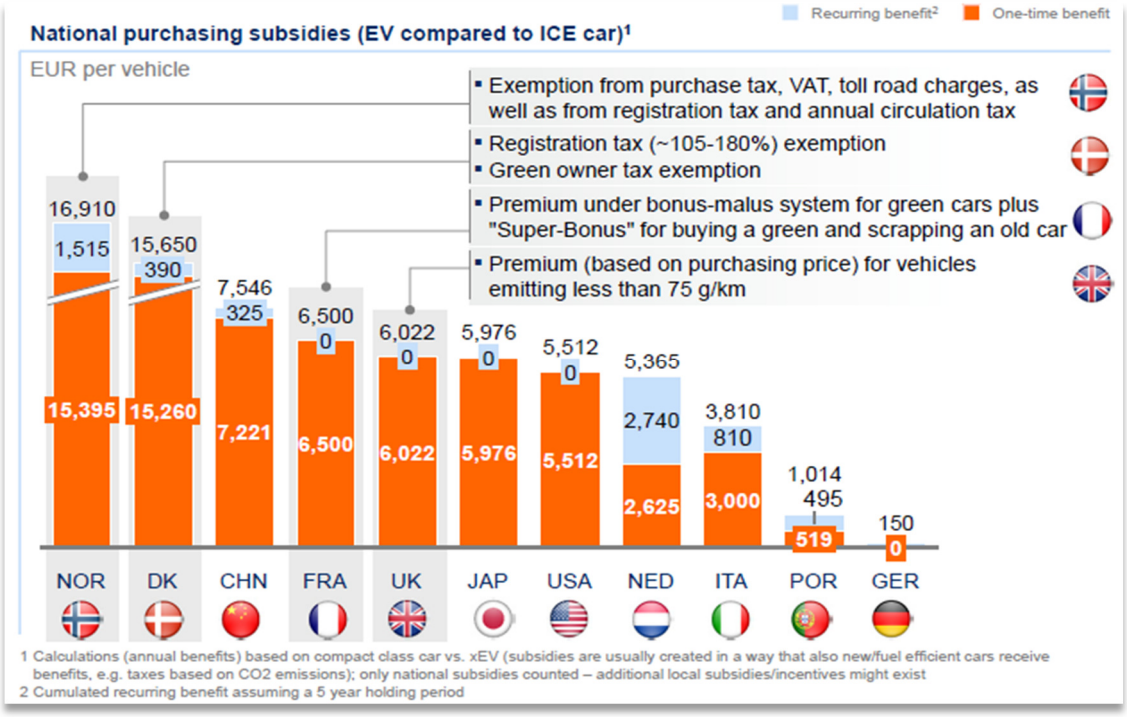
Source: Sierzchula et al (2014)

The following two graphs provide more recent and detailed data on incentives and EV uptake in selected countries. The first (which is based on incentives payable to private EV purchasers) illustrates that Norway and Denmark offer significantly higher incentives than other countries, while the UK is broadly comparable

[15] Analysis by Mock and Yang (2014) suggests that the additional tax benefits UK fleet purchasers could receive in 2013 amounted to anywhere between 3,000-17,000 Euros depending on whether a BEV or PHEV wass purchased.

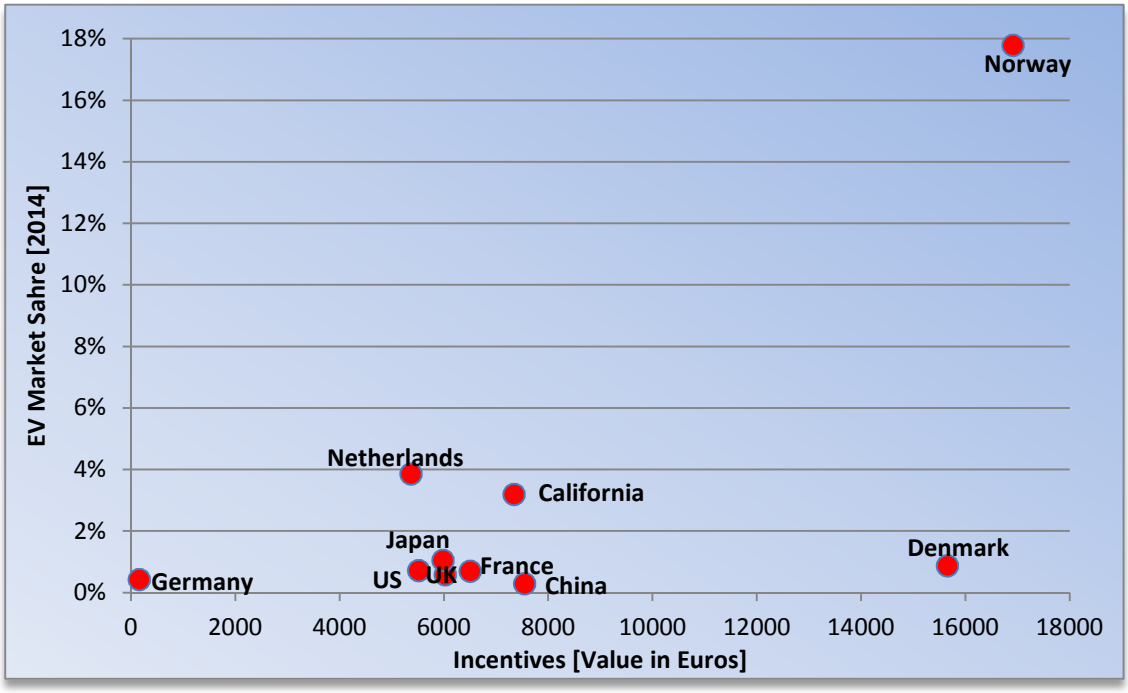
with several others in terms of what it offers private purchasers through the PiCG. The combined effect of incentives in Norway is such that price differences with equivalent ICEs have largely been removed[16].

Figure 31. Financial incentives by country in 2014



Source: Amsterdam Roundtables Foundation & McKinsey (2014)

Figure 32. Financial incentives and EV market share by country in 2014



Source: Amsterdam Roundtables Foundation & McKinsey (2014) and various sources (2014).

[16] Figenbaum et al (2014) report that "Small EVs are about as expensive as comparable ICE-vehicles; Compact EVs are less expensive than comparable ICE-vehicles; Large EVs (Tesla Model S) are about as expensive as large ICEs."

At face value, and without the benefit of any detailed regression analysis, it is apparent that there is some form of a positive relationship between incentives and market share, but also that there are confounding examples that don't conform to this – most notably Denmark, but also to a lesser extent China. Both have relatively large financial incentives but comparatively low EV uptake.

What studies have generally concluded is that financial incentives are one amongst several factors influencing uptake, and that these other factors can mediate the impact of a financial incentive. There are also features of financial incentives themselves (other than how big they are) that mediate their impact too. Evidence on these other factors and features of incentives are summarised below:

Figure 33. Other factors that influence EV uptake

Factors	Evidence
Measures that accrue EV owners benefits during ownership	These include measures which give EV owners further financial savings non-financial benefits in the form of time savings during ownership. Figenbaum and Kolbenstvedt (2013), based on an extensive evidence review, suggest that access to bus lanes have been as important to EV uptake in Norway as the main financial incentives for EVs in regions with large-rush hour traffic, because of the time-savings they afford EV owners. In a recent review of incentives across 50 US states, Jin et al (2014) conclude that "the most effective incentives in driving PEV purchases are subsidies, HOV lane access, access to charging infrastructure, and exemptions from emissions testing." HOV lane access is also the third most frequently cited motivation for buying an EV in California and over 90% of EV owners saying they have applied or will apply for the HOV lane sticker required to take up this option (Center for Sustainable Energy, 2015) Element Energy et al (2013) report that "uptake can be cost-effectively supported through other non-financial measures which are valued by consumers (such as free access to parking, bus lanes, longer term financing options and other soft benefits), as have been proven in countries where uptake of EVs is much higher than in the UK." Anable et al (2014) also state that "the higher than average uptake of EVs in London and the location of people owning these vehicles does suggest that parking incentives and the congestion charge can influence the level of adoption."
Public Charging Provision	Vergis and Chen (2014), Sierzchula et al (2014) and Anable et al (2014) suggest that public charging infrastructure (discussed in detail in chapter 7 of this report) may have an equal or greater impact on EV uptake than financial incentives – although again, the evidence for this comes with several caveats, and the strong suggestion that this may only be true for BEV uptake rather than PHEV uptake (Vergis, 2014).
Oil prices	Evidence from the US indicates that the uptake of EVs is correlated with oil prices (Vergis and Chen, 2014), and Anable et al (2014) emphasises consumers' sensitivity to changes in oil prices – as much as or more so than the price itself. Shepherd et al (2012) also suggest that future oils prices will have a significant influence on the ability of financial incentive to increase EV uptake in the UK in the future. In addition, Mock and Yang (2014) report that the size of the difference between electricity and oil prices may explain some of the variations in the relationship between incentives and in EV uptake in different countries. Norway, for example, has relatively

	high gas prices but relatively low electricity tariffs, whereas the difference is notably smaller in Denmark.

Figure 34. Features of financial incentives that mediate their impact on EV uptake

Features of incentives	Evidence
How long incentives are in place	Norway introduced its exemption from registration tax for EVs in 1996 and its VAT exemption in 2001, whereas other countries, including the UK, have introduced financial incentives in the last 5 years. Figenbaum and Kolbenstvedt (2013) and Element Energy et al (2013) suggest this is one reason why Norway's EV market share is so high. Financial incentives in the Netherlands were also introduced relatively early, in 2006, (Vergis et al, 2014) which may help to partly explain their large EV market share.
Fleet vs. Public incentives	Most countries, including the UK, offer financial incentives to private and fleet EV purchasers. Mock and Yang (2014) suggest one reason for Denmark's low EV market share is that despite their high financial incentives for private purchasers, none are available to fleet purchasers.
BEV vs. PHEV incentives	Mock and Yang (2014) and Element Energy et al (2013) suggest that differences in the value of incentives for BEVs and PHEV influence the relative market share of each - although no findings are ventured on the implications for overall uptake of EVs. In Norway, BEVs have been eligible for all financial (and non-financial) incentives since their introduction, whereas PHEVs have only recently been deemed eligible for some of these. Almost all EVs sold in Norway have been BEVs (Figenbaum et al, 2014). In contrast, in the Netherlands incentives have been similar for PHEVs and BEVs and it is suggested that this has resulted in most EV sales having been PHEVs. In California, BEVs qualify for higher financial incentives than PHEVs[17], which may explain why, in contrast to the Netherlands, BEVs represent around half of EV sales (Center for Sustainable Energy, 2015). However, no source was identified in this rapid evidence assessment that had explored this.
Leasing eligibility	Element Energy et al (2013) report that "cost incentives directed at the lease car market can be particularly effective in driving adoption. In the Netherlands, incentives aimed at lease cars are particularly favourable, which has resulted in significant uptake in the lease car market". In California, EV leasers are also eligible for financial incentives and just over half of all EV "owners" in the state are leasing their EV rather than having purchased it outright (Center for Sustainable Energy, 2015).

The implications of these findings are that separating out and accurately quantifying the impact of public incentives is not currently possible, and is always likely to prove challenging. What can be concluded is that all countries with an EV market share of above 1% (which based on data for the first three months of 2015 may now include the UK) have had financial incentives in place for 3 or more years previously. The example of Norway also suggests that very high financial incentives, in place for a longer time period, can contribute to a very high EV market share. However, the example of Denmark illustrates that generous financial incentives do not guarantee a high EV market share. Other factors (notably measures which accrue EV owners ongoing benefits during ownership) and features of how financial incentives are designed can play significant roles in mediating the impact of financial incentives on EV uptake. Although sources have tended to look at the impact of different factors independently, the evidence also suggests that a package

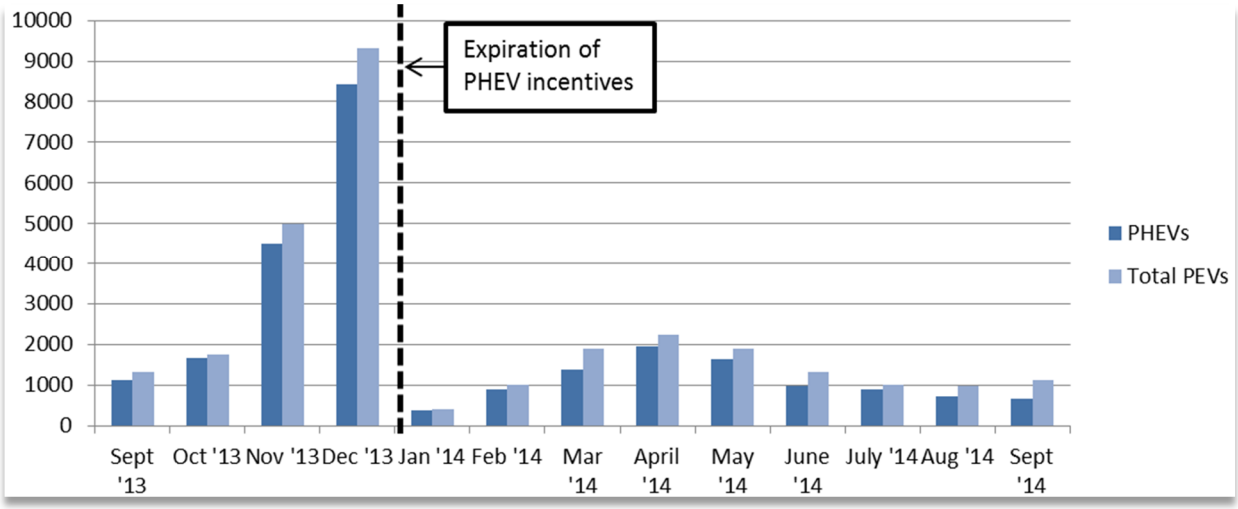
[17] The main incentive is a federal tax credit for BEV and PHEV purchases, ranging from $2,500 to $7,500 depending on the battery size and the California state incentive of $2,500 for BEVs and $1,500 for PHEVs.

of well-designed financial incentives plus non-financial incentives (and possibly also investment in public charging) may be the most effective means of increasing EV uptake.

One other aspect of incentives that this rapid evidence assessment sought to address was the impact on EV markets of reducing or withdrawing incentives entirely. Evidence of this having happened was only identified in two locations: the Canadian province of British Columbia and the Netherlands. In British Columbia, funding for a $5,000 purchase rebate for EVs expired in February 2014 and was not renewed[18]. Although some data on EV sales before and after February 2014 has been published in an online article, it does not provide a robust basis for assessing the impact the expiration of the rebate had.

The case of the Netherlands, where the main financial incentive for PHEVs expired on the 1st January 2014, was reported in Vergis et al (2014).

Figure 35. EVs sales before and after the withdrawal of incentives (Netherlands)



Source: Vergis et al, 2014

The authors comment that "It appears that in the months leading into the dissolution of PHEV incentives purchases were high, fell shortly after the expiration of the PHEV incentives, and have since regained ground". More recent data for the first three months in 2015[19] suggests that EV sales had returned to similar levels as those in September and October 2013. No further research or analysis was identified in this rapid evidence assessment and, overall, it is not possible to draw any firm conclusions about the impact of withdrawing incentives just on the basis of this one example. The sharp increase in sales immediately prior to their withdrawal, followed by the even sharper fall immediately afterwards does at least serve to further illustrate the influence of incentives on the car buying decisions made by consumers – reinforcing the findings reported in section 5.1. It is also worth noting that while EV sales in the Netherlands may have recovered to their pre-withdrawal levels in the first quarter of 2015, other countries with incentives still in place saw notable increases in their EV market over this same time period (including the UK and Norway, as reported in chapter 2). This does suggest that, based on the example of Netherlands, withdrawing incentives when an EV market is still in the early stages of developing and price differentials between EVs and ICEs are still significant is highly likely to have a negative effect on this development.

[18] On the 23rd March 2015 the British Columbia government announced it was reinstating the purchase rebate.
[19] 2,506 EVs sold in January, 1,412 in February, 1,863 in March. Source: http://ev-sales.blogspot.co.uk. Retrieved 08.05.2015.

6 Other key motivators and barriers

- The most important factors that private and fleet car buyers take into consideration when choosing a new car are costs – both purchase price and running costs – as well as size, style, reliability, comfort, engine power, design and safety.
- Private EV owners most commonly cite the following motivations for buying an EV: saving money on fuel costs; environmental factors; and interest in new technology.
- The most commonly cited barriers to private car buyers buying an EV in the future are: range concerns; purchase price; and a lack of knowledge about/familiarity with EVs.

  The most commonly cited motivations for buying an EV for fleet purchasers are: financial factors; and environmental factors (linked to CSR).
- The most commonly cited barriers to fleet purchasers are largely the same as those for private car buyers: range concerns; purchase price; and a lack of knowledge about/familiarity with EVs.

This chapter first provides a brief overview of general influences on car purchasing decisions and then examines motivations and barriers to buying EVs in more detail – for both private and fleet buyers.

6.1 General influences on car purchase decisions

6.1.1. Private buyers

General influences on car purchase decisions have been researched extensively. Key factors that people take into consideration include costs – both purchase price and running costs – as well as vehicle characteristics such as size, style, reliability, comfort, engine power, design and safety (Hutchins et al, 2013). Brand loyalty also comes into play, as well as the symbolic associations of different vehicles and how they relate to the prospective buyer's identity and self-perception (Morton, 2013).

Surveys have attempted to rank the relative importance of these attributes, but the results are influenced by changing consumer preferences as well as by research design. One recent survey identifies the top three considerations as purchase price, low fuel costs and insurance tax band (TNS-BMRB, 2014), while another suggests that fuel economy is the most important factor, followed by the style/appearance of the vehicle. Factors that have been identified as having less importance than those listed above include the environmental impact of the vehicle and its resale value (Anable et al, 2014).

6.1.2. Fleet buyers

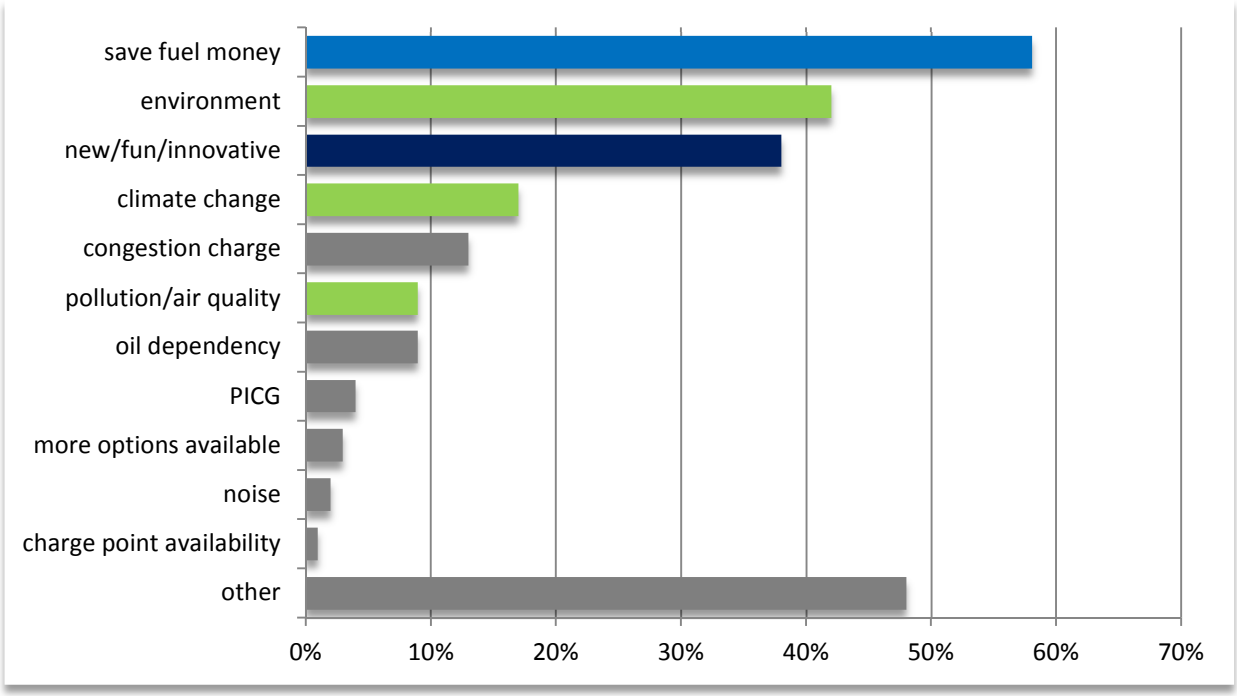
There is much more limited evidence on what influences the purchase choices of fleet car buyers, although what evidence there is suggests they give more weight to total costs of ownership and vehicle reliability than private buyers (Anable et al, 2014).

6.2 Motivations for buying an EV amongst private buyers

The evidence base on these motivations is reasonably well-developed, with quantitative data available from recent surveys of private EV purchasers in the UK and in some other countries. Findings from two of these surveys are presented below, and then evidence on specific motivations is discussed. It is worth noting that

although the survey findings are valuable in highlighting the prevalence of different motivations, they offer less insight into their relative importance in the decision-making of EV buyers at the point of purchase. There are also some motivations which aren't easily conceptualised and captured within a quantitative survey but which, based on more qualitative research, have been highlighted as potentially important influences. Evidence on these "softer" motivations is included in the more detailed discussion that follows.

Figure 36. Private owners' reasons for buying an EV (UK)

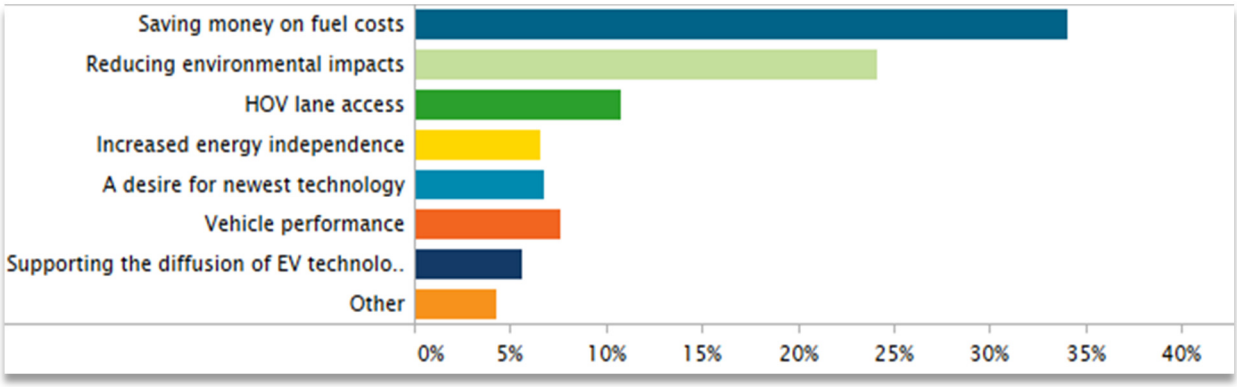


Source: Hutchins et al, 2013

The results above, based on a survey of UK private EV owners, highlight that financial and environmental factors, plus an interest in new technology, were the most frequently cited reasons for buying an EV. Respondents were not prompted with any response options and could provide more than one answer.

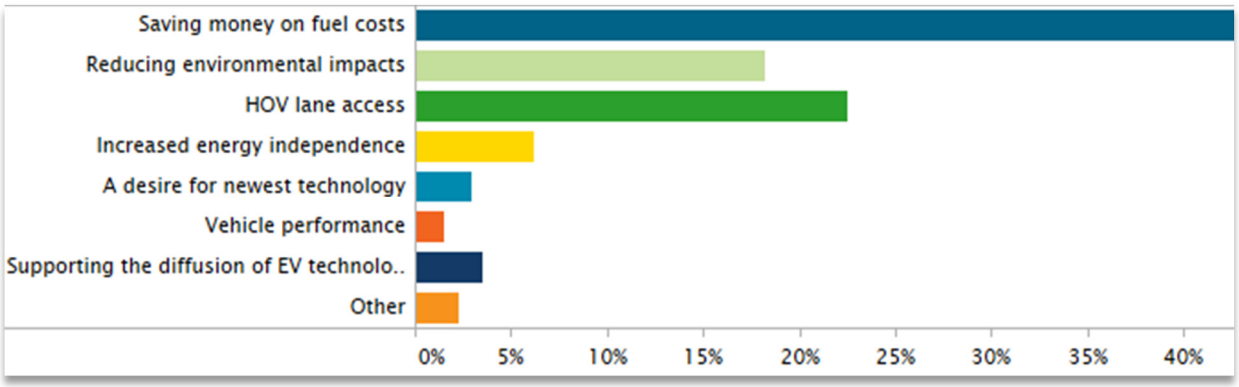
The next set of findings, based on a survey of EV owners in California, are the only ones found in this rapid evidence assessment that have separated out motivations for buying a BEV or a PHEV.

Figure 37. Private owners' main motivation for buying a BEV (California)



Source: Center for Sustainable Energy, 2015

Figure 38. Private owners' main motivation for buying a PHEV (California)



Source: Center for Sustainable Energy, 2015

The findings above illustrate that financial and environmental motivations again predominate, but also that there are some differences between BEV and PHEV buyers. More BEV owners said they had been motivated by environmental factors than PHEV owners, who were more likely to cite financial factors (and pragmatic ones too, in the form of HOV lane access). Respondents were prompted with response options in the survey and were only permitted to provide one answer.

6.2.1. Financial motivations

As highlighted above, a key motivation for private EV buyers is the lower running cost of an EV compared to a conventional vehicle, and the associated savings on fuel (Hutchins et al, 2013; Element Energy et al, 2013). The cost of recharging is considered to be significantly lower than the cost of refuelling (Hutchins and Delmonte, 2012). Similar findings emerge in research from other countries. In Norway, for example, EV owners highlight low operating costs as the most important consideration when buying a new car (Figenbaum et al, 2014), and 41% state that their main motivation for buying an EV was to save money (Amsterdam Roundtables Foundation and McKinsey, 2014). Research in California found that 91% of EV buyers felt that fuel savings had been an important factor in their purchase decision (California Centre for Sustainable Energy, 2013).

Increases in fuel prices appear to make the running cost savings of EVs more salient to buyers (Sierzchula et al, 2014). Evidence from the US suggests that the uptake of EVs is correlated with fuel prices (Vergis and Chen, 2014). However, it appears that the speed of price increases and the relative costs of different fuels are more important than absolute prices. People react to sharp rises in fuel prices, making purchase decisions on the basis of perceived costs and savings rather than detailed payback calculations – which in any case would be difficult to make, as future fuel prices are unknown. (Anable et al, 2014). People may consider EVs to offer "an insurance policy" against rising fuel prices. Although the purchase cost of an EV is higher than that of a conventional vehicle, the buyers may feel protected from the impact of potential or likely future increases in fuel prices (Hutchins et al, 2013). People tend to assume that electricity prices will rise more slowly than petrol prices (Anable et al, 2014).

6.2.2. Environmental motivations

Some private purchasers of EVs report that they were motivated by environmental concern (Hutchins et al, 2013), particularly the low emissions of EVs compared to conventional vehicles (Anable et al, 2014) and the opportunity to reduce their own personal environmental impact (Figenbaum and Kolbenstvedt, 2013). Research in various other countries, including the US (Vergis and Chen, 2014), Norway (Figenbaum et al,

2014), Portugal (Rolim et al, 2014), France (Pierre et al, 2011) and the Netherlands (Velthuis, 2012) has come to similar conclusions.

Evidence on how important environmental motivations are in comparison to other considerations is mixed. Anable et al (2014) suggest that the environmental benefits of EVs may only constitute a minor purchase motivation, or be important to a minority of EV buyers. However, over 40% of private EV owners in Hutchins et al (2013) cited "the environment" as a reason why they had chosen to buy an EV rather than an ICE. 17% also cited "climate change/CO2", and 9% "pollution/air quality". In line with this, research in Portugal suggests that 46% of EV buyers consider environmental benefits to be a key advantage of EVs (Rolim et al, 2014). A survey in California also found that 94% of respondents claimed environmental benefits were a factor in their decision to buy an EV (California Centre for Sustainable Energy, 2013), and research in Norway has put environmental reasons in the top three motivations for EV purchase (Figenbaum and Kolbenstvedt, 2013).

6.2.3. Personal motivations

A number of motivations are highlighted in the literature which centre around individuals' preferences and attitudes. For some, the opportunity to engage with a new, cutting-edge technology, and the resulting excitement and pride, were key motivations for purchasing an EV (Hutchins et al, 2013). These findings have been replicated in France (Pierre et al, 2011) and the Netherlands (Velthuis, 2012), where the novelty and pioneering nature of EVs have been identified as a motivator for some buyers. However, this is not, by any means, a consistent trait across all EV current owners (Hutchins et al, 2013; Pierre et al, 2011) and, as discussed in chapter 3, neither is it likely to be amongst all segments of future EV purchasers.

The symbolism associated with EVs and the associated perceived status conferred by EV ownership can be a motivator for some buyers (Element Energy et al, 2013). Bunce et al (2014) suggest that EVs do not yet have well-established symbolic meanings, but Anable et al (2014) highlight that there are a number of emerging associations with EVs which include lower resource consumption, independence from petroleum producers, advanced technology, financial responsibility, saving money, opposing war, and environmental and/or resource preservation. Where these meanings relate to the prospective buyer's identity or values, they can form a motivator for the purchase decision.

For some EV buyers, the prospect of fuel independence and avoiding the hassle of using petrol stations can be an attractive one. In the UK, this has only been explored in a qualitative context (Anable et al, 2014), but there is more extensive evidence from abroad. For example, in one survey in California, 91% of respondents said that fuel independence had played an important role in their decision to buy an EV (California Centre for Sustainable Energy, 2013). In another study in Northern California, participants in a PHEV trial were found to be somewhat more likely than average to consider energy independence a serious issue (Kurani et al, 2012). Small-scale research in France found that some EV buyers were keen to avoid energy wastage. Interestingly, this group were not motivated by the novelty of EV technology, did not want to be seen as the "forerunners", and had in fact purchased their EVs second-hand (Pierre et al, 2011).

6.2.4. Peer and marketing influences

These influences are not a motivation to buy an EV in and of themselves but are a potentially important facilitator to the process of diffusion, whereby a new behaviour is adopted by increasing numbers of consumers as they see others around them adopting it. Various authors have highlighted the anticipated role of diffusion in the uptake of EVs, although also acknowledged that the process "cannot be easily measured or observed for technologies as new as plug-in vehicles" (Element Energy et al, 2013).

In terms of the role of peer influences in the diffusion of EV purchasing, the evidence from Norway and California reported in section 3.1.3 highlighted that EV owners often had family or friends who had also bought an EV. The 'neighbour effect' has been put forward as a strong potential future motivator of EV uptake. The theory is that as EVs become more widespread and more visible, people become more confident in the technology, as well as being influenced by the social norming effect. (Anable et al, 2014). Increasing visibility of EVs has also been highlighted as a motivator in Norwegian research (Figenbaum and Kolbenstvedt, 2013). Another potential aspect is peer pressure, and Bevis et al (2013) suggest that environmental peer pressure could motivate some to purchase EVs, particularly if they live in a 'green' community. In addition, it has been suggested that marketing and advertising can play an important role in facilitating the process of diffusion and EV uptake, at least until the market has become sufficiently established (Shepherd et al, 2012). The influence of advertising is also highlighted in Norwegian research, where newspaper and television advertising are believed to have had an impact (Figenbaum and Kolbenstvedt, 2013). An older US study of diffusion and competition among alternative fuel vehicles by Struben and Sterman (2007) cited in Element Energy et al (2013) suggested that favourable conditions for diffusion (such as a marketing campaign and exposure to the technology) are necessary for the market to increase to a self-sustaining level.

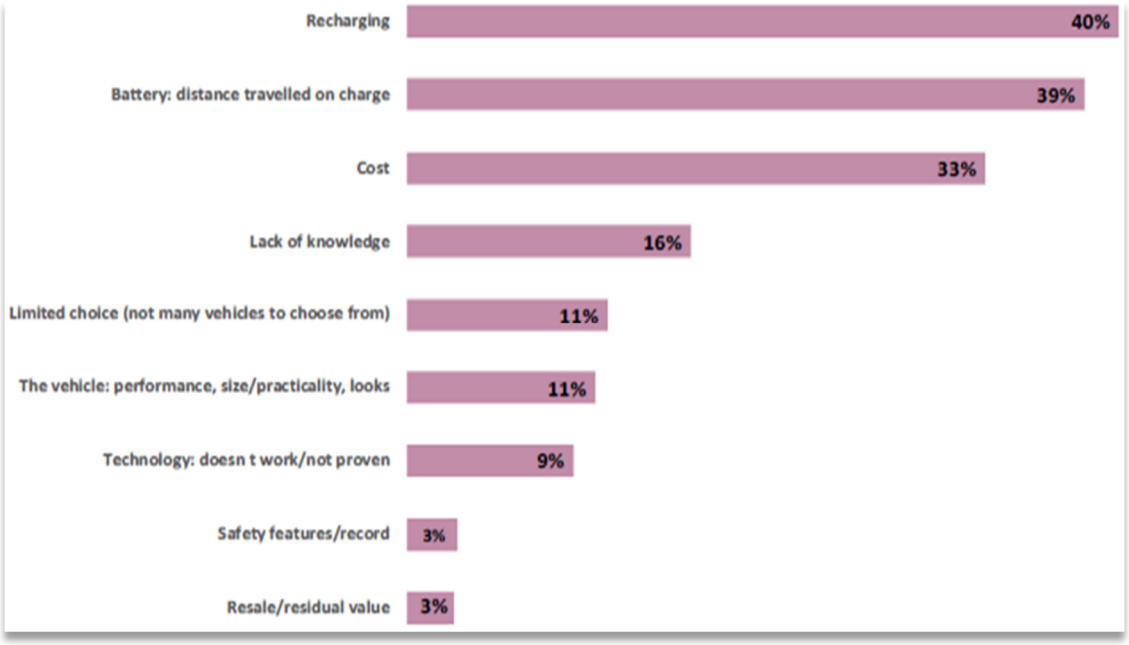
6.2.5. Experience of EVs

Evidence from EV trials in Germany suggests that experience of EVs tends to have a positive impact on people's attitudes towards them – though this is not a consistent finding across all research. In some cases, these positive attitudes then translated into an increased likelihood of purchasing an EV – though again, in some studies, purchase intentions actually remained unchanged or even declined after participation in a trial (Bühler et al, 2014). Nevertheless, some policy-makers feel that the experience of driving an EV is important in convincing people that they are "proper" and "fun" vehicles to drive (Bakker and Tripp, 2013).

6.3 Barriers for private buyers

The findings from a recent national UK survey, which asked respondents what factors deterred them from buying an EV, are presented below and then evidence on specific barriers is discussed in more detail.

Figure 39. Factors deterring people from buying an EV



Source: DfT, 2014

The results above illustrate that concerns about range, recharging and the cost of EVs are key barriers. Lack of knowledge, although only cited by 16% of respondents, may also be an important underlying factor given its potential to mediate or exaggerate several of the other perceived barriers. Respondents were not prompted with any response options in this survey and could provide more than one answer.

6.3.1. Range limitations and range anxiety

The reviewed literature repeatedly highlights the issues of limited range and range anxiety as key barriers to EV adoption (e.g. Hutchins et al, 2013; Anable et al, 2014; Element Energy et al, 2013). In one UK survey, over 70% of respondents stated that they would worry about not being able to travel as far as they needed (Bunce et al, 2014), while a DfT (2014) survey puts range anxiety at the top of the list of barriers. Similar results emerge from research in other countries (e.g. Sierzchula et al, 2014; Bühler et al, 2014; Wardle et al, 2014). Even in Norway, where the EV market is more mature, range issues remain a barrier to further EV uptake (Figenbaum and Kolbenstvedt, 2013).

Range is considered a barrier by many, regardless of their level of engagement with EVs (Hutchins et al, 2013). Prospective EV buyers consider it important whether EVs can drive long distances, even though they acknowledge that these long trips are rarely taken (Element Energy et al, 2013). Anable et al (2014) cite work which suggests that this desire to be able to travel long distances may be due to associating vehicle ownership with a sense of freedom. Burgess et al (2013) suggest that a day-to-day range of 83 miles would be ideal for private users, and a 230-mile range would be sufficient for all journey requirements. Anable et al (2014) suggest that a range of 100 miles would make EVs attractive as second cars, whilst a range of 150 miles would be required to make them attractive as main cars.

Range is widely assumed to be much less of a barrier for PHEVs as opposed to BEVs, although there is little direct evidence illustrating or quantifying this. What there is suggests that there is a minimum acceptable amount of all-electric range of PHEVs, and this figure is 20 miles (Anable et al, 2014).

6.3.2. Perceived lack of infrastructure

The perceived lack of public charging infrastructure has been frequently highlighted by non-EV owners as a barrier to EV uptake (e.g. Element Energy et al, 2013; Carroll, 2011). Survey data suggests that anywhere from 30% (Bevis et al, 2013) to 60% (Bunce et al, 2014) of people feel the public charging infrastructure is not sufficient for them to consider buying an EV. Again, these findings on infrastructure are replicated in studies abroad (e.g. Wardle et al, 2014; Rolim et al, 2014). Although most people have access to charging facilities at home, most also feel that they would want to see public charging facilities provided before considering an EV (Element Energy et al, 2013). However, Anable et al (2014) suggest that the lack of public charging infrastructure is not the biggest barrier to uptake of EVs, and that people are more concerned about range.

6.3.3. Charging issues

The amount of time required to charge an EV is another barrier frequently mentioned in the literature (e.g. Element Energy et al, 2013; Anable et al, 2014). In one UK survey, 70% of respondents rated the recharging time as their second most important concern (after a dead battery) about EVs (Bunce et al, 2014). Again, research in other countries also highlights this same issue (e.g. Bühler et al, 2014; Wardle et al, 2014; Sierzchula et al, 2014; Velthuis, 2012). It is not simply the waiting time that is an issue: associated with this is the idea of inflexibility and a concern that the vehicle may not be ready when required (Element Energy et al, 2013). However, the findings from an EV trial in Germany suggest that these worries may be at least in part overcome with experience of EVs, as the proportion of participants considering the long charging time to be a barrier decreased following three months' driving experience (Bühler et al, 2014).

People also worry that charging an EV will be inconvenient (e.g. Bunce et al, 2014; Wardle et al, 2014). However, as noted in chapter 4, evidence from vehicle trials suggests that in practice people tend to find charging easy and convenient (Bunce et al, 2014). There are also other potential problems with charging EVs that may create barriers to adoption. A lack of standardisation among connector cables is one (Bevis et al, 2013), and battery life is another (Bühler et al, 2014). However, these issues tend to be reported in the literature as barriers experienced by EV users, rather than as perceptual barriers to uptake.

6.3.4. Financial barriers

The issue of EVs' high purchase prices as a barrier to uptake recurs in much of the literature (e.g. Hutchins et al, 2013; Carroll, 2011). Some of the reviewed studies put purchase price at the top of the list as the most important barrier (Element Energy et al, 2013), whilst DfT (2014) suggests that it is in the top three (behind recharging and range). In one survey, 70% of respondents agreed with the statement "ULEVs are too expensive to buy at the moment" (TNS-BMRB, 2014). These findings on the importance of cost as a barrier to EV uptake are replicated in studies abroad (Wardle et al, 2014; Bühler et al, 2014; Sierzchula et al, 2014).

Although lower running costs have been identified as a motivator for EV purchase that can potentially compensate for the higher purchase price, the evidence suggests that people are more influenced by purchase than running costs (Bunce et al, 2014). Buyers would prefer EVs to be priced at a similar level to conventional vehicles, so that the running cost savings are immediate (Carroll et al, 2013). Only a minority of people think beyond the purchase cost and running costs, but those who do point to potential issues around battery replacement costs, resale value (Hutchins et al, 2013), maintenance, recharging and insurance costs (DfT, 2014). The question of resale value is highlighted as an issue in a study in Norway (Figenbaum and Kolbenstvedt, 2013), suggesting that these other costs may receive more attention in a more mature market.

Although in terms of their TCO EVs can compare favourably with conventional vehicles, most people either do not or cannot make such calculations (Morton, 2013). The TCO of a vehicle is very difficult to calculate, not least because future fuel prices are unknown. Instead, people tend to use simple rules and heuristics to draw conclusions about the fuel efficiency of vehicles and their likely TCO, for example comparing the fuel efficiency of a new vehicle to their old vehicle (Anable et al, 2014) or using the cost of their most recent refuel as an indicator of running cost (Morton, 2013). In addition, it is worth noting that the influence of financial considerations is further blurred by the fact that people's car purchasing decisions are not solely based on finances, but are also influenced by various emotional and other factors.

The relatively high upfront cost of EVs is particularly an issue in light of other limitations that they are perceived to have, such as range and refuelling time (Anable et al, 2014). Taken together, this combination of barriers means that people feel they would be paying more for a vehicle that is less convenient than the conventional alternative (Bunce et al, 2014). The evidence suggests that the upfront cost of EVs is likely to remain a key barrier for some time into the future. Element Energy et al (2013) use cost projections to indicate that this will be the case until at least 2030, particularly for BEVs. Cost is a key consideration in people's vehicle purchase decisions, and it will be crucial for EVs to be perceived as cost-competitive if mass uptake is to be achieved (Amsterdam Roundtables Foundation and McKinsey, 2014).

6.3.5. Novelty of EV technology

EV technology is new and therefore unfamiliar to many, and its novelty creates a barrier to acceptance. People's awareness of EVs and receptiveness to EVs are currently low: survey evidence suggests that at least 50% of UK car drivers say they are 'not at all familiar' with EVs, and only 20% are 'very familiar'

(Element Energy et al, 2013). One of the key issues around the novelty and unfamiliarity of EVs is that people know very little about them and have preconceptions about what they are like – including characteristics such as cost, range and driving experience. As a result, very little consideration is given to EVs as a purchase option (Hutchins et al, 2013). However, these preconceptions may be inaccurate: research suggests that people tend to have misconceptions about EVs' performance, acceleration, top speed (Anable et al, 2014), purchase price, driving range, operating costs and recharging time. As an example, 70% of drivers underestimated the extent of fuel savings (Bunce et al, 2014).

Some of the research suggests that people claim the novelty and unfamiliarity of EV technology is not a particularly important barrier to their uptake (Wardle et al, 2014). In one survey, only 16% of respondents felt that a lack of knowledge was a barrier to EV purchase (DfT, 2014). However, people do report that they do not want to stand out from the crowd by buying an EV, or take the risk of being one of the first to invest in a technology they knew little about and felt uncertain about (Hutchins et al, 2013). This issue of novelty and unfamiliarity is exacerbated by the media coverage of EVs, which is perceived to be largely negative. Television programmes have been highlighted in the research as a key culprit (Hutchins et al, 2013). However, some of the research suggests that EVs are becoming more normalized: people perceive them as something that both car manufacturers and car buyers are thinking more about. The barriers around the novelty and unfamiliarity of EVs may therefore be slowly eroding (TNS-BMRB, 2014).

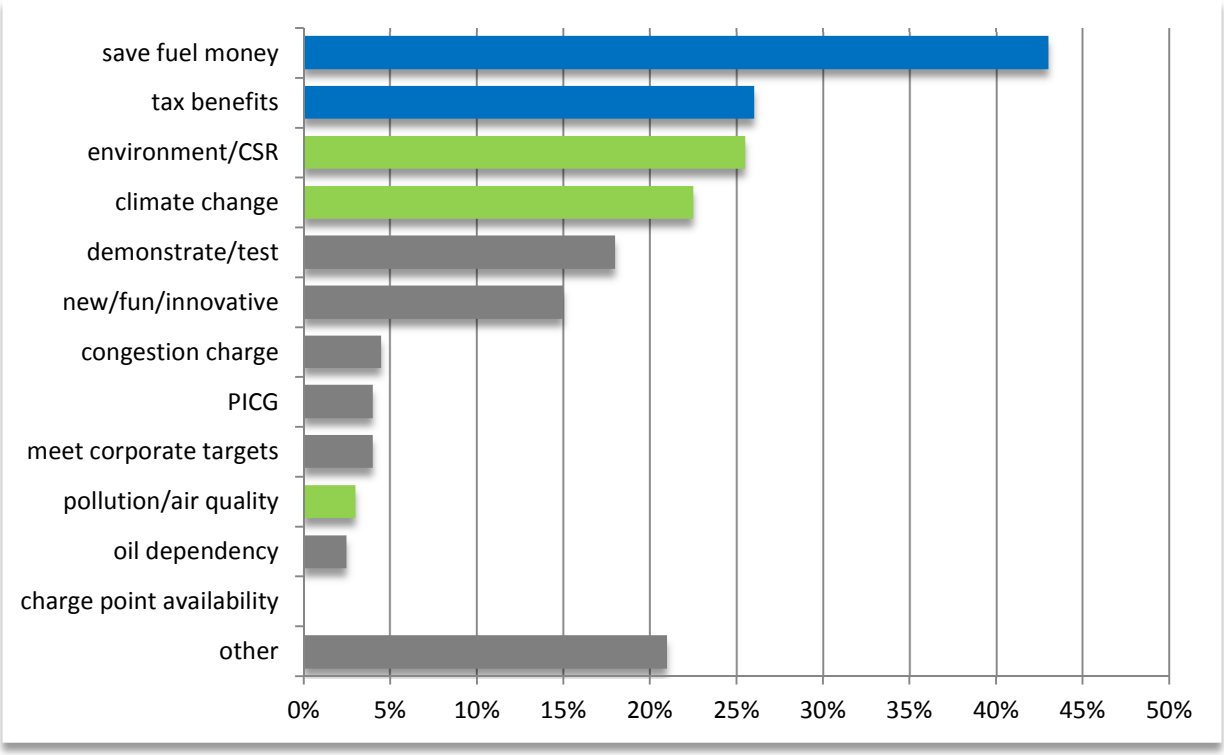
6.3.6. Personal barriers

The appearance and style of EVs can be a barrier to adoption for some people (Element Energy et al, 2013). Although some research suggests that EVs have a poor image (Velthuis, 2012) and that people are concerned about what others would think of them if they bought an EV (Hutchins et al, 2013), other reports suggest that these negative connotations – such as the association with milk floats – may be diminishing (Anable et al, 2014). EVs do not currently have established symbolic meanings, but a positive stereotype may be emerging (Bunce et al, 2014).

6.4 Motivations for buying an EV amongst fleet buyers

Evidence on the motivations of fleet buyers is more limited than that for private purchasers but the survey results from Hutchins et al (2013) does provide a valuable overview of what their key motivations are in the UK. These are presented below, then individual motivations are discussed in more detail.

Figure 39. Fleet owners' reasons for buying an EV



Source: Hutchins et al, 2013

The above results illustrate that financial and environmental factors (plus, linked to this, corporate social responsibility) were most frequently cited by fleet owners in the survey. Respondents were not prompted with any response options and could provide more than one answer.

6.4.1. Financial motivations

A key motivation for organisations to purchase EVs is the lower running cost compared to conventional vehicles. Hutchins et al (2013) suggest that this is the most important motivator for fleet buyers, and that although the upfront cost of an EV is higher than that of a conventional vehicle, fleet buyers (like private buyers) consider it to be an investment to protect them against future fuel price increases.

Costs are the main driver of business decision-making (Anable et al, 2015), and fleet buyers are likely to focus on considering the costs and practicalities associated with a vehicle, and to be less influenced by factors such as brand and image (Element Energy et al, 2013). The whole life cost of the vehicle, or total cost of ownership (TCO), appears to be an important factor in organisational decision-making (Amsterdam Roundtables Foundation and McKinsey, 2014), and some EU regulations may encourage public sector organisations to buy (or to at least consider) EVs, because of the stipulations around whole life costs (Anable et al, 2015). TCO calculations are complex, and the decision to buy an EV entails a number of unknowns. Businesses are likely to need decision-making support tools, including help with calculating the TCO of a vehicle (Anable et al, 2015).

6.4.2. Environmental motivations

The environmental benefits of EVs can be an important motivator for organisational buyers, with some of the evidence suggesting that the environmentally friendly nature of EVs is perceived as their most important characteristic (Hutchins and Delmonte, 2012; (Figenbaum and Kolbenstvedt, 2013). Evidence from Portugal suggests that the environmental benefits of EVs may in fact be a more powerful motivator for fleet buyers than their fuel efficiency and the associated running cost savings (Rolim et al, 2014).

EVs' low emissions are a key factor, as they can help private companies achieve their corporate CO2 emission reduction targets (Hutchins and Delmonte, 2012; Amsterdam Roundtables Foundation and McKinsey, 2014), as well as helping public sector organisations comply with their legislated responsibilities to improve air quality and reduce CO2 emissions. In addition, there are CSR benefits to be gained from incorporating EVs into an organisation's fleet (Bakker and Tripp, 2013). The public sector is also motivated by the opportunity to lead by example on environmental issues through the procurement of EVs (Element Energy et al, 2013).

6.4.3. Marketing motivations

Fleet buyers can also be motivated by what they perceive to be positive image associations of EVs, and some aim to use EVs as a means of highlighting their environmental commitment or standing out from their competitors (Hutchins et al, 2013). Similar findings emerge from research in other countries, including Portugal (Rolim et al, 2014) and the Netherlands (Velthuis, 2012).

6.5 Barriers for fleet buyers

6.5.1. Financial barriers

For fleet buyers, as for private buyers, the purchase cost of EVs is highlighted as an important barrier to uptake (e.g. Hutchins et al, 2013). However, it appears that the purchase price issue is somewhat less central to fleet buyers than to private buyers, as fleet buyers have a number of other considerations which they rate as equally important, notably range and charging time (Anable et al, 2014). Research in Portugal suggests that only one in four fleet buyers considers purchase cost a key barrier (Rolim et al, 2014), but other evidence argues that purchase cost is and is likely to remain the most significant issue preventing further uptake (Bakker and Tripp, 2013).

In contrast with private buyers, fleet buyers appear to give somewhat more consideration to other costs besides purchase and running costs. Research has found that fleet buyers are more concerned than private buyers about the residual value of EVs (Hutchins et al, 2013), as well as highlighting the cost of battery replacement (Hutchins and Delmonte, 2012).

As with private buyers, fleet buyers find it difficult to calculate the TCO of EVs, which can present a further barrier to uptake. These difficulties are put down in part to lack of financial training (Anable et al, 2015), as well as to lack of decision-making models and support tools (Hutchins and Delmonte, 2012). In addition, Bakker and Tripp (2013) note that the public procurement context in particular may be more geared towards thinking in terms of capital cost rather than TCO, which can make the purchase of EVs had to justify (Bakker and Tripp, 2013).

6.5.2. Range limitations

Range limitations are a particularly important barrier to fleet users, rated on a par with the purchase cost when considering barriers to adoption (Anable et al, 2014). It is crucial that fleet vehicles are fit for purpose, and fleet managers are concerned that a limited range could compromise operational efficiency (Hutchins and Delmonte, 2012). As a result, fleet managers will not consider EVs unless they can meet their range needs (Hutchins et al, 2013). Burgess et al (2013) suggest that the ideal corporate day-to-day range is 109 miles, with a range of 230 miles able to fully satisfy all journey requirements.

6.5.3. Charging issues

EV charging time, like range, can be a crucial barrier to fleet buyers, again on a par with purchase cost (Anable et al, 2014), and again the concerns are to do with potential impacts on operational efficiency (Hutchins and Delmonte, 2012). Fleet managers feel that the charging time reduces flexibility and may mean that the vehicle is not ready to use when needed. Fleet managers desire shorter charging times than the general public (Element Energy et al, 2013). In addition, there may be potential issues around charging that relate to the fact that fleet drivers may keep (or are required to keep) their vehicle at home. The scenario where a corporate vehicle is charged using a domestic energy supply is an entirely unprecedented one, with many unknowns (Hutchins and Delmonte, 2012).

6.5.4. Bureaucracy

Procurement rules and bureaucracy can create barriers for organisations procuring EVs. For example, Bakker and Tripp (2013) suggest that European procurement regulations tend to make the procurement process for EVs complex and lengthy. In addition, large organisations can simply be slow to make changes, due to a number of reasons. These are to do with the large numbers of people affected by any change, the entrenched expectations of employees, the complexity of doing something unfamiliar, the responsibility for travel practices being located in a non-transport-related or non-environment-related department, lack of resources, or the issue not reaching the right individuals within the organisation (Anable et al, 2015).

6.5.5. Novelty of EV technology

The reviewed literature suggests that fleet buyers can be reluctant to be among the first to invest in a new technology, and wish to see evidence that other organisations have had positive and successful experiences with EVs before considering adopting them (Hutchins et al, 2013). Fleet managers are concerned that the novel technology involved with EVs is at risk of obsolescence, either before or at the end of their purchasing lifecycles (Hutchins and Delmonte, 2012).

7 Current and planned infrastructure

- Public charging provision is seen to have two overlapping but different roles: meeting the needs of existing owners and addressing the concerns of potential future EV owners about buying an EV.
- Existing EV owners rely mostly on home and workplace charging but consistently report a desire for more extensive - and fast - public charging to enable them to undertake longer journeys.
- The evidence also suggests that additional public charging infrastructure can help to address the range concerns of potential future EV owners and increase EV uptake.
- Current public charging provision in the UK is comparable, even favourable in certain respects, to provision in countries with more developed EV markets.
- But additional evidence is needed in order to address key questions about how much more public infrastructure will be needed in the future in the UK and where this new infrastructure should be in order to maximise its impact.

This chapter assesses the role of public charging infrastructure in supporting the EV market in the UK. Overall, there is limited evidence on which to base this assessment. Authors have also generally approached the issue of infrastructure from two different perspectives:

- Its ability to meet the needs of existing EV owners; or
- Its role in attracting more non-EV owners to buy an EV.

In terms of the former, the last substantive research with EV owners in the UK was conducted in 2013 when public charging provision was considerably less extensive than it is now. In addition, usage data for charge points is yet to have been comprehensively analysed in the UK or elsewhere. In terms of the latter, indicative evidence on the impact of charging provision on the uptake of EVs is available but does not provide many fine-grained insights.

7.1 Public charging infrastructure and existing EV owners

Trial data (Azadfar et al, 2015) and research with EV owners (Hutchins et al, 2013) has consistently found that users can undertake a high proportion of their journeys without the need for public charging and, in the case of private EV owners, there is a strong preference for charging at home (Anable et al, 2014). This has been reflected in the relatively infrequent use of public charging reported by EV owners (as reported in chapter 4) and charge point data showing low utilisation rates. Element Energy et al (2013) report that "the low utilisation of public charge points is confirmed by recent European trials and on-going EV monitoring". Other evidence sources suggest that low overall levels of utilisation are likely to mask wide variations between charge points in different areas. Bevis et al (2013) report that "in parts of the UK we have very underused infrastructure, while in parts of London there are reports of "Charger rage" arising from demand exceeding available charging space." ECOtality (2013a) also report wide variations in utilisation rates between areas in the US.

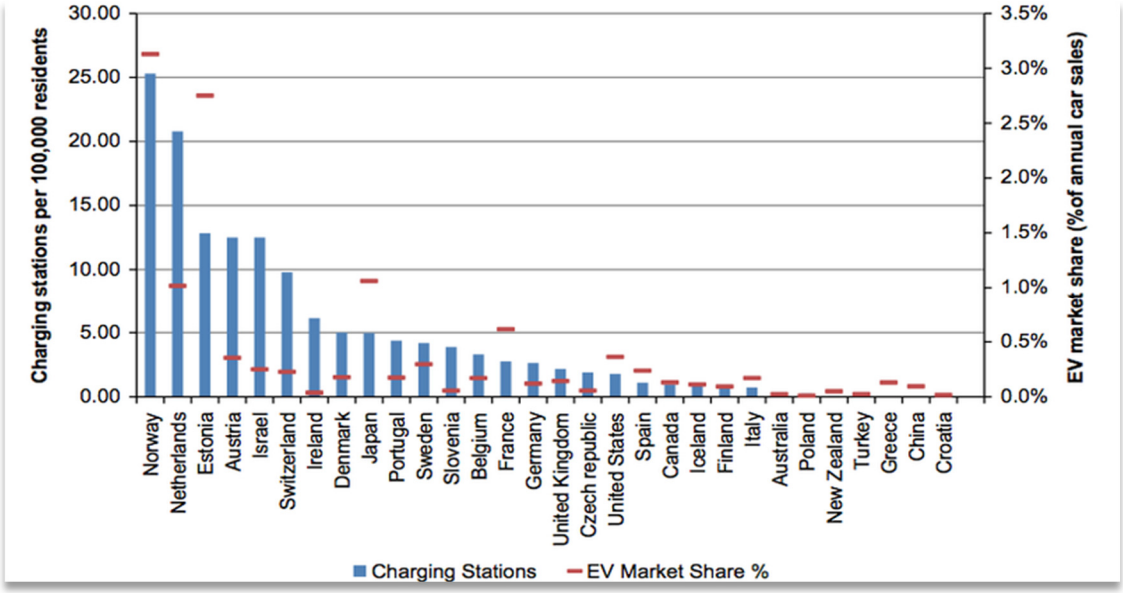
Notwithstanding these findings, research has consistently found that EV owners (especially fleet owners) want more public charge provision in order to enable them to undertake longer journeys (Azadfar, 2015; Hutchins et al, 2013). Previous research in 2013 reported some dissatisfaction amongst EV owners with different aspects of the public charging provision available at that time, in terms of its location, usability and reliability (Hutchins et al, 2013). These findings are not unique to the UK, with relatively low levels of satisfaction with public charging infrastructure amongst EV owners also being reported in other countries. For example, 71% of EV owners in California said they were dissatisfied with public charging provision in 2013 (CVRP, 2014). In a 2014 survey, 67% of Norway EV owners cited "access to public charging" as a disadvantage of owning an EV and 73% cited "time to charge" as a disadvantage (Figenbaum et al, 2014).

EV owners report that they want there to be more public charge points which enable fast charging at strategic locations (e.g. motorway service stations) and destinations (e.g. hotels and restaurants) rather than close to their home or in city centres (Hutchins et al, 2013). Analysis of UK National Travel Survey data, cited in Anable et al (2014), shows that the average resting time of a vehicle at its destination is around one hour, suggesting public slow charging facilities would be of limited value. Indicative findings from Japan, also cited in Anable et al (2014) and Figenbaum and Kolbenstvedt (2013), suggest the installation of fast charging points can stimulate EV owners to undertake additional journeys.

7.2 Public charging infrastructure and potential EV owners

Several sources reviewed in this rapid evidence assessment suggest that public charging infrastructure influences EV uptake. Element Energy et al (2013) report that "the perception that more public charging infrastructure is needed is widespread among non-EV owners, who cite the lack of a national network as a barrier to uptake." Anable et al (2014) report that "charging infrastructure will have an important function to diffuse public awareness of EVs and instil confidence in the technology." Bevis et al (2013) report that "although public infrastructure provides only a small proportion of […] charging, it nonetheless raises the profile of electro-mobility in a region, both practically and politically." In addition, comparative analysis has been conducted into infrastructure provision and EV uptake in different countries (Sierzchula et al, 2014 – see below) and different US states (Jin et al, 2014).

Figure 40. Public charging provision and EV uptake in 2012 by country



Source: Sierzchula et al (2014)

As with similar analysis conducted to explore the influence of incentives and EV uptake (see chapter 4) the authors are cautious about assigning causality to apparent relationships between infrastructure provision and EV uptake. Nonetheless, they suggest that additional public infrastructure could increase uptake. For example, Sierzchula et al (2014) conclude that "each additional charging station (per 100,000 residents) would increase a country's EV market share by 0.12%" and that "adding a charging station (per 100,000 residents) had a greater impact on predicting EV market share than did increasing financial incentives by $1000." Jin et al (2014) also suggest that additional investment in public charging infrastructure would offer better value for money than additional investment in incentives, at least from the perspective of increasing BEV uptake.

Few authors have questioned the need for additional public charging provision in order to increase EV uptake, although Element Energy et al (2013) indicate that because the majority of households in the UK have the ability to charge at home, the need for this additional provision may have been overstated: "Around 60% of cars are parked off-street [and] this high level of access suggests infrastructure is not the key barrier to the uptake of EVs". There has also been little consideration to date in the literature on the importance of public charging from the perspective of PHEVs and, for example, whether the increasing number of PHEV models on the market mediates the need for additional public infrastructure to convince more car buyers to purchase an EV.

On the basis that more public infrastructure *is* needed to allay the range concerns of EV non-owners, various authors suggest that this infrastructure will need to be in highly visible locations. For example, Pierre et al (2011) report that "it is vital to increase the volume of [charging] terminals in public areas" and the Government of British Columbia (2014) report that "the foremost concerns upon immediate deployment are visibility."

7.3 Current and future public charging provision

The following table summarises key features of the current public charging infrastructure in the UK and, by way of comparison, infrastructure in California and Norway.

Figure 41. Current public charging infrastructure in the UK and comparators

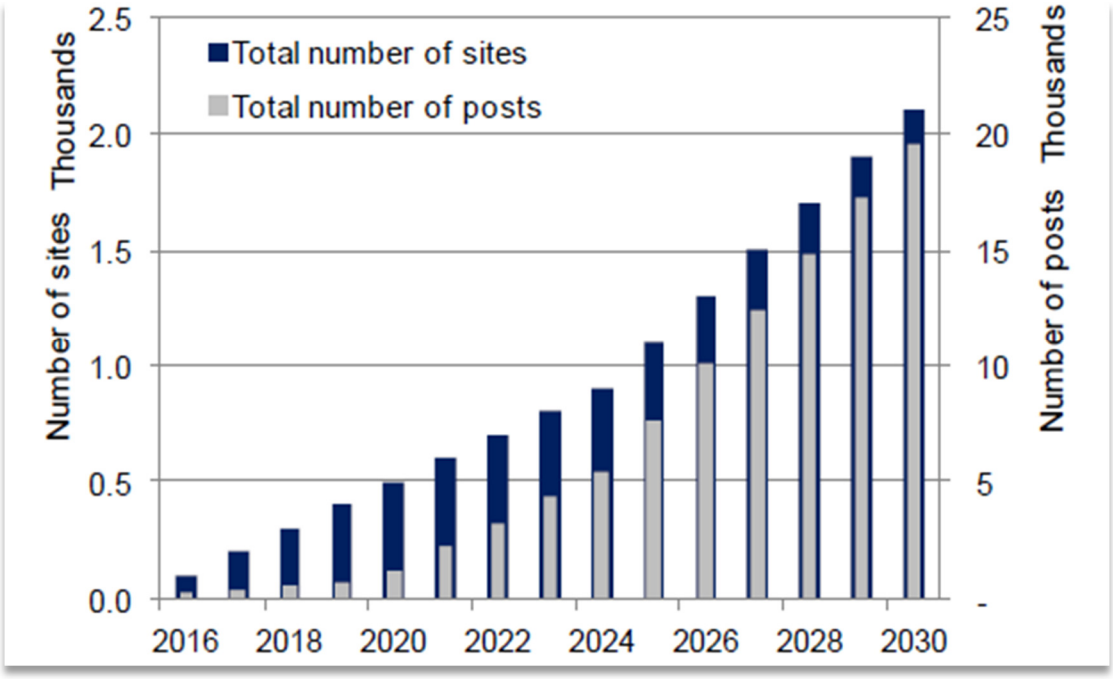
UK	California	Norway
8,230 public charging points*	6,702 public charging points*	8,803 public charging points*
At 3,172 locations	At 2,116 locations	N/A
1 charging point per 7,750 people	1 charging point per 5,700 people	1 charging point per 568 people
1 per 11.4 square miles	1 per 24.4 square miles	1 per 14 square miles
approx 1 for every 4 EVs	approx 1 for every 15 EVs	approx 1 for every 6 EVs
18.4% in London	12% in LA/San Francisco	27% in Oslo
***1,064 rapid; 4,912 fast**	*684 fast	*167 rapid

Sources: Lane (Zap-Map) - Retrieved 15.04.2015; Alternative Fuels Data Centre - Retrieved 15.04.2015; Grønn Bil - Retrieved 15.04.2015

The above suggests that UK provision compares favourably with that in California and Norway in several respects, particularly the number of charge points per square mile and proportion of these charging points that are fast or rapid. Although their geographical location is skewed towards London somewhat, there are similar concentrations in the main conurbations in California and Norway.

In terms of the future provision of public charging infrastructure in the UK, more evidence is ultimately needed in order to address key questions such as: how much more is needed? and where should it be located? The only source identified in this rapid evidence assessment that sought to address the first of these questions in a UK context was Element Energy et al (2013). They forecast that if EV uptake in the UK achieves the pathway targets set by the Committee on Climate Change there will be 13.6 million EVs on the road in 2030, and that around 6 million of these will be BEVs. Based on their analysis, a national rapid charging network representing around 20,000 units over 2,100 sites would be required in 2030 to meet the needs of EV owners. This translates into approximately one fast charger for every 300 BEVs.

Figure 42. Rapid charging network necessary to provide day coverage to 100% of BEV owners by 2030

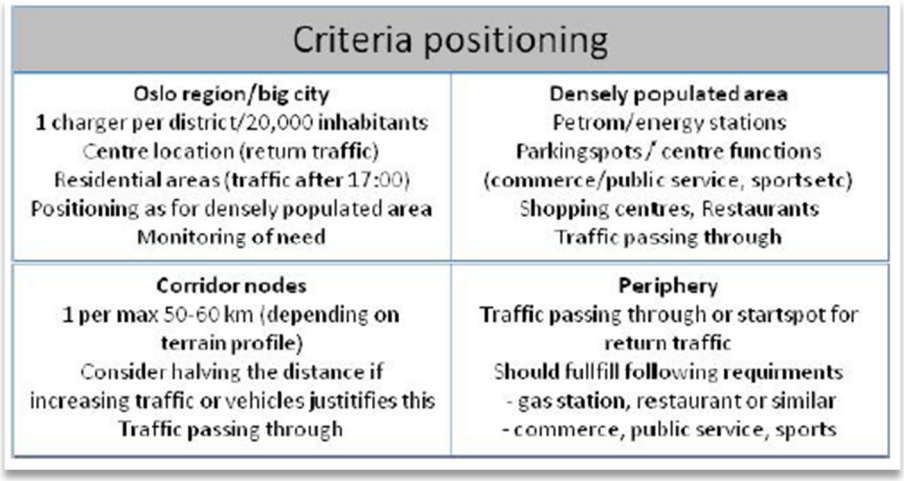


Source: Element Energy et al (2013)

In Norway, Figenbaum and Kolbenstvedt (2013) report that "the fast charge strategy (Econ. Pöyry 2012) is based on a roll-out rate that corresponds to about 1 fast charger per 250 EVs". The California state department has also published research forecasting the number of charge points that would be required if it achieves its target of 1 million EVs on the road in 2020 (National Renewable Energy Laboratory, 2014). They estimate that anywhere between 20,000-50,000 public charge points will be needed – a much higher charge point-per-EV ratio than the Element Energy analysis (2013) forecasts will be necessary in the UK, although this may be because they assume that only a minority of new public charge points will be rapid ones.

In terms of where new public infrastructure should be located, the answers to these question may vary depending on which perspective is taken – that of meeting the needs of existing EV owners or attracting more non-EV owners to buy an EV. The former implies the need for more charge points at strategic locations such as motorway service stations while the latter is more suggestive of highly visible locations such as town and city centres. Norway's fast charge strategy is based on a combination of both location types, i.e. big cities and densely populated areas, as well as corridors, nodes and "periphery" locations.

Figure 43. Criteria for location of fast chargers in Norway



Criteria positioning	
Oslo region/big city 1 charger per district/20,000 inhabitants Centre location (return traffic) Residential areas (traffic after 17:00) Positioning as for densely populated area Monitoring of need	**Densely populated area** Petrom/energy stations Parkingspots / centre functions (commerce/public service, sportsetc) Shopping centres, Restaurants Traffic passing through
Corridor nodes 1 per max 50-60 km (depending on terrain profile) Consider halving the distance if increasing traffic or vehicles justitifies this Traffic passing through	**Periphery** Traffic passing through or startspot for return traffic Should fullfill following requirments - gas station, restaurant or similar - commerce, public service, sports

Source: Econ. Pöyry (2012) cited in Figenbaum and Kolbenstvedt (2013)

What is acutely missing in the current evidence base, and which would help to inform future decisions about the location of public charging infrastructure, is analysis of utilisation rates of charge points in these different types of location. The following example provides some insight into how utilisation rates may vary at different venue types. For example, it suggests that, on average, charge sites at arts and entertainment venues are used most frequently, with roughly one charging event per day at each site. However, it also highlights wide apparent variations between sites at the same type of venue – from less than one charge event a week to over a hundred. Two key factors unaccounted for in the analysis are the number of individual charge points at each site and where, geographically, each site is located. Ultimately more sophisticated analysis is required to understand how charge point usage compares between different kinds of locations, for example using the classification employed in the Norwegian fast charge strategy.

Figure 44. Utilisation rates at different venue types (US)

Venue	Number of Sites	Lowest Events per Week	Highest Events per Week	Average of Events/ Week
Arts & Entertainment	42	0.02	189.25	7.10
Business Office	54	0.01	130.45	6.41
Retail, Big Box, National Accounts	61	0.20	63.04	4.60
Malls	18	0.03	32.40	4.43
Utilities	35	0.05	65.97	4.26
Parking lots & Garages	147	0.03	63.96	3.88
Healthcare/Medical	39	0.04	11.27	3.02
Retail, Small Business, Local	122	0.01	36.02	2.85
Educational Services	74	0.05	15.83	2.63
Hospitality/Travel	114	0.04	66.65	2.36
Govt/Public Admin	92	0.04	36.15	2.33
Non-profit	19	0.10	14.06	2.17
Automotive	20	0.06	12.50	2.04
Professional & Technical Services	19	0.08	6.09	1.94
Restaurants	82	0.01	38.14	1.83
Multi-family	19	0.08	11.52	1.74
Parks & Recreation	11	0.16	3.65	0.87

Source: ECOtality (2013b)

Charge point data is increasingly becoming publically available in the UK and other countries and represents a significant opportunity for future research.

8 Implications and priorities for future research

- More up-to-date evidence is needed on the characteristics, behaviours and attitudes of current EV owners in the UK. In order to keep pace with the rapid development of the market and inform future policy making aimed at supporting the growth of the EV market in the UK, evidence on EV owners should ideally be collected on a continuous or semi-regular basis.
- Representing fleet owners and users should be a priority for future research in order to address the many existing gaps in the evidence on their characteristics, attitudes and usage of EVs. This would help to assess the effectiveness of incentives and other policy measures targeted at fleet owners and inform their future design.
- Additional research is needed to understand the differences between BEVs and PHEVs - in terms of who buys them, and how they are being used and experienced - in order to help to inform future infrastructure provision.
- Other priorities and opportunities for future research include:
    - research to better characterise different segments of current EV owners
    - collecting additional insight into the role of diffusion in the uptake of EVs
    - research on the nature and extent of longer-term EV ownership issues, such as battery life, maintenance and resale value
    - choice experiments or local trials to test how new car buyers would respond to different packages of financial and non-financial incentives
    - further analysis of charge point utilisation rates in different types of geographical setting

This chapter summarises the research team's assessment of the key implications from the evidence presented in the preceding chapters and suggests priorities for future research. These suggestions are restricted to issues implied by the coverage of this rapid evidence assessment; there are other issues (e.g. the increasing choice of EV models and the evolution of the second-hand market) which may well be important in the evolution of the EV market in the next two or three years but which lie beyond the auspices of this review. Cross-cutting themes are discussed first, then additional implications and priorities that are specific to a particular aspect of the evidence base.

8.1 Cross-cutting themes

This rapid evidence assessment has underlined the difficulties inherent in generating evidence on what is a rapidly developing market. New EV models, batteries, charging infrastructure, and increasing numbers of EV owners are changing the shape and dimensions of the market on a monthly basis. Attitudes towards EV are also likely to be changing at a similar rate too. Despite this assessment being restricted to evidence published since 2010, it is notable how out of step much of it already seems. Predictions about the future characteristics of EV owners made in 2011 already appear to have been slightly wide of the mark by 2013. It is also notable that the EV market in the UK is now at least five times larger than when the last piece of substantive research was conducted with EV owners here in 2013.

The implications of this are that more up-to-date evidence is needed on the characteristics, behaviours and attitudes of current EV owners in the UK. In order to keep pace with the rapid development of the market, **evidence on EV owners should ideally be collected on a continuous or semi-regular basis**. For example, California's Center for Sustainable Energy has collected survey data on the characteristics, experiences, and attitudes to incentives and infrastructure of over 15,000 EV owners in the last five years, with additional owners surveyed each month. Much of this data is publically available[20] and having a similar source of evidence for UK EV owners would be a significant step forward in being able to answer several of the more specific evidence gaps discussed below, and better inform future policy-making in each of these areas.

In addition to this, there is an opportunity to make further use of the data that is already being collected in other countries – particularly ones that offer most comparability to the UK. Further analysis could usefully be carried out with the Center for Sustainable Energy dataset to, for example, explore more fully how BEV owners compare and contrast to PHEV owners. Casting the net wider than was possible in this rapid evidence assessment, there may be value in also exploring the availability of more evidence from EV users and owners in the Netherlands, given that a large proportion of these are thought to be organisations (as in the UK). They are the only developed country to date to have reduced public incentives for EVs – something that policy-makers in the UK and many other countries are likely to have to contemplate at some point in the future too.

The shortfall of **evidence on fleet owners and users** has been highlighted in other recent reviews and the findings from this rapid evidence assessment only reinforce this. Not only is there limited evidence, but what evidence there is currently raises as many questions as it answers. For example, if purchasers have initially bought an EV to assess their suitability for their organisation, how many are subsequently going on to buy larger numbers of EVs? Is usage and satisfaction with EVs as variable across different types of organisations as the findings suggest? The first of these questions could start to be addressed through analysis of data recorded by OLEV on PiCG recipients. However, to properly address this and the many other current unknowns, representing fleet owners and users should be a priority for future research above further research with private purchasers. Ideally any new research to collect evidence on EV owners would represent both. There is also a strong case for further research with organisations and businesses that don't currently buy EVs. Amongst other things this would help to assess the effectiveness of incentives and other policy measures targeted at fleet owners and inform their future design.

Another cross-cutting evidence gap suggested by this rapid evidence assessment is a detailed understanding of **the differences between BEVs and PHEVs – in terms of who buys them, how they are used and experienced, and the impacts of incentives and infrastructure**. A surprising number of sources don't make this distinction, even when presenting findings on issues such as range anxiety. There is also a growing potential mismatch between evidence from UK trial participants and EV owners in previous research (most of whom were driving BEVs) and the increasing number of new EV owners in the UK (most of whom are now buying PHEVs). Further research in this area would give policy-makers a more balanced and accurate basis on which to address key issues such as future infrastructure provision.

8.2 Additional implications and priorities

Further research possibilities include:

Characterising EV Owners. Further research to robustly segment current EV owners according to their socio-demographics, attitudes and other characteristics would be very beneficial, arguably more so than further attempts to build segmentation models of future owners. The evidence strongly suggests that

[20] http://energycenter.org/clean-vehicle-rebate-project/survey-dashboard

different segments of the population are already starting to buy EVs. Further uptake in the short-medium term is likely to be achieved through more and more members of these segments buying an EV. Understanding more about the characteristics of these segments would better equip policy-makers to design interventions that address their needs and support the diffusion of EV uptake within each segment.

Diffusion. Following on from the point above, the process of diffusion in relation to EV uptake is currently poorly understood and would benefit from further research. Understanding more about how diffusion works in the context of EVs, for example through qualitative research with existing peer groups, would potentially enable policy-makers to design interventions to support or help catalyse the process.

Longer-term EV ownership issues. Most pertinent amongst these issues are battery life, maintenance and resale value. These have the potential to mediate how existing owners experience their EVs over time, how EVs are perceived by non-owners, and the characteristics of the second-hand market for EVs in the UK. Very little evidence on the nature and extent of these issues was identified in this rapid evidence assessment. Research conducted with longstanding EV owners (potentially who participated in earlier research and could be re-contacted) would be valuable in shedding light on these issues and helping policy-makers assess the extent to which they may (or may not) need to be addressed through future interventions.

Incentives. There may be limited value in undertaking more studies attempting to quantify the impacts of incentives through comparing different international markets. All are liable to reach similar conclusions as to the difficulty and ultimate futility of trying to separate out incentives from other influences on EV uptake. Instead, UK-based research in the form of choice experiments or, more ambitiously, local trials, would be valuable in testing how new car buyers would respond to different packages of financial and non-financial incentives. This would help to inform future policy-making around the provision of such measures in the UK.

Infrastructure Provision. Priorities and future research in this area depend partly on whether infrastructure provision is intended to meet the needs of existing EV owners or attract additional car buyers to become EV owners. From the former perspective there are significant opportunities for new research to analyse data on charge point utilisation rates in different types of geographical setting – e.g. in town centres as opposed to motorway service stations. Equally, this type of data could usefully be accompanied by insights from non-owners in areas with differing and/or changing levels of public charging provision. This would help to inform any investment, by Government and others, in future charging infrastructure.

Bibliography

Amsterdam Roundtables Foundation and McKinsey (2014) Electric vehicles in Europe: gearing up for a new phase?

Anable, J., Kinnear, N., Hutchins, R., Delmonte, E. and Skippon, S. (2011) Plug-in Vehicles Infrastructure Project. Consumers and Vehicles: Consumer Segmentation and Demographic Patterns. WP 1.3.5 Project Report. University of Aberdeen and Transport Research Laboratory

Anable, J., Schuitema, G. and Stannard, J. (2014) Consumer Responses to Electric Vehicles Literature Review. Report for Energy *Technology* Institute Plug-in Vehicles Infrastructure Project *(*June 2010). Transport Research Laboratory Published Project Report PPR728

Anable, J., Darnton, A., Pangbourne, K., Lane, B., Banks, N. and Henry, N. (2015) Evidence Base Review of Business Travel Behaviour to Inform Development of a Segmentation of Businesses

Auto Outlook, Inc (2015) California Auto Outlook

Azadfar, E., Sreeram, V. and Harries, D. (2015) The investigation of the major factors influencing plug-in electric vehicle driving patterns and charging behaviour

Bakker, S., Trip, J.J. (2013) Policy options to support the adoption of electric vehicles in the urban environment

Bevis, K., Smyth, A. and Walsh, S. (2013) Plugging the gap – can planned infrastructure address resistance to adoption of electric vehicles?

Bühler, F., Cocron, P., Neumann, I., Franke, T. and Krems, J. (2014) Is EV experience related to EV acceptance? Results from a German field study

Bunce, L., Harris, M. and Burgess, M. (2014) Charge up then charge out? Drivers' perceptions and experiences of electric vehicles in the UK

Burgess, M., Harris, M., Walsh, C., Carroll, S., Mansbridge, S., King, N. and Everett, A. (2013) Assessing the viability of electric vehicles in daily life: A longitudinal assessment (2008–2012)

Business Green (2015) Councils charging up electric car use. Retrieved 15.04.2015 from http://www.businessgreen.com/bg/analysis/2393751/councils-charging-up-electric-car-use

Campbell, A., Ryley, T. and Thring, R. (2012) Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom

Carroll, S. (2011) The Smart Move Case Studies

Carroll, S., Walsh, C., Burgess, M., Harris, M., Mansbridge, S., King, N. and Bunce, L. (2013) The Ultra Low Carbon Vehicle Demonstrator Programme - Final report: Assessing the viability of EVs in daily life

Center for Sustainable Energy (2015) California Air Resources Board Clean Vehicle Rebate Project, EV Consumer Survey Dashboard. Retrieved 15.04.2015 from http://energycenter.org/clean-vehicle-rebate-project/survey-dashboard

Center for Sustainable Energy (2014) February 2014 Survey Report

Center for Sustainable Energy (2013) Clean Vehicle Rebate Project - Fiscal Year 2012-2013 Final Report

Center for Sustainable Energy (2012) California Plug-in Electric Vehicle Owner Survey

Davies, J. and Kurani, K. (2013) Moving from assumption to observation: Implications for energy and emissions impacts of plug-in hybrid electric vehicles

Department for Transport (2014) Public Attitudes to Electric Vehicles: 2014

Ecotality (2013a) The EV Project - Quarter 2, 2013 Quarterly Report

Ecotality (2013b) What are the best venues for publicly accessible EVSE units? (A first look)

Element Energy, University of Aberdeen, Ecolane (2013) Pathways to high penetration of electric vehicles

Figenbaum, E., Kolbenstvedt, M. and Elvebakk, B. (2014) Electric vehicles - environmental, economic and practical aspects: As seen by current and potential users

Figenbaum, E. and Kolbenstvedt, M. (2013) Electromobility in Norway - experiences and opportunities with Electric Vehicles

Grønn Bil (2015) BEV and PHEV sales and population. Retrieved 15.04.2015 from http://www.Grønn Bil.no/statistikk/?lang=en_US

Haugneland, P. (2014) Norwegian electric car user experiences 2014

Hutchins, R., Delmente, E., Stannard, J., Evans, L. and Bussell, S. (2013) Assessing the role of the Plug-in Car Grant and Plugged-in Places scheme in electric vehicle uptake

Jin, L., Searle, S. and Lutsey, N. (2014) Evaluation of State-Level U.S. Electric Vehicle Incentives

Kurani, K., Axsen J., Caperello, N., Davies, J. and Stillwater, T. (2012) Consumer Response to Plug-in Hybrid Electric Vehicles: Vehicle Design Priorities, Driving and Charging Behavior, and Energy Impacts

Lane, B. (Zap-Map) (2015) Charging Point Statistics. Retrieved 15.04.2015 from https://www.zap-map.com/statistics/

Mock, P. and Yang, Z. (2014) Driving electrification - A global comparison of fiscal incentive policy for electric vehicles

Morton, C. (2013) Accelerating the demand for low emission vehicles: a consumer led perspective

National Renewable Energy Laboratory (2014) California State-wide Plug-in Electric Vehicle Infrastructure Assessment

Namdeo, A., Tiwaryb, A. and Dziurlaa, R. (2014) Spatial planning of public charging points using multi-dimensional analysis of early adopters of electric vehicles for a city region

Office for Low Emission Vehicles (2013) High level analysis of the Plugged-in Places chargepoint usage data

Pierre, M., Jemelin, C., Louvet, N. (2011) Driving an electric vehicle: A sociological analysis on pioneer users

Robinson, A., Blythe, P., Bell, M., Hubner, Y., Hill, G. (2013) Analysis of electric vehicle driver recharging demand profiles and subsequent impacts on the carbon content of electric vehicle trips

Rolim, C., Baptista, P., Farias, T. and Rodrigues, O. (2014) Electric vehicle adopters in Lisbon: motivation, utilization patterns and environmental impacts

Shepherd, S., Bonsall, P. and Harrison, G. (2012) Factors affecting future demand for electric vehicles: A model based study

Sierzchula, W., Maat, K and van Wee, B. (2014) The influence of financial incentives and other socio-economic factors on electric vehicle adoption

Tal, G., Nicholas, M., Woodjack, J. and Scrivano, D. (2013) Who Is Buying Electric Cars in California? Exploring Household and Vehicle Fleet Characteristics of New Plug- I n Vehicle Owners

Thornton, A., Evans, L., Bunt, K., Simon, A., King, S., and Webster, T. (2011) Climate Change and Transport Choices: Segmentation Model - A framework for reducing CO2 emissions from personal travel

TNS-BMRB (2014) Ultra Low Emissions Vehicles Go Ultra Low Campaign Evaluation Wave 1

Velthuis, M. (2012) Future Users of Plug-in Hybrids and Battery Electric Vehicles - Characteristics of the future early adopters and early majority in the Netherlands

Vergis, S and Chen, B. (2014) Understanding Variations in U.S. Plug-In Electric Vehicle Markets

Vergis, S., Turrentine, L. and Fulton, L. (2014) Plug-In Electric Vehicles: A Case Study of Seven Markets

Wardle, J., Hübner, Y., Blythe, P. and Gibbon, J. (2014) The Provision of Public Recharging Infrastructure for Electric Vehicles in North East England - is there Life after Subsidies?

Wikström, M., Hansson, L., Alvfors, P. (2014) Socio-technical experiences from electric vehicle utilisation in commercial fleets