

elementenergy



***Pathways to high  
penetration of electric  
vehicles***

Final report

for

**The Committee on  
Climate Change**

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Element Energy Limited  
20 Station Road

Cambridge CB1 2JD

Tel: 01223 227764

Fax: 01223 356215

## Foreword

The Committee on Climate Change analysis for the 4<sup>th</sup> carbon budget shows it is appropriate to aim for a shift to ultra-low emission vehicles, with electric vehicles (EVs) playing key role in decarbonising transport through the 2020s. The Committee's original analysis suggested that it would be broadly appropriate to aim for EVs to constitute 60% new car sales by 2030.

Based on previous analysis<sup>1</sup>, given an expected reduction in technology costs, EVs should be cost-effective against carbon price in the 2020s. Relative to conventional vehicles, capital cost premiums for EVs are expected to be offset by significantly lower running costs; this balance means that EVs are expected to reach parity with conventional cars on an economic resource cost basis. The Committee therefore concluded the EV target made sense from an economic perspective.

Beyond these issues there is a need to consider if consumers will engage with EVs to deliver the ambitious trajectory set by the CCC. This presents challenges in terms of understanding consumer motivation, barriers and how best these can be addressed.

To do this, CCC commissioned Element Energy, Ecolane and Dr Jillian Anable to assess the current market in terms of the outlook on supply and examine the main factors influencing vehicle purchase, and to develop a roadmap to the CCC target. This is the focus of this study.

For consumer demand modelling a choice model was developed to assess the value people place on different aspects of purchasing and owning a car (e.g. up-front costs, running cost, driving range, servicing, infrastructure and charging times). As this element of the study focuses on individuals' driving preferences, most of these factors are independent of the current EV market and are unlikely to change significantly over time.

The analysis then matches the consumer preference modelling with the current and projected supply of EVs and their characteristics to assess whether people are likely to take them up given the state of the market, and if not, to assess what barriers to take-up remain and how these can be overcome.

Based on a comprehensive review, key findings on the EV market and supply are:

- The market for EVs has improved rapidly in the last three years in terms of make/model availability and OEM announcements suggest this will continue,
- EV production capacity needs to grow significantly to meet targets as announced by countries, including the UK.

Based on recent consumer research and international evidence, key findings on consumer preferences are:

- Consumers have short pay-back periods – they value up-front costs much more than running costs which they discount heavily. This means they are looking for typical pay-back periods of 4 years. This is consistent with other findings which extend outside of the automotive sector (e.g. the energy efficiency literature)

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<sup>1</sup> Element Energy, *Cost and performance of batteries for EVs*, 2012; Ricardo-AEA, *A review of the efficiency and cost assumptions for road transport vehicles to 2050*, 2012.

- This means that even if EVs make sense from an economic/lifetime perspective, consumers may not make purchase choices in this way.
- Consumers are also concerned by EV's short driving range and long charging times but these vehicle attributes are expected to improve.
- Awareness of EVs is relatively low at present and this must be raised in order for consumers to consider EVs as a serious option.

The core analysis assumes that awareness, vehicle performance, and infrastructure barriers can be overcome. However, even allowing for these, key barriers regarding the consumer focus on capital cost and short payback periods must be bridged in order to reach mass market deployment set out by the CCC.

Based on the modelling and analysis conducted for this report, key findings are:

- The pathway to high uptake requires that awareness and acceptance grows as EV performance improves, and through wider exposure to EVs.
- Continued *financial* support is unlikely to be the most efficient or even desirable way of delivering the high uptake. The EV sector has already demonstrated its ability to innovate with new ownership models, and these could prove critical in helping consumers make better choices which balance capital and running costs. Options range from vehicle leasing to battery leasing, extending to other mobility offers such as car clubs.
- 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.
- Most UK households have access to overnight parking and this could be used for an early, low cost charging network. While the driving range of battery EVs is improving year on year, there is still a need for a charging infrastructure to extend the mobility offer of EVs. The analysis finds that national coverage can be provided through a relatively limited (c. 2000 sites) network of rapid chargers.
- The analysis is sensitive to cost projections and actual payback periods. For example, if EV costs were to be 10% lower than projected, it is estimated the monetised value of barriers would be down to zero, i.e. the uptake pathway would be achieved without intervention beyond the aforementioned infrastructure and consumer awareness measures.

The roadmap developed for this study provides milestones to track progress in the deployment of support for EVs. These will need to be reviewed to take into account actual cost trajectories, innovative ownership and utilisation models, infrastructure deployment, and the growing awareness and acceptance of EVs

## Executive Summary

### Background and objectives

The Committee on Climate Change (CCC) has identified electric powertrains as a key technology to abate emissions of light-duty vehicles in support of the UK's target of an 80% reduction in greenhouse gases by 2050 (compared to 1990 levels). However, with electric cars and vans representing only 0.1% of light-duty sales in 2012, significant market barriers to widespread EV adoption remain.

In this context the CCC commissioned Element Energy, Ecolane Consultancy and the University of Aberdeen to identify possible pathways to achieve high penetration of light-duty electric vehicles (including car and vans, battery, plug-in hybrid and fuel cell electric vehicles) in the UK. The CCC's *high EV uptake pathway* is defined by:

- Indicative 16% market share for Plug-in Hybrid Electric Vehicles (PHEVs) plus Zero Emissions Vehicles (ZEVs) by 2020; ZEVs are defined as battery electric vehicles (BEVs) and fuel cell vehicles (FCVs);
- 60% market share (PHEVs plus ZEVs) by 2030;
- 100% market share for ZEVs by 2040, so that, taking the stock turnover into account, the vehicle parc is virtually decarbonised by 2050.

### Methodology

Previous analysis<sup>2</sup> has indicated that EVs should reach parity with conventional cars on an economic resource cost basis in the 2020s, as technology costs continue to fall and significantly lower running costs outweigh the higher capital costs. The CCC therefore concluded that EVs could be a cost-effective option to decarbonising the transport sector.

Alongside economic considerations, it is also important to consider how consumers will engage with EVs and in particular to assess the extent of potential non-financial barriers to take-up. The focus of this study is to develop a model to assess the value people place on different aspects of buying and driving a car. Together with information on the current state of the EV and conventional vehicle market (in terms of costs and supply), this enables the monetisation of the value of non-financial barriers.

The results highlight the significant barriers involved in reaching a high penetration of EVs in the set timescales, but this does not imply the need for financial incentives. The EV sector has demonstrated its ability to innovate to overcome barriers to uptake and the analysis sets out a range of non-financial measures that could be used to incentivise higher uptake.

### Current EV market and projected supply

Around 110,000 electric cars and vans were sold in 2012 globally (representing approximately 0.14% of car and van sales), more than double the previous year when less than 50,000 EVs were sold. In terms of absolute EV sales, the European and Asian markets are each about half the size of the North American market (21,500 sales in

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<sup>2</sup> Element Energy, *Cost and performance of batteries for EVs*, 2012; Ricardo-AEA, *A review of the efficiency and cost assumptions for road transport vehicles to 2050*, 2012.

Europe, 28,800 in Asia and 54,600 in North America). However in percentage terms, EVs have achieved a higher penetration in certain European countries; most notably, Norway has the highest EV market share (3.3% in 2012), which strongly reflects the broad range of incentives available to EV buyers in that country.

Based on existing OEM announcements, the annual global production capacity of EVs, currently standing at approx. 500,000 units, is projected to increase to 1.5 million by 2015 (representing a 50% annual growth from 2012).

To meet the aggregated EV targets set by at least fourteen key countries, the analysis finds EV annual production capacity will need to increase by an additional 30% per annum post-2015 to reach 5.6 million units by 2020 – Figure E1. Such a growth rate is credible as OEMs have the capability to scale up production (existing factories do not run at full capacity and some EV models are based on existing non-EV models). Even at this level, EV production capacity in 2020 would represent less than 7% of the current total light-duty vehicle production.

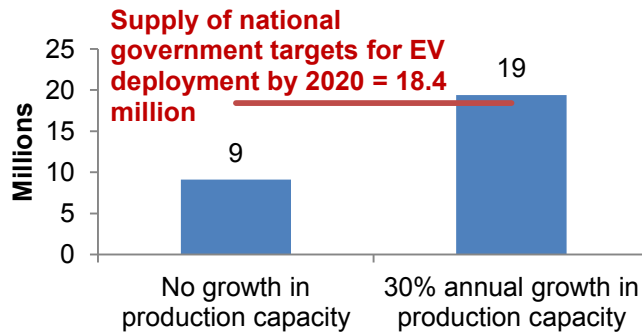


Figure E1 Cumulative global EV production capacity 2015-2020 and comparison with national targets

### Barriers to uptake

Identified barriers to EV uptake are based on extensive research regarding the main consumer factors influencing vehicle purchase. Taking into account the attitudinal factors that most strongly differentiate consumer segments (see below), together with more general vehicle purchase criteria, the key attributes affecting the purchase of EVs are: vehicle price and running costs, brand and segment supply, access to charging facilities, driving range and charging time and the consumers’ receptiveness to plug-in vehicles. With the exception of running costs (which are reduced), these attributes all currently act as barriers to EV uptake:

- **EVs have a high price premium over non-EVs**

As vehicle price is the most important factor influencing vehicle choice, financial incentives (including the Plug-in Car and Van grants of respectively up to £5,000 and £8,000) are currently essential to offset the higher purchase price of EVs and reduce the Total Cost of Ownership (TCO), even in cases where innovative acquisition models are employed (e.g. battery leasing). Given that consumers show high discounting rates for future spending, the potential running cost savings offered by EVs are insufficient to offset the EV capital premium as perceived by most car buyers.

While, in some circumstances, the current incentives make the four year TCO (the typical time horizon considered by consumers) of EVs competitive with conventional vehicles, cost projections suggest that without support measures the capital cost premium of EVs will remain a barrier to at least 2030, especially for BEVs.

- **Supply of EVs model is limited, in terms of vehicle segments and brands**

The choice of vehicle segment (e.g. small, medium or large car) is related to the consumer requirements of size, comfort and practicality, whereas brand choice reflects more emotional factors such as brand attachment (loyalty is strong among vehicle buyers), perceived reliability and the buyer's identity construct.

Based on OEM announcements of series model releases up to 2015, the overall outlook for brand supply of EVs in the next few years is noticeably improving: the UK's top three car brands will be represented by the end of 2013, and the top ten brands by 2015. The level of supply (in terms of model diversity) however varies across vehicle segments and EV types: the outlook for BEVs is better than for PHEVs, and is better for cars than for vans.

- **Consumers are concerned by EV's short range and long charging times**

Extensive trials and current usage of charging infrastructure indicates that utilisation of publicly accessible charging networks is low, EV owners instead preferring to use overnight charging (at home or workplace), and/or at work during the day. The level of access to overnight charging locations is high among new vehicle buyers in the UK (70% for new private cars and 60% for new vans) suggesting access to infrastructure is not a dominant barrier to *initial* EV adoption in terms of actual need (based on the typical daily distance travelled). However, potential EV buyers and EV owners frequently demand more public charging infrastructure, which is based on their *perceived* need to drive longer distances than currently offered by BEVs.

Recharging time is consistently reported as a barrier by EV users, regardless of the ability to recharge overnight. The level of utilisation of rapid 50 kW chargers observed in other countries, together with the proportion of sales of EVs with DC charger ports, confirms the high value placed on reducing charging time by EV users. The analysis conducted for this study finds that a network of *rapid* chargers would be the most efficient way to complement overnight charging and support the high EV adoption targeted in this study. A public network based on normal 3-7kW chargers would not be able to provide adequate day charging.

- **The majority of private vehicle buyers are not currently receptive to EVs**

Consumer *acceptance*, defined as the readiness to consider purchasing or using an EV, varies across consumers, with the majority of private consumers not accepting as sufficiently advanced the capability of current EV models. In addition to the concerns already discussed, reliability, safety and battery degradation issues, as well as uncertainty regarding residual values, also contribute to consumers' reluctance to purchase electric vehicles.

A pre-cursor to acceptance is consumer *awareness*. Evidence collated by this study shows that UK car buyers currently have a low level of awareness of EVs and their associated incentives, with only around 20% of UK drivers being 'very familiar' with the EV technology and only 25% being aware of the Plug-In Car Grant.

According to a recent study of around 3,000 UK car buyers, *attitudinal* segmentation is a better predictor of EV acceptance (and hence adoption) than more conventional demographic indicators, including travel patterns. The study, which develops a segmentation of the UK new private car buyers, identifies distinct market groups:

- ‘Enthusiasts’ who are driven by innovativeness and prepared to pay a premium for EVs. While they represent most of the early adopters of EVs, they only account for a small fraction of car buyers.
- ‘Aspirers’ who are interested in EVs but concerned by their technical limitations. EV adoption by this group improves with the increased availability of EV models from trusted brands and the provision of market incentives that address both cost and technical barriers.
- ‘Mass market’; while EVs have no particular interest or symbolic meaning to this group, they are followers of social norms and are likely to become more receptive to EVs as their numbers increase.
- ‘Resistors’ who are unlikely to buy EVs as they strongly reject their symbolism (the perceived status and social acceptability of owning an EV). This group’s receptiveness to EVs will change only once EVs have lost their current connotations, i.e. only once already widely adopted.

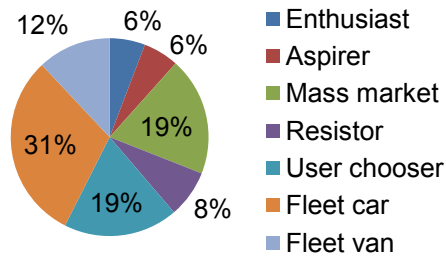


Figure E2 Consumer segments of the UK car and van markets

Analysis indicates that, if company-car ownership is considered as primarily an individual purchase behaviour (the ‘User Choosers’), private buyers represent around 60% of the UK car and van market. The remaining 40% of buyers are fleet managers who (evidence shows) are more likely to consider the total cost of ownership and practical issues (such as technical suitability) and are less concerned with the brand and image. According to the segmentation study, all attitudinal segments consider PHEVs more favourably than BEVs due to the performance characteristics of the respective technologies, and there is no clear bias towards owning an EV as a second car in the household.

### Lessons from international evidence

A review of uptake of EVs outside the UK confirms that their cost premium is a prevailing market barrier; countries with the highest rates of EV adoption all having introduced significant measures to reduce capital costs relative to conventional vehicles. Importantly, these countries have also vigorously addressed non-cost barriers including, vehicle supply and consumer receptiveness.

EV support in Norway is of particular interest, it being the most successful country with respect to EV adoption, with electric models accounting over 3% of new car sales. This success can be attributed to a *sustained BEV incentive programme*, with many measures being in place for nearly 20 years. The government has also committed to maintain purchase incentives until at least 2018; support that currently reduces the cost premium of BEVs to around €1,000.

The international experience also demonstrates the important promotional role played by non-financial benefits which translate into daily cost or time savings that are highly valued by EV users. Popular benefits include the ability to access bus lanes (shortening travel times) and extensive exemptions from road and ferry tolls. EV uptake in Norway also confirm that a publicly accessible charging network is not a precondition for *initial* EV market adoption; however a national plan has however now been formulated for future expansion of the market.



## Methodology: modelling EV uptake to 2030

This study required to project future vehicle sales, taking into account established vehicle buyer behaviour, consumer segmentation as well as market response to vehicles attributes, price signals and incentives (financial and otherwise).

The method employed to quantify market development is Choice Modelling, which estimates the purchase choice probability based on an assessment of overall vehicle 'attractiveness' (termed 'utility') from amongst a set of vehicle choices, each with their own financial and non-financial attributes. The model reproduces the variation in utility of different vehicles across consumer groups, and the variation over time as EV attributes improve.

The vehicle attributes represented in the choice model include both financial and non-financial attributes that are identified as key to the purchase decision, namely: capital and running costs, access to infrastructure, charging time, driving range, model/brand supply and consumer receptiveness to EVs. For the purposes of analysis, all barriers are monetised i.e. put on a 'perceived' basis. This does not mean that they represent actual costs.

Key assumptions of the choice model developed for this study include:

- Pre-conditions for purchase: BEVs (and PHEVs in the case of fleet managers) are considered for purchase only if the buyer has certainty of access to charging (which can be provided only by overnight charging). Fleet managers also only consider a BEV if the driving range meets the required duty cycle, in consistence with their technical suitability approach (whereas private buyers perceive a high penalty for the limited driving range of BEVs, regardless of their actual travel patterns).
- For consumer segments currently not interested in or rejecting EVs, the technology bias against EVs is assumed to decrease with increasing EV sales;
- Fleet managers are assumed to approach potential EV purchase based on a rational assessment of TCO and technology suitability (charging access, driving range compatibility), i.e. they show no technology preference.

The choice model is used to derive a set of '**action targets**' (market interventions or policy measures) which are needed to drive the market model so as to achieve the CCC target of 60% market share for EVs in 2030. Reflecting the key vehicle purchase criteria, action targets are defined for each the following areas: EV supply; consumer awareness and acceptance, charging infrastructure, and 'equivalent value support' which can reduce the set of monetised barriers. Note it does not necessarily imply financial support.

## High EV uptake pathway to 2030

The high EV uptake pathway targets set by the CCC are that EVs (BEVs and PHEVs, cars and vans) capture 16% share of new vehicle sales in 2020 and 60% by 2030. The 2020 target is however revised down to 9% in this study, corresponding to 12% of projected EU production capacity introduced earlier, which is similar to the UK's current share of overall EU car sales.

The high uptake targets for 2020 and 2030 correspond to 0.27 million and 2.1 million EV annual sales respectively – Figure E3 (left). Given delivery of the action targets described below, the model predicts that the 60% market share in 2030 is achieved with a technology split of 35% PHEVs and 25% BEVs. The pathway results in a cumulative fleet of 13.6 million electric cars and vans on UK roads by 2030 – Figure E3 (right).



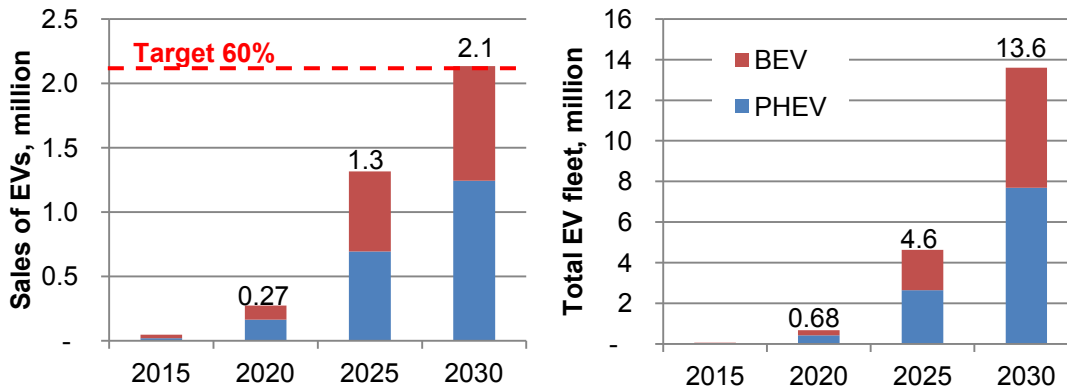


Figure E3 High EV uptake pathway targets: annual sales (left) and resulting EV fleet (right), million vehicles (cars and vans)

In order to achieve the 60% EV uptake in 2030 as defined by the high uptake pathway, the model identifies that the following optimised action targets must all be delivered:

- **Vehicle supply:** In the vehicle supply trajectory developed, within which the current rate of release of new EV models continues and accelerates, EVs are available in all vehicle segments over time. The key vehicle supply milestones are laid in Table E1.

Table E1 Supply of EVs: targets for share of EV models in 2020, 2025 and 2030

Segment	2020	2025	2030
<b>Small cars (A/B)</b>	>50%	Excellent* for BEV Marginal for PHEV	Excellent for BEV Improved for PHEV but less than 50% of models come in a PHEV variant
<b>Medium cars (C/D)</b>	15-30%	Good – around 50% of models have BEV and PHEV variant	Excellent – majority of models have BEV and PHEV variants
<b>Large cars (E/I)</b>	10%	Good – around 30% of models have BEV and PHEV variant	
<b>Vans</b>	>50%	Excellent	

\*'Excellent' is defined as >60% models within segment

- **Consumer awareness and acceptance:** by 2021, all vehicle buyers are aware of EVs including their capabilities and associated incentives (albeit not all are necessarily disposed to buy one). All drivers with off-street parking are also aware of the process for the installation of a dedicated socket for charging an EV.
- **Charging infrastructure:** the model identifies that the charging infrastructure strategy needed to deliver the high uptake pathway is based on high levels of overnight (mainly off-street) charging complemented by a national network of rapid charging points for day charging. In detail:
  - Off-street parking is put to maximum use with the majority of charging carried out overnight (using 3-7kW units), for both PHEVs and BEVs. The current proportion of households (70%) with access to off-street parking is assessed as adequate; increasing to 74% by 2030. This implies that all off-street parking is used, including resident car parks.

- A national rapid (40kW+) charging network extends across all UK regions by 2030, providing actual and perceived coverage<sup>3</sup> for all BEV buyers, and increasing the utility of BEVs for fleet operations. The cost of the rapid charging network is estimated at £300-£530 million (capital and installation), representing around 20,000 units over 2,100 sites by 2030. This compares to around 8,600 liquid fuel stations in the UK currently.
- It is expected that the current trend of installing non rapid chargers will continue, which will provide some value to PHEVs users. However no specific target is set for non-rapid units as the impact on uptake is modest and the relationship between real and perceived infrastructure coverage for PHEVs is less clear, due to their 'unlimited' range.
- **Equivalent value support:** This is the monetised value of the support required to mitigate the price premium of EVs and to compensate for any loss of utility of EVs over conventional vehicles. In the model, this is effectively an intervention on the vehicle price. However, in practice, the *equivalent value support can be provided in monetary and/or non-financial forms* – for example, preferential road access could be used to provide value to EV users (through reduced travel time, valued at a given £ per hour) which, as far as the model is concerned, would have the same impact on market share as an equivalent monetary benefit.

Assuming all other action targets are delivered, the model indicates that, in the baseline case (i.e. under CCC's central vehicle price projections and assuming current vehicle ownership models), a equivalent value support of around £3,000 per EV to 2020 and £2,500 post-2020 is expected to be needed to achieve the high uptake pathway by 2030..

However the analysis indicates this level of support can be significantly reduced with new models of vehicle ownership and finance. For example, a battery leasing scheme that spreads the capital cost premium of EVs over 12 years could reduce the support that may be required by two-thirds.

This reflects the fact that, under CCC's central cost projections, the price premium of EVs over non-EVs will remain a long term barrier to very high uptake. As a consequence, the modelled results are very sensitive to the cost assumptions: for example, if the cost of an EV is 12% lower than the CCC's central assumptions by 2030, the model forecasts that the monetised value of barriers to be addressed is cancelled out and the 60% market share will be delivered in 2030 without any additional equivalent support being required (although other action targets will need to be met). *This suggests support projections should be revised in the future, to account for changes in the cost differential of EVs and non-EVs.*

The level of equivalent value support required has also been modelled for cases when some (non-cost) action targets fail to be delivered or other key assumptions (e.g. the share of drivers with access to overnight charging) are challenged. This highlights that the rapid charging network as good value in promoting uptake, primarily as it increases the market base of BEVs, by making BEVs compatible with the duty cycle of a greater numbers of fleets. Without it, the equivalent value support that might be required to 2030 could be roughly double (assuming CCC's central vehicle price projections and assuming current vehicle ownership models).

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<sup>3</sup> Coverage means all drivers are a short driving distance away from a station, with added stations for inter city travel.

## Delivering the high EV uptake pathway

While the modelling identifies the action targets, it does not determine the detailed measures and stakeholders that could deliver the high uptake pathway. This is investigated through an extensive review of international evidence regarding the effectiveness of available interventions. The key findings and resulting recommendations concerning delivery are now summarised and shown in Figure E4.

### Vehicle supply

In order to deliver the high EV uptake pathway, the modelling indicates that the major OEMs must continue to release new EV models into the UK market at, or faster than, the current launch rate of over 10 new EV models per year.

While the UK should continue to stimulate supply through support of innovation and the manufacturing base, and through the provision of effective demand side incentives, European CO<sub>2</sub> legislation provides a significant market driver (in the form of emission standards and mandates). To be consistent with the high uptake pathway, the UK must therefore continue to engage in the debate at the levels of the European Commission and Parliament to support a trajectory of decreasing emission targets for cars and vans, as these targets (and the measures to implement them) may be decisive in determining the level of electrification of the fleet and the rate of EV adoption.

### Consumer awareness and acceptance

Generic and EV-specific evidence suggests that, achieving 100% EV awareness among UK car buyers by 2021 will require a large scale, coordinated and sustained promotional campaign, one that draws on the experience of large scale marketing that goes well beyond solely providing information. This supports the UK Government's planned EV promotional campaign to work with at least six major manufacturers on a public communication programme due to launch in late 2013/2014. Beyond awareness of EVs, the report cites extensive EV trials that show that consumer *acceptance* (i.e. not rejecting EVs on the basis of performance perceptions, concern over new technologies or identity issues linked to EV symbolism) can be fostered through direct consumer exposure to the vehicles. As such, government and industry should support further opportunities for mainstream consumers to gain direct experience of EVs through test-drives and short-term hire. Shifting attitudes of the most resistive consumer segments will however require a long time horizon as these segments will become receptive to EVs only once EVs have become a visible part of the fleet.

Another approach with which to create a platform for large scale consumer exposure to EVs (and incentivise supply) could involve the support of businesses procuring vehicles for new mobility services (e.g. EV taxi fleets, vehicle rental and car clubs). Incentivising all forms of vehicle leasing (and reinstating tax breaks recently withdrawn) would therefore support opportunities to experience an EV without the long-term commitment of ownership; incentives that have already proven effective in other countries such the Netherlands in supporting the early EV market.

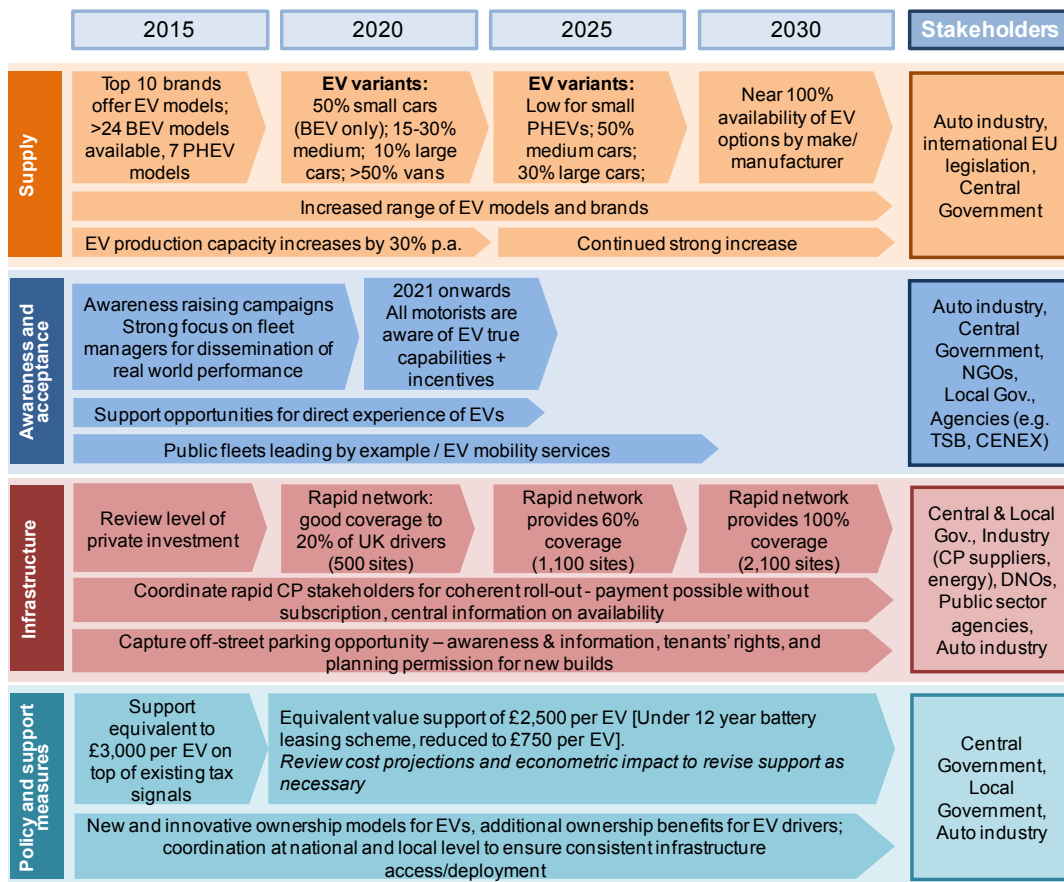


Figure E4 Summary of pathway to high uptake of EVs: action targets and key stakeholders

### Access to charging infrastructure

A key finding of this report is that the majority (70%) of new car buyers in the UK already have access to a garage or off-street parking, the highly preferred location for EV charging. In order that the EV market can grow, however, the provision of low-cost 'overnight' charging facilities must be progressed quickly, the analysis indicating that, by 2020, all car owning households with off-street parking should have either installed a dedicated EV charging unit, or should be aware of the process of having one installed.

Based on projected OLEV spend to 2015 and assuming continued growth in the level of private investment, the authors forecast a combined domestic and workplace network of around 160,000 normal chargers by 2020. Given that the high uptake EV pathway sees 680,000 EVs on the road by 2020, it suggests a steep acceleration in domestic and workplace charging point installation will be required. Before 2015, therefore, the report recommends an evaluation be conducted to determine if the projected private sector investment will be sufficient to deliver the scale of network required by 2020. Failing this, further public investment will be required to fully support the development of a home and workplace charging infrastructure.

As installing charge points in new builds and refurbishments is the most cost-effective way to increase home and workplace infrastructure coverage, it is recommended that local authorities adopt planning conditions that require all parking spaces in new developments to be 'EV-ready'; a policy which has already been adopted by Westminster City Council which has a 100% target for all new planning permits.

Regarding the development of a national rapid charger network, there is already evidence that the private sector is installing rapid chargers, suggesting the deployment of such a network will not have to rely on public funds alone. There will however be a continuing role for a central organisation to coordinate stakeholders (at the EU and UK levels) so that an agreement is reached on the key issues (such as interoperability, connector type, payment systems) that will ensure the installed rapid chargers form a coherent and visible network.

### Policy and equivalent value support

While capital incentives have been shown to be effective, their continued deployment over the period to 2030 (even at a reduced level) is unlikely to be either desirable or optimal. The evidence suggests that a package of measures, from innovative ownership models to EV ownership benefits could be required to address barriers to 2030, depending on evolution of EV costs and consumer attitudes.

Innovative leasing and new ownership models have the potential to address capital cost premiums of EVs (and the high discounting rates of consumers) with the added benefit of removing consumer concerns regarding component degradation and residual values. New vehicle ownership and financing models for EVs should therefore be supported, e.g. through smart and targeted taxation. As such, the reinstatement of the Enhanced Capital Allowance (or an equivalent instrument) for lease and rental EV fleets would be advantageous to supporting the future EV market.

In terms of possible financial support measures, options include capital subsidies and feebate schemes. Technology-neutral 'feebates' combine an system of 'fees' for the most polluting vehicles, with purchase 'rebates' for EVs. Self-financing feebate schemes offer the possibility of supporting market transformation over the medium- to longer-term.

One of the key lessons from the country case studies is that EV sales can be promoted successfully through the provision of non-financial benefits (e.g. preferential road access) which can provide high value benefits to end users at relatively low cost. Non-financial measures also have the advantage of playing a key role in supporting the used EV market. The key stakeholders responsible for delivery of these non-financial benefits are local and national government who will need to coordinate and standardise such local measures across the UK.

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While these measures could all be used to incentives EVs, the scale of the challenge may also call for market delivered solutions and the effective gradual phasing out of ICEVs through emission based regulations. This has already been proposed by the European Commission whose Transport 2050 Strategy sees cities as instrumental in creating strong value added to EVs, with goals for transport that include CO<sub>2</sub>-free city logistics in major urban centres by 2030 and phasing out conventionally fuelled cars in cities by 2050. The success to date of the London Congestion Charge in supporting EV sales in the South East suggests the proposed London Ultra Low Emission Zones would be an effective policy to promote the EV market in the UK.

## Role of fuel cell vehicles and 100% ZEV market pathway

The project conducted a qualitative assessment of the post-2030 pathway to 100% ZEVs uptake, with infrastructure implications based on an analysis of the future housing and parking landscape as well a review of existing literature on the potential uptake of fuel cell vehicles (FCVs).

### Fuel Cells Vehicles

The cost premium, supply of FCVs, and challenges of initiating a nationwide refuelling infrastructure are the greatest barriers to FCV uptake. However the UK is well placed in terms of infrastructure deployment and supply, due to the strong industry engagement, notably through the UK H<sub>2</sub>Mobility initiative that brings stakeholders together to resolve the roll-out challenges. These stakeholders include representatives from utility, industrial gas, fuel retail and car manufacturing sectors alongside three UK government departments.

The UK H<sub>2</sub>Mobility study indicates FCVs could reach 10% market share by 2030, thereby contributing to the 60% high uptake pathway target. This level of uptake is highly dependent on the roll-out of hydrogen refuelling stations that will require an estimated total financing of £420 million before becoming self-sustaining, £62 million of which is required before 2020.

While FCVs may be the most suitable zero emission technology in larger vehicle segments, their contribution to the 60% target in 2030 is difficult to assess on a *cost effectiveness of support* basis because of the interdependencies of the EV and FCV markets. For example, regarding vehicle supply, it is not clear whether OEMs have sufficient resources or can generate sufficient revenues to deliver all three technologies (PHEVs, BEVs and FCVs) simultaneously in all vehicle segments.

The benefit of developing a fuel cell pathway is clearer under the post-2030 high uptake target (of 100% market share for Zero Emission Vehicles) as FCVs could offer a valuable alternative to a BEV only strategy (with its challenging charging and range issues). This suggests that continuing efforts to bring the FCV technology closer to commercialisation would be a sensible hedging strategy in the delivery of the ZEVs uptake targets.

### Towards 100% ZEV uptake

A ZEV target which includes FCVs would help address the most difficult vehicle segments to electrify, in particular high-duty cycle vans and high mileage business cars. As noted above, the strength of the FCV market in 2030 depends in part on infrastructure investment decisions made over the next few years.

As not all BEVs would be able to park off-street overnight in a BEV-only scenario (around 10 million cars are expected to park on-street by 2050), a ZEV target which includes FCVs would also allow a smaller BEV fleet to rely on relatively cheap overnight off-street charging.

Capital cost projections of ZEVs, ICEVs and PHEVs, and the high value consumers place on these costs suggests achieving a 100% ZEV market share by 2040 will be challenging and will require a strong technology directed strategy and associated policies, particularly if PHEVs (even fuelled with advanced biofuels) are to be disincentivised as ZEVs are vigorously promoted.

Such outcomes could be delivered through direct measures (e.g. procurement rules, emission zones) or indirect actions (e.g. supply-side cross subsidies that benefit ZEVs). Major cities are likely to be instrumental stakeholders in supporting a future ZEV market at

the expense of ICEVs, in line with the Transport 2050 Strategy already advocated by European Commission.

The overarching implication of the findings is that reaching the high uptake pathway targets is achievable. However it will require a long term commitment to the support of electric powertrains which may go against a historical policy approach which has tended to be technology neutral.



Contents

**1 Introduction.....5**

1.1 Background ..... 5

1.2 Objectives of the work ..... 6

1.3 Project approach ..... 6

1.4 Structure of the report ..... 7

1.5 About the authors and reviewers ..... 8

**2 Plug-in electric vehicles: demand and projected supply .....9**

2.1 Current global demand for electric vehicles ..... 9

2.2 Electric vehicle sales in the UK ..... 10

2.3 Supply of plug-in vehicles..... 13

**3 Market barriers to EV adoption .....21**

3.1 Vehicle purchase priorities and barriers to adoption of EVs ..... 21

3.2 Purchase and ownership costs ..... 25

3.3 Access to charging infrastructure, driving range and charging time ..... 34

3.4 Consumer acceptance and technology maturity ..... 43

**4 Methodology: modelling high EV uptake to 2030 .....47**

4.1 Principles of choice modelling ..... 47

4.2 Modelling the uptake of electric vehicles ..... 49

4.3 Modelling efficient pathways to high EV uptake ..... 53

4.4 Factors beyond the scope of the model ..... 54

**5 Modelling results: EV uptake pathway to 2030 .....58**

5.1 EV uptake targets: setting the challenge ..... 58

5.2 High EV uptake pathway to 2030 ..... 59

5.3 Action target: vehicle supply and brand/model diversity ..... 61

5.4 Action target: consumer awareness and acceptance ..... 62

5.5 Action target: EV charging infrastructure ..... 63

5.6 Action target: equivalent value support ..... 66

5.7 Model sensitivities and discussion ..... 67

**6 Delivering the EV uptake pathway to 2030 .....80**

6.1 Stimulating vehicle supply ..... 80

6.2 Raising consumer awareness and acceptance ..... 86

6.3 Developing a national charging infrastructure ..... 91

6.4 Coordinated policy and supporting measures ..... 96

**7 Prospect for hydrogen fuel cell vehicles .....106**

7.1 Supply of Fuel Cell Vehicles ..... 106

7.2 Barriers to uptake of fuel cell vehicles ..... 107

7.3 The current landscape for fuel cell vehicles in the UK ..... 111

**8 Electric vehicles post-2030: towards 100% market share .....119**

8.1 Cost landscape post 2030 ..... 119

8.2 Infrastructure need and options post-2030 ..... 120

**9 Implications of the report .....124**

**References .....129**

**10 Appendix .....132**

10.1 Detailed country case studies ..... 132

10.2 The UK car and van market ..... 139

10.3 Targets for electric vehicle uptake in selected countries ..... 145

10.4 Model inputs and assumptions ..... 146

10.5 Model sensitivity ..... 163

10.6 Detailed results ..... 171

## Authors

This report has been prepared by Element Energy in partnership with Ecolane.

For comments or queries please contact:

Celine Cluzel	<a href="mailto:celine.cluzel@element-energy.co.uk">celine.cluzel@element-energy.co.uk</a>	0330 119 0984
Ben Lane	<a href="mailto:benlane@ecolane.co.uk">benlane@ecolane.co.uk</a>	0117 929 8855
Eleanor Standen	<a href="mailto:eleanor.standen@element-energy.co.uk">eleanor.standen@element-energy.co.uk</a>	01223 852498

## Reviewers

This report has been reviewed by Dr Shane Slater, Director, Element Energy, and Professor Jillian Anable, University of Aberdeen.

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## Timing of report and publication

The main analysis presented in this report was conducted between March and June 2013 inclusive; with additional modelling conducted in October 2013.

During that time, the government research on the effectiveness of the plug-in grant was published (TRL, *Assessing the role of the Plug-in Car Grant and Plugged-in Places scheme in electric vehicle take-up*, report for the DfT, 2013). In this report, some of the TRL findings are cited based on discussions with the DfT ahead of the TRL report publication; these are referred to in the text as “Research conducted by TRL for the DfT, due for publication in September 2013”.

Prior to this report’s completion, the UK government also published his strategy on low emission vehicle support (*Driving the future today, A strategy for ultra low emission vehicles in the UK*, the Office for Low Emission Vehicles, September 2013).

## Acronyms

AC	Alternating Current
AFV	Alternative Fuel Vehicle
APC	Advanced Propulsion Centre
AQ	Air Quality
AQMAs	Air Quality Management Area
ASC	Alternative Specific Constant
B2C	Business to Consumer
BEV	Battery Electric vehicle
BIK	Benefit in Kind
BSS	Battery swapping station
BVRLA	British Vehicle Rental and Leasing Association
C1NICs	C1 National Insurance Contribution
C2C	Consumer-to-Consumer
CARB	California environmental protection agency air resources board
CC	Congestion Charge
CCC	Committee on Climate Change
CEP	Clean Energy Partnership
CHIC	Clean Hydrogen in European Cities
CP	Charging Point
DC	Direct Current
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
Defra	Dept for Environment, Food and Rural Affairs
DfT	Department for Transport
DLA	Disability Living Analysis
DRDNI	Department for Regional Development, Northern Ireland
ECA	Enhanced Capital Allowance
EE	Element Energy
EST	Energy Saving Trust
ETI	Energy Technologies Institute
EU	European Union
EV	Electric vehicle
FCH-JU	Fuel Cell and Hydrogen Joint Undertaking
FCV	Fuel Cell Vehicle
FED	Federal Excise Duty
GW	Gross Weight
H2	Hydrogen
HOV	High Occupancy Vehicle
HRS	Hydrogen Refilling Station
HVM	High Value Manufacturing
HyTEC	Hydrogen Transport in European Cities
IBSA	advertisers' representative
ICCT	International Council for Clean Transportation
ICEV	Internal Combustion Engine Vehicle
IPPR	Institute for Public Policy Research
JRC	Joint Research Centre
kW	Kilowatts
kWh	Kilowatts hour
LA	Local Authority
LCV	Low Carbon Vehicle

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LEZ	Low Emission Zone
LowCVP	Low Carbon Vehicle Partnership
NEDC	New European Driving Cycle
NGOs	Non Governmental Organisations
NTS	National Travel Survey
OEM	Original Equipment Manufacturer (vehicle manufacturer)
OLEV	Office of Low Emission Vehicles
OTR	On The Road
PHEV	Plug-in Hybrid Electric Vehicle
PiCG	Plug-in Car Grant
PiP	Plug-in Places
RACF	RAC Foundation
RCD	Residual Current Device
REEV	Range-extender EV
SMMT	Society of Motor Manufacturers and Traders
SMR	Service, Maintenance and Repair
TCO	Total Cost of Ownership
TfL	Transport for London
TSB	Technology Strategy Board
UK	United Kingdom
ULCV	Ultra Low Carbon Vehicle
ULED	Ultra Low Emission Discount
ULEV	Ultra-Low Emission Vehicle
ULEZ	Ultra Low Emission Zone
US	United States
VED	Vehicle Excise Duty
VW	Volkswagen
WTP	Willingness To Pay
ZEV	Zero Emissions Vehicle

## 1 Introduction

### 1.1 Background

*“[The] almost complete decarbonisation of road transport is a possibility”* (King Review)<sup>4</sup>

Electric vehicles<sup>5</sup> (EVs) are considered a technologically effective means of reducing carbon emissions from the road transport sector and helping to meet the carbon reduction targets set to mitigate climate change. As road transport contributes about 20% of overall UK CO<sub>2</sub> emissions, decarbonisation of this sector is an important area of policy focus.

The UK was the first country in the world to introduce legally binding national targets for the reduction of greenhouse gas (GHG) emissions through the Climate Change Act 2008 (which includes an 80% reduction target by 2050 from 1990 baseline). As part of its strategy, the UK Government published the Carbon Plan which states that: *“the emergence of ultra-low emission vehicles (ULEVs) and hybrid and electric cars will be crucial in preparing for progress in the 2020s”*.<sup>6</sup>

The UK Government has introduced a range of significant fiscal incentives to stimulate the uptake of EVs including the Plug-in Car and Van grants, and infrastructure investment through the Plugged-in Places programme. The European Union’s proposals to amend the ‘Cars and CO<sub>2</sub>’ regulations for 2020 also include ‘super credits’ for manufacturers commercialising cars that emit less than 50g of CO<sub>2</sub>. The UK Government also recognises that decarbonisation of the power supply sector, whilst vital for decarbonisation of the economy in its own right, is also necessary so that EVs can contribute to decarbonisation.

However, significant market barriers remain, and growth in EV sales to date has been slow. In the United States, the world’s largest vehicle market, sales of battery electric and plug-in hybrids were fewer than 50,000 in 2012, and accounted for only around 0.04% of total sales.<sup>7</sup> In the UK, only around 2,200 EVs had been sold by the end of 2012 (representing approximately 0.1% sales).<sup>8</sup>

One of the key market barriers is vehicle price. Production costs remain high, and manufacturers face a difficult challenge in offering EVs at a price which is attractive when compared to conventional models. GM and Fiat-Chrysler are just two examples of manufacturers which report significant losses on every electric model sold.<sup>9,10</sup>

In addition to price, key consumer barriers to EV adoption include: ‘range anxiety’ (linked to access to recharging infrastructure); recharge time; limited model availability; and unfamiliarity of the technology. Supply-side barriers also exist, including the need to develop a new skills base. Despite major investment in EVs by the automotive sector,

<sup>4</sup> King Review of low-carbon cars, Part I: The potential for CO<sub>2</sub> reduction, HM Treasury. October 2007.

<sup>5</sup> The term ‘electric vehicles’ is used to refer to three types of technology: battery electric vehicles (BEVs); plug-in hybrids (PHEVs) and range-extended electric vehicles (REEVs).

<sup>6</sup> UK Government Department of Energy and Climate Change. The Carbon Plan: Delivering our low carbon future, 2011.

<sup>7</sup> Electric Drive Transportation Association 2012 US Electric Drive Vehicle Sales Figures. URL: <http://www.electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952>

<sup>8</sup> SMMT 2012. URL: <https://www.smmt.co.uk/2013/01/december-2012-%E2%80%93-ev-and-afv-registrations/>.

<sup>9</sup> <http://www.reuters.com/article/2012/09/10/us-generalmotors-autos-volt-idUSBRE88904J20120910>

<sup>10</sup> <http://www.economist.com/news/leaders/21578679-electric-car-stalls-race-be-green-wheels-future-not>

including battery and powertrain development, EV production costs remain relatively high with performance unable to yet match the driving range of conventional vehicles.

## 1.2 Objectives of the work

In the context of the key role that EVs are required to play in the UK's GHG emissions reduction strategy, and the significant market challenges that remain, the **Committee on Climate Change** (CCC) commissioned Element Energy, Ecolane Consultancy and the University of Aberdeen to identify possible pathways to achieve high penetration of light-duty electric vehicles (car and vans, battery, plug-in hybrid and fuel cell electric vehicles) in the UK.

As defined by CCC, the target used in this project is for 60% of new vehicles (cars and vans) sales in 2030 to be PHEVs and zero emission vehicles. For this study zero emission vehicles (ZEVs) are defined as battery electric vehicles (BEVs) and fuel cell vehicles (FCVs). Post 2030, the uptake pathway target for ZEVs increases to 100% of new vehicle sales from 2040 for the UK, so that, taking the stock turnover into account, the vehicle parc is virtually decarbonised by 2050.

In summary, the Committee on Climate Change's EV uptake pathway is defined by:

- Indicative 16% market share (PHEVs plus ZEVs) by 2020;<sup>11</sup>
- 60% market share (PHEVs plus ZEVs) by 2030;
- 100% market share (ZEVs) by 2040.

## 1.3 Project approach

To understand the EV market, an international review is undertaken to collect data on vehicle uptake in different countries as well as national uptake targets. These are compared to the announced short term vehicle supply to identify how EV production capacity will need to increase to meet these targets.

Based on research findings on the main attributes which consumers take into account when making decisions about purchasing vehicles, the attributes which represent a barrier to EV uptake are identified. Measures that have been put in place in the UK are then assessed against the identified barriers. Countries identified as leading in terms of EV uptake are also studied in more detail to, where possible, correlate incentives to uptake and assess the most important barriers to overcome in order to accelerate the uptake of EVs.

Consumers' elasticity to each of the identified key vehicle attributes is defined, and used in a choice model to determine the level of uptake. Choice modelling allows both financial and non-financial attributes of vehicles to be taken into account in calculating the probability of buyers choosing a given technology. The choice model is then run in a number of scenarios for interventions to overcome the barriers, to determine the most efficient route to meeting the 2030 deployment target of electric vehicles. The derived pathway defines milestones to be met and the relative importance of each milestone.

The potential uptake of fuel cell vehicles is studied in a qualitative way, by reviewing existing literature relevant to the UK, to comment on how they could contribute to the 2030 target. The pathway to the post-2030 targets for EVs is also approached in a qualitative way, with infrastructure implications based on an analysis of future housing and parking landscape.

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<sup>11</sup> As defined by the percentage of new car and van sales.

## 1.4 Structure of the report

This report presents the main findings of the project, following work conducted by the project team on behalf of the Committee on Climate Change. It is structured as follows:

**Section 2 presents the current and near-term demand and supply for electric cars and vans.** It presents the global demand and identifies the leading regions and countries in terms of electric vehicles sales. Sales of EVs in the UK are presented in more detail, with an introduction to the UK market structure and preferences in terms of vehicle segment and brands. The section also presents the current and near term supply capacities, by OEM and by region, as well as the supply outlook in the UK in terms of brand and number of models.

**Section 3 introduces consumer purchase behaviour and related barriers to the adoption of EVs.** Based on literature as well as the authors' primary research, this section presents the top purchase criteria for car buyers. It introduces a segmentation of car buyers in terms of attitude to plug-in vehicles, and based on these criteria and attitudes, derives the key barriers to uptake of EVs. Each barrier is then discussed in terms of current scale and future outlook in the UK.

**Section 4 presents the modelling methodology.** This section describes how the choice model combines consumers' purchase behaviour, future vehicle characteristics and identified barriers with interventions (action targets) to derive a pathway to the uptake of electric vehicles that reaches the 2030 target. The choice modelling technique is introduced and the consumer segmentation developed for this study is presented, along with the modelling assumptions.

**Section 5 presents the pathway to the 2030 target uptake of electric vehicles based on modelling results.** The scale of the challenge is first introduced by comparing the EV targets with other powertrain historic uptake pathway since introduction. The action targets developed to reach the 60% EV uptake in 2030 are then detailed and key sensitivities highlighted. Where possible, the costs of the action targets are estimated.

**Section 6 comments on the delivery of the pathway to 2030.** Pathway milestones derived from the modelling are summarised and measures that could deliver them are identified. For each action target, both measures in place in the UK as well as other measures that have proven successful in other countries are considered, and evidence of efficiency is reported on, when it exists. The section also comments on the stakeholders who are likely to implement or deliver the required measures.

**Section 7 is dedicated to the case of fuel cell vehicles and their possible contribution to the 2030 target.** FCV supply, barriers to uptake and projected demand are considered, drawing on Element Energy extensive work in the area as well as the findings from literature, more notably from the UK H<sub>2</sub>Mobility initiative. The opportunities and impacts of a successful FCV market are discussed in the context of the pathway to high EV uptake.

**Section 8 discusses the post-2030 targets.** The post-2030 cost landscape and infrastructure implication of a 100% ZEVs fleet are discussed. Other considerations are also briefly commented on, e.g. impacts of ZEVs beyond carbon emission reductions.

**Section 9 concludes the analysis by reflecting on the implications of the findings.**

The report is also supported by several Appendices, which give further detailed information on the topics covered in the main chapters.



## 1.5 About the authors and reviewers

The project was conducted in 2013 by consultants at Element Energy (project lead), Ecolane Consultancy and the University of Aberdeen.

**Celine Cluzel**, Principal Consultant at Element Energy, is an expert on electric vehicles. She has worked on both the supply side (study of battery cost and performance) and demand side with the study of consumer attitudes for uptake modelling. She has as well worked alongside cities in their development of policy strategies for EV uptake and advised several businesses developing new business models in relation to EVs.

**Eleanor Standen**, Senior Consultant at Element Energy, has significant experience in low carbon transport and low carbon energy policies. In particular, she has worked on the costs of infrastructure roll-out for FCVs, and the barriers to uptake of hydrogen vehicles.

**Dr Ben Lane**, Director of Ecolane, has extensive experience in consumer-focused attitudinal research relating to low carbon vehicles and has lead several authoritative studies focusing on car buyer behaviour and vehicle labelling. He also has an in-depth knowledge of the key drivers of the UK private and fleet vehicle markets.

**Professor Jillian Anable**, Senior Lecturer in Transport and Sustainability at the University of Aberdeen is an expert in travel behaviour, climate change and energy policy with particular emphasis on the potential for demand-side solutions. She has developed methods of applying market segmentation techniques to assess vehicle choice behaviours.

### Note on terminology

In this report, the term 'electric vehicles' is used to refer to plug-in vehicles: battery electric vehicles (BEVs); plug-in hybrids (PHEVs) and range-extended electric vehicles (REEVs). For simplicity, PHEV is used to refer to both PHEV and REEV.

Zero emission vehicles (ZEVs) include battery electric vehicles (BEVs) and fuel cell vehicles (FCVs).

## 2 Plug-in electric vehicles: demand and projected supply

This section presents the current global demand for EVs (BEVs and PHEVs) and identifies the countries that have fostered the highest adoption rates to draw some insights from their approach. The sales of EVs in the UK are presented in more detail, with an introduction to the car and van market segments.

### 2.1 Current global demand for electric vehicles



**Figure 1 EV sales in leading countries in 2012. Data compiled from various sources<sup>12</sup>**

Total EV sales in 2012 have been relatively strong, with over 110,000 sales of electric cars and vans, more than double the sales of 2011 (c. 45,000). This compares to sales of conventional vehicles of 82 million in 2012.<sup>13</sup> Amongst the top countries in terms of EV sales, the USA is the largest market in absolute terms, with c. 53,000 sales in 2012. In terms of absolute sales, Europe is the smallest regional market (see Figure 1), but it hosts six out of the top 10 countries in the world for absolute EV sales (see Figure 2). Europe also hosts the market with the highest percentage of EVs sold compared to cars sold, with Norway where EVs captured 3.3% of car sales in 2012.

The trends for the first two quarters of 2013 confirm the dynamism of the EV market in the US and Europe. By the middle of May 2013, the US had sold 24,550 plug-in vehicles, bringing the total sold in the US to 100,000 to date.<sup>14</sup> In the Netherlands there have been more than 10,000 pre-orders of one new model – the Mitsubishi Outlander Plug-in Hybrid.<sup>15</sup>

Figure 2 shows the leading countries for EV sales. The US, Japan and China are the leading markets in absolute terms. Estonia shows high percentage sales but this is due to an unusual circumstance in which Mitsubishi provided 500 i-MiEVs, as well as technical advice, to the Estonian Government in exchange for EU Emissions Trading Scheme allowances<sup>16</sup>. Estonia apart, Norway and the Netherlands dominate in terms of percentage

<sup>12</sup> Data sources: Automotive Industry Data, Japan Automotive Manufacturers Association, Plug-In America, ChinaAutoWeb, GreenCarReports, Institute of Public Policy Research: Leading the charge, can Britain develop an advantage in ultra-low emission vehicle, 2013.

<sup>13</sup> Organisation Internationale des Constructeurs d'Automobiles (OICA)

<sup>14</sup> Plug-in America, May 2013 <http://www.pluginamerica.org/drivers-seat/were-counting-100000-plug-ins-pia100k>

<sup>15</sup> <http://www.insideoutlander.com/posts>

<sup>16</sup> <http://cleantechnica.com/2011/11/02/mitsubishis-i-miev-travels-the-world/>

sales; both countries have significant packages of incentives for EVs; they have been studied in more detail as they offer interesting lessons on barriers to uptake and impact of incentives.<sup>17</sup> It is worth noting that in some countries, in particular Austria, Switzerland and Belgium, sales are dominated by quadricycles such as the Renault Twizy Z.E.

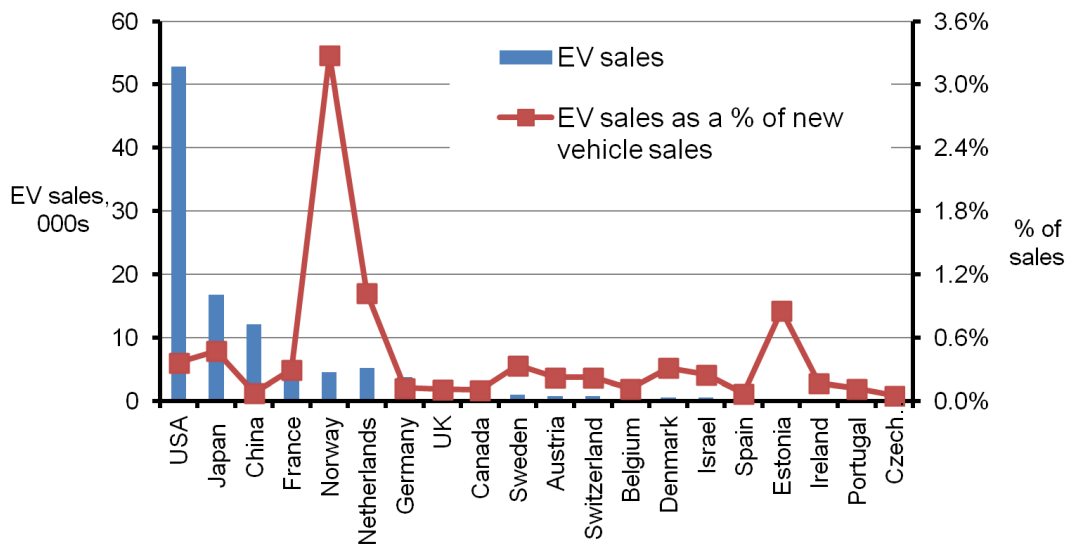


Figure 2 New vehicle sales of EVs in leading countries (2012) shown in absolute terms and as a % of total vehicles sold. Data compiled from various sources<sup>18</sup>

## 2.2 Electric vehicle sales in the UK

This section introduces the UK van and car markets in terms of vehicle segment, and vehicle class and brand preferences. Sales of EVs are also presented in terms of recent trends and near term prospects.

### 2.2.1 UK car market

Around two million new cars are sold annually in the UK, with a split of approximately 45% of cars registered as private and 55% as company owned. Company owned cars are referred to as ‘fleet cars’ in this report.

The Society of Motor Manufacturers and Traders (SMMT) categorises the market into nine car segments ranging from small city cars (‘A segment’) to multi-purpose vehicles (‘I segment’).<sup>19</sup> A simplified segmentation using three categories (small, medium and large) is shown in Table 1.

UK sales of electric cars have increased significantly since the introduction of the Plug-in Car Grant (PICG) in 2011 worth 25% of the purchase price, capped at £5,000. The market has also been boosted by the introduction of the Nissan LEAF, the first high-quality C-segment car (previously models were either small cars or luxury models).

From a base of over 1,000 EVs sold by 2011, sales in 2012 doubled with the introduction of further models) and brands. The newly introduced PHEVs/REEVs (from Vauxhall, Chevrolet and Toyota) have been particularly popular; they cumulatively captured over

<sup>17</sup> These insights are referenced where relevant in the report; also refer to Appendix 10.1 for detailed case studies.

<sup>18</sup> Data sources: EV sales as per previous footnote, absolute sales data from ACEA, Japan Automotive Manufacturers Association, ChinaAutoWeb, Reuters.

<sup>19</sup> Appendix 10.2 provides more details on SMMT vehicle classification.

40% of EV sales (983 units) and 86% of the sales increase between 2011 and 2012. The overall sales in 2012 represent 0.11% of total UK car sales, a level far from the CCC indicative target of 16% for 2020.

As of March 2013, there are approximately 3,900 PiCG eligible electric cars on the road in the UK (representing around 0.01% of the car parc).<sup>20</sup> The further increase in new models available in 2013<sup>21</sup> and continuation of the PiCG suggests that sales will continue their ascent – see Figure 3.

Table 1 Simplified car segmentation, based on SMMT segments and data

Car segment (SMMT segments)	Typical characteristics	Market share [among private and fleet car buyers]
Small (A/B)	From 2 doors city cars to larger 2/4 doors, up to 1.4l engine. Length up to 3m	40% (mostly segment B) [50% / 30%]
Medium (C/D)	Saloon, from 1.3l to 2.8l engine. Length up to 4.5m	40% [30% / 50%]
Large (E-I)	Includes executive, luxury and sport cars as well as dual and multipurpose vehicles. Variety of body shapes and lengths. Largest vehicles and engines.	20% [20% / 20%]

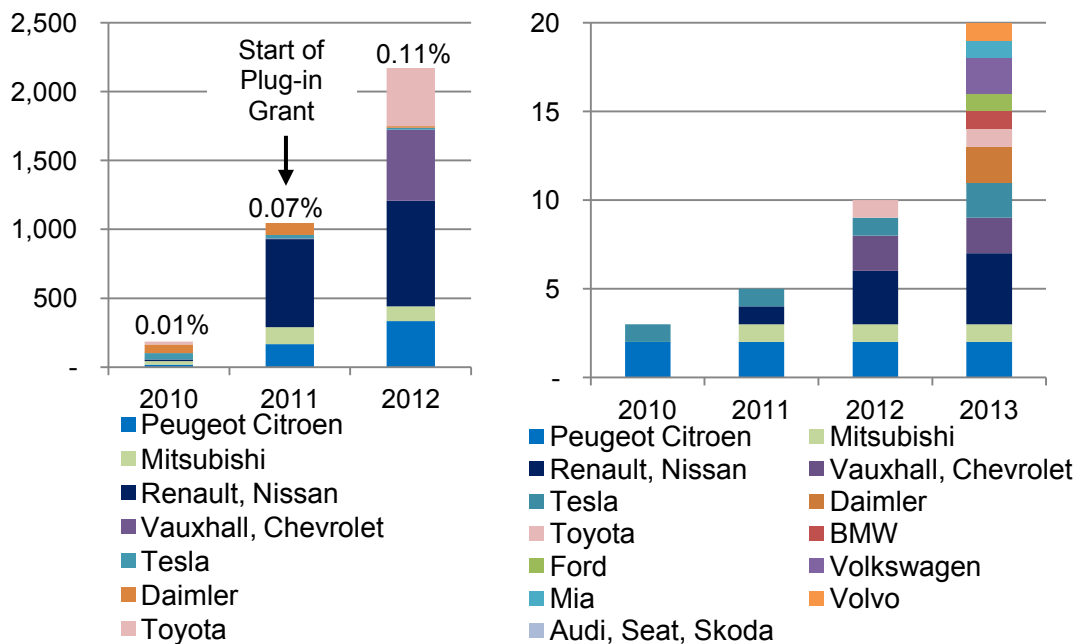


Figure 3 Sales of electric cars in the UK, absolute and percentage (left) and number of models available per brand (right)<sup>22</sup>. Source: DfT and team analysis

<sup>20</sup> <http://www.smm.co.uk/2013/04/march-2013-%E2%80%93-93-ev-and-afv-registrations/>

<sup>21</sup> The number of models increased by a factor of four between 2010 and 2013, from 3 in 2010 to 12 models by mid-2013.

<sup>22</sup> Some brands appear on the left from 2010 despite starting only in 2013 on the right; this is because some 2010 sales were for trials only and the models were not available on the market.

### 2.2.2 UK van market

Around 200,000 new light commercial vehicles (up to 3.5t GVW, referred to as ‘vans’ hereafter) are sold annually in the UK, with a split of approximately 10% registered as private and 90% as company owned.

In a study commissioned by the Department for Transport, Element Energy developed a van segmentation based on gross weight and body shape.<sup>23</sup> Figure 4 shows the market share breakdown of van segments with panel vans and small vans capturing 85% of the market. Further details on the van segments are shown in Appendix 10.2.2.

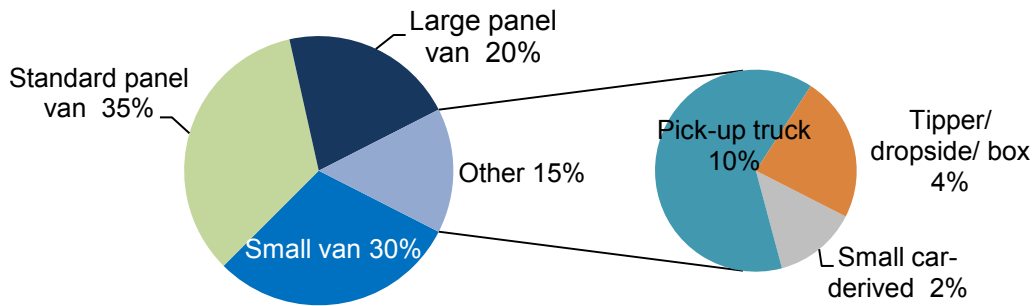


Figure 4 Typical market share of vans per van type<sup>24</sup>

In contrast to the electric car market, the use of electric vans is not a new trend with thousands of lead-acid electric vans having been in active service for decades. However, the majority of the 3,700 electric vans on the road are low performance vans used for night-time deliveries (‘milk floats’).

In contrast, the sale of new generation electric van based on lithium-ion battery technology is only nascent, with around 250 sold in 2012 (0.1% of new van sales), when only two panel van models were eligible for the Plug-in Van Grant (PiVG; worth 20% of purchase price, capped at £8,000) – see Figure 5. Note that the drop in EV sales in the fourth quarter of 2012 reflects a reduction on total van sales.

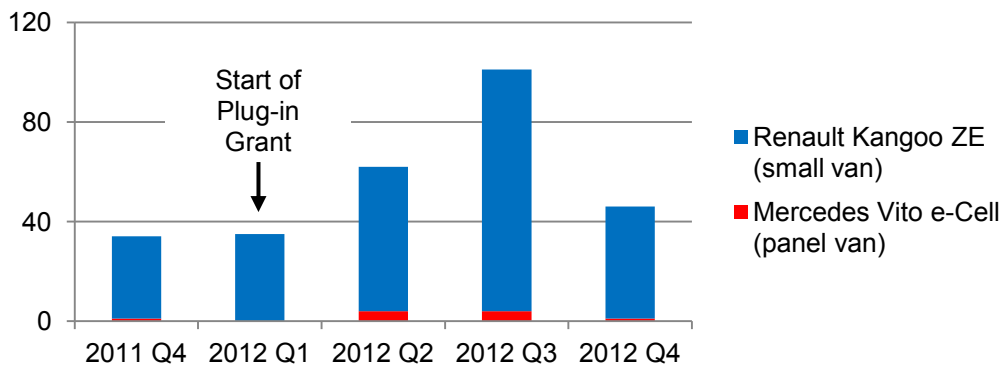





Figure 5 Sales of electric vans in the UK. Source: Dft

As of April 2013, nine electric van models are available in the UK and eligible for the PiVG (Table 2). Given the limited number of models in each segment – especially for small and panel vans – sales in 2013 are likely to be modest.

<sup>23</sup> Element Energy for the Dft, Ultra Low Emission Vans study, January 2012

<sup>24</sup> Ibid

Table 2 Van segmentation and electric models eligible for the grant available in 2013

	SMALL VAN	STANDARD PANEL	LARGE PANEL	OTHER
Example (non electric)				Various – see Appendix 10.2.2
Typical specification	2.1t GW Payload: 3 m <sup>3</sup> / 0.75t	2.6t GW (+ up to 3.4t) Payload: 6 m <sup>3</sup> / 0.9t	3.5t GW Payload: 13 m <sup>3</sup> / 1.3t	
EV models eligible for grant as of April 2013	3 models Renault Kangoo ZE Renault Kangoo ZE Max Mia	1 model Mercedes Vito e-Cell	2 models (conversions) BD eTrafic van Smith Edison	3 models Ecomile Jolly Edison

### 2.2.3 UK car and van brand preferences

11 brands currently capture 70% of the UK car market, while for vans only 10 brands capture over 90% of the market share due to the limited number of models – see Figure 6. In both cases, however, the three top selling brands are Ford, Vauxhall and Volkswagen.

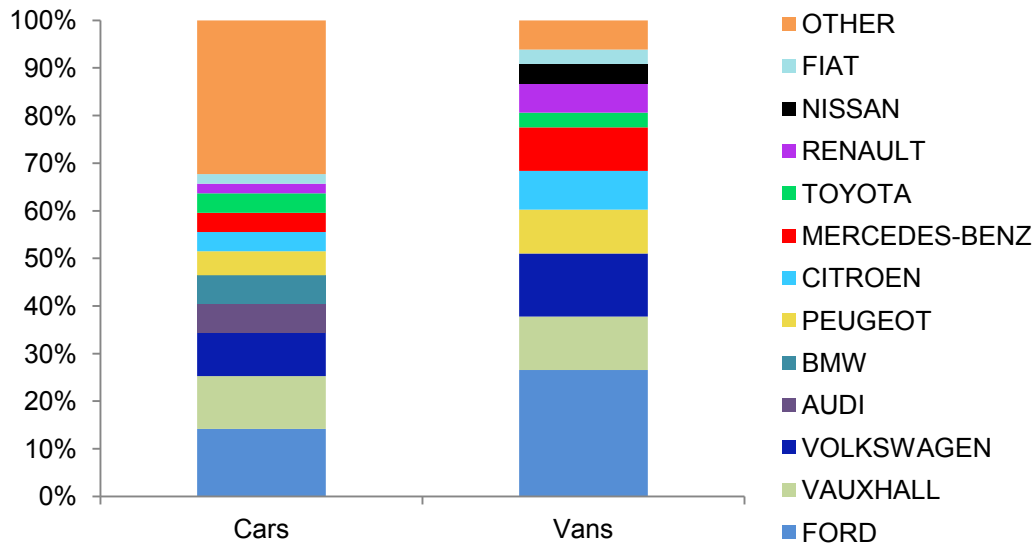


Figure 6 Sales of new cars and vans in the UK per brand in 2012<sup>25</sup>. Source: SMMT

## 2.3 Supply of plug-in vehicles

### 2.3.1 Supply volume projections and comparison to national targets

An assessment by the project team of the global supply of EVs in 2015 concludes that OEMs expect to manufacture 1.5 million EVs in 2015. This analysis, which includes BEVs

<sup>25</sup> 'Other' is the sum of all brands with less than 2% market share

and PHEVs, cars and light duty vans, is based on public announcements of production capacity and future scale-up plans, as well as direct communication with several OEMs. Given the commercially sensitive nature of sales and production projections, the assessment is an estimate primarily based on publicly available data.

As shown in Figure 7, the capacity breakdown by OEM reveals the projected dominance of the Renault-Nissan Alliance; supported by a high share of early EV sales. Although not yet producing a series EV, Volkswagen has set an ambitious target to sell 300,000 EVs annually by 2018.<sup>26</sup> One of the largest global OEMs, Ford, is not attributed a high EV production capacity, based on their sales projection of 0.5% of plug-in vehicles by 2015.<sup>27</sup>

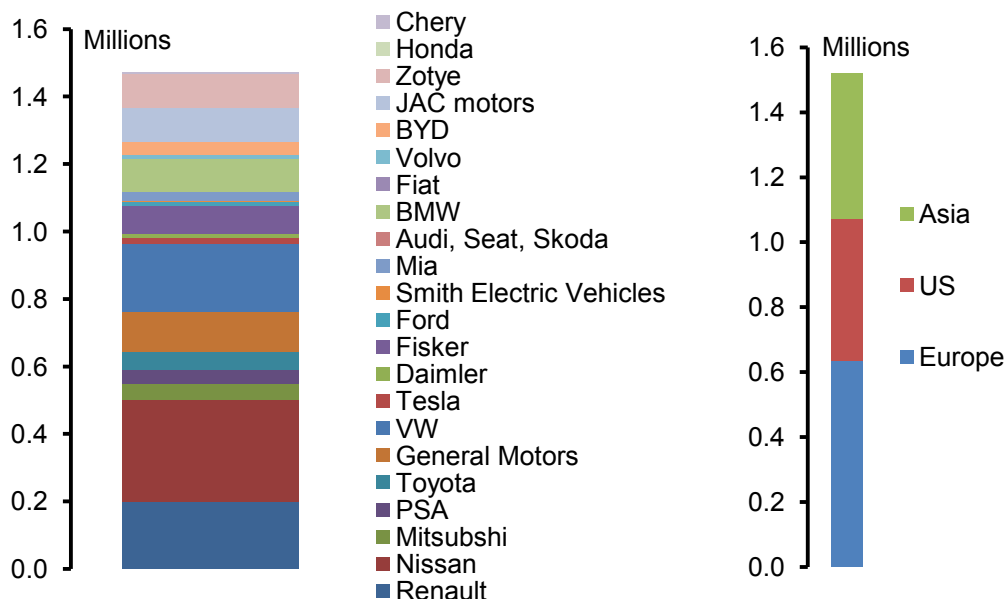


Figure 7 Estimate of global annual EV production in 2015, by OEMs (left) and production location (right). Project team analysis<sup>28</sup>

A number of countries have national targets for EV deployment. As shown in Figure 8, the sum of the national targets identified is 18.4 million EVs on the road by 2020. It is worth noting that not all countries that are keen to promote EV adoption have official government targets; as a result some key countries are not represented here (for example Australia).

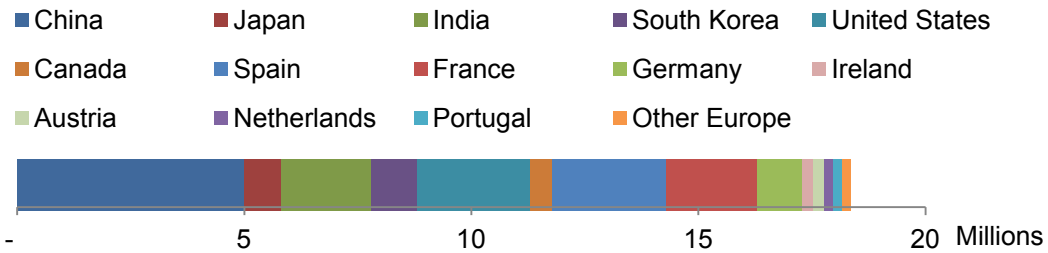
While China and the US have the greatest ambitions for EV introduction backed by early investment and promotion, some national targets appear overly ambitious with regard to progress made to date and the level of current political commitment (e.g. Spain). Although the UK has no official uptake target for 2020, the pathway to high uptake developed for this study suggests around 700,000 EVs on the road by 2020.

<sup>26</sup> IEA, Technology Roadmap: Electric and plug-in hybrid electric vehicles, 2011

<sup>27</sup> High Energy Automotive Application Energy Storage Needs, Ted J Miller, presented at the BATTERIES 2011 conference, Mandelieu, France, September 2011

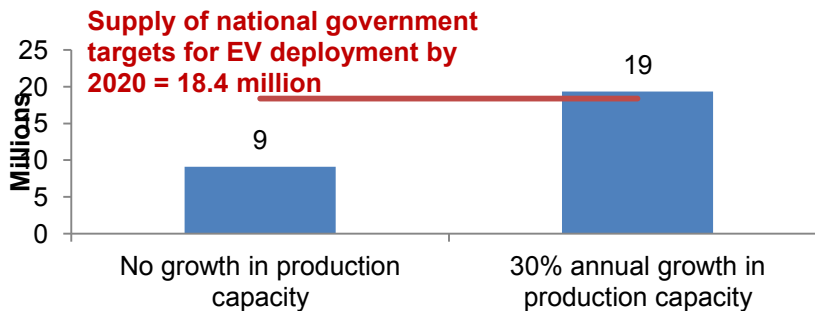
<sup>28</sup> Based on various sources, including OEM press releases (Nissan, Mitsubishi, Toyota) IEA Technology Roadmap: Electric and plug-in hybrid electric vehicles, 2011, Automotive news Europe, Bloomberg, Reuters, ChinaAutoWeb, as well as personal communication with several OEMs





**Figure 8 Targets for EV deployment by 2020 (millions, cumulative) by country.**  
Source: see Appendix 10.3

To assess the feasibility of the global target for 2020, it is instructive to cross-check the target with the announced total production *capacity*. Based on projected production capacity for 2015, the authors estimate that 9.1 million vehicles can be produced between 2015 and 2020. As this is clearly not sufficient to meet the 2020 targets for key countries, the 2015 levels of production capacity will therefore need to increase by around 30% each year until 2020 (reaching 5.6 million in 2020) to meet national government targets and ambitions – see Figure 9.



**Figure 9 Comparison of national deployment targets with cumulative production capacity**

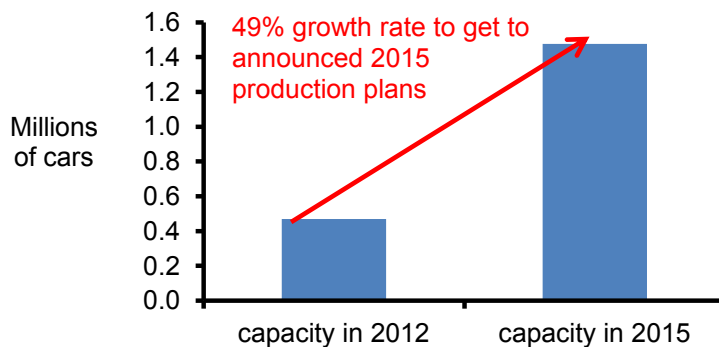
Although current plans for 2015 production already represents a 50% annual growth rate (see Figure 10), this raises the question of how credible is a 30% annual growth in EV production capacity from 2015 to 2020. While there is always degree of uncertainty with any market projection, there are two main points to consider as to whether this growth rate can be achieved. First, a 30% growth rate would result in an annual production capacity of 5.6 million EVs in 2020, representing less than 7% of the current total motor vehicle production.<sup>29</sup>

Secondly, there are good reasons supporting OEMs’ capability to scale up production at the required rate:

- As previously highlighted, OEMs are cautious in their announced production and can be highly responsive to demand;
- Where EV models are based on existing ICEV models (for example the Renault Fluence), rapid scaling up is possible;
- OEMs’ factories do not all run at full capacity;

<sup>29</sup> Global production of cars and vans was 84.1 million in 2012. Source: Organisation Internationale des Constructeurs d’Automobiles (OICA). No reliable statistics have been found on the production capacity (higher than the actual sales).

- The battery supply chain has been responsive to EV demand and is not limiting the short term production: battery production capacity suggests that by 2015, two million packs per year can be produced<sup>30</sup> against an estimated capacity for 1.5 million EVs.



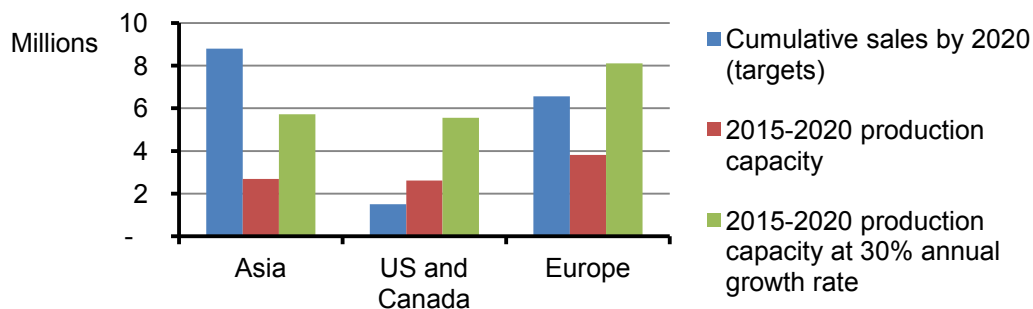
**Figure 10 Current production capacity compared to planned capacity in 2015**

It is also worth noting that world-wide sales in 2012, at around 110,000 units, are significantly below the current production capacity of 470,000. It is therefore likely that OEMs may have slowed down the development of planned production capacity.

While the assessment is positive at the global scale, when the targets and production capacity are compared by region, some larger disparities do become apparent (which are of importance as some markets heavily favour ‘local’ manufacturers) – see Figure 11. The picture for Europe appears positive, as the production capacity at a 30% annual growth rate is more than enough to meet the cumulative sales by 2020.

However, the analysis reveals a mismatch between the production capacity and national ambitions in Asia where production capacity is forecast to be significantly below the sales targets, even at a 30% annual growth rate in production capacity.<sup>31</sup> China is trying to develop national production to meet its sales target but progress has so far been slow.<sup>32</sup>

In contrast, production capacity in the US and Canada could be greater than demand, implying that a 30% growth in production capacity may not be required to serve this potentially important EV market.



**Figure 11 Sales targets and production capacity by region**

<sup>30</sup> Element Energy analysis

<sup>31</sup> Current production capacity estimates may be below actual production capacity due to limited data availability.

The UK is in strong position to have access to EV production as the EU is a significant market both in terms of demand and production. Within the EU, the UK is one of the top four markets and benefits from local EV production (including Nissan's new Sunderland plant). The UK is also the host to the largest European independent battery assembler, Axion, which is based in Scotland.

### 2.3.2 Brand and model supply outlook in the UK

Consumer research shows brand loyalty is very strong among vehicle buyers<sup>33</sup>; assessing EV supply in terms of brand is therefore an important consideration.

For private cars buyers, the symbolism and social status associated with the brand are important issues, as are perceived reliability and safety. While fleet vehicle buyers also exhibit brand attachment, it tends to be based on more practical considerations, and includes the dealer relationship, availability of discounts and equipment compatibility.

Based on OEM announcements of series model release, the overall outlook for EV brand supply in the next few years is very good – see Figure 12 for the UK case for cars, and Figure 13 for the UK case for vans. Based on current announcements, the UK top three car brands will be represented by end 2013 and the top 10 brands by 2015.

The number of models commercially available has also been identified as a choice factor, with consumers (of all types) more likely to desire a particular technology if it is available in a wide range of models.<sup>34</sup>

While the total number of models is rapidly improving, there is a disparity across different vehicle types, the forecast for cars being stronger than for vans – see Figures 14 and 15. The projection of new models by powertrain also reveals that OEMs are focussing primarily on BEVs with 25 models due by 2015. For comparison, the number of (non plug-in) models on the UK market is about 400 for cars and 40 for vans.<sup>35</sup>

Within the car market, no production PHEV models have yet been announced for the small car segment.<sup>36</sup> This lack of supply is likely to persist for many years due to inadequacy of the plug-in hybrid architecture (high battery cost premium on small packs<sup>37</sup>) within segments where margins are at their lowest and price competition is most acute. For medium to large cars, while the supply appears low, this should be only a short term issue as all main OEMs have PHEV models in development.

The plug-in van supply is also focussed on BEVs, the market only recently shifting from after-market conversions to OEM models (including the Renault Kangoo Z.E., the Mercedes e-Vito and released number of Citroen, Peugeot and Nissan models). To date, there has been no announcement of plug-in hybrid vans with the exception of the U.S. based company Emerald that is due to start production of the t-011 in 2014.<sup>38</sup> While some prototypes and concept vehicles were presented in European automotive shows in 2010 and 2011 (e.g. Vauxhall Vivaro and Vivaro Protean), no further announcements have been forthcoming.

<sup>33</sup> Purchasing of New and Second-hand Cars (The), Market Intelligence, October 2009

<sup>34</sup> Stephens, T. (March 2013). Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies. Transportation Energy Futures Series. Prepared for the U.S. Department of Energy by Argonne National Laboratory, Argonne, IL. DOE/GO-102013-3709.

<sup>35</sup> Approx. 700 car models if accounting for variants. Based on data supplied by ComCar.

<sup>36</sup> Note there has been some small PHEV presented as concept vehicles, for instance VW XL1 Concept vehicles are not considered as production vehicles in this analysis.

<sup>37</sup> Cost and performance of EV batteries, Element Energy for the Committee on Climate Change, 2012

<sup>38</sup> <http://www.fleetsandfuels.com/fuels/evs/2012/07/emerald-automotive-reports-uk-certification/>

Two reasons explain why low carbon van supply is lagging behind low carbon cars. First, as the market size is small (ratio 8:1 cars:vans in the UK), the introduction of new powertrain technology in vans is generally delayed compared to car segments. And second, the innovation in efficiency technology driven by CO<sub>2</sub> emissions and regulation for vans is being introduced later than for cars<sup>39</sup>.

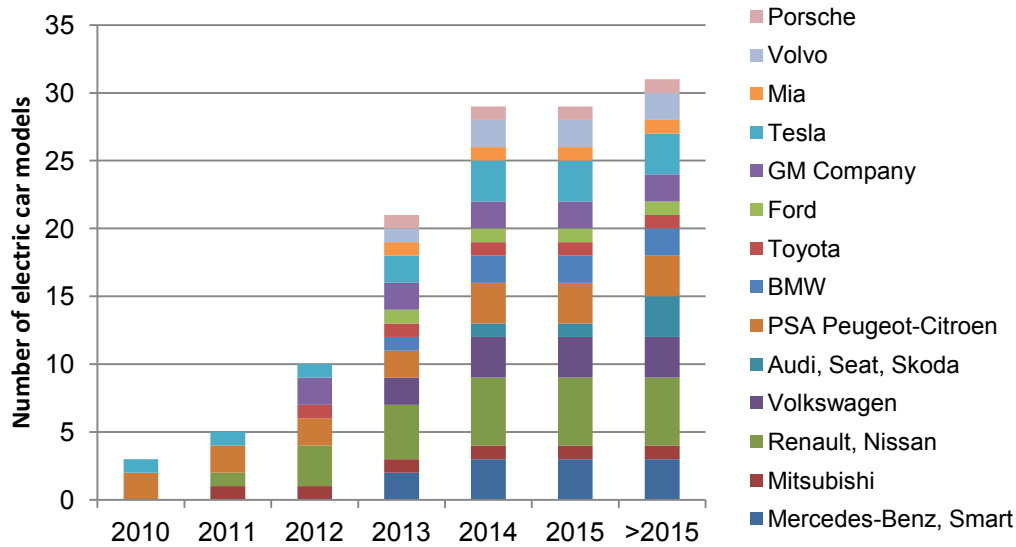


Figure 12 Available electric car models in the UK per brand. Source: authors' compilation of public announcements

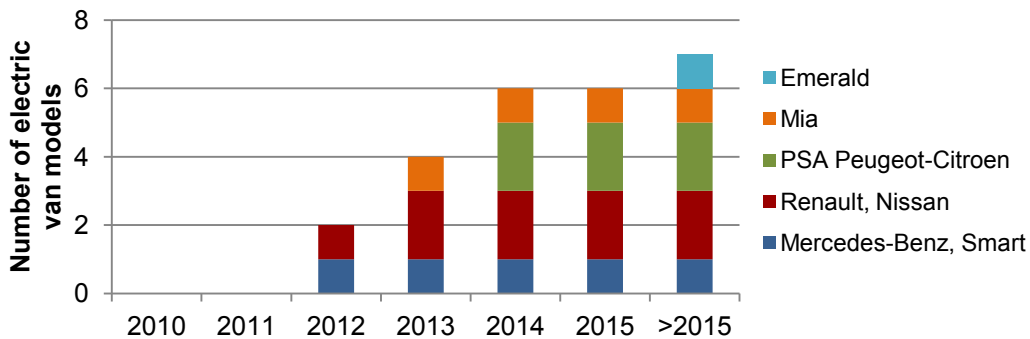


Figure 13 Available electric van models in the UK per brand (excludes conversion vans). Source: authors' compilation of public announcements

<sup>39</sup> The EU legislation on CO<sub>2</sub> emissions for passenger cars was introduced in 2009 with a first target in 2015 (130g/km) while it was introduced in 2011 for vans, with a first target in 2017 (175 g/km).

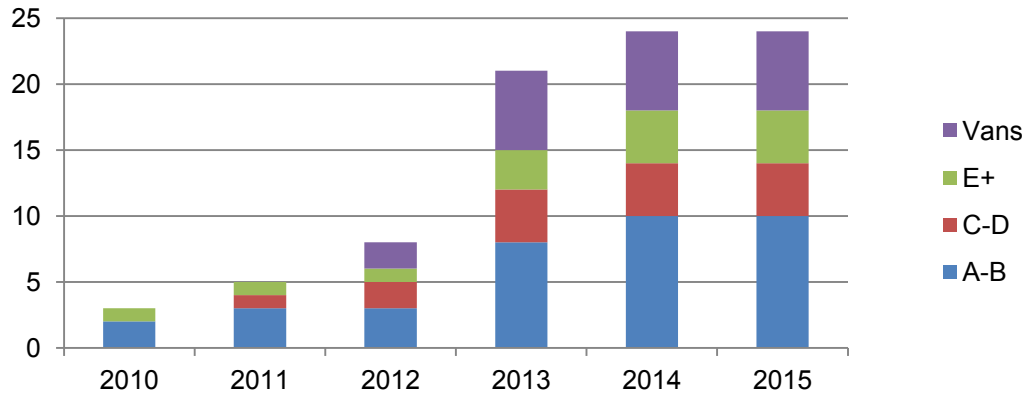


Figure 14 Number of available BEV production models in the UK per vehicle segment. 'Vans' refers to small and panel vans. Source: authors' compilation of public announcements

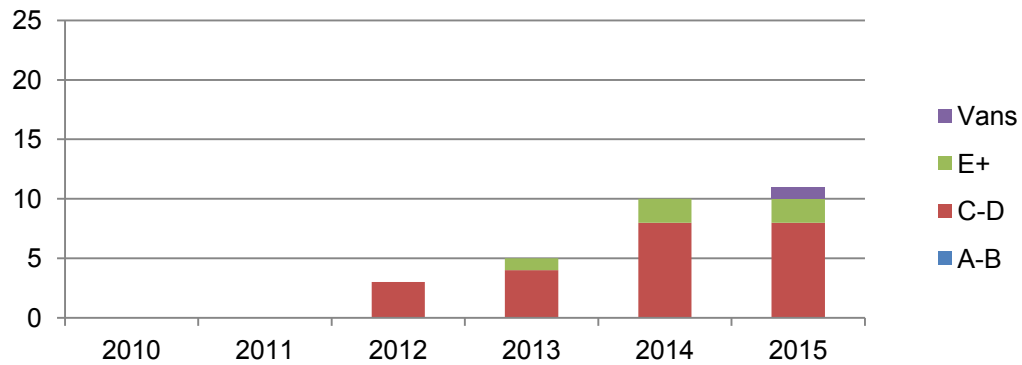


Figure 15 Number of available PHEV/REEV production models in the UK per vehicle segment. 'Vans' refers to small and panel vans. Source: authors' compilation of public announcements

**Summary of Section 2**

- Sales in the developing global EV market have been relatively strong in 2012, with global sales more than doubling compared to 2011 and amounting to around 110,000 electric cars and vans. In terms of absolute sales, Europe is the smallest *regional* market, but it hosts six out of the top 10 *countries* in the world for absolute EV sales. Europe also hosts the market with the highest EV market share in Norway, where EVs captured 3.3% of car sales in 2012.
- In the UK, EV sales have been modest, representing only 0.1% of new car and van sales in 2012. However, supported by the Plug-in Car and Van Grants and an improving supply of models and brands, the trend is of steady growth for sales of electric cars; the growth trend is likely to be lower for vans, where supply is lower in terms of models and brands.
- An assessment by the project team of the global supply of EVs in 2015 projects that OEMs will manufacture 1.5 million EVs in 2015 (includes BEVs and PHEVs, cars and light duty vans). This analysis is based on public announcements of production capacity and future scale-up plans, as well as direct communication with some OEMs.
- The national targets for EV deployment add up to 18.4 million EVs on the road by 2020. This would require annual growth in production capacity of 30% between 2015 and 2020. Such a growth rate is credible; the EV production capacity in 2020 would represent less than 7% of the current total light-duty vehicle production. The assessment concludes that OEMs will be able to scale up production capacity quickly in response to increased demand.
- Based on OEM announcements of series model releases up to 2015, the overall outlook for brand supply of electric vehicles in the next few years is very good for the UK: the UK top three car brands will be represented by the end of 2013 and the top ten brands by 2015. Supply varies across vehicle segments and EV types: the outlook for BEVs is better than for PHEVs and better for cars than for vans.

### 3 Market barriers to EV adoption

Understanding the consumer barriers to the adoption of electric vehicles requires an assessment of vehicle buyers' decision processes and priorities. This section provides an overview of light-duty vehicle purchase behaviour according to recent research and details the key issues relating to the uptake of EVs.

#### 3.1 Vehicle purchase priorities and barriers to adoption of EVs

According to extensive research, the key purchase factors for private car buyers involve a mix of financial and non financial attributes.<sup>40,41,42,43,44</sup> In approximate order of importance these are:

- Vehicle price (the leading car purchase factor);
- Size, practicality, comfort (vehicle segment is a proxy for these attributes);
- Fuel consumption (although this tends to be 'traded-off' against other factors);
- Reliability (often a perceived reliability, i.e. linked to the trust in a brand) ;
- Brand - brand loyalty is very strong among vehicle buyers who tend to limit the number of brands they would consider purchasing;<sup>45</sup>
- Style/ appearance;
- Driving performance (such as acceleration time and top speed);
- Other cost signals (cost of vehicle tax, cost of insurance).

Environmental issues have little direct influence on purchasing decisions,<sup>46</sup> due to the fact that the other key issues set out above are, or become, *more important* to consumers at the point of purchase.' This is also the case for fuel consumption; while it can be considered as a proxy for environmental impact, 'mpg' tends to be traded-off against other factors (such as vehicle size) which diminishes its importance closer to actual purchase. Moreover, whereas 'fuel efficiency' is ranked as an important factor when buying a car, 'impact on environment' is not ranked highly, suggesting that fuel economy conveys non-environmental information to car buyers; namely it is used to gauge fuel costs.<sup>47</sup>

While the relative importance of these key purchase factors continues to inform market responses to electric vehicles, additional issues are also important in determining vehicle selection. These factors, which include a mix of practical and attitudinal issues, reflect the key differences in cost and performance between EVs and conventional vehicle types and the associated factors of status and image which can be especially important in the early stages of market penetration of a new technology.<sup>48</sup>

<sup>40</sup> An affordable transition to sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2013.

<sup>41</sup> Car Buyer Attitude Survey. GfK Automotive for Low Carbon Vehicle Partnership, 2009.

<sup>42</sup> Post Wave: 'Act on CO<sub>2</sub>' car purchasing campaign awareness and communication. BMRB, 2007.

<sup>43</sup> New Vehicle Purchase Market Transformation Model, 2007, Element Energy for the Energy Saving Trust.

<sup>44</sup> Demand for Cars and their Attributes and; Cambridge Econometrics for Department for Transport, 2008.

<sup>45</sup> Purchasing of New and Second-hand Cars (The), Market Intelligence, Mintel, October 2009

<sup>46</sup> Climate Change Campaign. Benchmark stage: Driving Behaviour and Car Purchasing. BMRB for DfT, 2007.

<sup>47</sup> LowCVP Car Buyer Survey: Improved environmental information for consumers. Ecolane & Sustain for Low Carbon Vehicle Partnership, 2010.

<sup>48</sup> An affordable transition to sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2013.



As reported in the literature, the additional consumer concerns relating to EVs are: ‘range anxiety’ (linked to unavailability of recharging infrastructure); recharge time (when charging away from home); limited model availability; unfamiliarity of the technology (due to lack of experience and information); and other factors including safety concerns and uncertainty about other costs such as maintenance.<sup>49,50,51,52</sup> The common expectation that rapid technological and infrastructural developments will make current models obsolete also acts as a further barrier to near-term uptake.<sup>53</sup>

Based on the evidence already cited, the key factors that influence EV purchase (which will be studied in more depth in later sections of this report) are summarised in Table 3.

**Table 3 Key factors influencing EV purchase**

Purchase factors	EV issue
<ul style="list-style-type: none"> <li>• Vehicle segment: (size, practicality, comfort)</li> <li>• Vehicle brand</li> </ul>	Supply
<ul style="list-style-type: none"> <li>• Vehicle price (leading criteria for vehicle choice)</li> <li>• Fuel consumption and running costs</li> </ul>	Price
<ul style="list-style-type: none"> <li>• Performance and reliability</li> </ul>	Infrastructure, range, charging time
<ul style="list-style-type: none"> <li>• Symbolic motives, status, reliability</li> <li>• Concerns over uncertain costs, resale value, performance (of battery in particular), reliability and safety</li> <li>• Attitudinal segmentation reveal strong differences across UK consumers</li> </ul>	Technology maturity and consumer acceptance

### 3.1.1 Private EV attitudinal segmentation

A recent UK study led by the Energy Technologies Institute of just under 3,000 buyers found that *attitudinal* segmentation was a better predictor of EV adoption than more conventional demographic indicators. The study identified eight UK consumer segments relevant to EV market adoption;<sup>54</sup> these were each given descriptive names ranging from the ‘Plug-in Pioneers’ (the first early adopters of EVs), ‘Willing Pragmatists’ (more inclined to favour PHEVs) and Aspirers (interested in EVs but concerned by performance limitations), through to the ‘image-conscious rejecters’ (among the most sceptical about EVs).<sup>55</sup>

<sup>49</sup> Cited by Begley, J and N Berkeley. UK policy and the low carbon vehicle sector. Local Economy 2012 27: 705. Published online 14 September 2012. DOI: 10.1177/ 0269094212455003.

<sup>50</sup> Tsang F, Pedersen JS, Wooding S, Potoglou D, 2012, 'Bringing the electric vehicle to the mass market a review of barriers, facilitators and policy interventions', RAND Europe Working Paper

<sup>51</sup> UCLA Law/Berkeley Law, Sept 2012, Electric Drive by '25: How California can catalyse mass adoption of Electric Vehicles by 2025

<sup>52</sup> Stephens, T. (March 2013). Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies. Transportation Energy Futures Series. Prepared for the U.S. Department of Energy by Argonne National Laboratory, Argonne, IL. DOE/GO-102013-3709.

<sup>53</sup> Graham-Rowe E, Gardner B , Abraham C, Skippon S, Dittmar H, Hutchins R, Stannard J, 2011. Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations. Transportation Research Part A 46 (2012) 140–153.

<sup>54</sup> An affordable transition to sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2013

<sup>55</sup> It should be noted that these eight segments are only relevant to the UK market. Given the dynamic nature of attitudes and EV technology, the segments revealed in 2011 are unlikely to survive in the longer term.

Statistical analysis also found that the five attitudinal factors which most strongly differentiated the segments were: ‘willingness to pay’ (a premium for plug-in vehicles), ‘social identity’ (with respect to EV ownership), ‘anxiety’ (in particular in relation to driving range), ‘parking difficulty’ (linked to the ability to recharge at home), and ‘symbolic motives’ (positive and negative associations of EVs). While each segment is characterised by different attitudes towards EVs, all segments are more positive towards PHEVs than BEVs.

While not as strong an indicator as attitudinal factors, some demographic trends were apparent (and in common with buyers of new ICE vehicles), with Plug-in Pioneers tending to be highly educated, with above average income and a greater tendency to be based in urban areas. In the ETI study, Aspirers were also more likely to be urban dwellers. This is confirmed by the wider literature which also suggests that urban dwellers are disproportionately more likely to own smaller, more fuel efficient cars in general, even though the average level of car ownership reduces as urbanity increases.<sup>56,57,58</sup> However, it is worth noting that the urban/ rural distinction reduces if PHEVs are specifically considered as separate from BEVs.

There was also some evidence that early adopters are more likely to be male, although evidence from other literature is mixed on this point.<sup>59,60</sup> Overall it seems that women focus more on safety, reliability and environmental attributes and men more on size, power and (brand) image.<sup>61,62</sup> The Aspirers, however, are more likely to be younger and female than the earliest adopters. There is also some evidence that females tend to put greater value on environmental considerations in general but also during car purchase, but at the same time they are less likely to take financial risks.<sup>63</sup>

According to the analysis, the EV purchase segments were not distinguished by the number of vehicles owned, with the exception of company car owners who reside in households with above average car ownership.

Whether an EV is more likely to be owned as a main car or as a second car differs only marginally between segments but also depends on whether the EV in question is a BEV or PHEV. For instance, the ETI analysis showed the Plug-in Pioneers to be slightly more likely to own a PHEV as a main car but there was no difference between first and second car ownership preference for a BEV. Company Car Drivers on the other hand are slightly more likely to see both types of EV as a second car. However, overall the analysis revealed no clear bias towards owning an EV as a second car in the household. One of

<sup>56</sup> Whelan, G. (2007). Modelling car ownership in Great Britain. *Transportation Research Part A*, 41, pp. 205-219.

<sup>57</sup> Randi Hjorthol (2013) Attitudes, ownership and use of Electric Vehicles – a review of literature. Institute of Transport Economics, Norwegian Centre for Transport Research.

<sup>58</sup> EVIX (2012) Electric Vehicle Survey Panel: A national study of consumer attitudes toward and usage of EVs. November 2012. Electric Vehicle Information Exchange.

<sup>59</sup> Carroll, S. and Walsh, C. (2010). *The smart move trial: description and initial results*. London: Cenex.

<sup>60</sup> Ziegler, A. (2010). *Individual characteristics and stated preferences for alternative energy sources and propulsion technologies in vehicles: a discrete choice analysis*. Working paper 10/125. Centre of Economic Research at ETH Zurich

<sup>61</sup> Angle, H. et al. (2007). *Driving behaviour and car purchasing*. Report for Department for Transport

<sup>62</sup> Mintel (2009). *Purchasing of new and second-hand cars (The), market intelligence*. London: Mintel International Group Ltd.

<sup>63</sup> Garling, T., Kirchler, K., Lewis, A. and van Raaij, F. (2010) Psychology, Financial Decision Making, and Financial Crises. In *Psychological Science in the Public Interest*.

the reasons for this may be that whilst some barriers to adoption such as range anxiety are less for second car ownership, willingness to pay for running cost savings is also lower.<sup>64</sup>

A simplified four-segment classification of the current UK private car market, based on the eight detailed ETI segments, is shown in Table 4.<sup>65</sup> These market segments illustrate the approximate current market share and key attitudinal characteristics of each group. Although simplified, the four groups adequately reflect the main attitudinal groupings and permit the effective modelling of the key attitudinal groups over time (discussed in later sections).

**Table 4 Attitudinal segments related to EV purchase**

Segment / Market share	Attitude towards EVs	Prospect of attitude change
<b>Enthusiasts</b> 15%	Positive – driven by attraction to innovative technology	Already positive
<b>Aspirers</b> 15%	Interested but concerned by technical attributes	Attitude will become positive once model of trusted brands become available and attributes improve
<b>Mass market</b> 50%	Not interested and do not share identity or symbolic meaning of EVs	Followers of social norms – attitude will normalise when EVs become a more common sight
<b>Resistors</b> 20%	Strong rejection of identity and symbolism of EVs	Attitude will change once EVs have lost their current connotation, i.e. only once already largely adopted

### 3.1.2 Fleet EV attitudinal segmentation

While evidence of fleet attitudes to EVs is very limited, U.S. research suggests that organisations operating larger fleets are most likely to consider new vehicle types (including EVs) if they can be classified as ‘hierarchical’ (highly centralised with formalised internal procedures); as typified by large private sector corporations.<sup>66</sup> These organisations tend to be highly motivated by Total Cost of Ownership (or ‘TCO’, which includes a vehicle’s capital costs, depreciation and running costs) considerations and CSR policy, and view potential risks as opportunities.

In contrast, more ‘bureaucratic’ organisations, as are found in the public sector, organisations tend not to be among the earliest adopters. While they do aspire to adopt new technologies, aim to lead by example and are more motivated by government regulations, they tend to be risk averse, have overly complex decision making processes, and have less access to capital to invest in new technologies.

<sup>64</sup> 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 for the Energy Technologies Institute. University of Aberdeen and Transport Research laboratory. March 2011.

<sup>65</sup> Note that new names have been given to three of the four segments.

<sup>66</sup> Nesbitt K and D. Sperling (2001) Fleet purchase behaviour: decision processes and implications for new vehicle technologies and fuel. Transportation research Part C 9 (2001) 297-318.

According to the research, smaller organisations (operating fewer vehicles) are generally less important as early adopters of new vehicle technologies. These are classified as either: ‘autocratic’ (high centralisation, low formalisation), which are similar to private consumers in their attitudes towards new vehicle types; or ‘democratic’ (low centralisation, low formalisation) with organisational behaviour that tends to be dominated by internal knowledge champions (who either support or block adoption).

One practical consideration of the characteristics of the four segments identified by paper is the receptiveness of each to measures designed to incentivise cleaner vehicle adoption. The paper observed that:

- ‘Hierarchic’ (large fleets) respond to financial incentives (as they are more likely to assess TCO, and also see risk as an opportunity);
- ‘Bureaucratic’ (large fleets) respond to mandates (as these organisations have less access to investment capital and are often TCO insensitive);
- ‘Autocratic’ (typically <10 vehicles) respond to purchase incentives and information (as this group is highly risk averse);
- ‘Democratic’ (typically <10 vehicles) have low access to resources (money and time) and tend to respond most to information (i.e. they will act if they have the resources and are more likely to follow the example of the larger pro-active companies).

Although originating in the U.S., these findings are supported by a recent UK survey by GE Capital which reports that 18% of the largest fleets (500+ vehicles) operate EVs of some type as compared to only 2-3% for fleets with fewer than 500 vehicles.<sup>67</sup>

The following sub-sections present the key barriers to the uptake of electric vehicles (listed in Table 3) in terms of the current situation and future outlook in the UK while Section 4 describes how these findings are used to represent and quantify each barrier in the choice model.

### 3.2 Purchase and ownership costs

Due to higher production costs, the purchase price of most commercially available EVs is higher than for conventional vehicles. As a general (indicative) rule, the cost differential scales with the level of drive-train electrification; from around a 10% premium for a ‘strong’ conventional hybrid,<sup>68</sup> 30% for a PHEV with a 15-mile EV range, to at least a 50% premium for a BEV. (Note that prices comparisons are also highly dependent on other factors including brand, OEM pricing strategy, ICE comparator, build quality, trim level and options).

As discussed in the previous section, the focus of buyers on up-front costs is well established as well as revealed by the market. The higher purchase price of EVs is therefore a significant market barrier, one that is addressed through a range of consumer measures, the most notable (in the UK) being the Plug-in Car and Van Grants worth up to £5,000 for cars and £8,000 for vans.

Comparing the UK prices of current EVs with popular conventional and hybrid vehicles, Figure 16 shows that purchase incentives are essential to bridge the significant price gap; even with the Plug-in Car Grant (PiCG), the price differential between a Ford Focus ICEV and EV ranges from £6k to £12k (2013 prices). The use of a battery leasing sales model

<sup>67</sup> Company car trends. UK GE Capital Fleet Services, 2011.

<sup>68</sup> A ‘strong’ hybrid, also known as a ‘full’ hybrid, is a vehicle that can run on just the engine, just the batteries (EV mode), or a combination of both. In contrast, ‘mild’ hybrids are unable to operate in pure EV mode.

greatly improves the comparison on capex; the Renault Fluence having only a £550 price premium over an equivalent Ford Focus, and costing less than some Volkswagen Golfs.

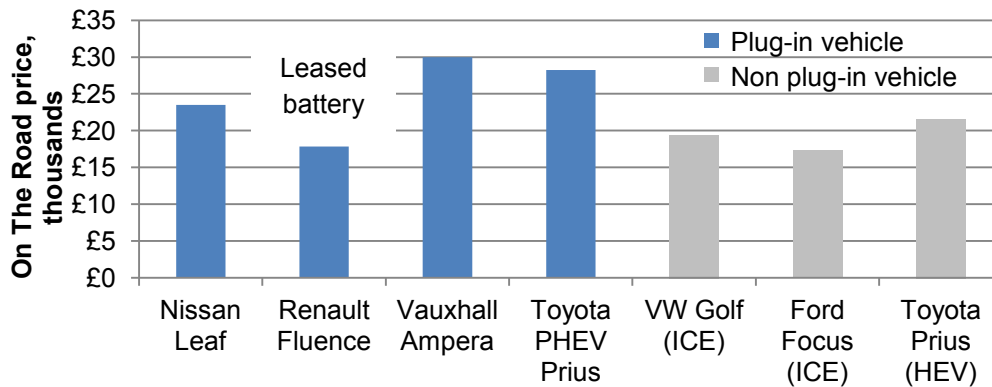


Figure 16 UK On The Road price (including Plug-in Grants where applicable)<sup>69</sup>

Purchase cost incentives

Supporting the assertion that vehicle price is the leading purchase factor for consumers is international evidence that purchase incentives are among the most efficient pricing signals with respect to increasing adoption rates of lower carbon vehicles.<sup>70,71</sup> Table 5 summarises the evidence on purchase incentives and other EV promotional measures used by a selection of the leading countries,<sup>72</sup> as well as the percentage of new EV sales achieved in 2012.

The high proportion of BEV sales in Norway, for example, is attributable in part to the introduction (as early as 1996 and 2001) of significant capital cost incentives in the shape of tax exemptions to support sales of new BEVs worth up to £12,200.<sup>73</sup>

<sup>69</sup> March 2013 prices sourced from ComCar for following C/D segment vehicles: Volkswagen Golf: 5Dr 2.0TDI BM Tech 150 SS SE DSG6 – 119gCO<sub>2</sub>/km; Ford Focus: 1.6 TDCi Edge 95PS DPF – 109g CO<sub>2</sub>/km; Toyota Prius: 1.8 T3 E-CVT – 89g CO<sub>2</sub>/km.

<sup>70</sup> Wallis, N. Encouraging the introduction of energy efficient and lower carbon road vehicles through carbon-based taxes at purchase. ECEEE, #3284, 2005.

<sup>71</sup> Electric vehicles in the UK and Republic of Ireland: Greenhouse gas emission reductions & infrastructure needs, Element Energy for WWF, 2010

<sup>72</sup> Estonia is not included in this analysis as the high uptake of EVs has been due to unusual circumstances which are not expected to be replicable for other countries, as commented in Section 2.1.

<sup>73</sup> VAT exemption (25%) was introduced in 2001, registration tax exemption was temporarily introduced in 1989 and permanently in 1996. The value of £12,200 is based on an average sized car Source: authors’ calculations. Conversion rate £1 = 8.90 NOK. See Appendix 10.1.1, page 116 for detail on value of exemptions.

Table 5 Overview of the cost incentives and infrastructure in place in selected countries<sup>74</sup>

	Norway	Netherlands	Japan	United States	Sweden	Denmark	France	Ireland	Germany	UK
Capital cost incentives <sup>75</sup> (either grant or tax break)	£12,200 (BEVs only)	£4,200 – £6,800 for private purchase	Up to £6,700	£1,590 - £4,770 Federal tax credit	£3,900	Up to £35,000 depending on segment (BEVs only)	£5,900	£5,650	Up to £8,500 (corporate purchase only)	Up to £5,000 for cars, £8,000 for vans
Running cost incentives	Annual tax exemption, Free parking, Exempt from road tolls.	Annual tax exemption, Exempt from income tax for lease vehicles, Some free parking.		State – specific incentives inc. insurance and parking charge exemptions	Annual tax exemption, Free parking in places, exempt from congestion charge in Stockholm	Annual tax exemption, Free parking	Annual tax exemption, Free parking in some places		Annual tax exemption	Reduced annual tax, Exemption from congestion charge in London
Charging infrastructure*	c. 4,000 public CP, and 127 fast chargers	c. 4,500 public and semi-public CP, and 89 fast chargers	Emphasis on fast charging, with 1,400 fast CP and c.4,000 slow CP	c. 14,000 slow CP and 200 fast CPs	c. 280 slow CP (although most people have access at home or work)	c. 1,080 slow CPs and c. 100 fast CPs	c. 1,600 slow CPs and 100 fast CPs	640 slow CPs	c. 2,000 slow CPs	C 8,500 public CP, <100 50kW chargers
<b>2012 EV sales, %</b>	<b>3.28%</b>	<b>1.02%</b>	<b>0.47%</b>	<b>0.36%</b>	<b>0.34%</b>	<b>0.31%</b>	<b>0.30%</b>	<b>0.17%</b>	<b>0.12%</b>	<b>0.11%</b>

\* Information is not always available regarding the power rate of ‘fast chargers’. Fast charging is likely to be a mixture of 22kW and 50kW, although some countries, e.g. Japan, are dominated by 50kW

<sup>74</sup> Information is collated from a variety of sources including national government websites as well as personal communications with local stakeholders; EV global outlook 2013, IEA; EV City Casebook 2012, IEA; Bringing Electric vehicles to the mass market, a review of barriers, facilitators and policy interventions. RAND Europe, 2012; Overview of incentives for EVs, ACEA, 2013.

<sup>75</sup> Capital cost incentives are either the maximum value of the grant available, or the tax break compared to purchase of a segment C ICE. Exchange rates are from xe.com on 17.06.13



The high number of (absolute) EV sales in the U.S. can also be attributed in part to the strong purchase price signal. The main incentive is a federal tax credit for BEV and PHEV purchases, ranging from \$2,500 to \$7,500 (£1,590 to £4,770) depending on the battery size, introduced in 2010.<sup>76</sup> Several States offer additional purchase support. For example, since 2011 in California, the Clean Vehicle Rebate Project (CVRP), funded by California Environmental Protection Agency's Air Resources Board (CARB), has provided up to \$2,500 (£1,590) for BEVs and \$1,500 (£950) for PHEVs (in addition to the federal tax credit).<sup>77</sup>

In the absence of significant UK vehicle *registration taxes*, the Plug-in Car and Van Grants are the UK method of delivering purchase incentives for EVs, and are a continuation of previous policy to incentivise low emission vehicles through the use of capital grants. From 1998 to 2005, for example, the Energy Saving Trust offered PowerShift grants worth up to 75% of the additional costs of alternatively fuelled vehicles.<sup>78</sup>

Another form of purchase incentive available to UK businesses are Enhanced Capital Allowances (ECAs), which permit the full write down of an EV's value in the first year of ownership.<sup>79</sup> Compared to the standard relief on vehicles of 18% per annum (on a reducing balance basis), this represents a cost benefit to company owned EVs worth between £1.5k and £3k over four years (equivalent to 7%-10% of an EV's OTR price).<sup>80</sup>

However, while Table 5 highlights the important role played by purchase incentives in promoting EV uptake, the figures also show that purchase cost incentives alone are not a guarantee of a successful market uptake. The majority of the leading countries have put in place a coordinated set of measures to tackle the purchase cost barrier and other barriers such as consumer awareness as well as introducing running cost benefits.

The case of Denmark, where tax exemptions lead to significant rebate, is an example showing that addressing the cost barrier does not necessarily lead to high uptake. Despite a more generous tax exemption for BEVs in Denmark as compared to Norway,<sup>81</sup> the uptake was only 0.3% in 2012 (vs. 3.3% in Norway). In contrast to the case on Denmark, the Norwegian EV incentive programme also includes significant running cost and non-financial benefits and has been in place for many years. Local Norwegian OEMs have also been supplying the market ahead of the introduction of models from international OEMs in 2011, meaning the car related industries (e.g. maintenance, insurance) were more prepared and consumers more aware of electric powertrains – see Box 1.<sup>82</sup> Another factor

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<sup>76</sup> The federal Qualified Plug-In Electric Drive Motor Vehicle Tax Credit applies to vehicles sold since December 31st 2009 and will continue to be available for EV purchases until 2014 (or until EV manufacturers sell more than 200,000 units in one quarter). The credit is worth \$417 for every 1 kWh above 4 kWh up to a maximum of 16 kWh. Vehicles such as the Nissan Leaf (24 kWh battery capacity) and the Chevrolet Volt (16 kWh battery capacity) will thus be eligible for the maximum \$7,500 credit. URL: <http://www.afdc.energy.gov/laws/law/US/409>.

<sup>77</sup> As of early March 2013, CARB has issued about 18,000 rebates totalling \$41 million. Of these, 9,559 all-electric vehicle and 8,842 plug-in hybrid owners had applied for the state's Clean Vehicle Rebate since January 2011. <http://www.afdc.energy.gov/laws/law/CA/8161>

<sup>78</sup> The scheme was instrumental in stimulating the market for mostly LPG and natural gas conversions and some hybrid electric cars.

<sup>79</sup> From 1 April 2013, leased business cars will no longer be eligible for the FYA. BVRLA Budget Summary March 2013.

<sup>80</sup> Ecolane analysis based on a comparison of six EVs with ICE equivalents. While the Finance Bill 2013 renewed the allowance for EVs until 31 March 2015, expenditure on leased vehicles was excluded from being eligible for the ECA. This exclusion effectively reduces the proportion of fleet and business cars eligible for the enhanced allowance from 70% to 30%, and for vans from 90% to 50%. EV leasing costs are expected to increase from 2013 by 3-5%.

<sup>81</sup> Vehicle registration tax is calculated as 105% of the first 79,000 DKK (~£10k) and 180% above.

<sup>82</sup> China is another example of high purchase incentive not delivering uptake in comparison to the results obtained in leading countries (grant of 60,000 yuan [ca. £6.3k] in 2012 and 0.08% uptake)



which may explain Denmark's relatively low EV uptake is the country having the highest electricity prices in Europe.<sup>83</sup>

**Box 1 Case study summary: Norway**

Norway is the leading country for EV sales as a percentage of total car and van sales; as of April 2013 there were over 12,000 EVs (mostly BEVs) on the Norwegian roads representing 0.5% of the total vehicle parc. The success of country's EV market can be attributed to a sustained EV supply and incentive programme, with many measures being in place for nearly 20 years<sup>84</sup>.

In particular, the case of Norway provides the following insights:

- The strong supply of models and brands has a positive effect on EV sales. While electric passenger vehicles (including quadricycles) have been available for almost two decades, EV sales have only increased significantly in Norway following the improved availability of models from major OEMs.
- Purchase incentives are central to promoting EV sales; significant purchase cost incentives for BEVs reduce the premium compared to ICE vehicles to around €1,000.<sup>85</sup> In addition, significant running cost benefits make the total cost of ownership very competitive with ICEVs.
- A publicly accessible charging network is *not* a precondition for initial market adoption; the growth of infrastructure has been organic, with a national plan being formulated only recently. Private EV owners mainly home charge vehicles overnight. While public charge points have been installed (with the provision of free charging and parking), the Norwegian experience suggests that cost incentives can drive EV early sales without the need for a comprehensive charging network.
- Non-financial benefits that translate into daily cost or time savings are highly valued. For example, one of the most popular benefits is the ability to access bus lanes and exemptions from paying road and ferry tolls.<sup>86</sup>

EV support measures in Norway are guaranteed for relatively long periods in order to send a long-term signal that the Government is committed to encourage the uptake of EVs (with particular focus on BEVs as opposed to PHEVs). Purchase incentives, for example, are guaranteed until at least 2018 or until there are 50,000 zero-emission vehicles on Norwegian roads.<sup>87</sup> Commitment is also demonstrated through public procurement; the City of Oslo's procurement framework only allows for replacement of municipal vehicles with electric vehicles.<sup>88</sup>

In terms of awareness raising, for over 20 years Norway has had a strong and active user groups, the Norwegian Electric Vehicle Association, who work on behalf of members, and with governments, NGOs and industry, to promote EVs.

<sup>83</sup> Denmark has the highest electricity prices in the EU27, as well as the second highest (behind Cyprus) differential between petrol and electricity: petrol is 38% cheaper than electricity on a €/kWh basis. [http://epp.eurostat.ec.europa.eu/statistics\\_explained/index.php/Energy\\_price\\_statistics](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Energy_price_statistics)

<sup>84</sup> Refer to Appendix 10.1 for details

<sup>85</sup> Norwegian electric car user experiences, Petter Haugneland and Hans Håvard Kvisle, 2013.

<sup>86</sup> Norwegian electric car user experiences, Petter Haugneland and Hans Håvard Kvisle, 2013.

<sup>87</sup> <http://www.averre.org/www/newsMgr.php?action=view&frmNewsId=611&section=&type=&SGLSESSID=mi3rnro4brrhkq4qi69nqjcd61>

<sup>88</sup> <http://c40.org/blog/driving-action-oslos-electric-vehicle-strategy-leading-the-way>

**Box 2 Case study summary: the Netherlands**

In 2012, electric car registrations in the Netherlands increased by 5,100, raising the market share to around 1% (mostly PHEVs) of all passenger car sales. As in Norway, the Netherlands have achieved this high level of adoption through the introduction of a comprehensive range of promotional measures and long-term government commitment including purchase tax incentives which will be available until 2018.

The Netherlands has also developed a fully interoperable national charging system. Working in close cooperation, the Government and the E-Laad Foundation<sup>89</sup> (which has installed 2,500 public charging points) have been instrumental in delivering this interoperability. Home charging has also been widely supported, with some local municipalities giving grants of up to €1,000 (£860) towards the installation of home charging units.<sup>90</sup>

The Netherlands has also been highly innovative to its approach to awareness raising. In Rotterdam, the Centre for EVs (Elektrisch Vervoer Centrum) provides members of the public with information and opportunities to test drive EVs. Since it opened at the start of 2012, the Centre has provided 5,000 test drives, and provided information to more than 1,500 companies.<sup>91</sup>

The Dutch experience provides the following lessons:

- If BEVs and PHEVs are incentivised to the same extent (as they are in the Netherlands<sup>92</sup>), sales are dominated by PHEVs. This confirms the consumer preferences as identified by surveys of EV drivers, and the high value placed by drivers on the ‘unlimited’ range offered by PHEVs<sup>93</sup>.
- Cost incentives directed at the lease car market can be particularly effective in driving adoption. In the Netherlands, incentives aimed at company cars and lease cars are particularly favourable, which has resulted in significant uptake in the lease car market.
- Non-financial benefits can act as very strong incentives, particularly within the used car market. For example, in Amsterdam, EV owners are able to jump the queue for processing parking permit applications, which in some areas can take up to four years.<sup>94</sup>

**3.2.1 Total Cost of Ownership (TCO)**

In addition to providing capital support, other incentives that reduce operational costs have been introduced to support the early UK EV market through vehicle and company taxation – these are summarised in Table 6. If these are taken into account, EVs can (in some UK contexts) compare favourably with ICE vehicles on a TCO basis.

Due to the current zero-rating of fuel excise duty (FED) on electricity (and its discounted VAT rating of 5%), EVs provide a significant reduction in fuel costs. Based on 2013 UK fuel prices, this cost benefit can amount to at least £600 per year for a private car with an average mileage (based on a Nissan

<sup>89</sup> <http://www.e-laad.nl/>

<sup>90</sup> Lode Messemaker, Innovation Manager, Rotterdam Electric, City of Rotterdam

<sup>91</sup> [elektrisch-vervoer-centrum.nl](http://elektrisch-vervoer-centrum.nl), personal communication

<sup>92</sup> See Appendix 10.1.2 for the detailed case study of the Netherlands

<sup>93</sup> 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 for the Energy Technologies Institute. University of Aberdeen and Transport Research laboratory. March 2011.

<sup>94</sup> [http://www.citizen.nl/main.php?obj\\_id=442832490](http://www.citizen.nl/main.php?obj_id=442832490)

LEAF compared with diesel VW Golf 109 gCO<sub>2</sub>/km). For fleet vehicles with higher mileages, annual cost savings of over £1,000 can be achieved.<sup>95</sup>

**Table 6 Measures in place in the UK addressing the EV cost barrier**

Cost addressed	Incentive measure	Typical saving value as of 2013	Buyers covered [scope]
<b>Capital cost</b>	Plug-in Car/Van Grant (until 2015)	£5k for eligible cars, £8k for eligible vans	Private and fleet, car and van buyers [UK]
	Enhanced Capital Allowance* (until 2017)	£1.5k to £3k (based on 4 year comparison with equivalent ICEV)	Approx. 35% of purchases by fleet car buyers [UK]
	First year VED*	< £200	All car buyers [UK]
	TfL procurement framework	Purchase discount	London based businesses and organisations [LOCAL]
<b>Annual/Running cost</b>	London Congestion Charge* and Low Emission Zone	< £2k p.a. (Ultra-Low Emission Discount)	All car and van buyers driving in London Congestion Charge Zone – ULED threshold 75 gCO <sub>2</sub> /km and Euro 5 [LOCAL]
	Company car tax*	< £1k p.a.	Approx. 15% of car users (30% of fleet car purchases) [UK]
	Energy costs <sup>#</sup>	< £1.5k p.a.	All car buyers [UK]
	Van benefit charge	£600 p.a.	10% purchases by van buyers (for private use only) [UK]
	Class 1A National Insurance Contributions*	< £600 p.a.	Approx. 15% of car and van users (30% of fleet purchases) [UK]
	Annual VED*	< £200 p.a.	All car buyers
	CO <sub>2</sub> based parking policy or free parking	£50 to £250 p.a.	All car buyers (mainly urban) [LOCAL]

\* CO<sub>2</sub> based incentive - not specifically designed to support EV sales

<sup>#</sup> The tax differential between liquid fuel and electricity is not an intended road transport incentive but arises due to electricity not being considered as a road fuel by HMRC

For drivers in South East England, London Congestion Charge discounts have historically provided a very strong incentive for EVs worth up to £2,000 per year. There is evidence that the original scheme (started in 2003) was highly effective in stimulating demand for new vehicle technologies including conventional hybrids and BEVs.<sup>96</sup> The more recent Greener Vehicle Discount scheme for Euro 5 vehicles with emissions of less than or equal to 100gCO<sub>2</sub>/km and the Electrically Propelled Scheme (introduced in January 2011) is likely, therefore, to have been a key reason for the majority of plug-in

<sup>95</sup> Based on combined cycle consumption (15 kWh/km for the LEAF and 4.2l/km for the Golf, source: <http://www.nextgreencar.com>) and energy prices of £1.4/l (UK average as reported on <http://www.petrolprices.com/> in June 2013) and 10p/kWh. Based on these numbers, 14,000km results in over £600 energy spending difference; £24,000km results in over £1,000 difference.

<sup>96</sup> Sales of the Toyota Prius in 2007 were particularly high in the South East; 12.5% of Toyota UK sales were in VED band B (Prius sales), as compared to 34% of the company's London sales were band B: Market delivery of ultra-low carbon vehicles in the UK. Ecolane for RAC Foundation, 2010. Prior to 2010, the Alternatively Fuelled Discount was the key reason that the majority (60%) of the UK's fleet of BEVs were operated in the capital: Turning London Electric. Presentation made by Marie-Barbe Girard, Commissioner's Delivery Unit, Transport for London. LowCVP Conference, 2010.

grant eligible EVs registered between 2010 and 2012 being located in London and the South East.<sup>97</sup> The new Ultra Low Emission Discount introduced on 1<sup>st</sup> July 2013 will provide 100% discounted access to the Congestion Charge Zone for all BEVs and any cars or vans with emissions of 75 gCO<sub>2</sub>/km or less (which are also Euro 5).

Other incentives are available for recipients of BEV and PHEV company cars and vans through the system of company car tax which is based on vehicle price and CO<sub>2</sub> and reflects the level of benefit-in-kind (BIK) received. Company car tax is currently paid by around 0.97 million drivers which, assuming a three year replacement cycle, represents around 0.32 million annual car sales (representing 16% UK car sales).<sup>98</sup> Under current rules, BEVs are zero-BIK rated until April 2015, and PHEVs with CO<sub>2</sub> emissions up to 75 g/km are rated at between 5%-9% (2013-2016).<sup>99</sup>

Historical data shows that, until the fuel price peaked in 2008, the company car tax system was a key incentive driving the reduction of new conventional car CO<sub>2</sub> emissions.<sup>100,101</sup> Before 2008, with a cost gradient of around £10 per gCO<sub>2</sub>/km-yr, new company car CO<sub>2</sub> emissions reduced on average by 1.4% per annum, as compared to only 0.9% per annum for private cars. However, taken in isolation, the tax signal was not successful in stimulating the EV market at the time, the main effect being a significant market shift from petrol cars to diesel vehicles.

In some areas, EV owners also benefit from reduced parking fees. While CO<sub>2</sub>-based charges do not generally differentiate between different vehicle types, the cheapest permits are generally for EVs. Notable examples include the London Boroughs of Camden, Islington, Enfield, Richmond, City of London and Westminster, and also Milton Keynes. While this incentive is small in monetary terms, it is often valued highly by EV owners (an issue discussed in more detail in section 6).<sup>102</sup>

Taken together, the lower running costs offered by EVs provide a way to offset the higher purchase price. Figure 17 shows a simple four-year TCO comparison (including depreciation, energy cost and battery lease fee where applicable)<sup>103</sup> for the models shown in the previous figure. The results indicate that some contexts (in particular for drivers entering the London Congestion Charge Zone), EVs are already competitive on a TCO basis with conventional ICE vehicles.

While this analysis accords with the findings of an Etec/Cambridge Econometric revealed preference study which found that UK private car buyers have an average payback<sup>104</sup> period of around four years,<sup>105</sup> it is worth noting that, based on the ETI segmentation survey, the average pay back period (for new private car buyers) varies across consumer segments, from seven years (Enthusiasts) to two

<sup>97</sup> Ultra-low emission vehicles (ULEV) registered for the first time, UK, quarterly, Table VEH0170. Department for Transport statistics, 2013.

<sup>98</sup> Benefits in Kind Statistics, HMRC, July 2012

<sup>99</sup> Beyond 2017, in 2017-18 there will be a 3% differential between the 0-50 and 51-75 g/km CO<sub>2</sub> bands, and between the 51-75 and 76-94 g/km CO<sub>2</sub> band; in 2018-19 and 2019-20 there will be a 2% differential between the 0-50 and 51-75 g/km CO<sub>2</sub> bands and between the 51-75 and 76-94 g/km CO<sub>2</sub> bands.

<sup>100</sup> Following the reform of company car taxation in 2002, a detailed survey of fleet managers by the Inland Revenue shows that over half changed their policies towards CO<sub>2</sub> emissions (driven by tax reductions); actively encouraging employees to switch to cars with lower carbon emissions, with almost a third being encouraged by the employees themselves. Source: Report of the Evaluation of Company Car Tax Reform, April 2004, Inland Revenue.

<sup>101</sup> SMMT Annual CO<sub>2</sub> Report 2006 Market. Society of Motor Manufacturers and Traders, 2007.

<sup>102</sup> Electric Vehicles in Urban Europe (EVUE). URBACT, 2012: [www.urbact.eu/project](http://www.urbact.eu/project).

<sup>103</sup> A zero discount rate assumed. A discount rate would result in the demand for longer payback times (as future savings are discounted).

<sup>104</sup> Payback period is defined as the time required to recoup capital investment through lower operating costs.

<sup>105</sup> Etec for Dft, 2008, Demand for Cars and their Attributes and; Cambridge Econometrics for Dft, 2008, Demand for Cars and their Attributes (two reports).

years (Resistors); for fleet vehicle buyers, the typical payback period for TCO comparisons is four years.<sup>106</sup>

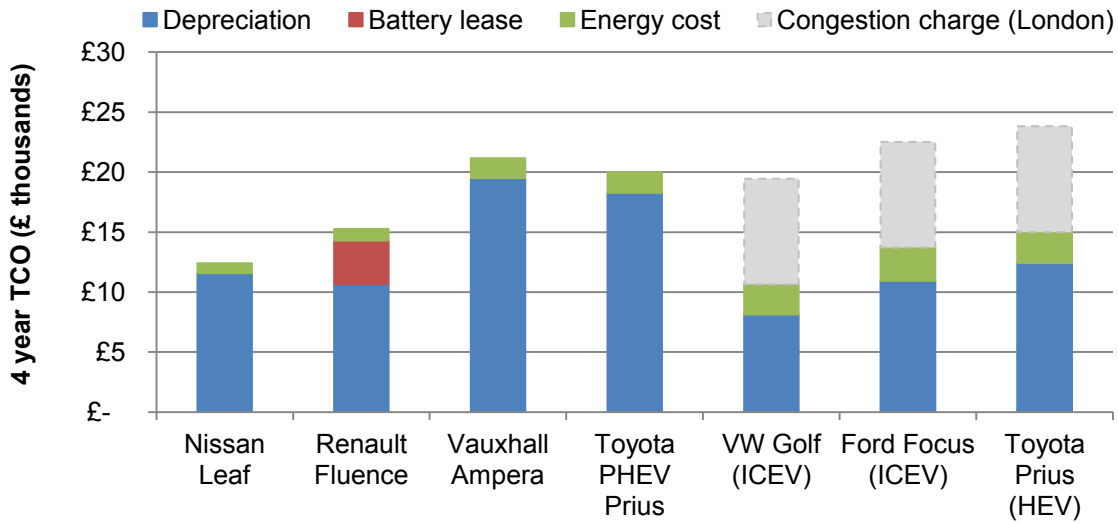


Figure 17 Four-year TCO based on 2013 prices (including PiCG)<sup>107</sup>

### 3.2.2 Cost outlook to 2030

In the absence of financial support, cost projections (developed for the Committee on Climate Change) for plug-in vehicles suggest that the price premium of EVs over ICE vehicles will remain significant until at least 2030.<sup>108</sup> Figure 18 shows the payback period (excluding incentives) to illustrate the order of magnitude of the cost barrier and its reduction over time. This analysis suggests that incentives (financial or otherwise) that address the cost premium of EVs will be required well into the 2020s if EV sales are to increase beyond early adopter markets.

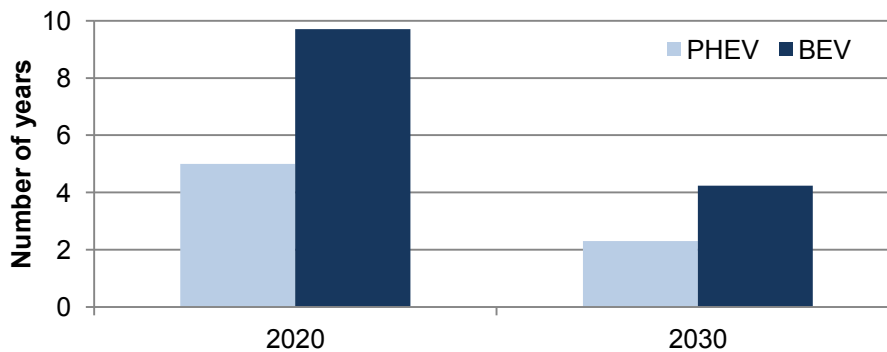


Figure 18 Payback period (number of years) for medium size car (C/D segment)<sup>109</sup>

<sup>106</sup> Consumer Research by Element Energy for the ETI Transport programme

<sup>107</sup> TCO for C/D segment vehicles based on perceived prices as of 2013, i.e. no change in energy prices. Electric mode 76% and 42% for Ampera and Prius PHEV; 14,000 km/year assumed; resale value sourced from FleetNews; no discount rate applied; based on new Ultra Low Emission Discount threshold of 75g/km.

<sup>108</sup> "A review of the efficiency and cost assumptions for road transport vehicles to 2050", 2012, Ricardo-AEA for the CCC. See Appendix 10.4.2 for performance and cost assumptions.

<sup>109</sup> Vehicle and energy cost as per CCC model (vehicle cost based on work by Ricardo-AEA and Element Energy) – as detailed in Appendix 10.4.2. No policy applied. Payback calculated based on energy prices as of given year, 14,000 km/year assumed, no discount rate.

### 3.3 Access to charging infrastructure, driving range and charging time

The high level of access to off-street parking in the UK (giving the option to charge vehicles overnight)<sup>110</sup> together with the Norwegian experience<sup>111</sup> strongly suggests that deploying a public charging network is not pre-requisite to the emergence of an EV market. However, the evidence that consumers perceive EV driving range and charging time as important issues suggests that mass market adoption – as targeted by the CCC – will require tackling barriers related to charging.

This section explores the interlinked attributes of EV charging: access to infrastructure, charging time and driving range. It first reports on the evidence that consumers value these attributes before detailing the current availability and cost of infrastructure in the UK. Lastly, conclusions are drawn regarding the available options to address these combined barriers in the future.

#### 3.3.1 Drivers' preferences

##### Access to infrastructure

Extensive research (both in UK and other countries) shows that home-based overnight charging is the charging option preferred by drivers and policy makers for at least five reasons. The home-base overnight option:<sup>112,113</sup>

- Requires low-cost / low-power hardware and installation;
- Is most convenient for EV owners (as demonstrated by trials and current charging patterns);
- Makes use of vehicle down-time spent at home location;
- Minimises electricity demand on the local network (if charging starts after 5-7pm peak time);
- Reduces grid generated CO<sub>2</sub> emissions.

Day charging at the workplace is considered as the second preferred charging location option as over 50% of UK cars commute, with 75% of them having access to a private office car park (allowing for cheaper hardware than in public places).<sup>114</sup> These cars park for an average of seven hours allowing the use of low power charging equipment.

Research by the Department for Transport reveals that home charging is currently the most used method for EV charging.<sup>115</sup> The workplace is the second most common location (20% EVs are charged at the workplace) regardless of the level of public infrastructure available (through Plugged-in Places or other networks).

A choice experiment involving around 3,000 UK new car buyers,<sup>116</sup> however, showed that, for BEVs, workplace charging is valued only if available in conjunction with access to home charging. Consumers displayed a preference for home-plus-workplace charging over the option of charging at public places, implying that *certainty of access* is highly valued. In the choice experiment,

<sup>110</sup> Strategies for the uptake of electric vehicles and associated infrastructure implications, Element Energy for the Committee on Climate Change. Final Report, October 2009.

<sup>111</sup> As previously discussed, see Box 1 and Appendix 10.1.1

<sup>112</sup> Strategies for the uptake of electric vehicles and associated infrastructure implications, Element Energy for the Committee on Climate Change. Final Report, October 2009.

<sup>113</sup> In the EU: Development of the European Framework for Electromobility, Green emotion project, January 2013; in the US: The EV Project, Quarterly Report:4<sup>th</sup> Quarter 2012

<http://www.theevproject.com/downloads/documents/Q4%202012%20EVP%20Report.pdf>

<sup>114</sup> Strategies for the uptake of electric vehicles and associated infrastructure implications, Element Energy for the Committee on Climate Change. Final Report, October 2009.

<sup>115</sup> Survey of 192 private EV owners and 329 organisations who own EVs. Research conducted by TRL for the DfT, due for publication in September 2013

<sup>116</sup> An affordable transition to sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2013



respondents valued the public infrastructure as much as home charging only if very widely deployed,<sup>117</sup> confirming the high value of certainly of access.

The low utilisation of public charge points (CPs) is confirmed by recent European trials and on-going EV monitoring.<sup>118</sup> UK research related to the Plug-In Car Grant also shows that the location of current UK EV buyers does not correlate with the density of public CPs; moreover, drivers stated that they did not consider the availability of public infrastructure before purchasing their plug-in vehicles (these early adopters all have the option to charge at home).<sup>119</sup> The Department for Transport research also shows that off-street CPs (e.g. paying and shop car parks) are more often used than on-street charging points.

While the overall use of public CPs is low (even in Plugged-in Places regions), post purchase, many EV owners cite the lack of public charging as a limitation to the use of their vehicle. Given that for at least 70% of these households the EV is the main car (implying high dependency) together with travel patterns representative of typical National Travel Survey findings,<sup>120</sup> this suggests a mismatch between actual and perceived need. In addition to location, EV owners give several reasons for not using public CPs including: the variety of access/ payment methods, lack of location information, and poor ease-of-use. The large number of connectors and sockets currently on the market also adds to confusion among users – see Box 3 (on page 37) for a summary of charging modes and connector types.

The perception that more public charging infrastructure is needed is also widespread among non-EV owners, who cite the lack of a national network as a barrier to uptake.<sup>121</sup> The ETI survey found that even around three-quarters of Enthusiasts and 80% of Aspirers believed that there was a need for *rapid* public charging infrastructure to be in place before they would adopt these vehicles.<sup>122</sup>

## Driving range

The National Travel Survey (NTS) dataset reveals that the majority of car trips are within the technical range of EVs, with 50% of respondents not exceeding 40 km on any day of the diary week. Certain trip purposes are dominated by short trips, e.g. over 90% of food shopping trips are less than 16 km and the average daily driving distance is 40-50 km.<sup>123</sup>

Based on ‘real-world’ EV range assumptions and the NTS dataset, a BEV driving range of 150 km could be considered as ‘sufficient’ for over 90% of car drivers on an average day; by 2020, projected battery improvement means that this share will increase to over 95% for medium to large cars – see Figure 19.

<sup>117</sup> Quantified as available at over 60% of public car parks and on-street parking spaces.

<sup>118</sup> Development of the European Framework for Electromobility, Green emotion project, January 2013; The EV Project, Quarterly Report:4<sup>th</sup> Quarter 2012; Electric Vehicles in Urban Europe (EVUE). URBACT, 2012:

<sup>119</sup> “Assessing the role of the Plug-in Car Grant and Plugged-in Places scheme in electric vehicle take-up” TRL for the DfT, 2013

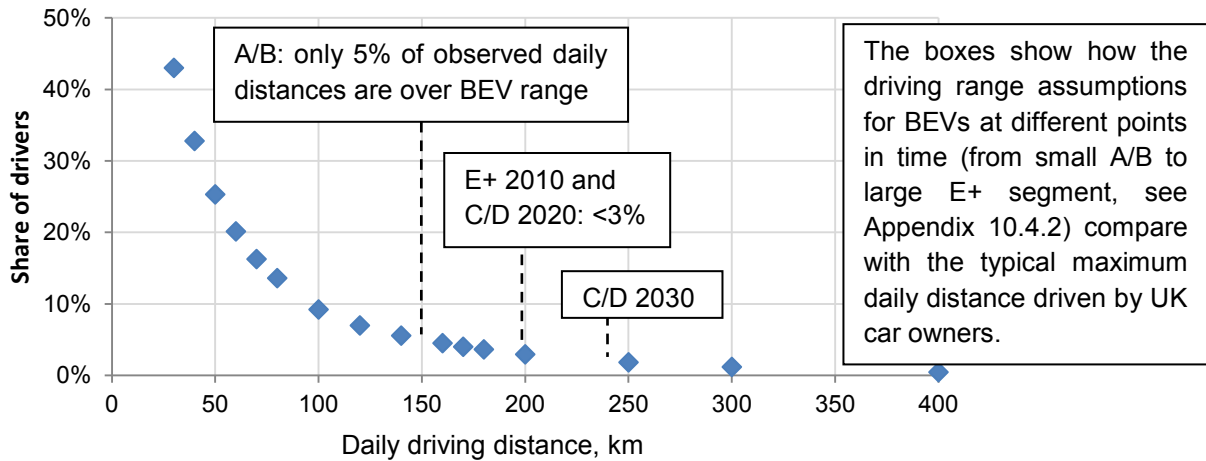
<sup>120</sup> Survey of 192 private EV owners and 329 organisations who own EVs. Research conducted by TRL for the DfT, due for publication in September 2013

<sup>121</sup> Anable et al., Consumer segmentation and demographic patterns, Feb 2011;

<sup>122</sup> 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 for the Energy Technologies Institute. University of Aberdeen and Transport Research laboratory. March 2011.

<sup>123</sup> Strategies for the uptake of EVs in associated infrastructure implications, 2009, Element Energy for the Committee on Climate Change





**Figure 19 Share of drivers who exceed daily distance limit. Source: analysis of NTS. BEV range per segment as per CCC model**

The Department for Transport’s PiCG research lends some support to the assertion that current BEV range allows for ‘normal’ vehicle use, as it shows that the majority of BEVs are used as main vehicles, and for the majority of journey purposes.

However, regardless of actual, average or ‘normal’ requirements, prospective EV buyers will also consider whether an EV will be able to drive longer distances, however rarely these longer journeys may be required. Indeed, surveys of UK car drivers – cited below – reveal that the maximum driving range offered by most BEVs is perceived (and experienced) as a significant limitation; and as such is a major barrier to the adoption of BEVs.

In one survey conducted by the European Commission in 2012, respondents were asked to choose what BEV attributes to improve.<sup>124</sup> From a list of attribute options including car price, range, recharging time, home charging and maximum speed, the majority of UK respondents chose to increase the 150 km range (followed by vehicle price). This suggests that, despite the low occurrence of trips over the maximum BEV range, these trips have a disproportionate effect on consumer attitudes; the result being that, in many cases, the car is perceived as ‘not fit for purpose’.<sup>125</sup>

This raises the question of how much range is enough? One estimate, which comes from research on drivers’ expectations conducted by Oxford Brookes University as part of the CENEX trials, found that a range of 370 km was the average ‘ideal range’ as stated by UK private car buyers.<sup>126</sup>

### Recharging time

Closely related to driving range and access to infrastructure, recharging time is also ranked as one of the main non-cost market barriers for BEVs.<sup>127</sup> Using a 7 kW rated charger, a medium sized car in 2020 would take around 5 hours to fully recharge. Responding to consumers’ demand for short charging times, OEMs are increasingly offering fast and rapid charge options with new EV models (e.g. Renault Zoe and Tesla Model S).

<sup>124</sup> European Commission (2012). Attitude of European car drivers towards electric vehicles: a survey. UK sample size = 716.

<sup>125</sup> Adding to the driving range barrier, is the fact that the real world range of a vehicle is generally less than the ‘official’ range (based on the NEDC) communicated to car buyers. This increases the risk of buyers not trusting the declared range and/or taking too conservative assumptions on what the real range will be. This problem is particularly severe for vans as the NEDC is carried on unladen vans.

<sup>126</sup> Burgess Mark, Facilitators, Challenges, and Potential Future Markets for EVs: Drivers’ Perspectives, Oxford Brookes University, 2013

<sup>127</sup> Stephens, T. (March 2013). Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies. Transportation Energy Futures Series. Prepared for the U.S. Department of Energy by Argonne National Laboratory, Argonne, IL. DOE/GO-102013-3709.

It could be argued that such charging periods should not result in a penalty as drivers can, with planning, effectively utilise this time. However, in addition to the waiting time is the notion of loss of flexibility, as the vehicle may not be ready for use as required. For example, if a BEV is being recharged overnight after being almost depleted, the owner loses the option of making unexpected trips while the battery level of charge remains low.

In the aforementioned Oxford Brookes University research, drivers were also asked what would be the ideal recharging time for a BEV. On average, car buyers stated 2.5 to 3.0 hours, with fleet managers requiring much shorter periods.

The value consumers place on having the *option* to drive longer distances or always having a car available to drive in emergency situations even if such trips are rare is also supported by international evidence. The case of Japanese EV drivers increasing their driving distance after the installation of 50kW chargers (despite not using the chargers in question) has been widely reported.<sup>128</sup> More recently, the introduction of options for the US Nissan LEAF (Model Year 2013) also reveal an appetite for charging time reduction, with 75% of buyers purchasing the package that allows for fast DC charging.<sup>129</sup>

**Box 3 Charger terminology, charging modes and connector types**

**Common Terminology**

- **‘Normal’ or ‘slow’ charge:** single-phase 3kW to 7kW AC charging. In most cases, uses Mode 2 in conjunction with BS1363 or Type 1 connector (see below).
- **‘Fast’ charge:** typically single- or three-phase 20kW to 25kW AC charging. In most cases, uses Mode 3 in conjunction with Type 1 or Type 2 connector (see below).
- **‘Rapid’ or ‘Quick’ charge:** either three-phase 40kW+ AC (Mode 3/ Type 2 connector), or more commonly 50kW DC (Mode 4/ JARI DC or Combo connector – see below).

**Charging Modes**

- **Mode 1:** single or three-phase AC, with a maximum permitted current of 16A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase. As no residual current device (RCD) is included in the equipment, Mode 1 is not recommended for public or commercial use.
- **Mode 2:** single or three-phase AC supply, with a maximum permitted current of 32A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase supply. Mode 2 includes the use of an RCD located within the cable.
- **Mode 3:** single or three-phase AC supply, with a maximum permitted current of 32A. The supply voltage is up to a maximum of 250V for single-phase or 480V for three-phase supply. As Mode 3 includes data connection, Mode 3 enables full vehicle isolation and ‘smart’ charging capability.
- **Mode 4:** incorporate an ‘off-board’ charger and provide a DC supply at the socket. The DC supply has a maximum permitted current of 1000VDC (typically 500VDC) and current of up to 400A (usually 125A). Mode 4 includes a full ‘handshake’ so enabling ‘smart’ charging capability.

**Connector Types**

- **BS1363 (3-pin):** While limited to single-phase charging with a maximum current of 16A (13A in UK) and voltage of 250V, a domestic 3-pin socket can be used for Modes 1 and 2 charging.
- **Type 1 (Yazaki):** SAE J1772 connector and plug can only be used for single-phase charging applications. International standard IEC 62196 Type 1 specification permits 250V at 32A or 80A.

<sup>128</sup> Strategies for the uptake of electric vehicles and associated infrastructure implications, Element Energy for the Committee on Climate Change. Final Report, October 2009

<sup>129</sup> <http://www.sae.org/mags/aei/12270>

- **Type 2 (Mennekes):** Allows both single and three-phase charging, and includes two data pins for a full 'handshake'. The Mennekes plug has a single size and layout for voltages up to 500V and currents from 16A single-phase up to 63A three-phase. Likely to become European standard.
- **JARI DC (CHAdEMO):** The CHAdEMO standard allows a high-voltage (up to 500VDC) high-current (125A) 'rapid' or 'quick' charging via a JARI DC connector, the standard connector used in Japan. And the most common DC connector used in UK.
- **Combo Coupler:** SAE is developing a 'combo' (combined) variant of the Type 1 (US) or Type 2 (EU) connector with additional pins to accommodate DC charging at 200-450 Volts up to 90 kW.

### 3.3.2 Availability and cost of charging infrastructure in the UK

#### Overnight charging

Overnight charging refers here to the use of a home or workplace (depot) charger to which the EV owner/ user is certain to have access, i.e. a 'personal' or reserved charging point.

By the end of 2012, there were around 2,000 dedicated home charging points (CPs) in the UK and approx. 2,200 installed at workplaces (not including non-dedicated sockets).<sup>130</sup>

The level of access to off-street parking is high in the UK. Figure 20 summarises the level of access, assuming drivers take advantage of their off-street parking, based mainly on data from the Department of Transport and taking into account that the off-street parking must close enough to the house to be used for charging – data sources and assumptions are detailed in Appendix 10.2.4. Although there is disparity of access across urban levels, even in London (high density urban population) around 60% of cars are parked off-street.<sup>131</sup>

This high level of access suggests infrastructure is not the key barrier to the uptake of EVs in terms of actual need – although drivers might have to be made aware of the opportunity of overnight charging or given the right to access the opportunity (e.g. in the case of residential or commercial tenants who wish to own an EV).

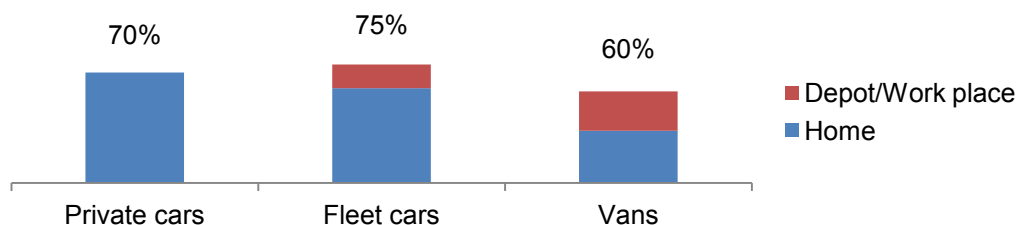


Figure 20 Access to overnight charging for UK new vehicle buyers as of 2013<sup>132</sup>

While there are no regulations prohibiting the use of standard (non-dedicated) domestic 3-pin 13A sockets for EV charging, EV owners are encouraged by OEMs, energy companies and OLEV to install dedicated EV chargers whenever possible.

As shown in Figure 21, the cost of installing a basic 3kW domestic charging unit is around £1,000 (typical upper bound). Workplace units, which typically have a 7kW power rating and include more back office support, cost in the region of £1,500-£2,500 per unit including installation.

<sup>130</sup> OLEV data.

<sup>131</sup> RAC Foundation report, Spaced out, perspectives on parking policy, 2012.

<sup>132</sup> Data sources and assumptions are detailed in Appendix 10.2.4.

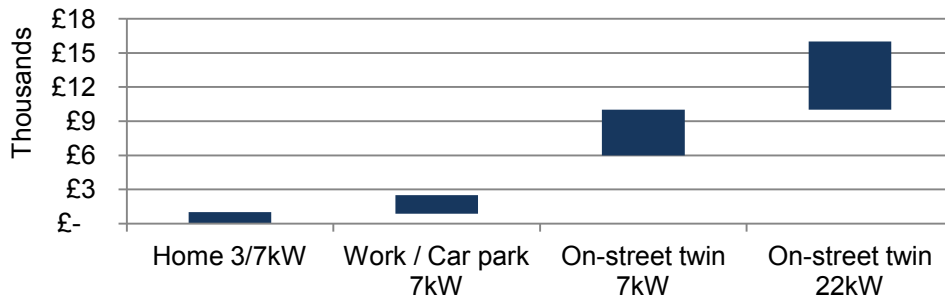


Figure 21 Typical cost of AC charging posts (including installation). Based on 2012 observed costs and 2013 quotes<sup>133</sup>

Day charging

Day charging refers to EV charging between 7am and 9pm, either at workplace or at public locations, not offering certainty of access.

By the end of 2012, there were around 6,300 public charging points (CPs) in the UK and approx. 2,200 installed at workplaces (not including non-dedicated sockets).<sup>134</sup> Figure 22 shows a breakdown of CPs according to location.

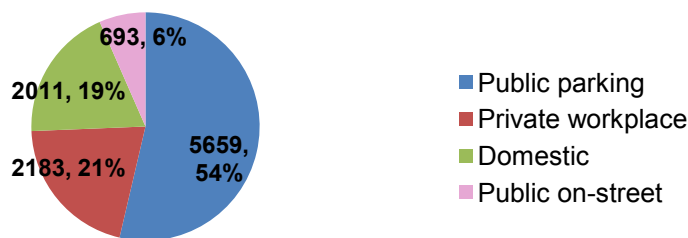


Figure 22 Number of charging points in the UK to end 2012. Source: OLEV

To date, the development of the UK network has been achieved through government support. In particular, the Plugged-in Places (PiP) program (2011-2013) provided match-funding worth £30 million for the installation of CPs and in doing so successfully stimulated private investment in the sector (non-PiP CPs now represent around 70% of installed points).<sup>135</sup>

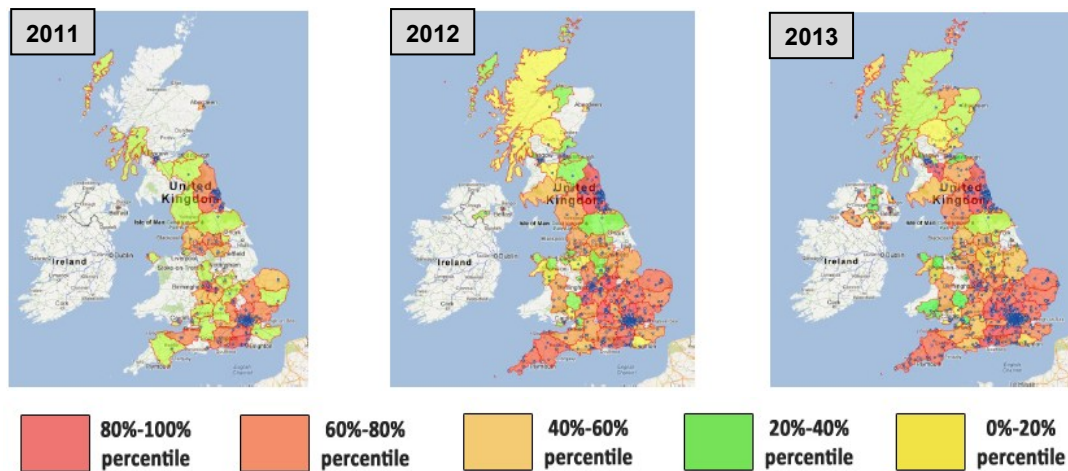
At the time of writing, half of public PiP charge points are rated at 7kW (~50%), followed by 3kW units (~45%), while ‘fast’ and ‘rapid’ CPs (20kW+ AC and 40kW+ AC and DC) only account for a small proportion of the network (~5%, < 100 50kW DC).

The PiP funding was initially allocated to eight regions (first London, North East and Milton Keynes; then extended to Northern Ireland, Scotland, Greater Manchester, Midlands and East of England) for the installation of up to 8,500 CPs by April 2013. The network maps shown in Figure 23 track the rollout across the UK, which first focused on two of the initial three PiP regions (London and the North East), before extending to the remaining PiP regions as well as to non-PiP areas.

<sup>133</sup> Assuming wall mounted charger for work and car parks. Source: Electric Vehicle Charging Points for Freight Vehicles in Central London, Sept 2012, TTR for the Central London Freight Quality Partnership as well as April 2013 quotes from ChargePoint Services, PodPoint and ABB.

<sup>134</sup> OLEV data.

<sup>135</sup> Ibid.



**Figure 23 Deployment of public charging infrastructure in the UK March 2011-March 2013.** Source: Zap-Map database; distribution density by county, red being the densest (white indicates no recorded infrastructure)<sup>136</sup>

OLEV estimates that the original target of 8,500 charge points will be exceeded, with PiP and non-PiP CPs amounting to around 14,000 by April 2013, of which about 8,500 are publically accessible.<sup>137</sup> The actual PiP spending (£13 million to 2012)<sup>138</sup> was lower than expected, due in part to the significant private sector contribution.

On-street CPs are significantly more expensive than wall mounted solutions designed for home, workplace and car park locations (see Figure 21). In addition to having a higher power rating than the majority of domestic and workplace charging units, there are at least three reasons why on-street units are (and will continue to be) more expensive:

- On-street CPs need to include a payment system (for possible third party use), must be more robust (weather and vandalism proof);
- Installation costs are higher (Traffic Management Order usually required) and also more variable (depending on the distance to feeder supply).
- Being in a public place, additional health and safety concerns apply to trip hazards of trailing cables.<sup>139</sup>

The cost premium of 7-22kW on-street CPs implies that priority should be given to the installation of domestic and workplace units where at all possible. Based on the costs presented in Figure 21, providing an on-street CPs to 10% of households buying a new car would cost about as much as providing 70% of all households having off-street parking with a domestic unit.<sup>140</sup>

As of mid-2013, rapid chargers (typically 50kW units using a CHAdeMO connector in the UK) are mostly installed at car dealerships. Cost of equipment and installation varies from £30k to £50k.<sup>141</sup>

<sup>136</sup> URL: <http://www.nextgreencar.com/electric-cars/charging-points.php>

<sup>137</sup> OLEV estimates. Actual data was not yet available at the time of writing.

<sup>138</sup> £7.2 million to December 2012, with an estimated further £5-6 million in 2013; OLEV data and estimates

<sup>139</sup> After conducting a risk assessment, Westminster City Council concluded that dual socket posts posed too high a risk, resulting in the LA commissioning only single socket posts. As the eligibility criteria for the current OLEV CP funding stipulates that the on-street CPs must be dual socket (more efficient use of funds), the Council will now install dual socket on-street posts, but place one per car space, to avoid the two sockets of one post being in use, as per the recommendation of the risk assessment report. Personal communication with Westminster City Planning, June 2013.

<sup>140</sup> Ca. £1 billion per year; based on six percent of UK households buying a new car in a given year (Department for Transport).

<sup>141</sup> The variation mostly due to installation costs. Source: Electric Vehicle Charging Points for Freight Vehicles in Central London, Sept 2012, TTR for the Central London Freight Quality Partnership, An affordable transition to



### 3.3.3 Options for future infrastructure provision

As already discussed, the certainty of access to charging infrastructure required by users is best provided by overnight charging (at home or at the workplace for depot-based vehicles). BEV users, however, also need a public ‘day infrastructure’ for reassurance and to extend the daily driving range. If coverage is sufficient, the public network can in some cases be used to replace overnight charging for drivers who do not have access to a home or workplace charge point. These roles are summarised in Table 7.

**Table 7 Roles and options for charging infrastructure**

	Overnight charging	Day charging
<b>Role</b>	Provide <b>certainty of access</b> and thus enable the purchase of a BEV	Day charging has value for: - Drivers with overnight charging access, as a <b>reassurance</b> and to <b>extend mobility</b> - Drivers without access to overnight charging, to <b>make EVs an option</b>
<b>Options</b>	Utilise high share of vehicle parking in garage, driveways and workplace car parks; Install CP in residential car parks or on-street (outside drivers’ homes)	Several options from normal 3kW AC to rapid 50kW DC and battery exchange.

A variety of conductive charging systems can be deployed as day infrastructure, from Mode 2, 3kW (AC), and Mode 3, 7-22 kW (AC) chargers, to 40-50kW (AC and DC) ‘rapid’ charging units.<sup>142</sup> Other alternatives include the introduction of a network of battery exchange stations. Table 8 summarises the strengths and weaknesses of each option.

‘Normal’ chargers (3-7kW) are adequate for long parking times, such as overnight charging and at workplaces. However, as day infrastructure, they are unable to deliver the fast charging times required to reduce range barriers. BEVs would need to be plugged-in at least an hour to provide any useful additional range.<sup>143</sup> Normal chargers are therefore not an option for longer journeys.

Furthermore, if 3-7kW CPs were to be deployed to provide sufficient reassurance to prospective BEV owners, the network would have to be very extensive, and potentially involve providing charging facilities at the majority of on-street and public parking spaces.<sup>144</sup> To gauge the scale of such a network, there are at least 11 million workplace car spaces in the UK<sup>145</sup> with a further 3-4 million places located in local authority car parks, shops, retail centres, hospitals, educational establishments, stations, airports, motorway service stations and park-and-ride sites.<sup>146</sup>

Although ‘fast’ (typically 22kW) to ‘rapid’ (40kW+) charging units are significantly more expensive (per CP), they are able to charge more vehicles in a given period and provide the charging rates to enable

sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2011 as well as April 2013 quotes from ABB.

<sup>142</sup> Due to the current low level of commercialisation, inductive charging is not explicitly assessed in this report. Inductive charging could however deliver the same charging rates so the analysis carried in the report is still valid in terms of value to consumers.

<sup>143</sup> Assuming vehicle energy consumption of 0.15 kWh/km, one hour charging at 3kW provides around 20km additional range. At 7kW, this increases to around 45km.

<sup>144</sup> As suggested by quantitative survey results, Consumer Research by Element Energy for the ETI Transport programme.

<sup>145</sup> Estimate based on Dft data: 50% of cars commute, 75% of car at work are parked in off-street parking and the UK car park is ca. 29 millions

<sup>146</sup> Source: RAC Foundation, Spaced out, 2012. Note some of these spaces would be included in the approximation of workplace car spaces.

practical EV range extension for most users. While rapid chargers do pose technical challenges (including impact on the local distribution network and battery compatibility),<sup>147</sup> rapid CPs provide a charging *experience* that is similar in many respects to using conventional fuel station (although fuelling times are increased from 2-3 minutes to 15-30 minutes). Rapid CPs can therefore offer a valuable decrease in charging time, one that makes driving long distances a practical option, providing BEVs that can achieve extended distances (e.g. 200km or more) at highway speeds.

A recent Dutch survey shows that, on average, BEV owners use rapid CPs around 0.5 times a month and that 45% are willing to pay at least 4 Euros for their use<sup>148</sup>. Based on a coverage analysis carried out for hydrogen fuelling stations (which takes into account traffic flows and population density), deploying 330 rapid CP sites would provide adequate coverage<sup>149</sup> for around 50% of the UK, with 1,200 sites providing total coverage.<sup>150</sup>

**Table 8 Comparison of day charging infrastructure options**

Type	Current status and indicative cost*	Pros	Cons
<b>Normal AC chargers (3-7kW)</b>	~8,500 in the UK. Located on streets, car parks, shops etc (£2k-10k)	Compatible with PHEVs; adequate for long parking situations e.g. work places, cheap in restricted access places. Plug standard agreed at EC level	Low km per hour charge ratio, perceived valuable only if deployed very widely
<b>Fast to rapid chargers (22kW AC - 50kW DC)</b>	~200 in UK, mostly located on motorway service stations and dealerships (22kW from £10k; £30k-50k for 50kW)	Better km per hour charge ratio, desirable to drivers based on usage and survey results. Provides both reassurance and mobility extension. AC socket standard convergence at EU level (Type 2)	Not suitable for PHEVs, <sup>151</sup> DC connector standard not yet fully agreed; frequent use has possible impact on battery life <sup>152</sup>
<b>Battery swapping stations</b>	None in the UK. At scale only in Denmark, Israel and China. (>\$500k)	'Recharge time' similar to ICEVs, only limited deployment necessary; no ownership of the battery	Relies on OEM standardisation of battery pack and vehicle adaptation

\*Status as of mid-2013; indicative cost ranges include unit cost and installation.

A third infrastructure option is the use of battery swapping stations (BSS). Although at least 50 swapping stations are in operation worldwide, the technology has not yet proved itself commercially in

<sup>147</sup> Current lithium ion batteries with graphite anode cannot withstand very high charging rates; titanate anodes can withstand greater charging rates but they make lower voltage cells and thus battery packs with lower energy density. The rate considered in this study (50 kW) is however compatible with the majority of existing BEVs; (Element Energy for the Committee on Climate Change, Cost and performance of EV batteries, 2012).

<sup>148</sup> Survey "Resultaten enquête snelladen", Goudappel Coffeng, Agentschap NL and Amsterdam Electric, March 2012. Sample size = 45.

<sup>149</sup> Coverage here refers to geographical density and spread appropriate to cover the travel needs of UK drivers; it does not account for potential perception issues related to charging points, e.g. consumers requiring over-coverage before perceiving the recharging network as adequate.

<sup>150</sup> UK H<sub>2</sub>Mobility Phase 1 Report: <https://www.gov.uk/government/publications/uk-h2mmobility-potential-for-hydrogen-fuel-cell-electric-vehicles-phase-1-results>

<sup>151</sup> All PHEVs to date only accept low AC power charging (and none has a DC option) – there is no need for them to have higher cost higher power on-board chargers as battery capacity is relatively low.

<sup>152</sup> Aging mechanisms linked to temperature are exacerbated by high charging rates. Dubarry et al., *Identifying battery aging mechanisms in large format Li ion cells*, Journal of Power Sources 196 (2011) 3420–3425



the mass market; its main proponent Better Place going into liquidation early in 2013.<sup>153</sup> While Tesla have also publicly demonstrated a battery swap system,<sup>154</sup> the company continues to base its charging strategy on the use of super-fast ('ultra-rapid') conductive chargers (see below).

Significant market barriers remain for the BSS option. While passenger cars must come in a variety of size, performance and brands to meet consumers' expectations, BSS requires battery pack and connector standardisation across OEMs and vehicle segments. This is a significant challenge, one that had yet to be met.<sup>155</sup> It is also likely that home charging would remain a preferred charging option for most consumers, making the BSS a high investment risk.

The likelihood of a BSS network being introduced in the UK for passenger cars in the next 15 years is, therefore, very low. Battery swapping may be more suited for use with depot-based commercial vehicles as these can more easily accommodate standardised battery packs (e.g. across van platforms). Where BSS is being used most successfully (most notably in China) this is for bus and municipal vehicle fleets.<sup>156</sup>

For these reasons, the option of a rapid charging network (40kW+) is considered in more detail by this study; not only do these units have the highest charging rate commercially available, they are also already being rolled out in many regions. In the longer term, higher charging rates could also become an option. Indeed, 'ultra-rapid' chargers rated at 120kW are also emerging; the US car producer Tesla rolling out a network of 'superchargers' on US and European highways for the exclusive use of Tesla car drivers.<sup>157</sup>

### 3.4 Consumer acceptance and technology maturity

While the performance and pricing of new vehicle technologies is influenced by the key drivers of innovation and commercialisation, the market success or otherwise of EVs also depends to a great extent on consumer *awareness* and *acceptance*, defined as the readiness to consider purchasing or using a new technology.

Awareness (and related knowledge) plays a key role during the early stages of technology adoption, and the provision of clear, relevant and timely information is vital in market development.<sup>158</sup> A recent study by Bank of America, for example, cited the current lack of consumer awareness and information as the first of three market barriers relating to the mass adoption of electric vehicles in California.<sup>159</sup>

According to a recent survey by the European Commission, at least 50% of UK car drivers are 'not at all familiar' with electric cars, with only 20% being 'very familiar'.<sup>160</sup> This is supported by a major study

<sup>153</sup> Better Place raised \$750 million in funding; it has deployed 19 BSS in Denmark and 37 in Israel, compatible only with the Renault Fluence model. Better Place filed for liquidation in May 2013. <http://www.greencarcongress.com/2013/05/ev-battery-swap-company-better-place-files-for-liquidation.html>

<sup>154</sup> Gone in 90 Seconds: Tesla's Battery-Swapping Magic, Businessweek, 21<sup>st</sup> June 2013: <http://www.businessweek.com/articles/2013-06-21/gone-in-90-seconds-teslas-battery-swapping-magic>.

<sup>155</sup> Better Place only succeeded in forming agreements with one OEM (Renault). It is also worth noting, however, that Tesla has announced its intention to install BSS in America (its model S is compatible with swapping): Tesla 'fast pack swap event', June 2013. <http://vimeo.com/68832891#>.

<sup>156</sup> [http://www.cse.anl.gov/us-china-workshop-2012/pdfs/session3b\\_demos\\_standards/hua\\_3B-4-HUA-Tsinghua%20Univ-Progress%20in%20Battery%20Swapping%20Technolo.pdf](http://www.cse.anl.gov/us-china-workshop-2012/pdfs/session3b_demos_standards/hua_3B-4-HUA-Tsinghua%20Univ-Progress%20in%20Battery%20Swapping%20Technolo.pdf). There is also an initiative in Slovakia, developing a battery swapping solutions for commercial vehicles; 2 stations have been installed as of May 2013; <http://www.greenway.sk/en/zona-pre-partnerov-nabijacej-infrastruktury>

<sup>157</sup> Tesla website: [http://www.teslamotors.com/en\\_GB/supercharger](http://www.teslamotors.com/en_GB/supercharger)

<sup>158</sup> Wallis, N. and B. Lane (2013). Electric vehicles: Improving consumer information to encourage adoption. European Council for an Energy Efficient Economy, Summer Study on energy efficiency 2013, paper 4-514-13.

<sup>159</sup> Elkind, E. N. Electric Drive by '25: How California Can Catalyze Mass Adoption of Electric Vehicles by 2025. Bank of America Climate Policy Associate for UCLA School of Law's Environmental Law Center and UC Berkeley School of Law's Center for Law, Energy & the Environment, September 2012.

<sup>160</sup> N=716. Attitude of European car drivers towards electric vehicles: a survey. European Commission, Joint Research Centre, Institute for Energy and Transport, 2012.

in Northern Ireland which found that 53% of the public are unable to name any EV models.<sup>161</sup> Furthermore, this study reported that: only a third knew that EVs typically take 6-8 hours to fully charge; a quarter that EVs can travel 80-100 miles on a single charge; and only 12% knew that the current cost of fully recharging an EV is £1-£3.

UK consumers' knowledge of existing EV incentives is also known to be low – in 2012 the RAC Foundation reported that 75% of UK car buyers surveyed were completely unaware of the Plug-in Car Grant, more than a year after its introduction.<sup>162</sup>

An interesting observation, however, is that current EV awareness may be higher than was the case for conventional hybrids when compared according to the date of first market entry. A recent U.S. study found that 68% had 'med/high familiarity' with HEVs, over a decade since their introduction, while 51% had 'med/high familiarity' of EVs even though market is still at the early adopter stage.<sup>163</sup>

Although EV awareness and knowledge may be poor, consumer *acceptance*, defined as the readiness to consider purchasing or using an EV, remains at an even lower level, with the majority of private consumers not accepting as sufficiently advanced the capability of electric vehicles and/or recharging infrastructure. In addition to the consumer concerns already discussed, reliability, safety and battery degradation issues also increase the uncertainty regarding residual value of EVs.

Remaining acceptance barriers also relate to psychological factors related to vehicle purchase including trust, symbolism, and normative behaviour.<sup>164</sup>

According to the attitudinal segments presented in Section 3.1, 20% of UK new car buyers strongly reject the identity and symbolism of EVs while a further 50%, while not concerned by the symbolism of EVs, are not interested in the technology.

The low acceptance level of EVs is reflected in figures from a YouGov survey which found that 48% would not consider an electric car for their next purchase and 18% had considered one but discounted it for their next purchase.<sup>165</sup> These figures are supported by a recent UK public attitudes survey which found that 53% had not considered buying an EV, with 16% having considered one but deciding not to buy at this stage.<sup>166</sup> Only 3% reported 'thinking about buying an electric car or van' in the future with 1% considering a purchase 'quite soon'.

Awareness issues specific to UK fleet buyers have been explored by the Plugged-In Fleets Initiative (PiFi). Managed by the Energy Saving Trust, the first phase of the Initiative supported twenty organisations with analysis on their fleets to identify and recommend where electric vehicles might offer a benefit to their business.

The 2012 Initiative confirmed that accurate TCO information plays a key role in effective fleet vehicle procurement.<sup>167</sup> The project, however, highlighted that fleet managers often have poor access to data

<sup>161</sup> N=1,131. Public Awareness of and Attitudes towards Electric Cars, Dept for Regional Development, Northern Ireland, September 2012.

<sup>162</sup> N=1,400. RAC alternatively fuelled vehicle survey, 2013. URL: <http://www.rac.co.uk/press-centre/press-releases/one-in-two-drivers-would-consider-buying-an-altern/>.

<sup>163</sup> Augustine, K., Sandidge, S.A., Williams, T. Alternative Fuel Vehicles: Which Shall Win the Race to Commercialization? ISTM 6233 Emerging Technologies, George Washington University, April 2011.

<sup>164</sup> Graham-Rowe E, Gardner B, Abraham C, Skippon S, Dittmar H, Hutchins R, Stannard J, 2011. Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations. Transportation Research Part A 46 (2012) 140–153; Schuitema G, Anable J, Skippon S, Kinnear N, 2013. The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. Transportation Research, Volume 48A, February 2013.

<sup>165</sup> N= 2,021. Green and electric cars. YouGov survey summary, 2012

<sup>166</sup> N= ca. 2,000 Public Attitudes Tracking Survey. Department of Energy & Climate Change, 2012.

<sup>167</sup> Plugged-in Fleets Initiative: Charging Forward. Energy Saving Trust, 2013.

(including baseline operational spend and potential EV costs and benefits), information often not available due to the low priority given (within many organisations) to vehicle fleet monitoring.<sup>168</sup>

PiFi also found that technical suitability of EVs was a crucial factor but observed that this was not always straightforward to assess. To address this issue, the project used route optimisation software to identify suitable routes over which EVs could be deployed. The software, developed by Route Monkey and supported by the Finance for North East Technology Fund, aims to remove range anxiety by intelligent route planning which takes account of road conditions, weight to discharge ratio, temperature and driver profiles when planning the most efficient journeys. Beyond identifying regular and predictable journeys of less than 100 miles per day (for BEVs), the results highlighted the need to account for route topography and the important role played by driver training in maximising vehicle range.

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<sup>168</sup> Fleet managers purchase criteria and EV adoption motives are presented in detail in Appendix 10.2.1

### Summary of Section 3

- When considering the purchase of EVs, demographic information alone is insufficient for understanding consumer behaviour, and attitudinal differentiation is a more important indicator of EV purchase intentions. The five attitudinal factors which most strongly differentiate the EV purchase segments are: 'identity' (association with EVs), 'anxiety' (in relation to driving range), 'parking difficulty' (ability to recharge at home), 'willingness to pay', and 'symbolic motives'.
- Taking these attitudinal factors and the more general vehicle purchase criteria into account, the key attributes affecting the purchase of EVs are: vehicle price and running cost, brand and segment supply, access to charging, driving range and charging time and the consumers' receptiveness to plug-in vehicles.
- In terms of receptiveness to plug-in vehicles, the UK new private car buyers can be segmented into four groups: 'Enthusiasts' (15% of the market) who are driven by innovativeness and prepared to pay a premium; 'Aspirers' (15%), interested but concerned by technical attributes; the 'Mass market' (50%), not interested but not opposed to symbolism of EVs; and the 'Resistors' (20%), who strongly reject EVs. All segments are more positive towards PHEV than BEVs.
- Financial incentives are currently essential to offset the higher purchase price of EVs and reduce the Total Cost of Ownership (TCO). In some contexts (and with financial support) EVs can cost less to own than conventional vehicles over a four year basis. In the longer term, the short payback times expected by consumers suggest that without support measures, the capital cost premium of EVs will remain a barrier, especially for BEVs.
- Countries with the highest rates of EV uptake have all put in place significant measures to tackle the EV cost premium. In addition, these countries have also vigorously addressed other non-cost barriers including, most notably, vehicle supply and consumer receptiveness to EVs. While extending access to public charging infrastructure is not a pre-condition for EV market development if sufficient home charging is available, the evidence suggests that mass market adoption will require an extensive infrastructure that addresses drivers' concerns over EV range and recharging time.
- Extensive trials and current usage of charging infrastructure indicates that EV owners prefer overnight charging (at home or workplace), and/or at work during the day, over charging at public locations. The level of access to overnight charging is high among new vehicle buyers in the UK (70% for new private cars and 60% for new vans) confirming access to infrastructure is not a dominant barrier to EV adoption in terms of actual need, based on the typical daily distance travelled. However, it is acknowledged that car buyers frequently *demand* more public infrastructure, which is likely to be based on their *perceived* need to drive longer distances than currently offered by BEVs.
- Recharging time is consistently reported as a barrier by EV users, regardless of the ability to recharge overnight. Level of usage of rapid 50 kW chargers in other countries and sales of EVs with DC charger ports confirm the value placed on reducing charging time. This supports the use of a rapid charging network for day charging as a way to complement the overnight charging provided by off-street parking.

## 4 Methodology: modelling high EV uptake to 2030

Section 4 presents the methodology used to model the uptake of plug-in vehicles and derive a *market pathway* to achieve the market share targets set by the Committee on Climate Change (detailed in Section 5).

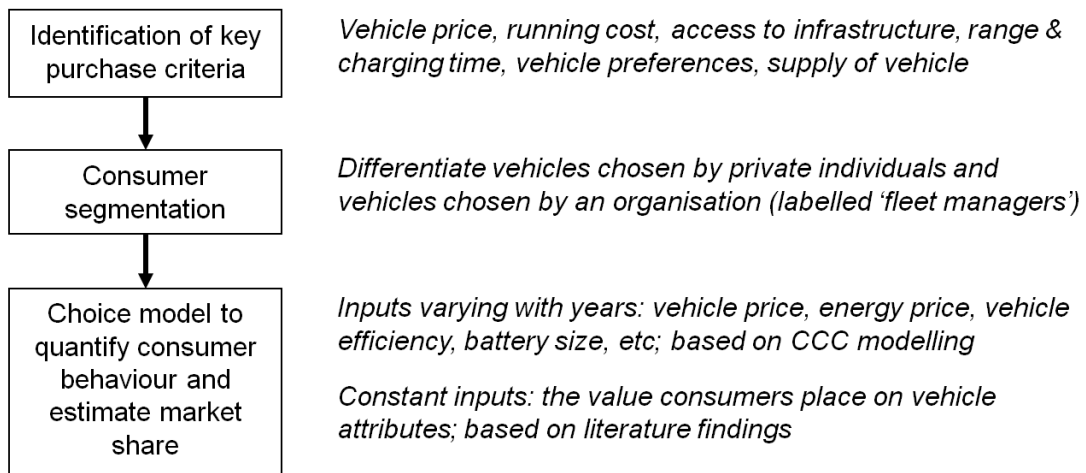
Central to the pathway modelling is a choice model which quantifies the vehicle attributes and barriers to uptake. The choice modelling allows for a study of trade-offs between the costs of addressing barriers and the level of EV adoption.

This section first introduces the modelling of vehicle uptake, before describing how a pathway was derived to reach the uptake targets.

### 4.1 Principles of choice modelling

The first step to modelling the uptake of a technology is to understand the key purchase criteria that influence the choice of the technology. In the case electric vehicles, the previous section identified that the key vehicle attributes are vehicle price, running cost, access to infrastructure, range, charging time, vehicle preferences and the level of supply. Almost all of these attributes (the exceptions being running costs and access to overnight charging infrastructure) currently present a barrier to EV adoption.

As summarised in Figure 24, the next modelling step is to understand how the market is segmented into groups of individuals or decision makers who are likely to place a different value on each attribute. The consumer segment responses are then used to provide input to a *choice model*, the principle of which is now presented in more detail.



**Figure 24 Overall steps to build a modelling tool to estimate the uptake of electric vehicles**

#### 4.1.1 Introduction to choice modelling and concept of ‘utility’

Choice modelling is a method that quantifies people’s priorities when they make a decision such as buying a product or a service. The method aims to replicate as closely as possible the decision making process used by consumers in the real world; it provides a tool to explore the effects of costs and non-financial attributes on adoption. It is particularly appropriate for vehicles as the purchase decision process rests on both financial and non-financial vehicle attributes.

Choice modelling is widely used by governments and industry to understand market dynamics. In the UK, the Department for Transport uses a market model based on choice modelling to understand the

impact of carbon focused taxation policy on the conventional vehicle market.<sup>169</sup> The U.S. Department of Energy uses choice modelling to study the uptake of diesel and alternative fuel vehicles (using the Transitional Alternative Fuels Vehicle Model).<sup>170</sup> The technique has also been used extensively for ‘mode choice’ studies; for example, in estimating the demand for high speed rail.

### 4.1.2 Terminology and model equations

The modelling technique is based on a statistical analysis of consumers’ purchase choices, where the *attributes* (e.g. vehicle cost, driving range) of each of the alternatives (e.g. ICEV, BEV) are known. Consumers are assumed to choose the alternative with the highest *utility* (attractiveness). The utility is a function of the product attribute. The weighting of different attributes varies according to consumer type or segment.

#### Box 4 Utility and market share equations used for choice modelling<sup>171</sup>

$U_i = \sum_j \beta_j \times \text{Attribute}_{i,j} + \text{ASC}_i$ $\text{Market share}_i = \frac{e^{U_i}}{\sum_k e^{U_k}}$	<p>Where</p> <p><math>U_i</math> is the total utility of alternative <math>i</math></p> <p><math>\beta_j</math> is the weighting factor for attribute <math>j</math></p> <p><math>\text{ASC}_i</math> is the Alternative Specific Constant</p>
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The market share for a particular alternative (denoted ‘ $i$ ’) is a calculation of probability that a consumer will choose alternative ‘ $i$ ’ from a range of options presented. The probability function is based on the utility of each alternative (‘ $U_i$ ’) which is derived using a weighted summation of a range of attributes associated with the alternative ‘ $i$ ’ (see Box 4).

An Alternative Specific Constant (‘ $\text{ASC}_i$ ’) is also used to represent the specific technology preference (positive or negative) not captured by the attributes. In this study, it captures the acceptance of the technology that varies across consumer segments; from Enthusiasts, who are willing to pay a premium, to Resisters, who exhibit a strong rejection of the technology.

### 4.1.3 Populating choice models

The weighting factors used in choice models can be derived from *revealed preferences* or from *stated preferences*. In both cases, regression techniques are used to derive the weighting factors (and clustering when segmenting the consumers).

Revealed preferences are derived from the analysis of past sales and markets. They have the advantage of statistical robustness but can only provide information on existing attributes of existing technologies. One example of a revealed preferences study is the Eftec/Cambridge econometric study for the Department for Transport in 2008, that looked at private sales of new and second hand cars, linking weighting factors to demographics.

Stated preferences are derived from a *choice experiment* (a survey where respondents must choose between two or more technologies described by their key attributes). It allows the study of non-existent or new technologies/ services and is therefore widely used in the case of electric vehicles.

<sup>169</sup> Eftec for Dft, 2008, Demand for Cars and their Attributes and; Cambridge Econometrics for Dft, 2008, Demand for Cars and their Attributes (two reports)

<sup>170</sup> Greene, D.L. 2001, TAFV Alternative Fuels and Vehicles Choice Model Documentation, ORNL/TM-2001/134, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July.

<sup>171</sup> For a full derivation of these equations, the reader should refer to the work of Kenneth Train, University of Berkeley: “Discrete Choice Methods with Simulation”. Cambridge University Press, 2009. URL: <http://elsa.berkeley.edu/books/choice2.html>.



Results of stated preferences need to be corrected for survey bias, typically by calibrating the price elasticity based on revealed data<sup>172</sup>.

## 4.2 Modelling the uptake of electric vehicles

The following sub-sections describe how this project has applied the principles of choice modelling to EV adoption with the objective of modelling high rates of EV adoption in the UK.

### 4.2.1 Consumer segmentation of UK car and van market

The market segmentation differentiates vehicles chosen by private individuals and fleet vehicles chosen by an organisation – see Figure 25.

It is assumed all the privately owned cars (44% of new UK registrations) are chosen by individuals or households that take into account the previously presented purchase criteria. Consumers vary in their attitude to EVs, from the Enthusiasts who are attracted to EVs to the Resistor who, on the contrary, display a strong rejection of EVs (as was presented in Table 4 ).

Among company-owned cars, some are chosen by private individuals (termed ‘User choosers’) – for whom the same purchase criteria as private cars apply – while the rest are selected by a decision maker within the organisation (often based on a restricted list). Based on HMRC data,<sup>173</sup> and including all cars provided to employees, the authors estimate that the proportion of ‘User choosers’ represents around 40% of fleet cars.<sup>174</sup> As new vans are mainly bought by organisations,<sup>175</sup> the van market is represented by a single ‘Fleet manager’ segment.

For car and van fleet managers, the purchase decision process significantly differs from the private user case. In general, it tends to be based on the suitability of the technology (as indicated by the vehicle range, loading performance and the supply of a given vehicle segment) and the Total Cost of Ownership (TCO) – refer to Appendix 10.2 for more details of the UK fleet car and van markets.

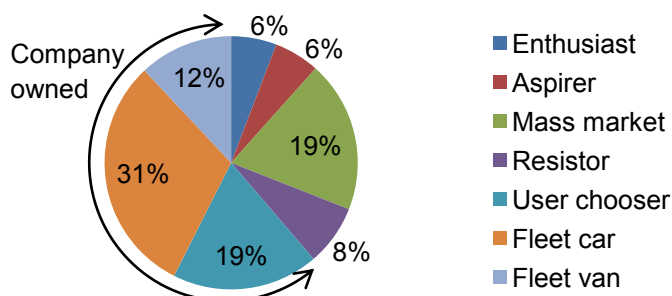


Figure 25 Consumer segments used in the modelling of the UK car and van markets

### 4.2.2 Choice model inputs and process

For this study, findings from the literature have been used to populate the choice model in terms of weighting factors (based mainly on stated preferences), supplemented by the authors own knowledge of the issues. The vehicle attribute inputs are mainly based on recent CCC modelling work.<sup>176</sup>

<sup>172</sup> In choice experiments, consumers are typically less price sensitive (i.e. spend money more readily) than revealed by real-world market share. For instance, the Efec study for Dft report an average elasticity of -3.7 (a 1% increase in selling price causes a 3.7% reduction in market share); in experiments, the price elasticity can be as much as twice lower.

<sup>173</sup> Benefits in Kind Statistics, HMRC, July 2012

<sup>174</sup> For more details about the proportion of company cars, see section 10.2.3

<sup>175</sup> Around 90% of new van sales; SMMT industry data, 2013.

<sup>176</sup> Two reports that were commissioned by the CCC in 2012: “A review of the efficiency and cost assumptions for road transport vehicles to 2050” by Ricardo-AEA and “Cost and performance of EV batteries” by Element Energy.



The key attribute values and weighting factors are summarised in Table 9. The attitude to EVs that varies across consumer segments is also captured (the ASC term); it is assumed the negative bias that some segments have against EVs decreases as EV sales increase. Details on input values are provided in Appendix 10.4, page 146.

As the model is highly sensitive to vehicle price (both the input value and the weighting factor) and running costs, the price coefficient is calibrated from observed data. While the input values themselves change over time, it is assumed that the weighting factors for price and other inputs do not change with time, e.g. the value drivers placed on driving range or charging speed does not decrease with time. Detailed sensitivity analysis to these assumptions and other inputs is provided in the Appendix while the results section shows the variation in results for the most sensitive inputs or assumptions.

**Table 9 Vehicle attributes taken into consideration in the choice model**

Attribute	Value (before measures applied) – varies with time	Weighting factors or value of penalty – constant with time
Vehicle price	Price of vehicle as per CCC model + existing policy price signals (e.g. VED)	Price coefficient calibrated based on revealed UK price elasticity
Running cost	Calculated from MJ/km and energy price (CCC model) + existing policy price signals Insurance and maintenance cost from EE previous work <sup>177</sup>	Based on literature findings, it varies across consumer segments; from high weighting for Enthusiasts to low weighting for Resisters.
Access to charging	Initially ca. 70% buyers have access to overnight off-street charging; 0% of buyers perceive access to public day charging	Overnight charging: pre-requisite for BEVs;  Day charging: based on literature findings for BEVs and 4 year fuel savings for PHEVs
Charging time	Battery capacity based on CCC model, kW based on projections from current trends (3kw to 7kW by 2020)	Based on stated preference, value (£250/h) is effectively assumed to decrease over time by taking the highest charging rate available to calculate the charging time.
Driving range	(For BEV only), as per CCC model increasing to 300km for large cars by 2030 (real world range*)	Value of km of driving range based on literature with the ‘ideal range’ from which there is no perceived penalty set at 370km <sup>178</sup>
Supply	Converge towards ‘full supply’ over time, projections on current trends (detailed in the next chapter)	Supply penalty is quantified as per the technique developed by Greene, based on the share of EV models for sale

\* Real world range means the driving range that can be achieved in real driving conditions; it is lower than the range calculated from test cycles

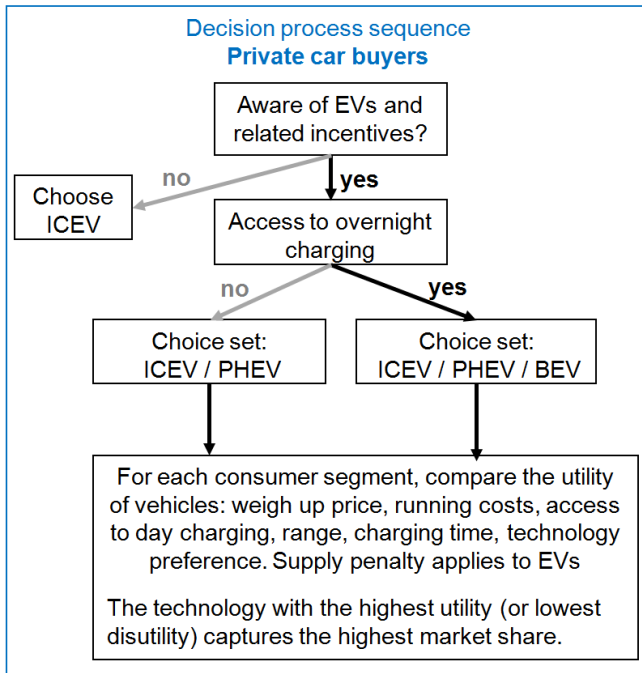
Assuming that the vehicle price differential between ICEVs and EVs decreases with time (as per CCC projections) and other attributes also improve (e.g. driving range), the utility of EVs improves over time; the result being that EVs capture a greater market share. It is, however, important to note that there are some minimum pre-conditions to be met for EVs to be part of the choice set: buyers must be

<sup>177</sup> Influences on low carbon car market from 2020-2030, Element Energy for the LowCVP, July 2011 for cars and Ultra Low Emission Vans study, January 2012, Element Energy for the DfT for vans

<sup>178</sup> As per Oxford Brookes findings, reported in section 3.3

aware of EVs and their incentives, they must have access to overnight charging (for BEV) and vehicles must meet the duty cycle requirement (for fleet vehicles).

Depending on the level of awareness, access to home charging facilities, and vehicle suitability, a decision-tree is built into the choice model used; this is summarised in Figure 26 for private car buyers and Figure 27 for fleet vehicle buyers. The starting values for the level of awareness and access to infrastructure are based on the evidence as previously presented in Section 3.



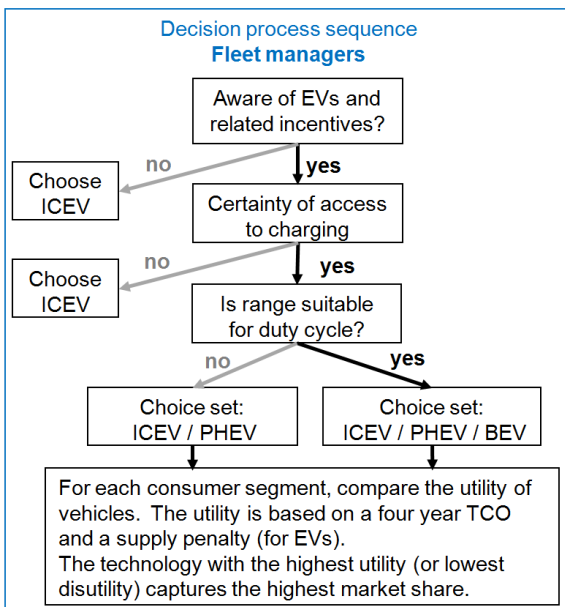
Start at 20% of buyers in 2013 and increase over time

70% buyers have off-street parking that could be used for overnight charging

EVs are in the choice set only if supplied in the given vehicle segment, e.g. there are no PHEVs in the small car segment until mid-2020s

The weighting factors stay constant but vehicle price, energy prices, driving range of BEVs etc change over time, meaning the utility of EVs improves. The share of consumers with access to day charging also increases (if network is installed) and the supply penalty decreases in line with the developed supply trajectory.

Figure 26 Vehicle decision modelling for private cars buyers and summary of main assumptions



Overnight parking in residential areas and depot provides certainty of access to 75% of fleet cars and 60% of vans. Vans spending night locations with unclear potential (10%) are assumed to have certainty of access only if a rapid charging network covers at least 50% of UK.

Driving range compatibility  
Vans: based on projected real world range and mileage data from Survey of Company Owned Vans. Share of vans with compatible duty cycle: 34% in 2013 increasing to 40% in 2020 and 48% in 2030. Access to rapid network increases the range compatibility; with a cap at 70%, as 30% of vans drive more than 300km a day at least once a month.

Cars: lack of specific duty cycle data; assume driving range compatibility is lower as usage more varied : 30% in 2020 increasing to 40% in 2030. Access to rapid charging network increases the range compatibility.

Figure 27 Vehicle decision modelling for fleet managers (cars and vans) and summary of access and range assumptions

For fleet vehicles, the assumptions on driving range compatibility act as the duty cycle compatibility criteria. In the case of vans, available data on range indicates that improvements in battery cost and

energy density will result in EV range being compatible with the duty cycles of 40% of ICE vans in 2020 and 50% in 2030, increasing from 34% today.<sup>179</sup> For fleet cars, as data on usage pattern is not readily available,<sup>180</sup> it is assumed that there is more variety in usage; as a result, range compatibility (before the widespread provision of day infrastructure) is set lower than for vans (30% in 2020 and 40% in 2030).

The decision process and choice model described in Figures 25 and 26 are run for each vehicle segment (defined as: small cars, medium sized cars, large cars and vans), i.e. the choice of vehicle segment is not estimated but rather kept constant. The respective shares for car segments are 40% small, 40% medium and 20% large, based on 2012 sales. The van market is represented through only one vehicle segment and the characteristics of the top selling segment is used (the standard panel van).

The vehicle technologies included in the model are ICEVs, PHEVs and BEVs. While the consumer response to REEVs is broadly similar to that for PHEVs (the technologies having similar performance characteristics), based on the CCC cost modelling REEVs are more expensive. As such they would therefore achieve a lower uptake than PHEVs (see Appendix 10.4). Hybrid vehicles are not included as an explicit technology category as the objective of the project is to look at the uptake of plug-in vehicles only. The ICEVs, being the cheapest technology, present the greatest competition faced by EVs, they are used to represent all the non plug-in technologies.

### 4.2.3 First insights from the choice model

In the choice model, the technology with the highest utility has the highest probability of being purchased, i.e. highest market share. The greater the differential in utility between two technologies, the greater the differential in market share. Conversely, the greater the disutility, the less is the probability of that technology being adopted.

Converting the utility into a 'perceived cost'<sup>181</sup> provides a way of understanding and comparing the utility/ disutility of different vehicles and the associated attributes. Figure 28 provides an example for the case of medium size cars in 2016, for drivers who have access to home charging.

Figure 28 clearly shows that the main barrier (i.e. the attribute causing the greatest utility differential with the ICEV) varies across consumer segments. For example, Enthusiasts are willing to pay a premium to drive a new technology (shown as a negative ASC), a premium which partly offsets the reduced utility of EVs due to their high cost. Even for Enthusiasts, supply (model and brand choice) remains as a significant market barrier. In the case of 'Mass market' to 'User choosers', the main barrier is their rejection of EVs (positive ASC) followed by cost.

Overall, the charts shows that, in the near term, access to day charging, charging time and driving range are secondary issues in the face of cost, supply and (for some consumers) acceptance of EVs. This reflects the trend observed in Norway and the Netherlands, where strong cost support has been put in place and resulted in increased uptake only once the supply of vehicle improved.

<sup>179</sup> Based on EE analysis of maximum daily distance of 8,000 van sample over 31 consecutive days. 80% factor used to account for loading effect and/or wanted margin. Range assumptions presented in Appendix.

<sup>180</sup> Although the National Travel Survey captures some company car data, the high mileages quoted indicate they are more likely to correspond to 'user choosers' than fleet vehicles.

<sup>181</sup> The conversion is done by dividing the utility term by the price coefficient.

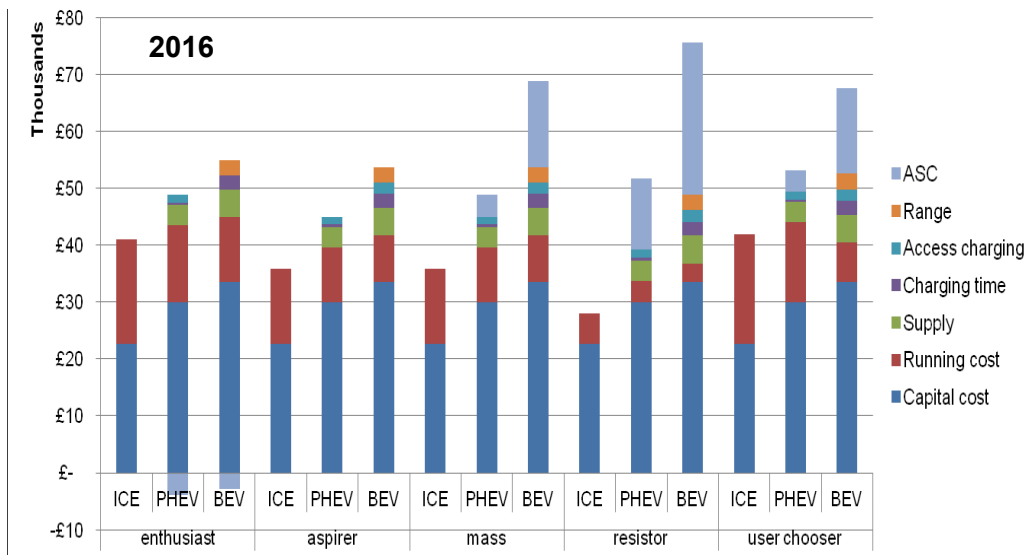


Figure 28 Perceived cost (disutility) for consumers with overnight charging but no access to day charging, medium size car, 2016

### 4.3 Modelling efficient pathways to high EV uptake

The previous sections introduced choice modelling and described how the approach can be used to combine consumer purchase priorities with vehicle attributes to forecast the market share of EVs to 2030. This sub-section provides an overview of how the choice model, once constructed, can be used to develop a market pathway.

#### Identifying action targets to address barriers

In addition to analysing the main barriers (as per the example shown in Figure 28), the choice model can also be used to forecast how the market share would change under a set of **action targets**, defined as interventions (or measures) designed to promote uptake.

#### Note on terminology

In this report, the term **'pathway target'** is used to define a specific market share target for key years (in most cases as set by the Committee on Climate Change in commissioning this report, e.g. EV market share should reach 60% by 2030).

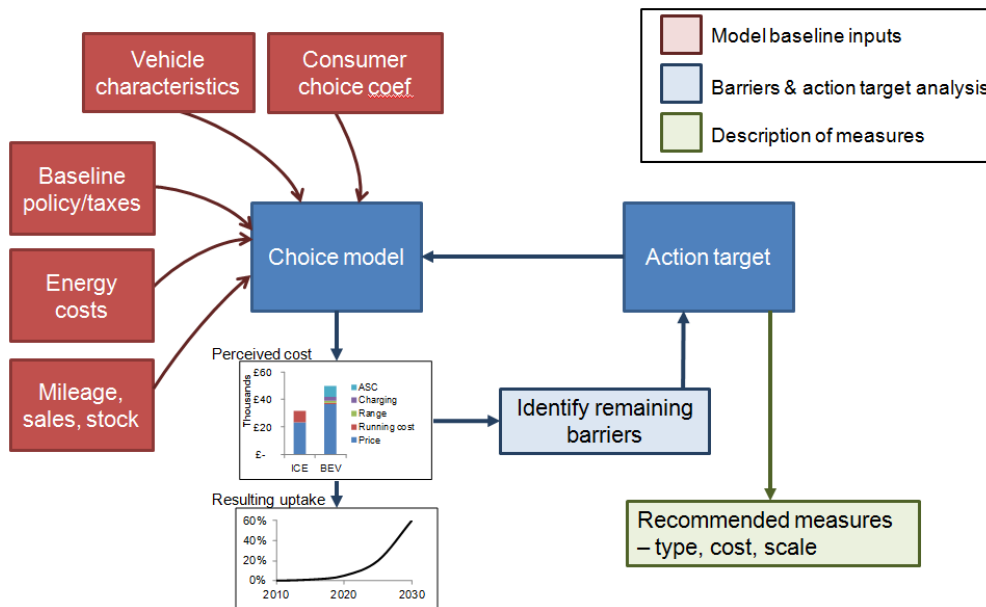
The term **'action target'** is used to describe a type of policy measure or intervention which could be used to increase EV market share in order to achieve a required pathway target (e.g. implementation of a public promotion programme to increase level of awareness to 100% by 2021 as part of larger strategy to meet 60% pathway target for 2030).

To address the key barriers identified in the previous sections, action targets are defined for each the following areas:

- **Supply of EVs:** a trajectory is developed based on announced model releases;
- **Equivalent value support:** to mitigate the cost premium of EVs and/or compensate for the loss of utility. In the model, this is effectively an intervention on the vehicle price seen by buyers in the showroom, in practice it can be delivered by non-financial measures, as discussed later in this report;
- **Charging infrastructure:** this encompasses the level of access to overnight charging, the proportion of drivers who have access to day infrastructure and the charging rate available. The infrastructure in place also influences the driving range compatibility for fleet vehicles;

- **Consumer awareness and acceptance:** how rapidly EVs become part of the choice set of all vehicle buyers.

Figure 29 illustrates how the choice model is used to develop a market pathway.



**Figure 29 Process for the development of pathway to high adoption of EVs**

The definition of the action targets is informed by both the choice model and the lessons learnt from EV uptake in UK and other countries – see Section 3. For the short term (to 2020), both the supply and cost of EVs are key attributes; the action targets therefore focus on these aspects and the 2020 uptake target is reviewed in light of projected EV supply.

While the choice model can inform the required level of action to achieve a given uptake, it does not inform how to deliver the action target. The recommended measures that might be implemented to deliver the action target are based on an analysis of cost as well as observed trends in the UK and other countries.

For example, providing access to day charging infrastructure can be delivered through the deployment of a network of normal or rapid chargers. Analysis of cost and required level of installation in Section 3 has shown that deploying a rapid network is a more efficient method (least cost) of promoting uptake as it can provide national coverage with a limited number of sites as well as offer low charging times and thus truly extend the driving range of BEVs.

To conclude the modelling process, the developed market pathway is characterised by a roadmap of action targets (implemented at key stages) and the recommended measures required to deliver them. When it can be quantified, the pathway cost is also estimated. Results of the EV pathway modelling are described in Section 5.

#### 4.4 Factors beyond the scope of the model

##### Changes in personal mobility: from ownership to service

This study is based on current vehicle segmentation and ownership models – with the exception of the sensitivity test on battery leasing options which will be discussed in Section 5. Looking towards 2030, there are several technology and consumer trends that could radically alter road transport and possibly be favourable to the adoption of EVs. These include: the downsizing of cars, a general change in ownership models (away from outright ownership to towards pay-as-you-drive) and new car

services such as Intelligent Transport Systems including the development of the driverless car. Given that the amplitude and timescale of these changes are however hard to predict and beyond the scope of this study, they are not captured in the modelling.

The downsizing of passenger cars could be led by two factors: the future fuel economy targets and the rise of mobility in East Asia, in particular China. Increasing urban density, an expanding middle class and worsening air quality and congestion, is likely to increase demand for smaller cars than the products currently designed for the American and European markets. An increasing demand for A-segment cars, for which the battery electric powertrain is ideally suited, would support EV development. An improved supply of such vehicles (from the Far East) could also increase the current low UK market for small city cars.<sup>182</sup> Economic and regulatory drivers in Europe and the U.S. might also increase demand for smaller cars in these regions.

New business models will also impact on vehicle type and future acquisition methods. As will be discussed in more detail in Section 6, most new car purchases rely on some form of vehicle finance with most OEMs offering highly competitive finance deals for new car purchases. Many of these contract purchase options (such as personal Contract Purchase or 'PCP') are increasingly popular and effectively delay or avoid the full ownership of the vehicle. Recent trends suggest that the move away from outright vehicle ownership is already underway; a trend that could be of significant benefit to the emerging EV market (where vehicle price premiums remain).

A related and potentially more radical trend is the shift from vehicle ownership to the purchasing of new mobility services (as is already being offered by UK car clubs). Where vehicle fleets are no longer owned by end-users, consumer choice is less distinguished by the vehicle's powertrain and more by the service package. A number of EV-only car clubs have already been launched in the UK and EU.

An extreme mobility service scenario that could be envisaged is the large-scale deployment of driverless cars,<sup>183</sup> combined with an intelligent data infrastructure to control vehicle positioning and delivery to the customer. This would have significant impact on the business model for EVs as, in addition to removing the need for vehicle ownership (and associated capital cost barriers), the system would automate recharging; with wireless technology replacing the potentially more hazardous automatic liquid refuelling of conventional cars.

### EV impacts on electricity transmission and distribution networks

The high adoption of EVs will create new demands on the national electricity grid, with potential impacts throughout the electricity system from generation to transmission and distribution. Impacts on the transmission and distribution networks are covered in a parallel study commissioned by the CCC in 2013: "Characterisation and cost of infrastructure to 2030", by Element Energy, Imperial College London and Grid Scientific.

Covering infrastructures of transmission, distribution, carbon capture and storage, and smart grid solutions for delivering demand side response, the Element Energy- led study characterises the cost, scale and extent of infrastructure deployment to 2030 for several grid decarbonisation scenarios. The study also assesses the feasibility of deployment considering timelines for delivery and barriers for each infrastructure.

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<sup>182</sup> Note that current fuel economy targets have not led to a downsizing in cars so far, the average car size bought in the EU continues to increase (with the exception of a dip in engine size and vehicle mass in 2009); European Vehicle Market Statistics, ICCT, 2011.

<sup>183</sup> In France, Induct has developed a technology to make EVs 'park themselves' to save parking space in car sharing schemes as well as a driverless electric shuttle (for up to c. 10 people) that can navigate between cars, bikes and pedestrians to reach the destination chosen by the user. Vehicles are being trialled in several French cities, including Lyon <http://induct-technology.com/blog/category/actualites>. Google is working on a driverless car too.



### Potential environmental impacts of high EV uptake

Although potential reductions in CO<sub>2</sub> emissions are the reason for the Committee on Climate Change to target a high adoption of EVs, large scale EV adoption would lead to a reduction in urban areas of several airborne pollutants which currently impact on human health. For example, the number of deaths attributed to long-term particulate exposure is over 4,000 per year in London alone.<sup>184</sup> While these benefits are not explicitly factored in the choice modelling, they do add to many stakeholders' support for electric powertrains - as will be discussed in later sections.

Against this potential health benefit at point of use, EVs may increase the potential impact on human health in areas where resources are extracted for battery production. Indeed, the sourcing of some elements key to EV batteries remains contentious relating to the level of reserves and the local impacts on human health where mining occurs.

However, other than noting these potential impacts, these wider environmental and health impacts of large scale EV uptake are beyond the scope of this report and are therefore not included in the model developed for this project.

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<sup>184</sup> Greater London Authority, 2008. URL: <http://www.london.gov.uk/priorities/environment/clearing-londons-air/air-pollution-and-public-health>



#### Summary of Section 4

- Choice modelling is the method used in this study to model the uptake of EVs in the UK. The technique calculates the probability of choosing one of several products given the value of a product's key attributes which are weighted by buyers to calculate the overall utility of the product (a vehicle in this study). The weighting of attributes varies across consumer segments, because consumers' opinions on the importance of different vehicle attributes vary.
- The vehicle attributes represented in the choice model developed for this study include both financial and non-financial attributes: capital and running costs, access to infrastructure, charging time, driving range, model/brand supply and consumer receptiveness to EVs.
- Research shows that the consumer segments for private and company vehicles are different, and so this differentiation is represented in the choice model. Key assumptions include pre-conditions for purchase: BEVs (and PHEVs in the case of fleet managers) can be considered for purchase only if the buyer has certainty of access to charging (which can be provided only by overnight charging) and fleet managers also require the BEV's driving range to meet their duty cycle.
- The data for the model is taken from previous CCC work in terms of vehicle cost and performance, and from literature or the authors' own research for the attributes' weighting factors.
- The model results demonstrate that the scale of market barriers vary across consumer segments. For example, Enthusiasts are willing to pay a premium to drive a new technology, a premium which partly offsets the reduced utility of EVs due to their high cost. However, even for Enthusiasts, supply (model and brand choice) remains as a significant market barrier. In the case of 'Mass market' to 'User choosers', the main barrier is their rejection of EVs as a technology, followed by cost.
- The choice model has been used to derive 'action targets' (sets of market interventions or measures) which are needed to achieve the CCC target of 60% market share for EVs in 2030. Reflecting the key purchase criteria, action targets are defined for the following areas: level of supply of EVs, equivalent value of support, charging infrastructure and consumer awareness and acceptance. The definition of the action targets is informed by both the choice model and the lessons learnt from EV uptake in UK and other countries.
- Changes in mobility patterns, such as the downsizing of cars, the increasing popularity in leasing options and the emergence of new mobility services (such as car clubs) is likely to accelerate EV uptake. Given that the amplitude and timescale of these changes is hard to predict and beyond the scope of this study, these trends are not represented in the model. Also excluded are the impacts of EVs on life cycle emissions and on the electricity transmission and distribution networks (the latter is covered in a parallel study commissioned by the CCC).

## 5 Modelling results: EV uptake pathway to 2030

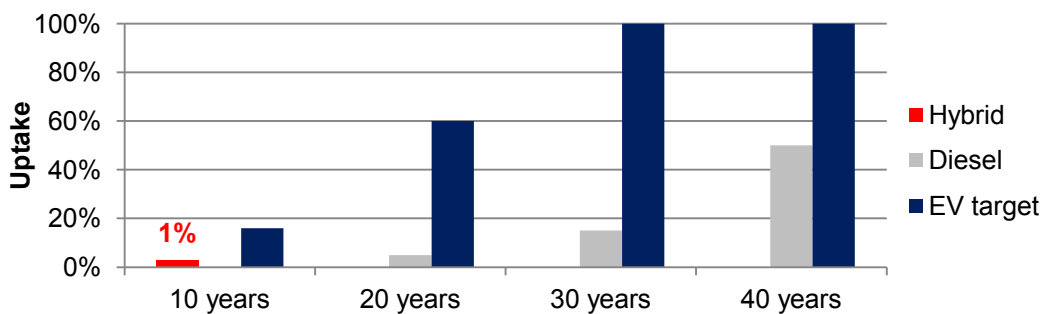
This section introduces the EV uptake pathway targets for 2020 and 2030 and presents the *action targets* that would (according to the model), if adopted, increase the market penetration of EVs to the target market share as defined by the Committee on Climate Change. Each action target is described in terms of milestones, associated cost or other indicators. The impact of each action target on overall EV uptake is presented in the last sub-section; it discusses the model sensitivity to action targets and other key assumptions.

### 5.1 EV uptake targets: setting the challenge

The Committee on Climate Change’s EV uptake pathway for cars and vans is defined by:

- Indicative 16% market share (PHEVs plus ZEVs) by 2020;<sup>185</sup>
- 60% market share (PHEVs plus ZEVs) by 2030;
- 100% market share (ZEVs) by 2040.

To put these targets in perspective, and to appreciate the challenge they present, it is worth reviewing how other ‘new’ vehicle technologies have previously penetrated the UK car market. As shown in Figure 30, in 1990, diesel cars had a 5% market share in the UK, 20 years after first introduction. By 2000, their market share was around 15% after which their adoption accelerated to almost 50% in 2010. In contrast, in 2012, conventional hybrid cars captured 1.3% of UK sales, more than a decade after their introduction.



**Figure 30 Observed market share after years of introduction on UK car market (diesel, hybrid) and market share target (EV). Source: SMMT**

As Figure 30 also shows, the pathway targets for EVs are highly ambitious in comparison, with 100% sales being required within 30 years.<sup>186</sup> Furthermore, in contrast to the case for EVs, diesel and conventional hybrids have relatively minor consumer acceptance and supply issues;<sup>187</sup> nor has introduction of these technologies had to overcome the significant cost premium or infrastructure barriers currently faced by plug-in vehicles.

Another way to demonstrate the level of challenge of the high EV uptake pathway is to consider the market share predicted by the model under the current development trajectory; i.e. a ‘business as usual’ (BAU) scenario where no new measures are being introduced beyond existing (announced) grant and tax incentives, but where the supply of new models increases according to current trends and accelerates post-2020. Figure 31 presents these baseline BAU results which include a 1% EV market share by 2020 and 20% by 2030 (mostly PHEVs). The high uptake pathway as defined therefore represents an additional 40% EV market share by 2030.

<sup>185</sup> As defined by the percentage of new car and van sales.

<sup>186</sup> Assuming the first high quality lithium-ion car and van models were launched in 2010.

<sup>187</sup> Hybrid vehicles still do face some level of consumer awareness and acceptance barrier and are not supplied in all vehicle segments or in many brands. Diesel vehicles sales are still modest for small cars (A and B segments) as their supply is lower in these segments, a reflection of them being better suited to high mileage applications.

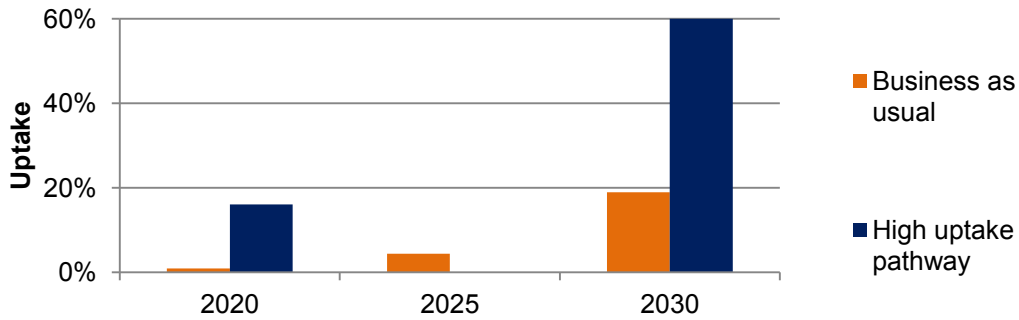


Figure 31 EV market share for no new measures (but increasing supply) and pathway targets

### 5.2 High EV uptake pathway to 2030

The model predicts that, to reach the high EV uptake pathway required by this study, the 60% market share in 2030 is achieved with a technology split of 35% PHEVs and 25% BEVs - see Figure 32. Figure 32

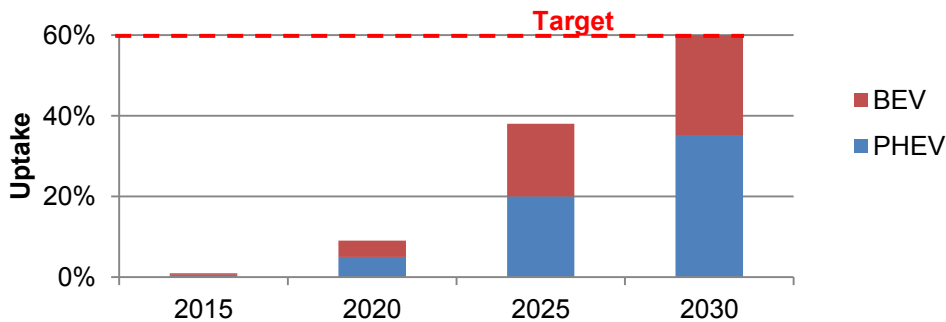


Figure 32 EV market share under high uptake pathway (cars and vans)

This technology split is however different across vehicle class (private or fleet), as shown in Figure 33, with the BEV uptake being higher among fleet vehicles (even after accounting for more limited suitability), a result of the assumed more rational approach of fleet managers. Overall, BEVs rely heavily on fleet sales; they represent 80% of the BEVs uptake in 2030 (while fleet vehicles capture 62% of overall car and van sales). More details on consumer segment breakdown are provided in Appendix 10.6.

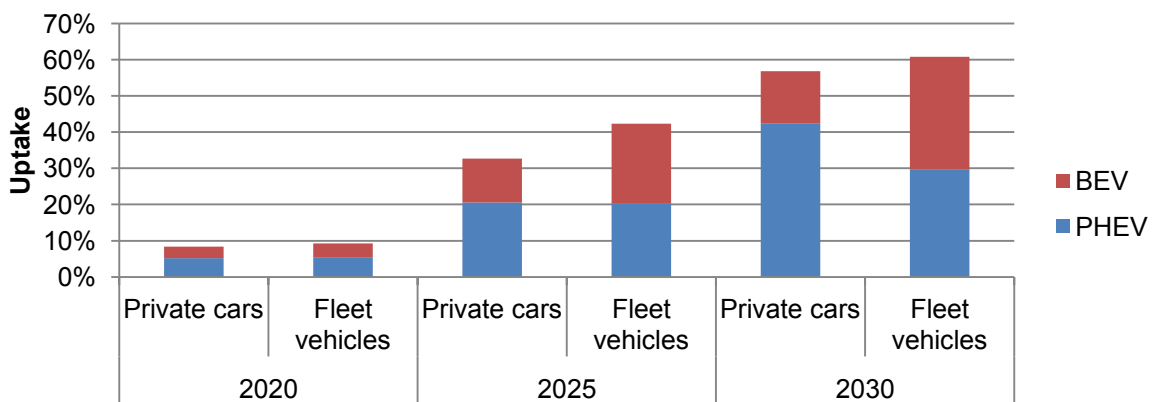


Figure 33 EV market share under high uptake pathway (cars and vans) within private / fleet markets

**Market pathway to 2020**

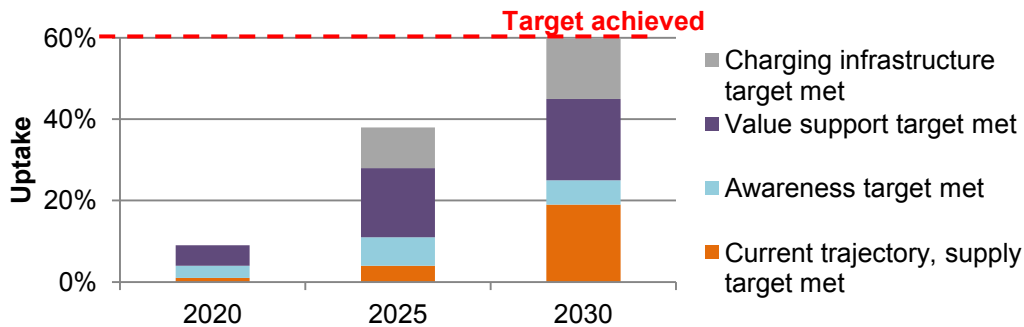
Under the supply projection (based on EV production meeting national EV targets which assumes 30% annual growth in production capacity post 2015, see Section 2.3), the European EV production capacity is estimated at 2.36 million in 2020. The set target of 16% market share for the UK (488 thousand vehicles) thus seems unrealistic; as it would represent 21% of the total European production capacity. As a point of comparison, the UK captured 9% of EV sales in the EU in 2012 and 15% of all car and van sales in 2012.

The developed pathway therefore does not attempt to reach the 16% target by 2020. Under the high uptake pathway, EVs achieve instead a 9% market share in 2020. This represents around 275 thousand sales corresponding to 12% of the projected European EV production capacity, or 5% of the world capacity.<sup>188</sup>

In addition to the supply of EVs, the choice model results show that, up to 2020, the two main barriers are the cost of EVs and the low level of awareness (see Appendix 10.5 for detailed results). While access to overnight charging is a key parameter for purchasing EVs, the analysis of overnight parking has shown 70% UK drivers have access to overnight charging. The pre-2020 action targets therefore focus on cost and raising consumer awareness (i.e. the share of buyers who consider EVs in their vehicle purchase decision).

**Market pathway to 2030**

Post-2020, while all buyers are assumed to be aware of EVs, the model highlights that acceptance issues among the consumer segment most biased against EVs will remain. The uptake post-2030 is however mostly dependent on the cost (vehicle price and to a lesser degree running cost) and the share of buyers who have access to charging. The action targets are therefore a trade-off between the utility that a developed infrastructure can provide (access, charging time and driving range for fleet vehicles) and the available equivalent value support (implemented in the model as an intervention on the vehicle price, but which in practice could be delivered through a range of financial and/or non-financial measures).



**Figure 34 High uptake pathway – cumulative impact of action targets**

Figure 34 shows how the pathway targets are achieved in the model through actions made in four key areas: EV supply, EV consumer awareness and acceptance, EV equivalent value support and (more important post 2020) charging infrastructure.

Based on the results of the choice modelling, the action targets required to achieve the high EV uptake pathway as defined above are now presented in more detail. Each action target is presented in terms of milestones, possible indicators of progress and impact on uptake. How the action targets can be delivered in terms of possible measures and policy key stakeholders is discussed in the subsequent Section 6 .

<sup>188</sup> Based on projections from 2015 capacity and 30% annual growth assumption, presented in Section 2.3

### 5.3 Action target: vehicle supply and brand/model diversity

This section details the supply assumptions per vehicle segment, to provide indicators for the high uptake pathway.

A supply volume trajectory has been estimated to 2020 based on the projected European EV production capacity, under the assumption of a 30% annual growth post-2015 (to meet announced national targets). The supply of models per vehicle segment (small to large cars and vans) is projected based on announced model releases. If insufficient, the projected model supply per segment is converted to a penalty in the choice model that influences the level of uptake.

The uptake pathway requires that the release of EV models to 2020 will continue on the same trajectory as the trend observed for 2012-2014 (presented in Section 2.3.2). This translates into a very strong supply for small BEV car and van models by 2020 (more than 20 models). Table 10 summarises the expected level of supply consistent with the model results, to provide indicators for the high uptake roadmap.

Under the high uptake pathway, EVs achieve a 9% market share in 2020 which is assessed as achievable in view of the projected European EV production capacity. This represents around 275 thousand sales corresponding to 12% of the projected capacity.<sup>189</sup>

**Table 10 Supply of EV models – targets and indicative numbers in 2020**

Vehicle segment	Share of EV models per segment	Indicative number of EV models*
Small cars (A/B)	>50%	> 25 BEV models only, no small PHEV/ REEV on the market yet
Medium cars (C/D)	15-30%	10 BEV and 25 PHEV models
Large cars (E/I)	10%	15 BEV and 15 PHEV models
Vans	>50%	> 20 BEV models (>6 panel vans); >10 PHEV models

\* Approximation based on today’s total number of models per segment

Post-2020, to achieve the pathway targets, it is required that the release of EVs will improve to the extent that **the supply of EVs models is excellent in 2030 for all segments: the majority of models offering a BEV and PHEV variant**. The exception is the plug-in hybrid platform for small cars that is assumed will not enter the market before 2025, and then remain a marginal option. Table 11 provides indicators for the roadmap to the high EV uptake pathway, consistent with the model results presented.

**Table 11 Supply of EV models – targets post-2020**

Segment	2025	2030
Small cars (A/B)	Excellent* for BEV Marginal for PHEV	Excellent for BEV Improved for PHEV but less than 50% of models come in a PHEV variant
Medium cars (C/D)	Good – around 50% of models have BEV and PHEV variant	Excellent – majority of models have BEV and PHEV variants
Large cars (E/I)	Good – around 30% of models have BEV and PHEV variant	
Vans	Excellent	

\*‘Excellent’ defined as >60% models within segment

<sup>189</sup> Based on projections from 2015 capacity and 30% annual growth assumption, presented in 2.3

### 5.4 Action target: consumer awareness and acceptance

This section details the assumptions regarding the required levels of consumer awareness and technology acceptance to achieve the high EV uptake pathway.

Given the issues raised in section 3.4, consumer awareness of EVs will have to be increased through a dedicated information campaign. To achieve the high uptake pathway, a target for the level of awareness is required (as a precondition to achieve the pathway). This target is that, **ten years after the introduction of the first series EVs (i.e. by 2021), all car buyers are aware of EVs including their key capabilities and associated incentives** (although they may not all necessarily be disposed to buy one). This target is consistent with the assumptions on the continuing release of new EV models.

Consumer awareness and acceptance of EVs is represented in the model by two parameters:

- The share of vehicle buyers who are aware of EVs and related incentives and thus can consider EVs in their vehicle choice set; this level is estimated at 20% in 2013 (based on evidence presented in 3.4). Figure 35 presents the EV awareness trajectory (shown in blue) required by the high uptake pathway.
- The technology preference of each private buyer segment: while the ‘Enthusiasts’ consumer segment display a preference for EVs, the ‘Mass market’ and ‘Resistors’ have on the contrary a bias against EVs.<sup>190</sup> The negative bias (indicating a resistance to adopting an EV) is assumed in the model to decrease over time as EVs become more common, i.e. as a function of EV sales. The threshold for the bias to disappear is set at 10%, based on literature findings (as discussed in 4.2).<sup>191</sup>

One important issue within the modelling of awareness and acceptance is that fleet managers are assumed to not display any technology preference (or negative bias) but instead base their choice purely on technology suitability and total cost of ownership (TCO). Given the potential implications of this assumptions being incorrect, this was sensitivity tested (see next section).

Post-2021, there will still be a role for consumer education to increase *acceptance* of EVs among the more resistant consumer segments. Direct exposure to vehicles, at this stage of the market pathway, will remain an important way to achieve this goal – relevant measures and costs are discussed in Section 6 .

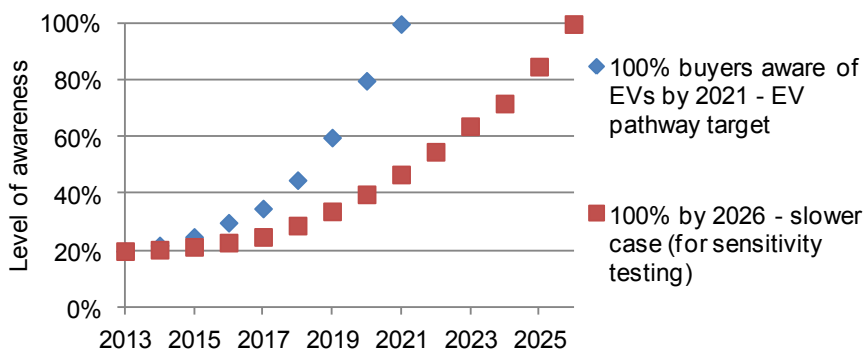


Figure 35 Trajectories for level of consumer awareness to EVs

<sup>190</sup> This is captured in the choice model through the Alternative Specific Constant, refer to the methodology section for details

<sup>191</sup> See Appendix 10.4 for details. This is applied separately for PHEVs and BEVs.

## 5.5 Action target: EV charging infrastructure

This section details the assumptions regarding the required access to charging infrastructure to achieve the high EV uptake pathway.

### Access to overnight charging

The modelling assumes that EV buyers install a charging point at their home or work depot parking location. The overnight infrastructure action target is that: **by 2020, all vehicle buyers who have access to off-street parking are aware they can install a charge point for overnight use.**

As discussed in Section 3.3, data suggests that 70% of vehicles parked in residential areas<sup>192</sup> have access to off-street parking adequate for charging (i.e. close enough to house power supply). If 80% of new houses with car owners built between 2015 and 2020 provide a charge point and 95% post-2020, the current 70% share would increase to 74% by 2030.<sup>193</sup> These rates imply all off-street parking is used, including resident car parks.

### Access to day charging

The EV pathway assumes that EVs will mostly charge overnight, with some ‘opportunity charging’ used during the day at publicly accessible normal to rapid chargers (as per the observed trend). To make BEVs more attractive to vehicle buyers, consumers must however be confident that the network is sufficiently developed to support day recharging wherever and whenever required.

The day infrastructure action target is that: **the rapid charging infrastructure coverage provides for at least 20% of UK drivers by 2020, 60% by 2025 and 100% by 2030.**

The percentages included in the action target reflect the share of vehicle buyers with the confidence that they will have access to a rapid charging point; as such they therefore perceive no ‘infrastructure penalty’. Providing this level of charging infrastructure requires sufficient sites to provide national coverage for drivers, and sufficient posts/ charge points at each location to account for the projected utilisation. The scale of network required is discussed in the next sub-section.

As part of this action target, the perceived charging rate is assumed to increase over time (i.e. charging time decreases) and the driving range and compatibility (with rapid CPs) of fleet vehicles is assumed to increase (see below). The perceived public CP coverage for PHEVs is assumed to be lower to reflect their non-compatibility with rapid charge. The sensitivity of the results to changes in these parameters is discussed in Section 5.7.2.

### Rapid charging network characteristics

As discussed in section 3.3, providing the level of day charging infrastructure required by the high uptake EV pathway using normal charging points (CPs) is a challenging task, as they are unable to deliver the fast charging times required to reduce range barriers. However, rapid CPs can cost-effectively provide the required coverage using relatively few locations.

Table 12 details the assumptions regarding the number of rapid CP sites needed to provide the target coverage. 500 sites are assumed to result in 20% of EV users being confident they have access to the rapid network. An analysis of hydrogen infrastructure coverage found that 500 hydrogen refuelling stations would provide for the travel needs of over 50% of the UK population, based on traffic flow

<sup>192</sup> Giving a rate of 70% of private car buyers, 75% of company owned cars and 60% of vans; see 3.3 for details

<sup>193</sup> The rate of change is low as the stock turnover is slow, see page 123 for housing projections. Numbers used in the model are 70% in 2015-2020 increasing to 70.5% by 2025 and 74% by 2030. Keeping the rate at 70% reduces the uptake in 2030 from 60% to 58%.



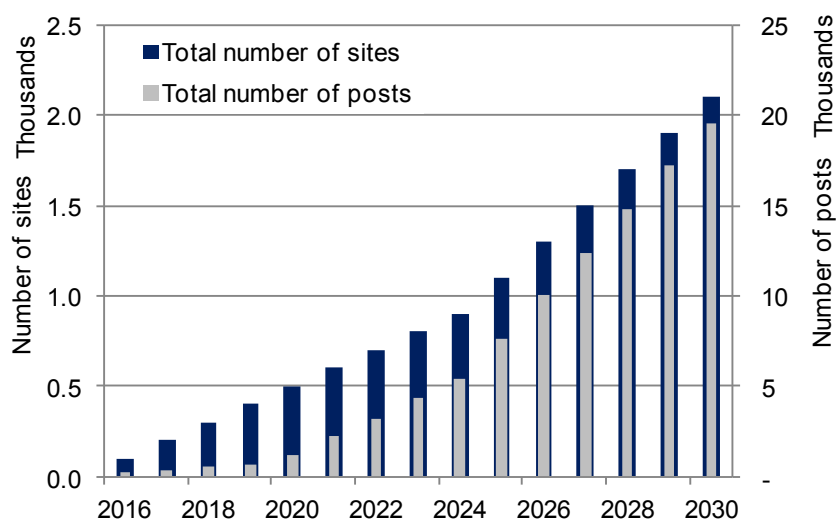
analysis.<sup>194</sup> While there is no data as such on the perceived to actual coverage ratio, consumer surveys reveal a general concern over BEV driving range and thus access to charging infrastructure (discussed in Section 3.3). The 50% actual coverage value is therefore set to a more conservative 20% value to account for the difference between actual and perceived coverage, and because the driving range of BEVs is shorter than for hydrogen vehicles. The same process has been applied to the 2025 value. By 2030, to provide 100% perceived coverage, over 2,000 sites are assumed, almost double the number identified as sufficient for actual coverage. In line with the rollout of rapid CPs, the perceived charging rate for BEVs increases from 3kW in 2010 to 7kW in 2020, 30kW in 2025 and 50kW by 2030.<sup>195</sup>

**Table 12 Rapid network perceived coverage assumptions and corresponding number of sites, compared with actual coverage**

Coverage metric	2015	2020	2025	2030
% private buyers that perceive rapid CP access (for BEVs)	1%	20%	60%	100%
Number of sites assumed for cost analysis	100	500	1,100	2,100
% UK population covered by this number of sites*		>50%	~100%	

\* Based on the hydrogen infrastructure coverage analysis carried out in the UK H<sub>2</sub>Mobility project, (H<sub>2</sub>Mobility Phase 1 report, 2013).

The number of rapid CP sites that would meet the EV pathway’s infrastructure action target are presented in Figure 36 along with the number of rapid CPs (several per site) required to meet the projected demand. The level of demand assumes that BEVs will, on average, use a rapid CP once every two weeks. This results in the number of BEVs per CP of around 250 BEVs per rapid post. Based on the National Travel Survey, this is a *high* estimate; it is however the level of use observed in the Netherlands.<sup>196</sup>



**Figure 36 Deployment of a rapid charging network to provide day coverage to 100% of BEV drivers by 2030**

<sup>194</sup> Ref: H2Mobility Phase 1 report, 2013 – the hydrogen infrastructure coverage analysis is discussed in more details in section 7.

<sup>195</sup> For PHEVs, the perceived rate is capped at 7kW which is consistent with the assumption that future PHEVs will be not fitted with high rate AC chargers or rapid DC charge ports.

<sup>196</sup> The NTS shows that only c. 2% of daily total driving distances are above 160km. Dutch CP average usage calculated from survey answers (“Resultaten enquête snelladen” by Agentschap, March 2012; n=45)

Based on current and projected unit costs for 50kW DC rapid chargers (including installation), the cumulative cost of deploying a rapid network is estimated at between £300 million and £530 million by 2030 (see Figure 37)<sup>197</sup>.

While cheaper 22kW fast chargers are likely to be deployed at some locations as part of a fast/rapid network (e.g. in urban areas), the value of these CPs to EV users is lower (as discussed in section 3.3). Likewise, higher power (up to 120kW) CPs might be deployed on some highways, as have been developed by Tesla for deployment on key U.S. routes – see Box 9.

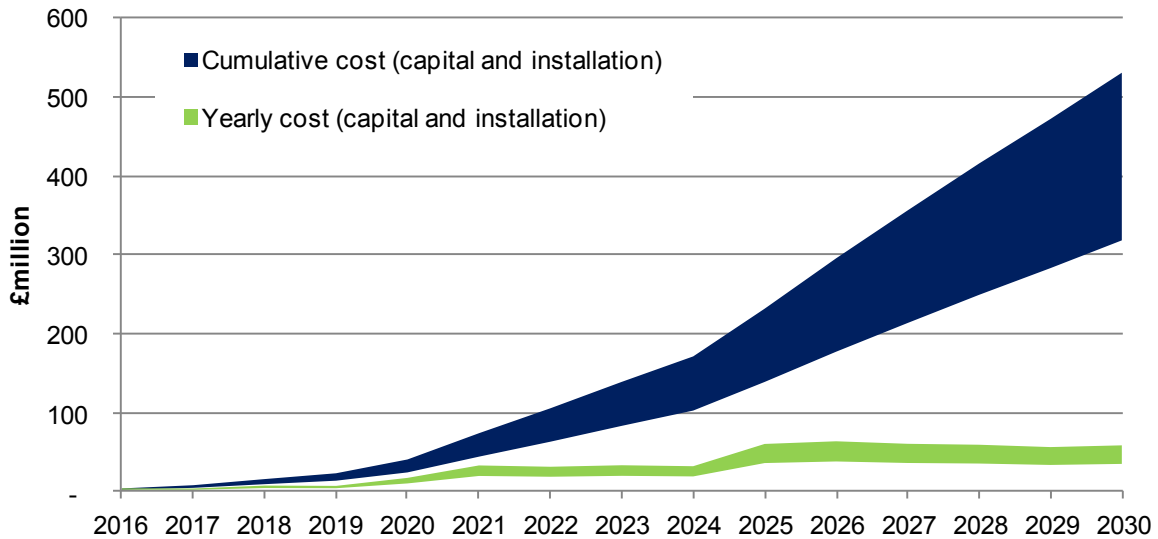


Figure 37 Cost of rapid network deployment in £millions; showing a range based on min/max cost range projections

It is assumed that the rapid CP network increases the share of fleet managers (for both cars and vans) that will assess BEVs as adequate for their operational requirement.<sup>198</sup> For vans, it is assumed the rapid network influences the driving range compatibility only when exceeding 50% perceived coverage,<sup>199</sup> the overall range compatibility being capped at 70%<sup>200</sup>.

The graphs in Figure 38 show the impact of these assumptions on the share of fleet buyers who can consider BEVs. Implementing the infrastructure action target increases the BEV market among fleet car buyers by increasing their share from 40% to almost 80% by 2030. As fleet car buyers represent only a share of the total buyers, the overall impact is more modest (charts on right); the share of vehicle buyers who can consider BEVs increasing from 60% to around 75% in 2030.

<sup>197</sup> Cost range assumptions: £30k to £50k in 2013 (observed costs), decreasing to £12.5-£21k in 2030 (corresponding to 5% annual cost decrease). The installation of several posts per site will bring cost reduction opportunity, on top of a decrease in equipment cost. Posts are replaced after 10 years in use. Maintenance costs are not included for lack of reliable data, especially for sites with several posts. A flat figure of £500 per post per year adds c. £50million cumulative by 2030.

<sup>198</sup> Reminder: as part of the modelled purchase decision process, fleet managers do not consider BEVs if their driving range is not assessed as sufficient for the duty cycle, see Figure 27 on page 45

<sup>199</sup> Below this van purchasers are assumed to be not sufficiently confident for the network to affect their decision

<sup>200</sup> In the CCC modelling van driving range is assumed to stay under 300km. As it was identified that 30% of vans exceed a 300km daily distance at least once a month (based on Element Energy analysis of the Survey of Company-Owned Vans), the range compatibility is capped at 70%, to reflect that not all businesses will be willing to/ be able to afford the time to recharge during the day. No cap on range compatibility is applied on fleet cars to reflect the more varied use (private and company mileage, in average lower than for vans)

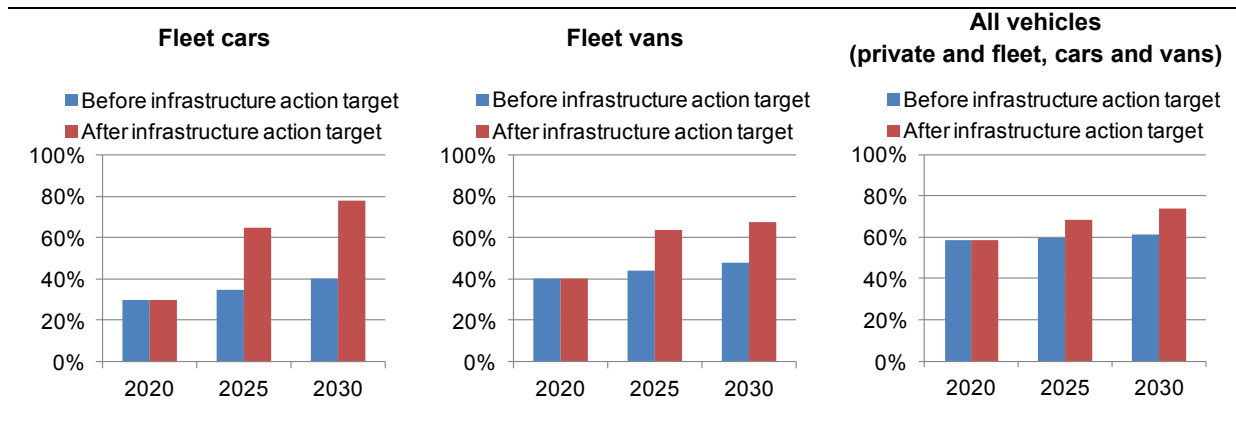


Figure 38 Share of vehicle buyers who can consider BEVs based on access to overnight infrastructure and driving range compatibility

### Day normal charging

While current trends indicate that the number of work place and other normal (3 to 7kW) public CP will continue to grow, no hard target is set for them as their value for BEVs is limited – see Section 3.

For PHEVs, as the rapid CP coverage presented above does not apply (in line with assumption that PHEVs will be not fitted with high rate AC chargers or rapid DC charge ports), normal sockets at workplaces, retail locations and public sites will continue to provide coverage. However, the model indicates access to public normal chargers has little impact on the overall EV uptake. Therefore the baseline assumption taken on the share of buyers that perceive normal CP access for PHEVs (60% by 2030) is not translated into a number of charging points. This is discussed in more details in Section 5.7.2.

## 5.6 Action target: equivalent value support

This section details the assumptions regarding the level of *equivalent value support* required to achieve the high EV uptake pathway as well as the sensitivity of results to the cost input assumptions.

### Note on terminology

The term '**equivalent value support**' is used to describe the monetised value of the support required to mitigate the project capital cost premium of EVs. In the near term, it also compensates for any loss of utility of EVs over conventional vehicles.

While the equivalent value support is modelled through a change in vehicle purchase price it is important to note that the value of support can be provided in monetary and/or non-financial forms – for example, preferential road access could be used to provide value to EV users which, as far as the model used in concerned, could have the same impact on market share as an equivalent monetary benefit. In practice, providing the support as a direct financial contribution is unlikely to be desirable or optimal.

For example, in practice, £1,000 of equivalent value support could be delivered in a number of ways including: (i) £1,000 capital grant; (ii) £350 annual equivalent value support - the 3.5 ratio was calculated by running the model iteratively and stems from the fact than running costs are weighted over approx. 4 years by consumers when comparing vehicles; (iii) use of a leasing model, for the battery or the whole vehicle, which replaces the capex with a regular payment (iv) non financial measures, e.g. preferential access to High Occupancy Lane lanes, congestion charge rebate. Measures and evidence of their efficiency are discussed in Section 6 .

Achieving the ambitious high EV pathway target of 60% market share by 2030 will require significant equivalent value support, both to address the higher capital cost of EVs, as well as to compensate for the loss of utility associated with reduced range and longer charging times.

The monetised value of this equivalent value support (as estimated by the model) is now presented; the range of measures and stakeholders that could deliver this support is then discussed in Section 6 .

### Equivalent value support to 2020 and to 2030

Assuming all preconditions are favourable to EV adoption – including a sufficient vehicle supply of EV models, the implementation of a successful awareness and demonstration campaign which improves consumer acceptance of EVs, and the use of overnight parking for charging and the rollout of infrastructure – the model indicates that significant equivalent value support will nevertheless be required to achieve the high EV pathway targets of 2020 and 2030.

The model indicates that a **equivalent value support equivalent to £3,000 per vehicle post-2015** would be required to reach a 9% market share in 2020. This support is in addition to measures already in place (such as preferential Enhanced Capital Allowances, C1NICs and BIK rates – as discussed in Section 3.2). **Post-2020, the equivalent value support is reduced to £2,500 per vehicle but must be maintained to 2030** to reach the 60% uptake target. This support could be provided through financial support or through non-financial measures with an equivalent perceived value to consumers.

The reduction in equivalent value support post-2020 is possible thanks to the reduction of EVs capital cost premium, increased supply and acceptance of EVs and the roll out of infrastructure – all of which influence the level of required support, as discussed next in Section 5.7 .

## 5.7 Model sensitivities and discussion

The model was tested for sensitivity to the many inputs entering the estimation of EV market share. While all sensitivity results are given in Appendix 10.5, the most sensitive parameters or assumptions are discussed here in more detail. Where relevant, the impact on the equivalent value support required to reach the EV uptake targets is also estimated. This leads to a discussion on how to address the greatest long term barrier of EVs with the simulation of alternative payment terms, before summarising the sensitivity findings and making some remarks on the factors that are beyond the modelling scope but could influence the future EV automotive market.

### 5.7.1 Sensitivity of results to vehicle supply, consumer awareness and technology acceptance

This sub-section assesses the impact of delaying one of other of two preconditions assumed by the high EV uptake pathway: the supply of EVs and consumer awareness (and technology acceptance). The analysis shows the effect of EV supply not increasing as per the assumed trajectory as well as the potential impact of fleet managers – high EV buyers in the EV pathway – not being as receptive to EVs as assumed by the baseline assumptions.

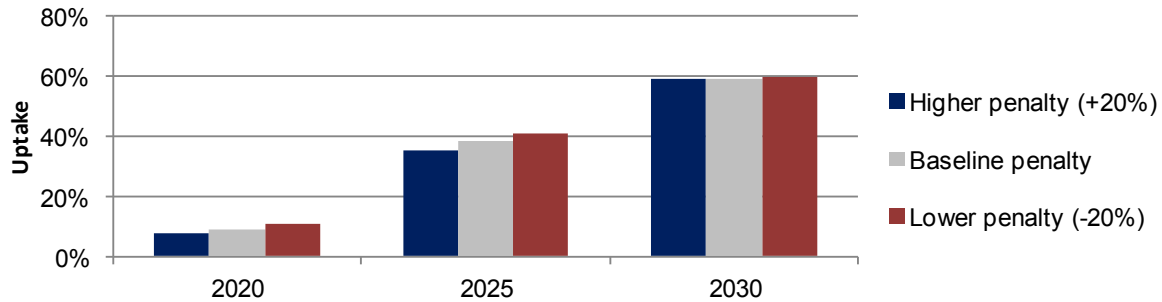
#### Sensitivity of model results to vehicle supply

In the choice model, for each vehicle segment, the supply penalty is quantified based on the percentage of models available on the market<sup>201</sup>:

$$\text{Penalty} = K \times \ln(\text{share of EV models})$$

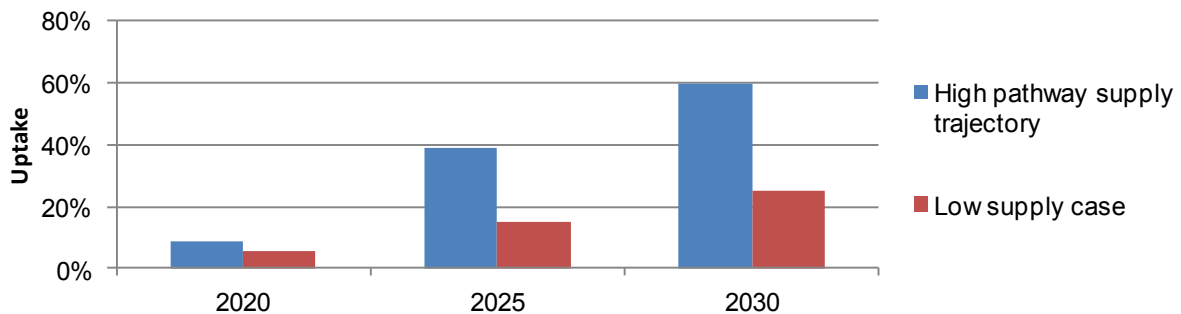
<sup>201</sup> See Appendix 10.4.1 for details on methodology and penalty values used in the model

Figure 39 shows the uptake pathway based on the supply assumptions as already presented (with all other action targets are met) but the supply penalty is set 20% lower or 20% higher than assumed for the baseline (i.e. the value of K is 20% lower or higher). By 2030, applying a 20% change has a negligible effect as the supply is by then assumed to be very good (and thus the penalty gone for most vehicle segments); even in earlier years (with lower supply), the impact is modest.



**Figure 39 Market share of EVs: sensitivity of pathway to quantification of supply penalty under pathway supply trajectory**

Results are, however, sensitive to the assumptions on the share of EV models available in each segment. Figure 40 shows the pathway to 2030 based on the supply assumptions (as above) and on an alternative ‘low supply’ case that assumes that only one new model a year is introduced in each segment from 2017, with the exception of small PHEVs which do not reach the market.<sup>202</sup> The comparison of achieved market shares (‘low’ versus ‘high’) illustrates the significant impact of vehicle supply (in terms of available models) on the uptake of EVs.



**Figure 40 Impact of EV supply on market share of EVs (all other action targets met)**

**Sensitivity of model results to levels of awareness and acceptance**

In addition to the key awareness action target of 100% by 2021, an alternative trajectory was tested in which 100% awareness is delayed until 2026 – see Figure 35 page 62 (shown in red). This was combined with a delayed technology acceptance trajectory whereby the technology bias towards BEVs and PHEVs is removed when sales reach 20% rather than 10%.

**Delayed awareness and technology acceptance**

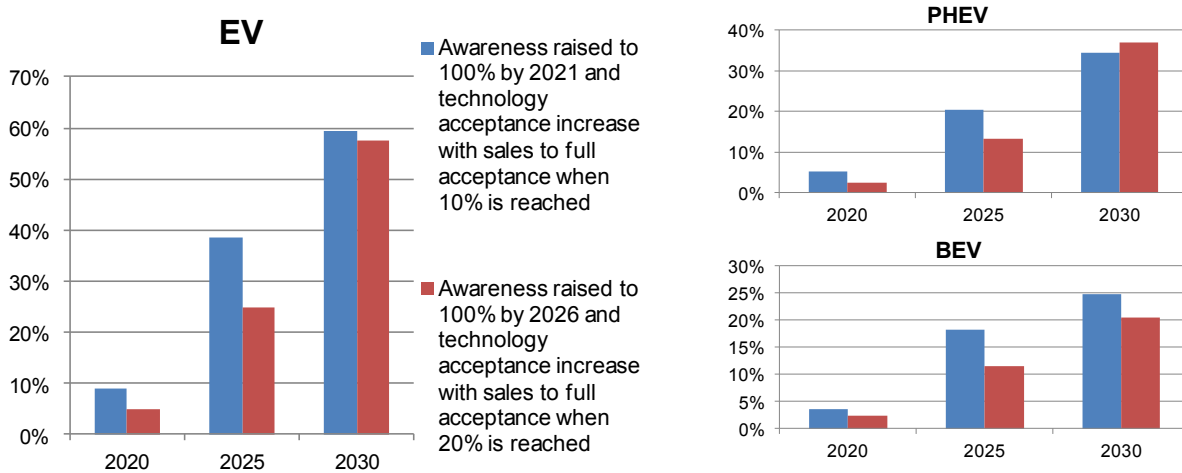
While delaying awareness and acceptance has significant impact on market share in 2020 and 2025, it has little overall impact by 2030 as full awareness and acceptance is eventually reached, albeit at a later date<sup>203</sup> – see Figure 41. Interestingly, the breakdown by PHEV/BEV shows the impact to be

<sup>202</sup> See Appendix 10.4.1 for details on the scenario and corresponding penalty values

<sup>203</sup> Note this is not entirely consistent with the assumed good supply and the deployment of a visible rapid CP network; this is a sensitivity test only.

technology dependent, to the advantage of PHEVs: which gain market share at the expense of BEVs (due to a higher bias against BEVs).

Although a change in attitudes can only be modelled to first order, these results highlight that the uptake of BEVs is more dependent than PHEVs on a change of attitudes by the more resistant consumer segments. It also illustrates that not reaching 9% in 2020 (and approx. 40% in 2025) should not be interpreted as a sign that the 60% market share target cannot be met in 2030.



**Figure 41 Market share of EVs. Impact of delayed awareness and slower technology acceptance (all other action targets met)**

In the extreme case where EV acceptance does not improve with increasing sales, i.e. the bias against EVs displayed by some consumer segments does not decrease with time, the equivalent value support required to reach the EV uptake targets would need to be increased from £2.5k per EVs post-2020 to £4.5k post-2020 and £5.5k post 2025.

**Impact of fleet managers displaying technology bias**

Given the importance of fleets regarding vehicle sales, the awareness and acceptance of EVs by organisations and businesses is a key factor in the pathway to 2030. Figure 42 shows that, assuming fleet decision makers adopt a ‘rational’ approach to vehicle choice based on TCO and technology suitability,<sup>204</sup> the market uptake could reach 9% by 2020 and 60% in 2030.

However, if fleet vehicle selection is made with the same technology preferences as private car buyers,<sup>205</sup> the market share will be significantly lower; around 5% in 2020 and around 45% in 2030, despite the provision of equivalent value support (£3,000 post-2015 and £2,500 post-2020) and the roll-out of a rapid charging network (as discussed previously). Within EV sales, the share of BEVs is most impacted; a reflection of the Mass market buyers’ preferences.

Although the EV market is at a very early stage, current UK statistics of EV sales suggest that this sensitivity test of fleet managers’ technology preferences is highly unlikely to represent the future market as sales to date do not currently show a strong fleet buyer preference for PHEVs over BEVs.

<sup>204</sup> Modelled through filtering process based on access to overnight charging and, for BEVs, driving range compatibility with duty cycle, see 4.2 for details

<sup>205</sup> This is modelled by assigning a technology acceptance penalty to fleet managers



'Rational' fleet managers; if their range need can be met by BEVs they do not have a bias against BEVs. If access to overnight charging, no penalty against EVs.

Fleet managers display same technology preferences than mass market private car buyers, i.e. high penalty against EVs

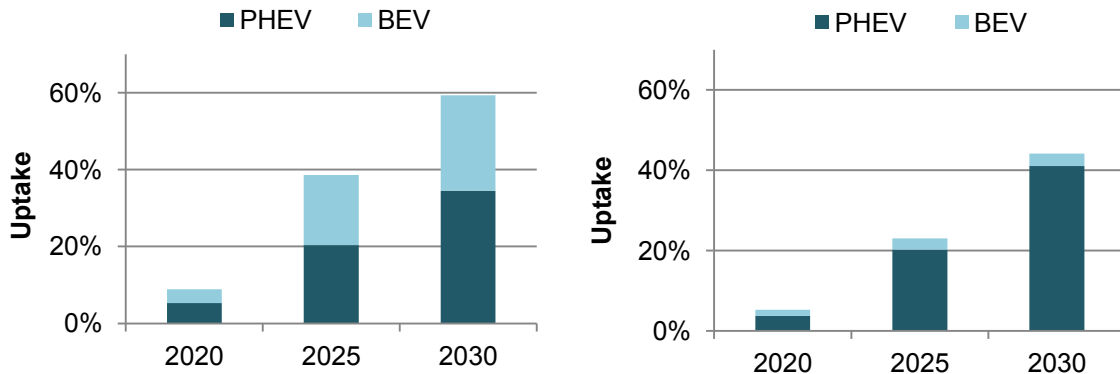


Figure 42 Market share of EVs to 2030 if action targets are met, depending on level of fleet acceptance of plug-in vehicles (cars and vans)

Under the assumption that fleet managers are rational (vehicle choice based on TCO and technology suitability), the model predicts that in 2020 fleets will account for 30% of the total EV market, and 50% of the BEV market – see Figure 43 (left).

If the awareness campaign is successful at increasing awareness levels to 100% but fleet managers are biased against EVs (or do not have the technical data needed to assess the suitability of EVs for their operational requirements), the uptake of EVs will rest mainly on the 'Enthusiast' private car buyers (who are already prepared to pay a premium for EVs) and company car recipients (the 'user choosers' whose high mileage make EVs more attractive through running cost savings but who, like other private buyers, show a strong preference for PHEVs over BEVs) – see Figure 43 (right).

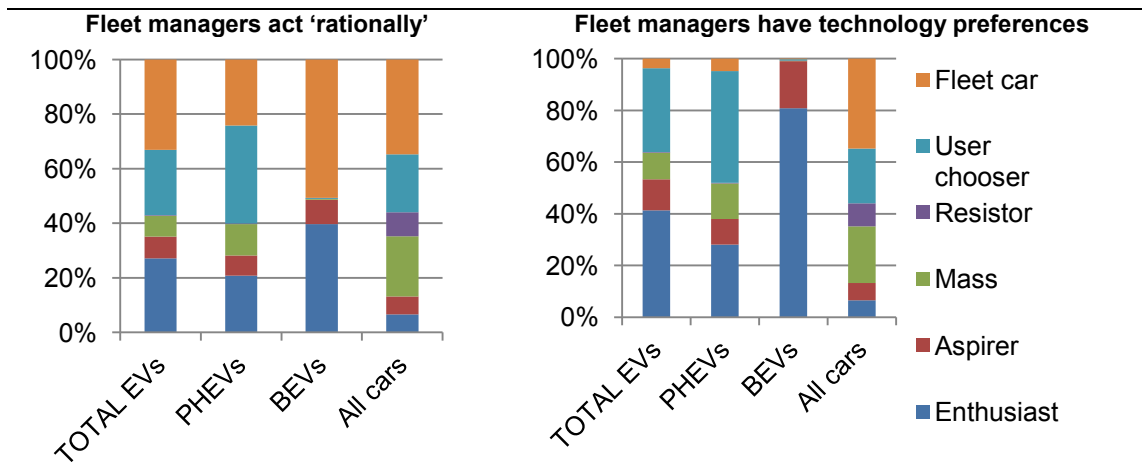
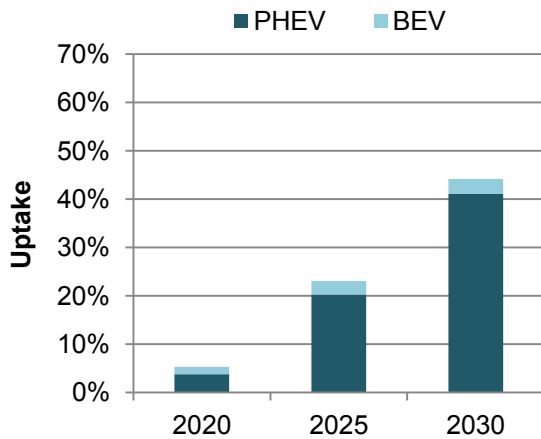


Figure 43 Consumer segment sales in 2020, depending to fleet attitudes to EVs

Assuming that fleet managers display with the same technology preferences as private car buyers (i.e. high penalty against EVs), with a baseline equivalent value support of £3.0k per EVs to 2020, £2.5k post-2020, the EV market in 2030 is dominated by PHEVs – see Figure 44 (left). This is because the penalty against EVs is more pronounced for BEVs than for PHEVs.

To achieve the 60% high EV market pathway for 2030, and also to ensure that BEVs are well represented (>20% market share) in the fleet, the **equivalent value support post-2020 would have to be increased to £4.5-5.0k per EV for BEVs** (while maintaining support for PHEVs at the original level of £2.5k per EV) – see Figure 44 (right).

Original pathway equivalent value support post-2020: £2.5k for EVs



New equivalent value support to achieve uptake target: £5k (2021-25) and £4.5k (2026-30) for BEVs (£2.5 for PHEVs)

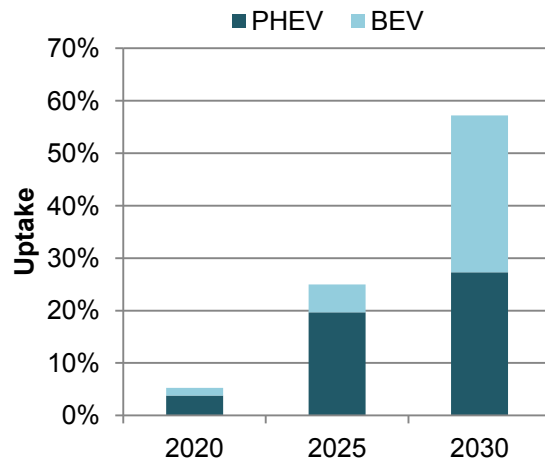


Figure 44 Comparison of EV market share breakdown (PHEV/BEV) under different equivalent value support in the case of fleet managers displaying the same technology preferences than Mass Market buyers (all other action targets met)

### 5.7.2 Sensitivity of model results to EV charging assumptions

This sub-section assesses the impact of changing the extent of the EV charging network assumed by the high EV uptake pathway: for both overnight charging and day charging infrastructure.

#### Overnight charging

If, instead of 70%, only 50% of buyers are aware they can install a charge point for overnight use (e.g. tenants less likely to install home-based CP), the high uptake EV uptake projection is moderately impacted, the uptake falling from 60% to 53% by 2030 – see Figure 45 (left).

However, achieving the 2025 and 2030 targets as per the high EV uptake pathway would then require a significant **increase in equivalent value support: from £2.5 to £3.0k post 2020, increasing to £3.5k per EV post 2025** – see Figure 45 (right). A high equivalent value support is necessary as access to overnight charging is a pre-requisite for most EV sales<sup>206</sup>: the lower access level reduces the EV market base among which a very high uptake must be achieved to reach the overall 60% target. Note that if access to overnight charging is reduced by this level, the PHEV/BEV market share is not significantly altered.

<sup>206</sup> Overnight charging is a pre-requisite for BEVs (and for PHEVs for fleet managers); lack of access is a penalty for PHEV purchase for private consumers – Section 4 for detailed decision process assumptions.

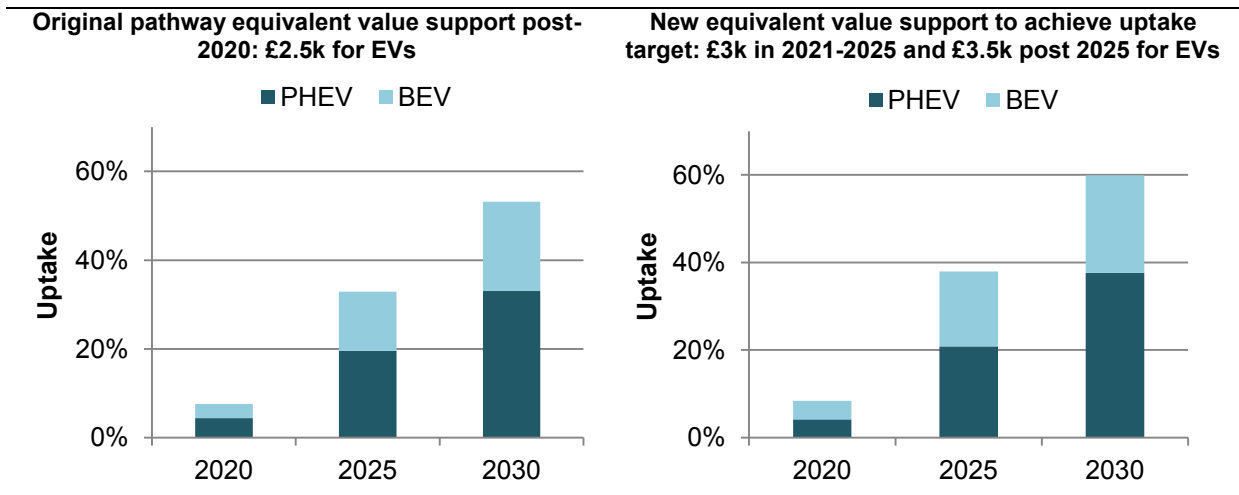


Figure 45 Comparison of EV breakdown (PHEV/BEV) under different equivalent value support if only 50% of buyers are aware of the overnight charging opportunity (versus 70% in baseline; all other action targets met)

Day charging infrastructure

Without the full deployment of a reliable rapid charging network and related attributes, the high EV uptake projection is significantly impacted, the uptake falling from 60% to 45% by 2030 – Figure 46. The proportional share of BEVs (compared to PHEVs) is also reduced due to their higher dependence on a comprehensive rapid CP network.

Achieving the 2025 and 2030 targets as per the high EV uptake pathway would then require a significant increase in equivalent value support: from £2.5 to £4.0k post 2020, increasing to £5.0k per EV post 2025 – Figure 46. This high level of support is necessary as fewer buyers can consider an EV (as commented before and illustrated in Figure 38); even for EV users with access to overnight charging, the utility of EVs is lower than in the case of a charging network deployment.

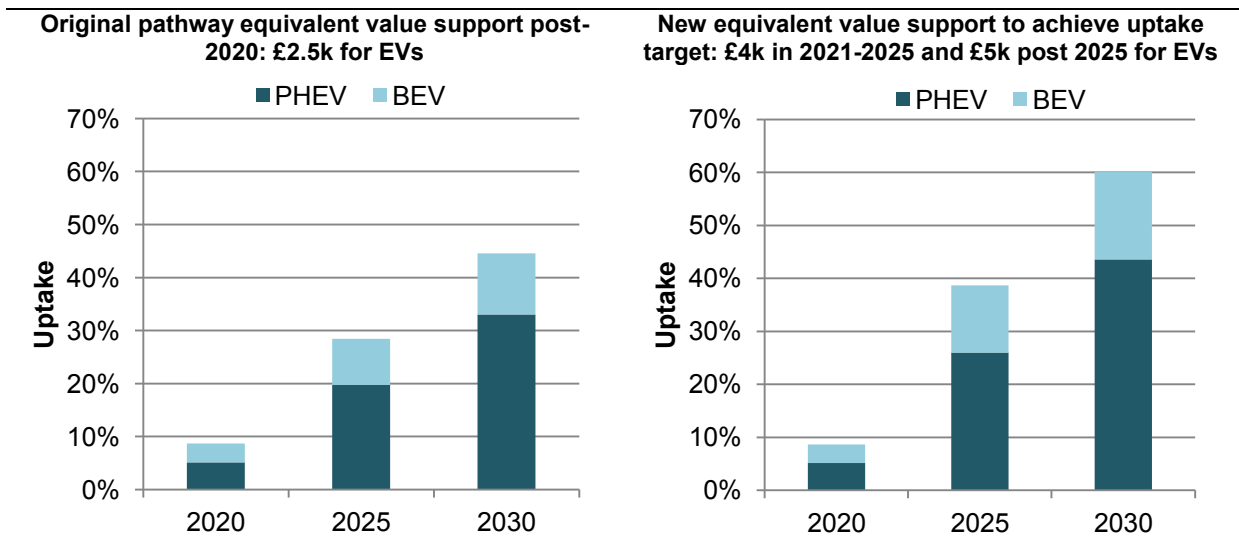


Figure 46 Comparison of EV market share breakdown if the infrastructure action target is not met and needed equivalent value support to reach the set uptake target

The efficient use of resources potentially offered by a rapid charging network can be illustrated by converting the capital cost invested in the network to a cost per BEV sold. Figure 47 shows that based on the high cost estimate (presented in Section 5.5), the annual network capital expenditure per BEV sale decreases from £260 in 2016 to £70 by 2030,<sup>207</sup> which provides very good value compared to the additional equivalent value support that would otherwise be necessary to compensate EV user uncertainty should rapid day charging not be widely available (which would increase from £2,500 to £5,000 per EV post-2025 – as discussed above).

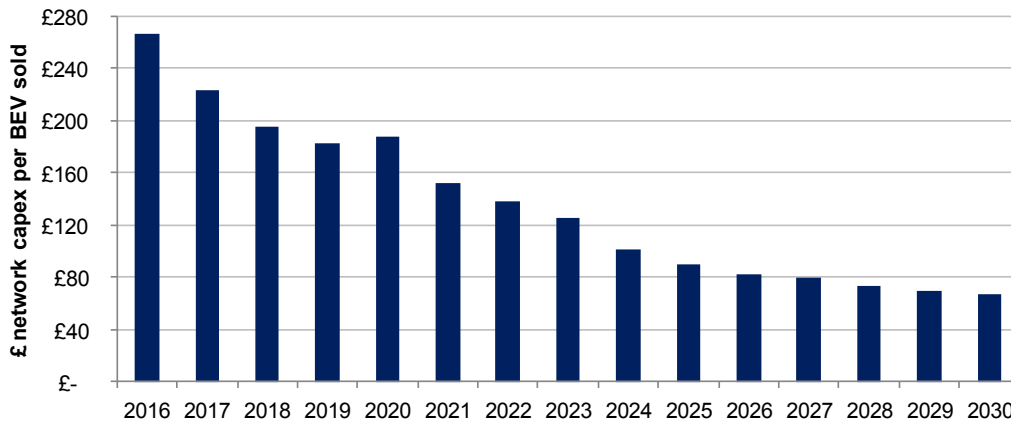


Figure 47 Annual capital cost of rapid charging network per BEV sold, £/BEV

### Access to normal public infrastructure for PHEVs

To reflect the growth in the normal (3-7 kW) charging network, the share of buyers that perceive normal CP access (for PHEVs) is increased in the model, in line with the increase of the rapid network perceived coverage, with a ratio set at 0.6, i.e. from 0.6% in 2015 to 60% in 2030 (vs. 1% and 100% for rapid network for BEVs). Based on the projected number of public and workplace CPs of around 21,000 posts by 2015<sup>208</sup> and an estimated 3-4 million car park places in the UK<sup>209</sup>, the figure of 0.6% in 2015 is close to the actual coverage. The 0.6 ratio is kept, somewhat arbitrarily, constant but has overall little influence on the model results: if buyers perceive no access to public infrastructure for PHEVs, the 2030 EV uptake is decreased from 60% to 58%, and reaching 60% requires an increase in equivalent value support, for PHEVs only, from £2,500 to £2,800 post-2025.

A 60% perceived coverage by 2030 would involve a continued high annual growth in number of installed public CPs and/or a high ratio 'perceived/ real' coverage (consistent with the assumed acceptance of the technology). In the case of PHEVs, it is not clear if the current ratio of perceived to actual coverage is lower than unity as there is no 'range anxiety' factor; the results are however not sensitive to this input (as discussed above and shown in the Appendix). The 60% share of buyers that perceive access is thus not converted into a target number of charging points.

The reasons for the normal charging access having little impact on the overall EV uptake include the assumption that fleet managers consider PHEVs only if they have access to overnight charging; a public infrastructure of slow chargers do not influence this. Secondly, the fact that most private buyers already have access to overnight charging means the added value of a public infrastructure is small for most buyers.

<sup>207</sup> It should be noted that this cost assessment does not include the rapid chargers impact on distribution and transmission costs – these are evaluated in a parallel study (“Characterisation and cost of infrastructure to 2030”) also commissioned by the CCC.

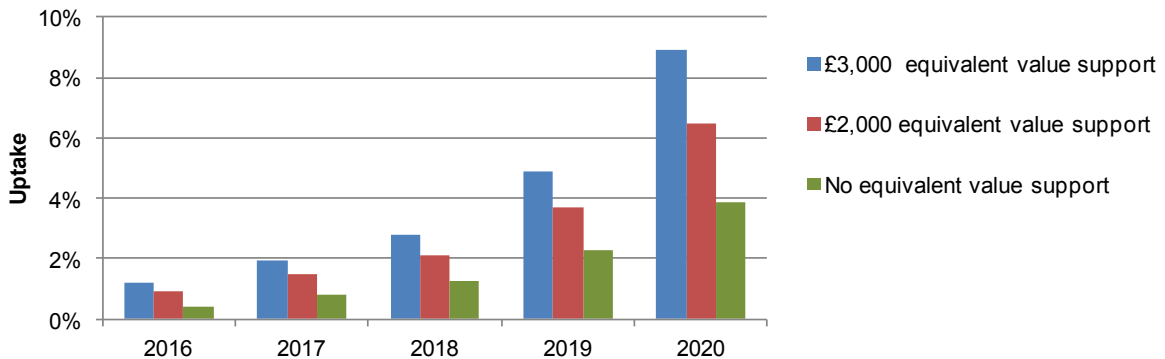
<sup>208</sup> Authors’ analysis, based on current numbers plus allocation of OLEV funding

<sup>209</sup> RAC Foundation report, Spaced out, perspectives on parking policy, 2012 – Commented in more detail in section 3.3

### 5.7.3 Sensitivity of model results to equivalent value support and cost inputs

This sub-section assesses the impact of changing the level of equivalent value support provided (in financial and/or non-financial forms) on future EV market share. The analysis also assesses the potential market impact of future reductions or increases in projected EV production costs.

Figure 48 illustrates the impact on market share of providing different levels of equivalent value support (assuming all other action targets are met) and demonstrates that, even if the majority of consumers are sufficiently aware of EVs (as already assumed) and that EV supply is high, **without equivalent value support (beyond existing support such as tax differentials), the market share would remain below 4% in 2020.**



**Figure 48 Market share of EVs to 2020 for different level of equivalent value support (assuming all other action targets are met)**

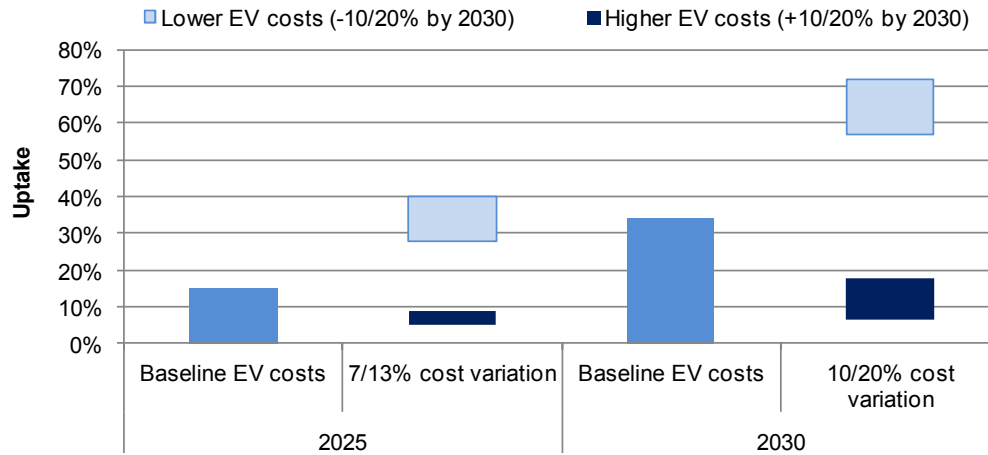
The analysis detailed above is based on vehicle cost and technical performance projections developed for the Committee on Climate Change (as described in Section 10.4.2), that forecasts that EVs will still have a significant capital cost premium over ICE vehicles by 2030.

In the context of the high EV uptake pathway, and assuming other countries also implement ambitious incentive programs, it is interesting to consider the impact on market share of a reduced production cost for EVs. Two cases are considered: a 10% and 20% variation in the 2030 costs. The variation is time dependant, for example the ‘-10% by 2030’ applied to EVs costs means 0% change is applied in 2016, - 3% in 2020, -7% in 2025 and -10% in 2030.

Figure 49 plots the uptake of EVs if all action targets are met except the equivalent value support (none applied), for the baseline cost inputs and when EV cost are decreased by 10% or 20% by 2030 (light blue) or increased by 10/20% (dark blue).

The modelling predicts that, the EV uptake target would be exceeded (70% market share reached) under the lowest **(-20% by 2030)** cost trajectory and almost reached for the -10% case, *without any equivalent value support post-2015*. **For the high EV pathway target of 60% to be exactly reached without the need for any equivalent value support, an EV production cost decrease of 12% by 2030 is necessary.**

Conversely should the production costs of EVs be 10% or 20% higher than in the baseline by 2030 would result in a UK market uptake of less than 20%, despite the supply, awareness and infrastructure action targets being met in full. **Should therefore EV production costs be 10%-20% higher than assumed, the model indicates reaching the 60% uptake target would require a equivalent value support of at least £5k per EV in 2030.**



**Figure 49 Market share of EVs in 2025 and 2030 for baseline EV costs and higher and lower EV costs, (assuming no equivalent value support but all other action targets met)**

### 5.7.4 Sensitivity of model results to consumer payment terms

This sub-section assesses the impact of changing the payment terms of EV purchases – in particular replacing the EV capital premium with an extended lease purchase agreement – on market uptake.

The sensitivity results presented above illustrate how the capital cost assumptions greatly influence the uptake of EVs – and thus the level of equivalent value support needed to reach the target uptake. Related to this cost barrier is the way consumers trade-off capital cost premium and running cost savings. In the baseline model, private consumers are assumed to balance running cost savings against any capital cost premium over a 2 to 7 year period (with variation across consumer segments); fleet managers are assumed to compare the TCO of vehicles over 4 years.<sup>210</sup>

If, as a sensitivity test, these time horizons are extended, setting all private consumers at 7 years and fleet managers at 6 years, the equivalent value support needed to reproduce the high uptake pathway is reduced post-2020 from £2.5k per EV to £1.5k. While this is a significant reduction, the remaining equivalent value support is still considerable.

While there is no evidence of a shift in time horizons (and hence discount rates) used by private and fleet car buyers, new ownership models already emerging in the EV market may effectively have the effect of extending the periods over which vehicles are purchased. One such example is where the battery (and possibly the vehicle) is leased instead of being purchased outright (examples of schemes on offer are discussed in Section 6.1.3).

The choice model can be used to assess the impact of vehicle/battery leasing on market uptake. While a leasing scheme where the capital cost premium of EVs over ICEVs is spread over 4 years (typical of leasing terms on the market today)<sup>211</sup> has no impact on the uptake of EVs – as 4 years is close to the average time horizon of UK buyers<sup>212</sup> – spreading the battery cost over longer periods has a strong impact on the EV market.

<sup>210</sup> Based on consumer research, see Section 3 and 4

<sup>211</sup> When leasing the battery, the Nissan Leaf is £5,000 cheaper up-front, with monthly fee ranging from £70 to £129 (depending on length of contract and mileage). In the case of the Smart fortwo ED, the price reduction is £3,120 and the monthly lease £55 (no mileage limit). <http://www.cars21.com/news/view/5397>

<sup>212</sup> It translates into an average discount rate of c. 20%, see Appendix 10.4.1 for details



Table 13 shows the results of modelling two extended leasing periods (8 and 12 years) and compares the equivalent value support required to deliver the high EV pathway. Under the extended lease period, the capital cost premium of EVs over the ICEV is removed and instead repaid on a monthly basis, based on a 3.5% interest rate.

The results show that, assuming the previously defined action targets are met in full (vehicle supply, consumer awareness and acceptance, and charging infrastructure), **the equivalent value support needed to reproduce the high EV pathway is significantly decreased under a repayment scheme: from £2k per EV post-2020 to £1k-£1.25k for a 8 year period, and £0.75k for a 12 year period.**

**Table 13 Comparison of equivalent value support required to reach the uptake targets, with and without a repayment scheme in place**

Case	Equivalent value support per EV		
	2016-2020	2021-2025	2026-2030
High EV uptake pathway	£3,000	£2,500	£2,500
Repayment scheme - 8 years	£1,000	£1,000	£1,250
Repayment scheme - 12 years	£750	£750	£750

It should be noted that the choice model does not include market generated data regarding consumer response to battery leasing options, and as such only models the impact of battery leasing scheme or new car ownership models by extending the time periods over which costs are considered. To more fully understand the robustness of the modelling conducted, EV and/or battery lease pricing options and subsequent sales will have to be monitored over the next few years to better quantify the actual consumer response to new models of vehicle ownership. Consumers’ response could be more positive than indicated by the current model (e.g. with EV buyers embracing leasing as a way of removing concerns over battery residual value) or more negative (e.g. consumers may be reluctant to abandon the conventional ownership model or consider outright purchase to be better value). Nonetheless, the results indicate the level of equivalent value support required could be significantly reduced through a different approach to electric vehicle purchase.

### 5.7.5 Summary of sensitivity results

In the high EV uptake pathway developed for this study, the model suggests that the equivalent value support required is significant and necessary until at least 2030.

Table 14 summarises the per EV equivalent value support as forecast by the model, depending on the degree to which other (non-cost) action targets are met.

The results show that, under the baseline assumptions, a post-2020 equivalent value support of £2,500 per EV is the minimum level of support required. Conversely, the results also show that, using extended battery lease options, the equivalent value support would be significantly reduced (by a factor of two or three under an 8 or 12 year scheme respectively).

Table 14 Summary of equivalent value support variations

Under vehicle supply trajectory and following action targets / assumptions:	Equivalent value support per EV to reach 2020 and 2030 uptake targets
Awareness and acceptance action targets met All charging infrastructure action targets met	£3,000 to 2020 £2,500 2021-2030
Awareness and acceptance action targets met All day charging infrastructure action targets met <i>but only 50% (not 70%) of private car buyers have option to charge overnight</i>	£3,000 to 2020 £3,000 2021-2025 £3,500 post-2025
Awareness and acceptance action targets met Overnight charging action target met but <i>no day charging infrastructure targets (rapid network and related attributes)</i>	£3,000 to 2020 £4,000 2021-2025 £5,000 post-2025
Awareness and acceptance targets met <i>but fleet managers display the same technology bias against EVs as Mass Market consumers</i> All charging infrastructure action targets met	£3,000 to 2020 £5,000 2021-2025 and £4,500 2021-2025 for BEVs £2,500 post-2020 for PHEVs
Awareness targets met <i>but acceptance of EVs do not increase among consumer segments currently biased against EVs</i> All charging infrastructure action targets met	£3,000 to 2020 £4,500 2021-2025 £5,500 post-2025
Awareness and acceptance action targets met; All charging infrastructure action targets met <i>Battery repayment scheme for EVs (over 8 to 12years, 3.5% interest) from 2016</i>	12 year horizon: £750 to 2030 8 year horizon: £1,000 to 2025 £1,250 2026-30

Excluding extended leasing options, the primary reason for equivalent value support being required in the long term is the cost premium of EVs over ICEVs that remains significant until at least 2030 (approx. 10% for PHEVs and 20% for BEVs in 2030) together with the fact that car buyer behaviour is particularly dependent on capital cost. However, the model also shows that should EV costs be 12% lower than the baseline costs by 2030, no equivalent value support would be needed to achieve the high uptake pathway. That said, this level of cost reduction would be unlikely to result solely from reductions in battery costs, as a 12% EV cost reduction would represent a 42% reduction in baseline battery costs (assumed to be £113/kWh for battery packs in medium to large cars and vans in 2030).

While long term model inputs (such as vehicle costs and functionality) are uncertain, the order of magnitude of the findings presented (regarding the level of equivalent value support required) indicates the potential scale of the funding and policy challenge that will be needed to secure high uptake of EVs. (Other input scenarios were tested and show similar level of equivalent value support – see Appendix 10.5.2). The results also highlight two key strategies which could accelerate EV adoption: new ownership models and future reductions in EV production costs.

Section 6 will discuss what measures can be put place to deliver the four key action targets developed for the EV pathway: vehicle supply, consumer awareness and acceptance, charging infrastructure and equivalent value support.

Another interesting consideration is the impact of a reduction of the 2030 target, from 60% to 50% uptake e.g. in the case of emission reductions being achieved instead in other sectors than transport or from other transport technologies, without knock-on effects on EV market. The model shows that reaching a 50% target requires, on top of the rapid-charging network, a equivalent value support of £1,500 post-2020 (down from £2,500).

Fuel Cell Vehicles are an example of technology that could contribute to the target of 60% uptake of ZEV/EV by 2030; there are however some inter-dependencies between the EVs and FCVs markets – the case of FCVs is discussed in Section 7.

### Summary of Section 5

- The high EV uptake pathway targets set by the CCC are that EVs (BEVs and PHEVs, cars and vans) capture 16% share of new vehicle sales in 2020 and 60% by 2030. As a result of studying the supply of EVs (Section 2), this study recommends that the 2020 target be revised down to 9%, which would deliver a fleet of 0.7 million electric cars and vans.
- In the **vehicle supply** trajectory developed, within which the current release of EVs continues and accelerates, EVs are available in all vehicle segments over time. Key vehicle supply milestones are as follows. Number of EV variants by 2020: >50% small cars (BEV only); 15-30% medium cars; 10% large cars; >50% vans. By 2030: >60% of models have BEV and PHEV variants (exception of small cars < 50% of models have PHEV variant). The pathway to 60% target equates to UK EV sales of 275,000 EVs in 2020, which would represent around 12% of projected EU production capacity.
- Under this supply trajectory, the actions targets needed to reach 60% EV uptake in 2030 are:
  - **Consumer awareness and acceptance:** by 2021, it is assumed that all vehicle buyers are aware of EVs including their capabilities and associated incentives (albeit not all are necessarily disposed to buy one). All car owners with off-street parking are also aware of the available incentives for the installation of a dedicated socket for charging an EV;
  - **Charging infrastructure:** most of the charging is conducted overnight; with a national rapid charging network in place by 2030, providing actual and perceived coverage for all BEV buyers, and increasing the utility of BEVs for fleet operations. The cost of the rapid network is estimated at £300-£530 million (capital and installation), for approx. 20,000 posts over 2,100 sites by 2030. The deployment of this network broadens the BEV market base and significantly reduces the equivalent value support needed to reach the 2030 target. It is expected that the current trend of installing normal chargers will continue, providing some value to PHEVs buyers.
  - **Equivalent value support:** the model indicates an equivalent value support of around £3,000 per EV to 2020 and £2,500 post-2020 could be needed. This support is modelled as a vehicle price intervention but could be delivered through operational costs incentives or non-financial measures highly-valued by consumers.
- The high EV uptake model results are particularly sensitive to:
  - Vehicle cost: overall the model indicates that, under the baseline vehicle costs, the cost premium of EVs over non EVs will remain a long term barrier to very high uptake. However if the cost of an EV is 12% lower than the baseline scenario in 2030, the model forecasts a 60% market share in 2030 without any equivalent value support. Related to this sensitivity to cost, modelling a 'repayment scheme' under which the cost premium of EVs is spread over 8 to 12 years greatly decreases the equivalent value support needed to reach the uptake targets.
  - Vehicle supply assumptions: under a very low rate of supply increase, the uptake of EVs is estimated to be around 20% in 2030, even with the other action targets met.
  - Acceptance of EVs by fleet managers: it is assumed fleet managers do not show technology preferences but rather base their choice purely on cost and practicality (charging access, driving range compatibility). If, however, fleet managers show the same level of 'rejection' of EVs as the Mass market buyers, the uptake of EVs is reduced from 60% to 40% in 2030.

## 6 Delivering the EV uptake pathway to 2030

This section summarises the key action targets and stakeholders necessary to deliver the high EV uptake pathway as detailed in the previous section. For clarity, the pathway targets are re-presented in Figure 50. Where the evidence is available, interventions available to deliver the action targets are assessed as to their effectiveness in promoting EV market share.

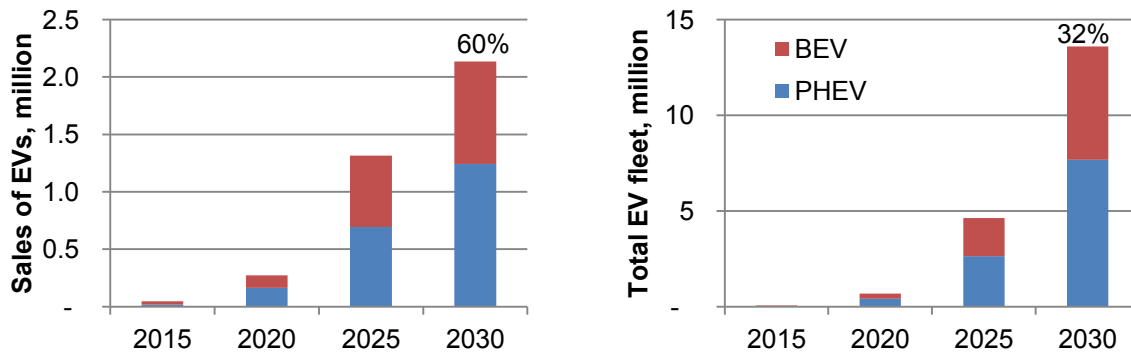


Figure 50 High EV uptake pathway targets: annual market share (left) and resulting EV fleet (right), million vehicles (cars and vans)

### 6.1 Stimulating vehicle supply

As highlighted by the choice modelling, meeting the challenging EV sales targets for 2020 and beyond is strongly dependent on the availability of high-quality EVs, with consumers (of all types) more likely to adopt electric powertrains if available across a wide range of models and brands.

Despite some disparity across different vehicle segments, the overall outlook for supply of EVs in the next few years is strong with over 10 new EV models being introduced into the UK market each year.<sup>213</sup> As highlighted by the sensitivity analysis on supply (in Section 5.7.1), in order to deliver the high EV uptake pathway, **the major OEMs must continue to release new EV models in the UK market at, or faster than, the current launch rate of over 10 new EV models per year.**

This section examines the issues and stakeholders influencing EV supply and assesses the key success factors required to achieve sufficient supply.

#### 6.1.1 The role of legislation

At the European level, supply-side regulation promoting low- and ultra-low emission vehicles (ULEVs) has until recently favoured a *minimum standards* approach and has tended to be technology-neutral (based on tailpipe emissions).<sup>214</sup> Since 1992, new vehicle emissions have had to conform to rolling ‘Euro’ standards, which limit the maximum level of four ‘regulated pollutants’<sup>215</sup>. While spark-ignition and compression engine cars have had to meet different standards, these have converged over time reflecting the on-going development of petrol and diesel engine technologies.

Only recently has a *sales mandate* approach been used within the European vehicle sector. In 2009, technology-neutral CO<sub>2</sub> emission sales targets for new passenger cars were adopted, each manufacturer required to achieve at least a fleet-average CO<sub>2</sub> target of 130 g/km by 2015 and 95

<sup>213</sup> Average new light-duty EVs launched in UK 2012-2014 based on historical data or as announced to date, see Section 2.3.2 for details.

<sup>214</sup> It could be argued that, in the extreme case, ‘zero-emission vehicles’ do in fact limit the technological options to battery electric and hydrogen fuel cell.

<sup>215</sup> The regulated emissions are: carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HCs) and particulate matter less than 10 microns in size (PM<sub>10</sub>).

g/km by 2020.<sup>216</sup> Under the original CO<sub>2</sub>-based legislation, ULEVs with CO<sub>2</sub> emissions of 50 g/km or less receive *super-credits*; an incentive to accelerate the early market uptake of EVs until 2016.<sup>217</sup> A review of the CO<sub>2</sub> regulations in 2013 confirmed the 2020 targets and proposed new targets for 2025 of 68-78 g/km.<sup>218</sup> The review also reintroduced super-credits from 2016, the ULEV threshold remaining open to further negotiation.

The key issue here is the extent to which the existing and future system of super-credits will succeed in stimulating EV supply within the EU. While a full assessment is beyond the remit of this report, a study conducted by Ricardo-AEA in 2013 concluded that, while super-credits provide a short-term incentive for ULEV production, they may lead to a weakening of the 2020 target.<sup>219,220</sup> Indeed, super-credits essentially ‘trade-off’ ULEV supply with total CO<sub>2</sub> reduction from new vehicles sales.

An alternative approach, and one supported by the Ricardo-AEA study, is a *flexible mandate* system which varies the qualifying thresholds used to define ULEVs as well as the targets for percentage sales in future years. The report concludes that, in the longer-term, this would be a more effective way of stimulating investment in ultra-low carbon technologies (including EVs), and would increase the likelihood of their adoption in order to meet ever tightening targets. A flexible mandate approach is also less likely to undermine the achieving of future CO<sub>2</sub> targets.

Whatever details are finally agreed, the European post-2020 CO<sub>2</sub> emission targets will be a key driver for the supply of electric powertrains within the EU and beyond. Whatever details are finally agreed, the European post-2020 CO<sub>2</sub> emission targets will be a key driver for the supply of electric powertrains within the EU and beyond. **The UK Government should therefore continue to engage in the debate at the levels of the European Commission and Parliament, to ensure that the agreed legislation is beneficial for EV (and low-CO<sub>2</sub>) market development** and to support the emerging EV manufacturing base.

**Key recommendation:**

- **The UK Government should continue to engage in the debate at the levels of the European Commission and Parliament, to ensure that the agreed legislation is beneficial for EV (and low-CO<sub>2</sub>) market development.**

### 6.1.2 Developing the UK manufacturing base

The sensitivity of the analysis results presented above to EV supply highlights the importance of investing in the UK automotive sector in order to support innovation, and secure the future UK manufacturing base for low carbon vehicles.<sup>221</sup>

The Government’s recent automotive strategy<sup>222</sup> notes that the UK automotive industry is already of strategic importance to the country accounting for 5.2% of manufacturing employment and 7.3% of

<sup>216</sup> The CO<sub>2</sub> targets for each manufacturer are mass adjusted to reflect the average mass of the passenger car fleet in the previous three calendar years. For vans, the corresponding CO<sub>2</sub> target is 175 g/km from 2016 and (provisionally) 147 g/km from 2020. <http://www.dieselnet.com/standards/eu/ghg.php>

<sup>217</sup> ULEVs currently receive 3.5 credits (2012-2013), with future credits counting as 2.5 cars in 2014, 1.5 cars in 2015, the system ending in 2016. <http://www.dieselnet.com/standards/eu/ghg.php>

<sup>218</sup> EU vote on cars CO<sub>2</sub>: <http://www.theicct.org/blogs/staff/eu-vote-cars-co2>

<sup>219</sup> Low Emission Car Measures Under the EU’s CO<sub>2</sub> Regulations for Passenger Cars. Ricardo-AEA, 2013. Report commissioned by Greenpeace and Transport & Environment (an environmental NGO based in the EU): <http://www.transportenvironment.org/publications/low-emission-car-measures-under-eu%E2%80%99s-co2-regulations-passenger-cars>.

<sup>220</sup> Under the new agreed proposals, even if all manufacturers made full use of the super-credit option, the 2020 target is only permitted to vary by 2.5 g/km (i.e. 97.5 g/km instead of 95.0 g/km).

<sup>221</sup> UK automotive sector includes 11 global vehicle and engine manufacturers: Aston Martin, BMW (MINI and Rolls Royce), Ford, General Motors (Vauxhall), Honda, Jaguar Land Rover, Lotus, MG, Nissan, Toyota and Volkswagen (Bentley).

<sup>222</sup> Driving success – a strategy for growth and sustainability in the UK automotive sector. Automotive Council, July 2013.



UK manufacturing output. Despite the economic downturn, the industry is the fourth largest automotive producer in Europe, and 14<sup>th</sup> globally.

There has been a range of support for UK production of ULEVs from both Government and industry over the last decade, including the establishment of a number of agencies, technology centres and other bodies, and significant levels of investment (see Box 5).

**Box 5 Support for ULEV production in the UK**

**Agencies**

With the objective of supporting UK production of ULEVs, five key agencies have been established during the last decade by the UK government through the Department for Transport (DfT), and the Department for Business, Innovations and Skills (BIS), in addition to significant industry investments. These are:

- The Centre of Excellence for Low Carbon and Fuel Cell Technologies (CENEX) established in 2005 to promote UK market development in low carbon transport technologies;
- The New Automotive Innovation and Growth Team (NAIGT) formed in 2008. At its outset, the industry-led NAIGT commissioned a major report which set out the future ‘roadmap’ of technology pathways (including EVs);<sup>223</sup>
- In response to the NAIGT report, the Automotive Council was established with the support of UK manufacturers to develop a long-term strategic framework for the industry;
- The Technology Strategy Board (TSB), established in 2007, was charged with promoting innovation within the automotive industry (as well as across other sectors). An early TSB funded programme was the Low Carbon Vehicles Innovation Platform (worth £200 million);
- The Office for Low Emission Vehicles (OLEV), established in 2009 as a cross-government team working to position the UK as a premier global market for ULEVs. With a budget of around £400 million until 2015, OLEV provides targeting funding for R&D, administers the Plug-in Car and Van Grants and is developing the national recharging network through capital support.

**Local Carbon Economic Areas**

In response to the Climate Change Act, in 2009, the Department of Energy and Climate Change (DECC) also established Local Carbon Economic Areas across the UK to support low carbon specialisation within the UK economy.<sup>224</sup> Two of these areas are specifically related to low carbon vehicles: the North East is designated as the provider of EV expertise, while the Midlands region is linked more generally to advanced automotive technology, which includes EV design.

**Catapult centres**

Integrating many of the R&D themes already described, 2011 saw the launch of the first of seven ‘Catapult’ technology and innovation centres designed to support UK product development. Funded by the Technology Strategy Board, R&D grants and the private sector, two of the centres have direct relevance to the automotive sector: High Value Manufacturing (HVM), and Transport Systems and Integration.<sup>225</sup> HVM, the first Catapult to become operational, has secured funds of over £200 million, and includes Jaguar Land Rover and Rolls-Royce among its partners.

**Industry investment**

The UK automotive industry has also invested significant resources of its own to support the domestic

<sup>223</sup> Automotive Council: <http://www.automotivecouncil.co.uk/wp-content/uploads/2011/07/COM-OH-Roadmap.pdf>

<sup>224</sup> Begley, J and N Berkeley. UK policy and the low carbon vehicle sector. Local Economy 2012 27: 705. First published online 14 September 2012. DOI: 10.1177/ 0269094212455003

<sup>225</sup> Catapult update: Shaping the network of centres. Technology Strategy Board, March 2012.



EV skills and manufacturing base, with over £6 billion of investment announced between 2010 and 2012.<sup>226</sup> Working through the Society of Motor Manufacturers and Traders (SMMT), an Electric Vehicle Group<sup>227</sup> has been established to focus on six key priorities, the majority aiming to improve the UK production capability, EV policy, charging infrastructure, technical issues, investment and consumer acceptance.

While it is not possible to *directly* attribute this extensive investment with an increased supply or production capacity of EVs, a number of notable developments have transpired relevant to EV production, many of which benefitted from the extensive Government and private sector support as outlined above – see Box 6. While covering low carbon ICEV as well as EV development, it is estimated that this investment will secure up to 30,000 jobs within the UK automotive sector and ensure that it will be well placed to capitalise on the global market shift to electric powertrains.<sup>228</sup>

**Box 6 Investment in North East boosts UK production of EVs**



Nissan has based production of both its advanced lithium-ion battery (from 2010) and European production of the LEAF in Sunderland (from 2013), securing the region as a key manufacturing base for EVs.<sup>229</sup> Indeed, Sunderland is now the third global manufacturing location for Nissan EVs.

The new production facilities, which represent a commitment of over £420 million, are expected to secure 2,250 jobs at Nissan and across the UK supply chain. The investment is supported by a £21 million Grant for Business Investment (GBI) from the UK Government and a proposed finance package from the European Investment Bank of up to £197 million.

As the UK's first designated Low Carbon Economic Area, the North East is a pioneering UK manufacturing base for EVs. The location of the North East Enterprise Zone sites next to Nissan in Sunderland reflects this ambition having already secured £50 million of public/private investment.<sup>230</sup>

Vantec, part of the Hitachi group, for example, has been supporting the Nissan car plant from its 39,000 square metre logistics plant since 2013. Gateshead College is also expanding onto the Enterprise Zone investing further in R&D and training in automotive low carbon technologies.

Evidence that the UK Government is committed to further supporting the market transition to EVs is provided by a major programme (announced in July 2013) which will see the Government and automotive industry each invest £500 million over the next 10 years in a new Advanced Propulsion Centre (APC) to support the development of new supply chains for low carbon vehicles.<sup>231</sup> The objective of the APC is to improve the positioning of the UK for powertrain development and manufacturing, and increase the UK's global market share for low carbon vehicle production.

The modelling conducted for this project results presented suggest that uptake is very sensitive to EV supply and that achieving the high EV uptake pathway will require that at least 10 models per year are launched in the UK every year, until all vehicle segments offer 50% or over EV variants. In order

<sup>226</sup> Driving success – a strategy for growth and sustainability in the UK automotive sector. Automotive Council, July 2013.

<sup>227</sup> <http://www.thegreencarwebsite.co.uk/blog/index.php/2009/07/01/smmt-creates-industry-wide-electric-vehicle-group/>

<sup>228</sup> Driving success – a strategy for growth and sustainability in the UK automotive sector. Automotive Council, July 2013.

<sup>229</sup> <http://www.nextgreencar.com/news/1759/Sunderland-plant-set-to-build-LEAF-EV>

<sup>230</sup> Driving success – a strategy for growth and sustainability in the UK automotive sector. Automotive Council, July 2013.

<sup>231</sup> <https://www.smmt.co.uk/2013/07/uk-motor-industry-and-government-commit-to-investment-and-long-term-growth-in-a-competitive-sector/>

to ensure this supply, Based on the evidence cited above, **this report supports the continuing high levels of UK and OEM investment into the low carbon vehicle sector with particular focus on electric vehicles**, if the high EV uptake pathway is to be achieved.

**Key recommendation:**

- **The modelling conducted for this project suggests that at least 10 new EV models per year will have to enter the UK market if the high EV pathways targets are to be achieved. To ensure this supply, this report supports the continuing high levels of UK and OEM investment into the low carbon vehicle sector with particular focus on electric vehicles.**

*The UK Government is to publish its next detailed strategy document on ultra-low emission vehicles in September 2013.*

### 6.1.3 The role of OEM controlled finance

Of the two million new cars registered in the UK in 2012, the title of at least 0.65 million fleet vehicles and at least 0.20 million private cars (together accounting for around 40% new car sales) remain with the OEMs and independent finance institutions (including banks), end users acquiring cars through leasing contracts (the most popular being contract hire).<sup>232</sup> For vans the proportion is higher at almost 50% (0.11 million sales).

Given that *captives*,<sup>233</sup> the finance arms of the major OEMs, account for around 20% of the corporate leasing market in Europe,<sup>234</sup> OEMs, therefore, remain the owners of 7%-10% of their own annual UK vehicle outputs (accounting for around 170 thousand cars and vans in 2012). As such, OEMs have pricing and management control over a significant proportion of the new vehicle fleet. This control over captive leased fleets can potentially be used to influence technology choice and manage the market supply of new technologies.

On the demand side, private UK car buyers are increasingly using finance to acquire vehicles, a method historically associated with fleet purchases. Whereas in 2006 only 45% of new private sales were bought on finance (including loans, hire purchase, and lease contracts), as of mid-2013, this has increased to around 70%, according to figures published by the Finance and Leasing Association (FLA);<sup>235</sup> the option gained most in popularity among private consumers being Personal Contract Purchase or 'PCP', which includes the option to own the vehicle outright at the end of the contract.

Building on these market trends, new leasing and ownership models potentially offer a significant opportunity to overcome the capital cost premium of EVs (and the high discounting rates of consumers). For example, to address high battery costs, several OEMs are already offering innovative ownership models by selling vehicles without the battery, which is provided on a separate lease contract, or only offering EVs on a lease basis. Vehicle and/or battery leasing removes consumer concern regarding component degradation and addresses resale issues, the lessor being in a better position than the consumer to assess residual values and place the vehicle (or battery) in the used car market.<sup>236</sup>

Since Daimler started offering a battery lease option in Europe, 97% of smart ED purchasers have chosen the lease option, confirming that the pricing structure is attractive to car buyers.<sup>237</sup> Other EV

<sup>232</sup> Authors' estimate based on data supplied by the BVRLA, FLA and SMMT – see Appendix 10.2.3. The proportion increases to around 60% if Personal Contract Purchases are included with other leasing agreements.

<sup>233</sup> The triumvirate of manufacturer, captive finance arm, and franchised dealer is a key provider of new cars and vans to the fleet market.

<sup>234</sup> Automotive Sales to Corporations. Booz & Company, 2009.

<sup>235</sup> [http://www.fla.org.uk/media/080812\\_motor\\_jun](http://www.fla.org.uk/media/080812_motor_jun)

<sup>236</sup> As noted in Section 5.7.4 the value vehicle buyers place on the battery leasing option has not been researched enough to be quantified and used in choice modelling. Therefore the impact of battery leasing schemes cannot be modelled accurately.

<sup>237</sup> <http://www.cars21.com/news/view/5397>

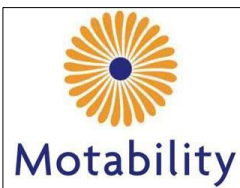
manufacturers are taking a similar approach. With the 2013 LEAF, Nissan now offer this financing option in addition to outright purchase.<sup>238</sup> More significantly, the Renault Z.E. range is only offered on a battery lease basis.<sup>239</sup> French sales figures (2013 Q1) for the Renault ZOE indicate a positive consumer response to this business model with the ZOE capturing 1.2% of total segment B sales in (compared with 4.5% of the 'Renault Clio market', the Clio being the closest ICE model to the ZOE in terms of vehicle size).<sup>240</sup>

For the reasons presented here, **this report recommends the use of new vehicle ownership and financing models for EVs**, e.g. through smart and targeted taxation (including capital allowances, which will be discussed in detail in the next section). Well established vehicle leasing providers should also be encouraged to **use existing financial instruments (such as contract hire and finance lease)<sup>241</sup> to promote EV uptake** – such as provided through the highly successful Motability Scheme (see Box 7) – as should new and emerging enterprises which offer mobility services (e.g. car clubs) as an alternative to vehicle ownership.

**Key recommendations:**

- **New vehicle ownership and financing models for EVs should be used to address the capital cost premium of EVs (and the high discounting rates of consumers);**
- **Well established vehicle leasing providers should be encouraged to use existing financial instruments (such as contract hire and finance lease) to promote EV uptake. In particular, the Motability scheme presents an ideal opportunity to promote EVs in a managed environment.**

**Box 7 Role of Motability Scheme in UK vehicle supply**



One UK market sector under direct control of OEMs, and with high potential for the managed introduction of EVs, is the Motability fleet. Established in 1978, the Motability Scheme offers cars at discounted rates to the higher rate recipients of the Disability Living Allowance (DLA) or War Pensioners' Mobility Supplement.<sup>242</sup>

In 2012, the Scheme accounted for around 10% of all car sales (around 0.2 million in 2012).<sup>243</sup> While most new models are available through the Scheme, OEMs have often used the fleet as a market buffer, the discounts providing an efficient method of placing surplus vehicles. While the size of the Scheme is predicted to fall following the replacement of the DLA with a new Personal Independence Payment (PIP) in 2012 – one forecast is a reduction of 50 thousand sales per year (to 7.5% total car sales)<sup>244</sup> – Motability is likely to remain a significantly large fleet supplying cars on contract hire (the most common type of lease agreement) to end users in the private market. As such is has the potential to supply large numbers of EVs on contract through an existing and highly financed and controlled environment.

<sup>238</sup> <http://www.nissan.co.uk/GB/en/vehicle/electric-vehicles/leaf/prices-and-equipment/prices-and-specifications.html>

<sup>239</sup> <http://www.renault-ze.com>

<sup>240</sup> Based on sales data from the Comité des Constructeurs Français d'Automobiles (French equivalent to SMMT). Renault introduced the battery leasing scheme but Renault EV models for sales in the UK have not been as successful as in France so far, due in part to the lack of acceptance by the auto industry. Several insurance companies are still not covering the Renault EV models as of May 2013. Leasing companies also have concerns over the battery contract and the vehicle resale process. Personal communication with Renault UK.

<sup>241</sup> BVRLA Guide to Vehicle Funding, March 2013.

<sup>242</sup> Economic and social impact of the Motability Car Scheme. Oxford Economics and Plus Four Market Research, 2010.

<sup>243</sup> Source: SMMT

<sup>244</sup> <http://www.fleetnews.co.uk/news/2013/1/15/insight-motability-fleet-set-to-shrink/45941/page/2/>

## 6.2 Raising consumer awareness and acceptance

In the high EV uptake pathway, **the consumer awareness action target is for the level of awareness to reach 100% by 2021**; indeed it is a precondition of the pathway (as is the roll-out of a comprehensive charging network) if the equivalent value support is to be limited to £3,000 per EV 2015-2020 (followed by £2,500 per EV 2020-2030).

Whereas the choice model assumes that Enthusiasts, Aspirers and fleet managers are either positive or neutral to EV choice throughout the EV pathway, the Mass market and Resistors will require persuasion to overcome their negative perceptions of EVs. This section examines the measures that can be used to increase consumer awareness and acceptance of EVs among these groups.

### 6.2.1 The role of information

While providing information is necessary but not sufficient to support behavioural change, the ‘deficit’ model – the assumption that if only people knew more they would act rationally and change their behaviour – is now largely discredited.<sup>245</sup> Instead, the evidence supports an alternative conceptual framework, one that includes social and psychological perspectives. This is particularly the case for car purchase given the high symbolic value attributed to vehicle ownership.<sup>246</sup> The implication is that providing information regarding the benefits of EVs is not enough on its own to persuade car buyers (who are not early adopters) to purchase or use EVs.<sup>247</sup>

Pro-EV information campaigns therefore need to adopt approaches more closely aligned with marketing than education. Indeed, some OEMs are doing just that. BMW, for example, is now positioning itself as an innovative vehicle and mobility services provider with the concept of the BMW *i*. The marketing strategy is based on a new ‘premium’ concept, which blends high quality with sustainability.<sup>248</sup> This approach is apparent throughout the recent global launch of the *i3*, BMW’s first all-electric model.<sup>249</sup>

Tesla has also done more than many other EV manufacturers to shape the future car market. Not only did it develop the first production BEV with a range of over 200 miles, with the Roadster it helped change perceptions of EVs from low to high performance vehicles. In June 2013, Tesla continued its disruptive influence by announcing the roll-out of a U.S. and European ‘supercharger’ network (see Section 3.3.3 and Box 8) and demonstrating a battery swap option for Tesla owners. In embracing celebrity endorsement, live performance and social media platforms, the style of the battery swap demonstration event was as innovative as the new service being developed.<sup>250</sup>

The key observation here is that **raising awareness of EVs among the public in general, and the Mass market and Resistors in particular, will require a concerted campaign that draws on the experience of large scale marketing campaigns going well beyond solely providing information.** The level of success (or otherwise) of future awareness campaigns could be tracked relatively easily through existing surveys such as the ‘Public attitudes tracking survey’ that is run

<sup>245</sup> Anable, J., Lane, B. and Kelay, T. (2006) An Evidence Base Review of Attitudes to Climate Change and Transport. Report for the UK Department for Transport, London.

<sup>246</sup> Anable, J., B. Lane, N. Banks. Car buyer survey: From ‘mpg paradox’ to ‘mpg mirage’: How car purchasers are missing a trick when choosing new and used cars. LowCVP, 2008. *Ibid*.

<sup>247</sup> Providing environmental information may even be detrimental to making the case for EVs. ‘Low carbon’ cars are often associated (by private buyers) with small cars, offering functionality at the expense of size and comfort – such cars tend to be accepted reluctantly rather than embraced.

<sup>248</sup> Electric Vehicles in Urban Europe (EVUE). URBACT, 2012: [www.urbact.eu/project](http://www.urbact.eu/project).

<sup>249</sup> <http://www.nextgreencar.com/news/6290/Watch-the-BMW-i3-launch-live-on-NGC>

<sup>250</sup> Tesla ‘fast pack swap event’, June 2013. <http://vimeo.com/68832891#>

several times a year by DECC<sup>251</sup> and the National Travel Survey that is run bi-annually by the Department of Transport.

**Key insight:**

- **In addition to providing consumer information, raising awareness of EVs among the general public will require concerted and sustained promotion that draws on the experience of large scale marketing campaigns.**

### 6.2.2 Consumer exposure to EVs

A key finding to emerge from global EV trials is the positive role played by test drives in increasing consumer acceptance of EVs. Between 2009 and 2012, for example, as part of the Ultra-low Carbon Vehicle Demonstrator Programme,<sup>252</sup> the consumer testing of 110 EVs in the West Midlands CABLED project,<sup>253</sup> found that private and fleet drivers' acceptance of driving performance, range and recharging significantly increased. **Begley and Berkeley (2013) consider further opportunities for consumers to gain direct experience of EVs to be: "critical to disseminate findings from the government-funded demonstrator trials to promote and improve awareness".**<sup>254</sup>

New mobility services can also play a role in demonstrating the market-readiness of EVs. OEMs and mobility service providers are increasingly offering short-term EV rental, services which are likely to deliver many of the promotional benefits demonstrated by EV trials. In 2011, for example, Peugeot included the use of the iOn as part of their 'Mu' short-term hire scheme, which is operated by participating Peugeot dealerships.<sup>255</sup> Another larger scheme is DriveNow, a joint venture launched in 2011 between BMW and Sixt that provides short-term car hire across five cities in Germany and San Francisco.<sup>256</sup>

UK car clubs, now well established with a customer base of over 150,000 members,<sup>257</sup> are also introducing electric vehicles into existing fleets alongside conventional vehicles. EV-only sharing clubs have also started to be introduced into UK (including 'E-Car' in Milton Keynes and 'Go-Low' in Bristol) emulating the Autolib' electric car scheme launched in Paris in 2011 - see Box 8. The French scheme allows a large number of drivers to experience driving an EV as well as raising the visibility of EVs.

**The authors contend that these new mobility services (car clubs and short-term rental) have great potential to raise the visibility of EVs among the wider UK public and therefore recommend increased support for their development and roll-out.** Given the complexity of setting up new EV mobility services, national and local government should explore ways to accelerate implementation of such schemes.

<sup>251</sup> <https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/public-attitudes-tracking-survey>

<sup>252</sup> Ultra-low Carbon Vehicle Demonstrator Programme. TSB, 2009. URL:

[http://www.innovateuk.org/\\_assets/pdf/press-releases/ulcv\\_reportaug11.pdf](http://www.innovateuk.org/_assets/pdf/press-releases/ulcv_reportaug11.pdf).

<sup>253</sup> Coventry and Birmingham Low Emission Demonstrators (CABLED) project. URL:

<http://www.arup.com/Projects/CABLED.aspx>.

<sup>254</sup> Begley, J and N Berkeley. UK policy and the low carbon vehicle sector. Local Economy 2012 27: 705.

Published online 14 September 2012. DOI: 10.1177/ 0269094212455003.

<sup>255</sup> URL: <http://www.mu.peugeot.co.uk/>.

<sup>256</sup> More radical than other schemes, customers use a smart phone 'App' to first locate vehicles, and then collect them from the parking space where they were returned by the previous customer. As of December 2012, the service operated over 1,000 (ICE and electric) vehicles, with a reported customer base of 60,000 users. URL: <http://en.wikipedia.org/wiki/DriveNow>.

<sup>257</sup> Membership also includes almost 14,000 corporate drivers. Carplus Annual Survey of Car Clubs Report 2011/12. URL: [http://www.carplus.org.uk/wp-content/uploads/2012/07/PPR612-Carplus-annual-survey-of-car-clubs-2011-12\\_London.pdf](http://www.carplus.org.uk/wp-content/uploads/2012/07/PPR612-Carplus-annual-survey-of-car-clubs-2011-12_London.pdf)



Taxi and minicab fleets are another service that could help to demonstrate the capabilities of EVs to a wider audience.<sup>258</sup> Indeed, at least two companies based in the South East are due to trial and/or launch all electric fleets in 2013-14: Greentomatocars, the first minicab service to use hybrid-only fleets, has partnered with Chinese manufacturer BYD to deploy 50 e6 BEVs,<sup>259</sup> and new entrant Thriev which is planning a chauffeured BEV service, trialling in 2013 with 200 cars, with 1,000 cars planned by the end of 2014.<sup>260</sup>

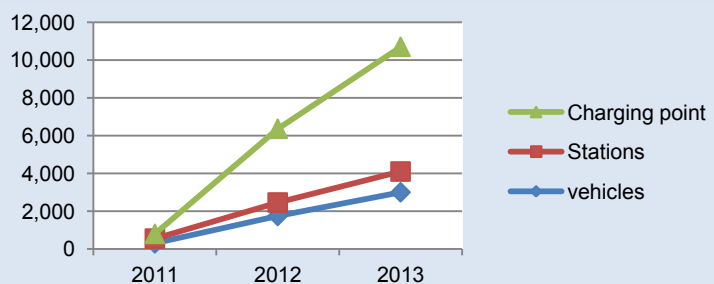
More traditional methods of providing test drives for prospective consumers are also being used to promote EVs. A number of innovative projects are leading the way in this regard including the Rotterdam Centre for EVs, a multi-OEM test drive and information centre for members of the public (see Section 10.1.2) and the Centre de Mobilité Électrique in Paris.

**Box 8 Autolib' scheme in Paris, France**

Autolib' is a car sharing scheme operating in Paris. The scheme was launched by the Bolloré Group in 2011, who also manufactures the Bolloré Bluecar BEV used for its entire fleet. To access the service, users choose a subscription type (year, month, week or day) and can then use a car for a small fee (€5 to €7 for 30 minutes), the car being returned to any car stations within the city.

At the scheme's launch, the company expected to break even in 2018 once membership had reached 80,000 subscribers<sup>261</sup>. However, uptake has been much more rapid than forecast with over 65,000 members joining by February 2013 (with over 0.5 million rentals and 15 million kms driven)<sup>262</sup>.

Total investment in the Paris scheme to date is at least €200 million,<sup>263</sup> including €75 million provided from the European Investment Bank<sup>264</sup>. Bolloré expects the scheme to become profitable in 2014<sup>265</sup> and is planning to launch next in Bordeaux.<sup>266</sup>



**Figure 51 Bolloré Bluecars (left)<sup>267</sup> and growth in Autolib fleet and infrastructure (right)**

<sup>258</sup> Assuming 700 EVs were deployed as part of London taxi/Personal Hire Vehicle fleet of 70,000 licensed vehicles, and that EVs used for 1% of the 300,000 daily taxi/PHV trips, EVs would carry over 1 million fee-paying passengers per year. Ref: Travel in London, Report 3. Transport for London, 2010.

<sup>259</sup> <http://www.nextgreencar.com/news/6239/BYD-trials-e6-electric-vehicles-in-UK>

<sup>260</sup> [www.thriev.com](http://www.thriev.com); personal communication

<sup>261</sup> <http://www.michelinchallengebibendum.com/en/NEWS-AND-PUBLICATIONS/News/Bolloré-s-BlueCar-could-break-even-by-2018>

<sup>262</sup> <http://www.lefigaro.fr/societes/2013/02/21/20005-20130221ARTFIG00507-la-bluecar-sera-vendue-12000-euros.php>, <http://www.leparisien.fr/transports/autolib/bolloré-lance-la-bluecar-en-region-parisienne-05-10-2012-2207469.php>

<sup>263</sup> Reuters: <http://www.mobile.reuters.com/article/CARMFG/idUSL5E7KT32W20110930>

<sup>264</sup> [www.eib.org/projects/pipeline/2011/20110479.htm](http://www.eib.org/projects/pipeline/2011/20110479.htm)

<sup>265</sup> <https://www.automotiveworld.com/analysis/96496-france-eib-lends-bollor-75m-for-autolib>

<sup>266</sup> <http://www.lesechos.fr/economie-politique/regions/aquitaine/0202662928475-bordeaux-confirme-autolib-fin-2013-552471.php>

<sup>267</sup> Image credit: Bolloré Bluecars recharging at an Autolib' station on Rue du Quatre-Septembre in Paris by Mario Roberto Durán Ortiz. [http://commons.wikimedia.org/wiki/File:Paris\\_Autolib\\_06\\_2012\\_Bluecar\\_2905.JPG](http://commons.wikimedia.org/wiki/File:Paris_Autolib_06_2012_Bluecar_2905.JPG)

**Key recommendations:**

- **Building on previous success of trials in raising the profile of EVs, the government and industry should support further opportunities for mainstream consumers to gain direct experience of EVs (including test-drives) to promote and improve awareness;**
- **Given their potential to raise the visibility of EVs among the wider UK public, national and local government should explore ways to accelerate the implementation of new EV mobility services.**

### 6.2.3 Designing a successful EV campaign

Achieving 100% EV awareness among UK car buyers by 2021 will require a significant and coordinated promotional campaign, of the type already being designed by key stakeholders. In partnership with the SMMT, the UK Government (working through OLEV) is to work with at least six major manufacturers on a public communication programme due to launch in late 2013/2014.<sup>268</sup>

While details have yet to be published, to be effective, the OLEV campaign will need to put in place many of the recommendations of Elkind (2012)<sup>269</sup> formulated in a U.S context, as well as the experience of initiatives being developed by the German auto industry and government. In summary these are as follows:<sup>270</sup>

- *Message:* should be simple and use consistent terminology;
- *Content:* inform potential consumers regarding the availability, cost and specification of new electric models;
- *Style:* EVs should be characterised as trendy, emotional, fascinating, modern, fun;
- *Audience:* Campaigns should find ways to get drivers to reassess their vehicle requirements; opportunities should be provided for EV test drives;
- *Infrastructure:* Charging options and availability should be highlighted;
- *Approach:* Campaigns should involve celebrities and well-known politicians;
- *Consistency:* Marketing approach, information and incentives must be highly coordinated.

It is important to note that shift in attitudes to new technology among non-receptive consumer segments will require promotional measures to be deployed over significant timescales. A study of diffusion and competition among alternative fuel vehicles by Struben and Sterman (2007)<sup>271</sup> found that favourable conditions for diffusion (such as a marketing campaign and exposure to the technology) are necessary for the market share to increase to a self-sustaining level and that, due to slow vehicle parc turnover, the marketing campaign would have to be sustained for twenty years.

OLEV's co-ordinating role in the forthcoming government-industry EV campaign is supported by Elkind (2012) who recommends that **EV promotional campaigns should be highly coordinated among stakeholders to be effective.**<sup>272</sup> It is also worth noting that other UK government departments (including DfT and DECC) and established agencies such as the Low Carbon Vehicle Partnership (LowCVP) and the Energy Saving Trust (EST) are also well placed to play an important

<sup>268</sup> OLEV announcement made at SMMT EV Group. London 28 February 2013.

<sup>269</sup> Elkind. E. N. Electric Drive by '25: How California Can Catalyze Mass Adoption of Electric Vehicles by 2025. Bank of America Climate Policy Associate for UCLA School of Law, September 2012.

<sup>270</sup> Electric Vehicles in Urban Europe (EVUE). URBACT, 2012: [www.urbact.eu/project](http://www.urbact.eu/project).

<sup>271</sup> Struben J., Sterman J, Transition challenges for alternative fuel vehicle and transportation systems, 2007, MIT Sloan School of Management, Cambridge MA 02142

<sup>272</sup> Elkind. E. N. Electric Drive by '25: How California Can Catalyze Mass Adoption of Electric Vehicles by 2025. Bank of America Climate Policy Associate for UCLA School of Law, September 2012.



role in this type of campaign, with (as is already envisaged) private sector marketing agencies being used for delivery.

To gauge the minimum cost of such a publicly funded campaign, previous campaigns of this type have included 'Are You Doing Your Bit?' (1998 to 2002) which cost £19.4m<sup>273</sup> and, more recently, 'Act On CO<sub>2</sub>' (2008-2010) which cost £5.75m.<sup>274</sup> The auto industry will also need to increase marketing spend through conventional and new channels (TV, websites, print, new media, brochures); one early example being Nissan's 'Big Turn On' campaign in 2012. It is worth noting that OEMs typically spend in the region of £50 to £70 million on the introduction of a substantially new or all-new model.<sup>275</sup>

Representing the auto industry, the SMMT is likely to play a central role coordinating OEM activity (e.g. through the EV Group and future forums). Potential promotional actions for OEMs (as identified by the authors of this report) include: **increasing spend on model-specific EV marketing campaigns, developing real-world EV performance (cost and range) metrics, training dealerships in order to support and inform prospective buyers**, as well as offering opportunities for EV test drives and demonstrations.

Given the importance of new vehicle sales to businesses, **fleets will need specific information and tools (including range, TCO, and payload) to be able to assess the suitability of EVs for their operations**. Agencies such as the Energy Saving Trust, CENEX as well as membership organisations such as the British Vehicle Rental and Leasing Association (BVRLA), the Institute for Car Fleet Management (ICFM) and the Association of Car Fleet Operators (ACFO) are already well placed to provide relevant information and support.

The first phase of the UK's Plugged-in Fleets Initiative<sup>276</sup> for example, highlighted the current low level of fleet related information<sup>277</sup> and recommended the wider use of data logging and route planning software – tools invaluable to assessing the potential fleet use of EVs. PiFi is already extending its reach, supporting a further 100 companies in its second phase.

Local government also has an important role to play promoting local incentives (including charging infrastructure) through existing channels of communication with residents and local community networks. As already discussed in Section 6.2.3, procuring EVs for public fleets will also demonstrate benefits to local residents and businesses.

With the high use of the internet for auto related consumer research, **the authors note that digital platforms will be central to any future EV campaign** for at least four reasons. First, at least a third of new car buyers use the internet at every phase of the car-buying process, with two thirds going online for information and to compare options.<sup>278</sup> Secondly, the internet can present complex information in a simple and personalised form. In the U.S., for example, the Department of Energy has launched the 'eGallon' tool to demonstrate to consumers that EVs are significantly cheaper to drive than conventional cars.<sup>279</sup> A recent study for LowCVP also highlighted the potential for 'hard-linking' paper based information to online resources where more detailed information can be provided.<sup>280</sup> Indeed the U.S. EPA Vehicle Label now includes a QR Code for precisely this reason.<sup>281</sup>

<sup>273</sup> Development of the UK's Campaign to Stimulate Public Action To Protect the Environment (March 1998 – October 2000). Department of the Environment, Transport and the Regions, November 2000.

<sup>274</sup> House of Commons, Hansard. Written Answers for 18 Jan 2010.

<sup>275</sup> <http://www.forbes.com/sites/dalebuss/2012/05/14/ford-invests-car-launch-size-budget-in-go-further-effort/>

<sup>276</sup> See Section 3.4. Plugged-in Fleets Initiative: Charging Forward. Energy Saving Trust, 2013.

<sup>277</sup> Based on 150 cases, one consultant estimates that no more than 5% fleets regularly monitor mpg/fuel costs. STS, *private communication*.

<sup>278</sup> The Role of the Internet in New Car Purchases, Netpop Research, 2011.

<sup>279</sup> <http://energy.gov/articles/egallon-how-much-cheaper-it-drive-electricity>

<sup>280</sup> Wallis, N. and B. Lane (2013). Electric vehicles: Improving consumer information to encourage adoption. European Council for an Energy Efficient Economy, Summer Study on energy efficiency 2013, paper 4-514-13.

<sup>281</sup> <http://www.epa.gov/carlabel/index.htm>

Third, vehicles of all types are becoming increasingly connected to the internet, with many of the major manufacturers planning to incorporate high levels of connectivity in new cars.<sup>282</sup> From 2014, for example, all cars sold by GM in the United States and Canada will come with 4G mobile broadband as standard.<sup>283</sup>

Fourth, not only is social media being increasingly used by marketing companies to reach potential consumers, it can also deliver peer-to-peer support and the sharing of experiences of early adopters with the wider, more conservative, community (e.g. the Resistors). Social-psychological research suggests that this is conducive to developing normative behaviours, which will be fundamental to any high level of EV adoption.<sup>284</sup>

**Key recommendations:**

- **While all key stakeholders (including OLEV and the SMMT) are well represented in the forthcoming government-industry EV campaign, established agencies such as the Low Carbon Vehicle Partnership (LowCVP) and the Energy Saving Trust (EST) have key roles to play in supporting EV adoption by private users and fleets;**
- **Regarding industry-led EV promotion, the authors recommend that OEMs: increase spend on model-specific EV marketing, develop real-world EV performance metrics, provide fleet-specific EV information and tools, prepare dealerships to support and inform prospective buyers, and increase opportunities for EV test drives and demonstrations.**
- **Given the increasingly important role played by digital media in consumer behaviour, and the rapid increase in vehicle connectivity, the authors recommend that digital platforms should play a key role in all future EV campaigns.**

### 6.3 Developing a national charging infrastructure

In the high EV uptake pathway, the charging infrastructure action target is a precondition of the pathway (as is the roll-out of a comprehensive awareness raising campaign) if the equivalent value support is to be limited to £3,000 per EV 2015-2020 (followed by £2,500 per EV 2020-2030).

As introduced in Section 5.5, the key infrastructure action targets are as follows:

- **Overnight charging: By 2020, all car owning households with off-street parking should have either installed a dedicated EV charging unit, or should be aware of the process of having one installed;**
- **Day charging: By 2020, the rapid charging network should provide coverage for 20% of drivers, increasing to 60% by 2025 and 100% by 2030.** The number of CPs per site will depend on the level of BEV usage; based on a high usage estimate, the authors estimate that around nine CPs per site would be sufficient, with a national coverage of 2,100 sites.

#### 6.3.1 Overnight charging infrastructure

As discussed in Section 3.3.2, not only did the £30 million Plugged-in Places programme (2011-2013) exceed its original target of supporting 8,500 CPs, it also succeeded in leveraging private sector

<sup>282</sup> <http://www.bbc.co.uk/news/technology-21411335>

<sup>283</sup> <http://www.economist.com/news/special-report/21576224-one-day-every-car-may-come-invisible-chauffeur-look-no-hands>

<sup>284</sup> Graham-Rowe E, Gardner B, Abraham C, Skippon S, Dittmar H, Hutchins R, Stannard J, 2011. Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations. Transportation Research Part A 46 (2012) 140–153.

investment to develop the UK’s EV charging network; the ratio of points funded by private/public sector increasing from 1.4 in 2010/11 to 2.0 in 2011/12.<sup>285</sup>

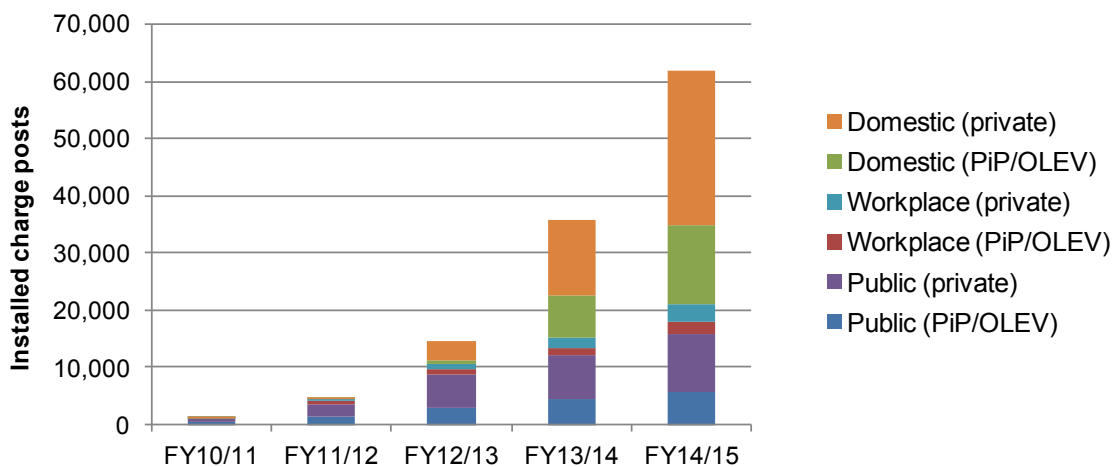
Regarding the near-term development of the UK charging infrastructure, in early 2013, the Office for Low Emission vehicles (OLEV) announced a second £37 million funding package for the further development of the UK’s charging network with a more targeted and particular focus on domestic, residential on-street, public estate and modal interchange sites.<sup>286</sup>

With respect to the specific infrastructure actions targets for overnight charging, and based on the typical unit costs already discussed (see section 3.3.2), the new OLEV funding for 2013-2015 includes an estimated provision for:<sup>287</sup>

- At least 13,500 domestic chargers (£13.5 million allocated);
- Around 1,300 residential on-street CPs (£8 million allocated);

Based on the existing installed network, projected OLEV spend for 2013-2015, together with an assumption that the private-public investment ratio will continue to increase to 3.3 in 2013/14 and 4.0 in 2014/15, the authors forecast a combined domestic and workplace network of almost 46,000 CPs by 2015, the majority being privately funded by that date – see Figure 52.

If the level of deployment continues at the current rate (with around 22,000 points being added between 2014 and 2015 and the private-public investment ratio being maintained at 4) the number of home and workplace CPs would be around 160,000 by 2020. Comparing this projection with the model estimate of 680,000 EVs (comprising 260,000 BEVs) on the road by 2020 suggests a steep acceleration in domestic/depot CP installation will be necessary to support the EV pathway; the model indicating an annual increase in the rate of installation of around 40% being required. This will require a strong, coordinated and long-lasting promotional strategy for home and workplace charging infrastructure until 2020 and beyond.



**Figure 52 Historical (2010-13) and projected (2013-15) UK charging infrastructure (cumulative)**

In the high EV uptake pathway, it is assumed that the availability of government grants for domestic CPs continues to be widely communicated. Once the announced OLEV funding has ended, it is also assumed that post-2015 consumers will still have access to sufficient public and/or private sector support such that costs do not present a barrier to widespread installation.

<sup>285</sup> Ratio based on data supplied by Department for Transport.

<sup>286</sup> <https://www.gov.uk/government/organisations/office-for-low-emission-vehicles/series/plug-in-vehicle-chargepoint-grants>

<sup>287</sup> The OLEV funding also includes provision for an estimated 1,600 CPs at train stations (£9 million allocated), around 700 public sector workplace CPs (£3 million) and 100 rapid CPs (£3 million).

Given current trends, it seems most likely that the private sector will dominate future infrastructure development. It will be imperative therefore that sources of private finance are fully engaged with the emerging EV market, and are able to generate value from investments, whether that be in monetary or less tangible terms (e.g. improved company image).

Before the end of the allocated OLEV budget in 2015, therefore, **the authors recommend an evaluation be conducted to determine if the expected private sector investment will be enough to deliver the scale of network required by 2020**, or if further support to investment will be needed before the private sector is in a position to fully support the further development of a home and workplace CP infrastructure.

As discussed previously, the projected EV market share is particularly sensitive to the acceptance of EVs by fleets. As fleet vehicles can either remain at the workplace overnight be parked at employees' homes, domestic infrastructure support must therefore also be communicated to fleet managers. Continued support may, therefore, be required to install charging facilities for fleet vehicles to enable overnight charging, either at depots or at employees' places of residence.<sup>288</sup>

As installing charge points in new builds and refurbishments is the most cost-effective way to increase home and workplace infrastructure coverage (due to low CP unit and installation costs), **it is recommended that local authorities adopt planning conditions that require all parking spaces in new developments to be fitted with an EV-ready socket**, or have at least the cables in place for a quick installation at a future date. This policy has already been adopted by Westminster City Council which has a 100% target for all new planning permits (including new builds, retrofits and change in use); with low domestic unit costs, developers have accepted the policy and internalised the costs of sockets.<sup>289</sup>

The London Plan (Greater London Authority, 2011) includes clauses that will result in an increased number of CPs located at workplaces and retail car parks. Under the Plan, 10% of all spaces at retail locations must be fitted with charging points (with an additional 10% passive provision for future EVs) and 20% in workplaces and residential locations (20% passive provision).<sup>290</sup>

**Key recommendations:**

- **An evaluation should be conducted to determine if the expected private sector investment will be enough to deliver the scale of the residential and workplace recharging network required by 2020;**
- **Local authorities should adopt planning conditions that require all parking spaces in new developments (residential and workplace) to be fitted with an EV-ready socket.**

### 6.3.2 Rapid charging infrastructure to 2030

The pathway date marking the start of a national *rapid* charging network deployment is 2016. By this date, the model assumes key stakeholders (mainly local authorities and car dealerships currently) begin to install 50kW DC charge points in a coordinated way. The action target then assumes that the rapid charging is available to 20% of drivers by 2020 (corresponding to 500 sites), increasing to 60% (1,100) by 2025 and 100% (2,100) by 2030.

<sup>288</sup> Special billing systems might have to be put in place for the vehicle electricity consumption to be billed separately to the employees' personal electricity use (such systems are emerging in the Netherlands).

<sup>289</sup> All car spaces must be fitted with a socket or be 'socket ready' i.e. the cables must be in place for an easy socket installation in future if demand requires it. Source: Westminster City Planning.

<sup>290</sup> London Plan 2011. Already in effect. 10% of spaces at retail parking must be fitted with socket and an additional 10% must be socket ready; shares are 20% and 10% for work place car spaces. Also: Land For Industry and Transport, Supplementary Planning Guidance, Greater London Authority, September 2012.

Based on the typical unit costs discussed in Section 3.3, the new OLEV funding worth £3 million for 2013-2015 includes a provision for up to around 100 additional rapid chargers (by 2015) which will effectively double the size of the current UK rapid network. Given the high units costs, it seems unlikely that national or local government will be able to play a significant role beyond 2015 in further developing rapid infrastructure. Instead, **new business models (e.g. pay-as-you-charge type services) will have to be developed, as will new service providers, to allow private sector enterprise to invest in the rapid network to achieve the coverage required.**

Outside of the UK, there is already evidence that the private sector is installing rapid chargers for public access and fleet use, suggesting the deployment of such a network will not have to rely on public funds alone. Tesla, for example are already deploying a US and European ‘supercharger’ network for their Model S users – see Box 9. In the Netherlands, Fastned is rolling out a nationwide 50kW DC charger network on highways.<sup>291</sup> In the UK, for example, Ecotricity are in the process of replacing their motorway based EV charging network of 3-22kW units with AC and DC 40kW+ rated chargers.<sup>292</sup>

**Box 9 Tesla to introduce a ‘supercharger’ network<sup>293</sup>**



Tesla has announced the intention to develop a U.S. coast-to-coast network of superchargers rated at 120 kW which will be able to half charge a Tesla BEV in around 20 minutes.

The first superchargers will be designed for Model S owners to travel for free between cities in North America, strategically placed to allow owners to drive from station to station with minimal stops. The superchargers are located near amenities like roadside diners, cafes, and shopping centres. Each station is estimated to cost in the region of \$100,000 and \$175,000.<sup>294</sup>

According to Tesla, 27 stations are to be installed by the summer of 2013, with an east-west coast-to-coast route in operation by the end of 2013. In the longer term, the aim is provide sufficient coverage for 80% of the US population and parts of Canada by 2014 and 98% of the US population and parts of Canada by 2015.

The business model being adopted by the company is to partner with owners of parking lots across the U.S. Tesla covers all installation, power and maintenance costs. In return, the owner of the parking spaces receives 4-6 ‘enabled’ parking bays for general parking for a limited period, with an additional 4 spaces being reserved for use by Tesla vehicle owners only.

Whilst the number of charging posts and their power rate are important to drivers, there are other factors which can increase the value of the network to drivers. A working group of European cities concluded that public charging locations must be easy to use, easy to find, and offer easy access and payment options to be considered valuable to EV users.<sup>295</sup> Some examples of positive initiatives include the energy company Fortum, which has installed CPs in Norway and Sweden. The CPs can be operated by a simple text (no need for a smart phone) and Fortum offers 24 hour helpline support.

Reflecting this, other issues included in the day/rapid infrastructure action target are that the UK network must be fully accessible to all consumers, with a choice of payment and subscription options

<sup>291</sup> 200 sites to be installed by 2015, starting in Sept 2013 <http://www.fastned.nl/en/2734/The-plan.html>

<sup>292</sup> <http://www.ecotricity.co.uk/for-the-road/our-electric-highway>

<sup>293</sup> <http://www.teslamotors.com/supercharger>

<sup>294</sup> <http://techcrunch.com/2013/07/26/inside-teslas-supercharger-partner-program-the-costs-and-commitments-of-electrifying-road-transport/>

<sup>295</sup> Electric Vehicle in Urban Europe, Final report, September 2012



as has been achieved in the Netherlands.<sup>296</sup> This report therefore recommends **the development of a common data platform to enable real-time mapping of rapid CPs and offer the option of setting-up a central booking system.** The network must also be 'visible', meaning that rapid CP locations must be mapped and physically signposted as well as petrol stations.

**Key recommendations:**

- **The Government should actively support the private sector to develop and deliver new rapid charging services to ensure adequate growth of rapid charging facilities across the UK;**
- **All stakeholders should work closely together to develop a common rapid charger data platform to enable real-time mapping and the setting-up of a central booking system.**

### 6.3.3 Importance of stakeholder coordination

While the focus for the infrastructure action target is to fully utilise overnight charging and deploy a national rapid charging network, stakeholders installing normal and fast public CPs will need to be highly coordinated to promote interoperability and national access.

Although the Source London and Source East networks became interoperable in 2012, and despite the emergence of new private networks (including POLAR and Charge Your Car) which combine a number of regional networks under one brand, there is as yet no integrated UK charging network as has been developed in the Netherlands and Portugal.<sup>297</sup> There is also a lack of centralised information regarding the location of public CPs.<sup>298</sup> In response to this identified need, in 2012, the Department of Transport launched the National Charge Point Registry (NCPR),<sup>299</sup> a resource that places location data into the public domain, alongside other private sector mapping tools;<sup>300</sup> it has improved significantly since being criticised for its poor coverage by the House of Commons Transport Committee in late 2012.

Regarding the coordination required for rapid CP development, **infrastructure suppliers and vehicle OEMs will need to finalise connector standards and communication system protocols within two years (by 2016).** While only a few standards are available, there continues to be some disagreement across regions as the most suitable DC connector solution, with some manufacturers using the Japanese JARI DC connector (CHAdeMO standard – see Box 3) and others wanting to adopt a new 'Combo' connector based on the Type 2 (already adopted by the European Commission) which incorporates additional DC capability.<sup>301</sup>

The central government already currently plays a key role (funding and developing policy) through the Office for Low Emission Vehicles (OLEV). There are however many other stakeholders installing charge points and offering network services (e.g. back-office support). All stakeholders will require **sustained coordination (regarding connectors, communication and payment systems) to ensure the CPs installed form a coherent national network with the aim of being interoperable, visible, and contractually inclusive.** This is particularly important for the emerging rapid infrastructure which must provide UK coverage, so allowing the mobility of BEV users nationwide.

<sup>296</sup> A range of subscription contracts are available from a variety of providers but drivers are given the option to recharge by paying a fee on site if they are not a member. Norway is implementing a non-exclusion policy, see Appendix 10.1

<sup>297</sup> See Appendix 10.1 for more detail on the Netherlands. Portugal has deployed a national scheme, 'MOBIE' that lets private stakeholders install CP but all under a single branding and system. Drivers get a card giving access to all CPs <http://www.mobie.pt/>

<sup>298</sup> House of Commons Transport Committee, Plug-in vehicles, plugged in policy? Fourth Report of Session 2012–13, Volume I, September 2012

<sup>299</sup> <http://www.nationalchargepointregistry.com/>

<sup>300</sup> For example, <http://www.zap-map.com/>, <http://www.pod-point.com/live-availability> ;

<sup>301</sup> <http://green Autoblog.com/2013/02/05/european-commission-decides-on-mennekes-type-2-plug-standard/>

Other stakeholders in the installation of charge points include: local authorities, energy utilities, CP providers and support services, public sector agencies (e.g. NHS, Royal Mail) and businesses (including corporates, car dealerships, car park operators, and retail sites). Distribution Network Operators (DNOs) also have a part to play in the successful expansion of the charging network by advising on suitable locations for CP siting taking into account local network capacity and managing peak electricity demand. OEMs are also needed to match CP capabilities and standards with vehicle specifications.

**Key recommendations:**

- All charging network stakeholders should increase levels of coordination to ensure the development of an interoperable, visible and contractually inclusive national network;
- To assist EV uptake, infrastructure suppliers and vehicle OEMs should finalise connector standards and communication system protocols within two years (by 2016).

## 6.4 Coordinated policy and supporting measures

The choice model analysis suggests that, to reach the pathway target of 60% market share by 2030, EVs are expected need a significant equivalent value support<sup>302</sup> to address their higher capital cost and compensate for the loss of utility associated with reduced range and longer charging times. These figures are sensitive to capital cost estimates, and a reduction of ca. 10% could bring this cost support to zero.

This section considers the range of measures and stakeholders that could deliver the support required to achieve high EV market share. *As already discussed, it is important to note that the value of equivalent value support can be provided in monetary and non-financial forms.*

### 6.4.1 Financial incentives to 2030

As detailed in Section 3.2, the UK Government already deploys a number of cost incentives for low carbon light-duty vehicles, some of which are targeted specifically at EVs and ULEVs (as currently defined by tailpipe CO<sub>2</sub> emissions of 75 g/km or less).

While the Government has yet to publish its review of the effectiveness of the Plug-in Car and Van grants,<sup>303</sup> cost analysis conducted for this project shows that, to date, the plug-in vehicle grants have been crucial for stimulating the EV market in the UK between 2011 and 2013 (see cost comparisons presented in Section 3.2.2) as well as signalling Government support for the EV sector. As cost projections of plug-in vehicles suggest that the price premium of EVs over ICE vehicles will remain significant until at least 2030,<sup>304</sup> incentives that address the cost premium of EVs will be required well into the 2020s if EV sales are to increase beyond niche markets.

With UK fleets currently accounting for around 75% of those who have claimed the Plug-in Car Grant and over 95% of those who have claimed the Plug-in Van Grant,<sup>305</sup> the 100% first-year capital allowance (worth around 7%-10% of the value of the vehicle over four years)<sup>306</sup> has also played a key role in supporting the early UK market. Given the potential of the leasing market for supporting EV sales, the authors note the recent exclusion of leased and rented EVs from Enhanced Capital Allowances (as announced in Finance Bill 2013) which has removed the cost benefit previously available for some leased EVs.

<sup>302</sup> See section 5.6 for a definition of 'equivalent value support'.

<sup>303</sup> Research conducted by TRL for the DfT, due for publication in September 2013

<sup>304</sup> "A review of the efficiency and cost assumptions for road transport vehicles to 2050", 2012, Ricardo-AEA for the CCC

<sup>305</sup> <http://www.publications.parliament.uk/pa/cm201213/cmselect/cmtran/884/88404.htm>

<sup>306</sup> Authors' analysis based on a comparison of six EVs with ICE equivalents



The effects of the exclusion will be to halve the proportion of fleet vehicles eligible for the allowance<sup>307</sup> and (according to one estimate) increase EV leasing costs from 2013 by 3%-5%.<sup>308</sup> Although the increase could be considered marginal, anecdotal evidence suggests that, since the change in ECA rules, key players in the vehicle leasing sector are less likely to recommend EVs to fleet clients based solely on consideration of total life costs.<sup>309</sup> **The analysis conducted for this project would suggest that reinstatement of the ECA, or an equivalent capital support for leased and rental fleets, would be highly advantageous to supporting the future EV market in the UK.**

While support could be provided through capital incentives (through purchase grants and/or allowances), the scale of funding that would be required to support a growing EV market would present a challenge to a future UK administration.

This raises the question of how equivalent value support can be provided at scales well beyond the available resources of either the UK government or automotive sector. Should purchase incentives continue to be provided beyond 2015, one alternative approach is the use of technology-neutral 'feebates', which combine an system of 'fees' for the most polluting vehicles, with purchase 'rebates' for cars with the lowest emissions (including EVs).<sup>310</sup> With many being self-financing, feebates schemes offer the possibility of supporting market transformation over the longer-term. In support of feebates, the International Council for Clean Transportation (ICCT) highlights the cost-effectiveness of the approach in market transformation and cite the French feebate system (which includes all vehicle types) with evidence that the average CO<sub>2</sub> emissions of new cars reduced by around 6% in its first year (2008); significantly higher than the previous annual trend of a 1.2% reduction (2000-2007).<sup>311</sup>

The ICCT identifies three reasons for the effectiveness of feebates – all highly relevant to EV adoption and the market barriers as already discussed. First, consumers tend to be 'loss averse', tending to reject products where the benefits are unknown; being able to offer incentives at the point of purchase is therefore more effective in changing purchasing decisions. Second, consumers find future fuel cost reductions (and other costs benefits) difficult to quantify due to unknown future energy prices and uncertainties in future policy. Third, as feebates provide clear pricing for CO<sub>2</sub> abatement technologies, manufacturers are more able to assess the costs of bringing new technologies to the market, and plan their innovation strategy accordingly.

Support for feebates as an effective driver of low carbon vehicle technology also comes from Brand *et al.* (2013)<sup>312</sup> who used the UK Transport Carbon Model to test different pricing scenarios in a UK light-duty vehicle context. Of the policy incentives modelled,<sup>313</sup> the paper reports that purchase feebate policies were the most cost-effective in reducing CO<sub>2</sub> emissions from the light-duty vehicle sector and (of particular relevance to this project) accelerating low carbon technology uptake (including EVs and FCVs) to high levels of market share. The authors also note that, with careful design and adjusted over time, feebates avoid excessive levels of vehicle taxation (such as VED) whilst ensuring revenue neutrality.

Given the extent and quality of the existing research base (including the literature cited), **this report recommends that feebates should be further explored for future application in the UK.** A useful

<sup>307</sup> Authors' analysis of UK fleet and business vehicle market, see Appendix 10.2.3

<sup>308</sup> <http://www.fleetnews.co.uk/news/2013/2/11/industry-split-over-impact-of-capital-allowance-changes/46176/>

<sup>309</sup> Company Cars, Costs and the Climate workshop hosted by BVRLA, July 2013 (held under Chatham House rules).

<sup>310</sup> M. Fergusson. A Feebate Scheme for the UK. Arguments in Favour and Suggestions for Scheme Design. Report for Campaign for Better Transport, June 2012.

<sup>311</sup> Best Practices for Feebate Program Design and Implementation, International Council on Clean Transportation, 2010.

<sup>312</sup> Christian Brand, Jillian Anable, Martino Tran. Accelerating the transformation to a low carbon passenger transport system: The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK. Transportation Research Part A, 2013.

<sup>313</sup> Including: feebates, graduated vehicle taxation, fuel duty and scrappage incentives.

starting point for this work would be the recent report by Malcolm Fergusson (2012) commissioned by the Campaign for Better Transport.<sup>314</sup>

However, the authors would also note that in the high EV uptake pathway, operating a self-financing feebate scheme would not be sustainable beyond 2025 when EV sales match or exceed ICEV sales, due to the inherent imbalance this would cause between ‘fees’ and ‘rebates’. As a result, therefore, any remaining financial support required to address TCO premiums in a mature EV market (should they continue to exist) will have to be delivered by the private sector or by the vigorous phasing out of non-EVs through fuel and vehicle taxation and/or legislation.

**Key recommendations:**

- **The immediate reinstatement of the ECA, or an equivalent capital support for leased and rental fleets, would be highly advantageous to supporting the future EV market in the UK;**
- **Feebates should be explored for future application in the UK in order to sustainably support the development of a strong EV market in the medium term (2015-2025).**

**6.4.2 Non-financial incentives**

One of the key lessons from the analysis of country case studies (see Appendix 10.1), is that EV sales can be promoted successfully through the provision of non-financial benefits (such as preferential parking and road access) which have high perceived consumer value. In terms of the choice modelling, some or all of the equivalent value support could therefore be delivered by providing EV owners with non-financial incentives.

A particularly good illustrative example is the case of allowing EVs to access High Occupancy Vehicle (HOV) lanes (with one occupant only) in California. Due to drivers’ high value of saving time, regional sales of the GM Volt increased sharply after the model was granted permission to use the HOV lanes in that State. These low cost measures therefore can be a very cost-effective method of encouraging the uptake of EVs – see Box 10. Although no UK councils have yet given EVs preferential access to road space, it has been considered (but not adopted) by at least one local authority to date.<sup>315</sup>

One key observation is that identifying these low-cost, high-value measures needs to take in account local driver priorities. For example, in Amsterdam EV owners are given preferential treatment when applying for a parking permit by accelerating what is normally a long drawn out process (which can take as much as four years – see Appendix 10.1.2).

Measures also have to be suited to local contexts: while allowing EVs access to bus lanes in Oslo has been successful, it was not adopted in London following an assessment by Transport for London. While recognising that emission benefits would result with the adoption of EVs, the reasons cited for rejecting the use by EVs of bus lanes were safety concerns for cyclists and pedestrians, as well as enforcement concerns as many EVs are based on existing ICE models and are therefore difficult to identify.<sup>316</sup>

Where resources allow, UK local authorities are generally very supportive of using locally based measures to support EVs. Several London Boroughs including Camden, Richmond, City of London and Westminster have taken a lead in supporting the use of EVs through the provision of reduced

<sup>314</sup> M. Fergusson. A Feebate Scheme for the UK. Arguments in Favour and Suggestions for Scheme Design. Report for Campaign for Better Transport, June 2012.

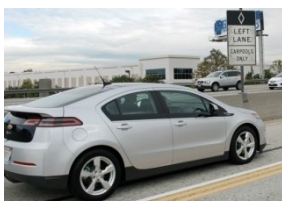
<sup>315</sup> In 2011, Hounslow considered implementing a HOV lane along the A4 corridor which could be used by multi-occupancy vehicles and (U)LCVs. Going Green: How local authorities can encourage the take-up of lower-carbon vehicles. SKM Colin Buchanan for RAC Foundation, November 2011.

<sup>316</sup> TfL, Electric Vehicles in bus lanes, <http://legacy.london.gov.uk/electricvehicles/docs/Electric%20Vehicles%20in%20Bus%20Lanes.pdf>

cost residential and on-street parking schemes.<sup>317</sup> In a 2011 assessment of measures available to local authorities aimed at reducing EV ownership costs, the RAC Foundation found that five out of the top eight measures preferred by LAs for EV support included reduced parking fees/ charges (residential and business) and priority parking,<sup>318</sup> the study identified the following available powers:<sup>319</sup>

- The Road Traffic Regulation Act (RTRA) 1984 can be used by local authorities to provide **parking incentives** for ULCVs/EVs;
- The Environment Act 1995, the RTRA 1984 and the Transport Act 2000 are the primary mechanisms by which local authorities can implement preferential EV **highway and access measures**. This includes issuing a traffic regulation order to create a ULCV lane, introducing a Low Emission Zone or congestion charging; and
- The Localism Bill 2010–11 which allows for the setting up of ULCV-related social enterprises or the **reduction of business rates**.

**Box 10 Access to restricted lanes in California**



Many US states have High Occupancy Vehicle (HOV) or ‘car pool’ lanes, to which access is restricted to vehicles with two or more occupants. These measures aim to encourage car-sharing to reduce congestion, and access to these lanes significantly reduces journey time.

In some states, notably California, access to the HOV lanes has been expanded to include low-emission vehicles, and EVs qualify for access.

The ability to access HOV lanes has had a significant impact on the sales of EVs. In 2011, the GM Volt did not qualify, and accounted for 10% of California EV market. After GM made changes so the Volt did qualify, market share rose to 28%.<sup>320</sup> One dealer estimated that 9 out of 10 Volt purchasers primary motivation for buying the Volt was access to the HOV lanes.<sup>320</sup>

Previous programs which gave hybrid vehicles access to the HOV lanes reveal the value of access to be as much as \$5,000 per vehicle,<sup>321</sup> well below the actual cost to the authorities of implementing the measure. However, another study looking at the resale value of hybrids with the stickers compared to equivalent vehicles without the sticker revealed a price premium of \$1,200 - \$1,500.<sup>322</sup>

In the UK, London is currently at the forefront of providing preferential road access for EVs; the Ultra Low Emission Discount which provides a 100% discount for EVs entering the London Congestion Charge Zone (see Section 3.2.2). In 2013, the London Mayor’s office also announced the intention to introduce an Ultra Low Emission Zone (ULEZ) in central London, possibly from 2020.<sup>323</sup> While the scheme is still at the design stage, the measure will effectively bar a significant proportion of ICE vehicles from a central core area within the capital, and is likely therefore (if implemented) to promote EV sales for private motorists and business requiring access.

While progress has already been made with regard to introducing non-financial EV incentives in the UK, the authors note a recent recommendation made by the Institute for Public Policy Research (IPPR) that local authorities and enterprise partnerships should work towards greater coordination of

<sup>317</sup> Going Green: How local authorities can encourage the take-up of lower-carbon vehicles. SKM Colin Buchanan for RAC Foundation, November 2011.

<sup>318</sup> The top three focused on EV marketing and infrastructure development.

<sup>319</sup> Ibid.

<sup>320</sup> <http://www.ibtimes.com/hov-lane-access-drives-electric-car-sales-california-702526>

<sup>321</sup> <http://www.pluginCars.com/california-grants-plug-hybrids-access-car-pool-lanes-125408.html>

<sup>322</sup> [http://www.greencarreports.com/news/1021405\\_california-hov-lane-stickers-for-hybrids-worth-1200-to-1500](http://www.greencarreports.com/news/1021405_california-hov-lane-stickers-for-hybrids-worth-1200-to-1500)

<sup>323</sup> <http://www.bbc.co.uk/news/uk-england-london-21443439> ; <http://www.nextgreencar.com/news/6167/London-to-get-Ultra-Low-Emission-Zone>

EV incentives, with one option being the introduction of a ‘green badge’ scheme to simplify identification of qualifying vehicles.<sup>324</sup> This point was also raised in the RAC Foundation report already cited and is a view shared by others in the industry.

To conclude, if carefully selected, non-financial incentives can provide high value benefits to end users at relatively low cost; they should therefore be used where appropriate to cost-effectively promote EV uptake. Non-financial measures also have the advantage of playing a key role in supporting the used EV market, which generally receives no direct benefit from purchase incentives which normally only apply to new vehicles. Supporting the used vehicle market, however, will be crucial for high levels of EV adoption; only if demand for used EVs is strong will residual values remain high which in turn will sustain new EV sales.

**Key recommendations:**

- **Local authorities (and national government) should promote EV uptake through the provision of non-financial benefits (such as preferential parking and road access) which have high perceived consumer value;**
- **The implementation of non-financial promotional measures by local and national government should be highly co-ordinated to provide consistent signals to EV owners across all UK regions.**

**6.4.3 Public fleet procurement**

Figures from Defra (2012) show that the public sector accounts for around 20% of all purchasing power in the UK with goods and services procured worth around £250 billion (2009-10).<sup>325</sup> This includes the public procurement of public sector fleet vehicles which alone amounts to over £400 million each year (2009).<sup>326</sup> As highlighted by the IPPR, therefore, as a significant fleet purchaser, government at all levels can play a significant role in accelerating the early adoption of low emission vehicles. Leading by example is also important in demonstrating the benefits of new technologies to local communities and businesses.

Public sector organisations such as local authorities are well motivated to procure EVs given their legislated responsibilities to improve air quality<sup>327</sup> and reduce greenhouse gas emissions. This is supported by the results from a survey of UK local authorities conducted on behalf of the RAC Foundation, which found that around 30% had either implemented, or were in the process of implementing policies requiring or encouraging contractors to use ultra-low carbon vehicles (<75 gCO<sub>2</sub>/km).<sup>328</sup>

<sup>324</sup> IPPR, Leading the charge, April 2013.

<sup>325</sup> Of which central government spending comprised £158 billion and the wider public sector (including local public bodies such as NHS trusts, schools, hospitals and local authorities) £93 billion.. Source: <http://sd.defra.gov.uk/2012/04/driving-green-growth-through-sustainable-procurement/>

<sup>326</sup> OGC 2009 – cited in IPPR report – Leading the charge, 2013

<sup>327</sup> Under the Environment Act 1995, councils have a statutory duty to manage local air quality as prescribed in regulations for the purpose of Local Air Quality Management, and are required to prepare an Action Plan if local air quality is found to breach the regulations. The Health and Social Care Act 2012 has also increased responsibility for local authorities regarding the public health impacts of air quality, responsibility which formerly rested with the NHS. Sources: Local Carbon Framework pilot: developing a council framework on climate change. Baseline Data and Methodology review. Energy Saving Trust, September 2011. <http://www.airqualitynews.com/2013/04/17/responsibility-for-air-quality-increasingly-lies-with-boroughs/#sthash.e1XHBiQj.dpuf>

<sup>328</sup> Going Green: How local authorities can encourage the take-up of lower-carbon vehicles. SKM Colin Buchanan for RAC Foundation, November 2011.

European legislation in the form of the Cleaner Vehicle Directive (2009) now requires the public sector to use its purchasing power to promote clean and energy efficient vehicles. Transposed into UK law through the Cleaner Road Transport Vehicles Regulations (2011), the public fleet procurement process is required to consider a vehicle's whole life energy use, environmental impact and costs. As EVs can compare more favourably with ICEVs on a whole life cost basis (in some applications), it is anticipated that these regulations will assist their market uptake.

In 2011, Defra introduced new Government Buying Standards (GBS) for Transport which mandates that the fleet average CO<sub>2</sub> emissions of new cars procured must be 130 gCO<sub>2</sub>/km or less.<sup>329</sup> These standards, which are aligned to the European Commission's Green Public Procurement (GPP) initiative, are mandatory for all government departments, their executive agencies, non-departmental public bodies and non-ministerial departments. In the future, the maximum threshold is likely to be reduced in line with technological advances across all powertrains. Indeed, the IPPR has recommended that, to support low emission vehicle adoption, by 2020, the GBS threshold should be reduced to 95 gCO<sub>2</sub>/km for cars and 147 gCO<sub>2</sub>/km for vans, to mirror the emissions target set for manufacturers by the EU.<sup>330</sup>

Given the buying power of the boroughs combined, London could play a central key role in stimulating EV demand in the UK. The London Mayor has already announced plans to introduce 100,000 EVs through the London Electric Delivery Plan<sup>331</sup> including at least 1,000 Greater London Authority fleet electric vehicles by 2015. To help achieve this, Transport for London has established a London Electric Vehicle Procurement Framework (worth initially £67 million) to achieve cost reductions in the EV market, allowing accelerated market penetration.<sup>332</sup>

European best practice of EV procurement is exemplified by Norway and the Netherlands where several key cities have adopted set ambitious electrification targets for their respective fleets. The City of Oslo's procurement framework, for example, now only allows for replacement of municipal vehicles with electric vehicles and has set a target that its car fleet will be zero emission by 2015 – see Appendix 10.1.1.

Based on the evidence cited, **this report therefore recommends the establishing of a pro-EV fleet procurement policy which sets ambitious targets for EV adoption within public sector fleets.** This would build on previous UK experience of supporting electric and hybrid vehicles through the Low Carbon Vehicle Public Procurement Programme (LCVPPP),<sup>333</sup> which in 2011 made £1.7 million available for the purchase up to 500 low carbon (hybrid) vans,<sup>334,335</sup> and the Scottish Electric Vehicle Procurement Support Scheme which launched in 2011 with a total value of £4.2 million.<sup>336</sup>

<sup>329</sup> <http://sd.defra.gov.uk/advice/public/buying/products/transport/standards/>

<sup>330</sup> IPPR, Leading the charge, April 2013.

<sup>331</sup> An Electric Vehicle delivery plan for London, 2009,

<http://www.london.gov.uk/priorities/transport/publications/an-electric-vehicle-delivery-plan-for-london>

<sup>332</sup> <http://www.tfl.gov.uk/assets/downloads/Item08-Electric-Vehicle-Delivery-Project-STP-30-june-2010.pdf>

<sup>333</sup> In its first phase in 2007, the LCVPPP provided £20 million to support the fleet purchase of 210 electric and low emission vans. In 2011, a second phase made £1.7 million available for the purchase up to 500 low carbon (hybrid) vans. RAC Foundation. Powering Ahead, 2013; POSTNOTE, 2010. Recipients of LCVPPP funding have included the Environment Agency, HM Revenue & Customs,

<sup>334</sup> <https://www.gov.uk/government/publications/the-low-carbon-vehicle-public-procurement-programme-support-for-low-carbon-vans>

<sup>335</sup> Recipients of LCVPPP funding have included the Environment Agency, HM Revenue & Customs, Metropolitan Police, Royal Mail, Transport for London, Government Car & Despatch Agency, plus a number of local authorities that have significant fleets and a strong motivation to reduce emissions. Source:

<http://www.cenex.co.uk/programmes/lcvppp>.

<sup>336</sup> <http://www.transportscotland.gov.uk/road/sustainability/low-carbon-vehicles>



- Key recommendations:**
- Public sector fleets should adopt a pro-EV fleet procurement policy which sets ambitious targets for EV adoption;
  - To support public fleet adoption, Future Government Buying Standards (GBS) for Transport should include EV procurement.

Figure 53 provides a graphic summary of the action targets and key stakeholders. Figure 54 (page 105) shows the sales and stock volume for EVs.

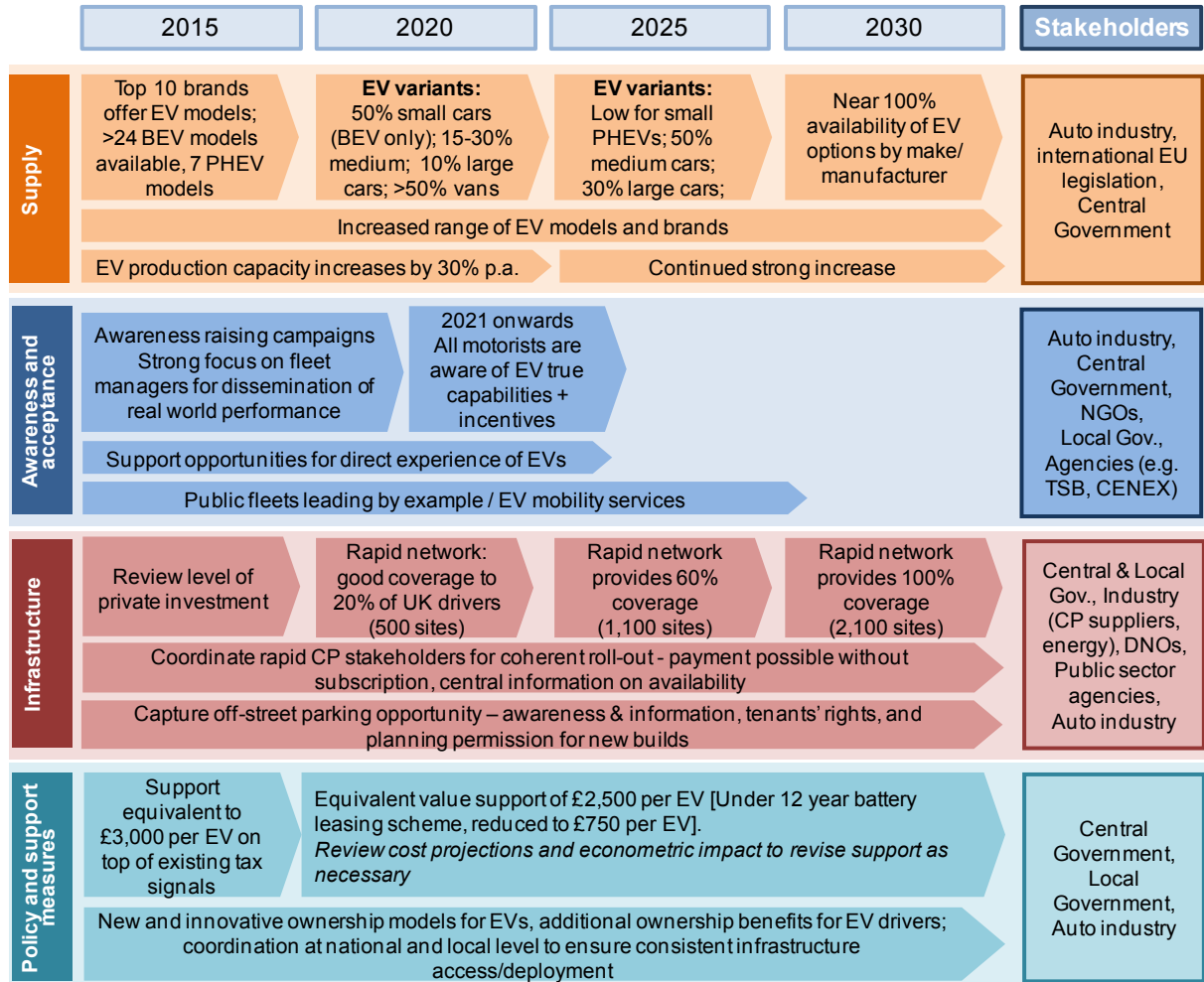


Figure 53 Summary of pathway to high uptake of EVs: action targets and key stakeholders

**Summary of Section 6**

- **Vehicle supply:** In order to deliver the high EV uptake pathway, the major OEMs must continue to release new EV models into the UK market at, or faster than, the current launch rate of over 10 new EV models per year.
- As the European post-2020 CO<sub>2</sub> emission targets will be a key driver for EV supply within the EU and beyond, the UK would be advised therefore to continue to engage in the debate at the levels of the European Commission and Parliament, to ensure that the agreed legislation is beneficial for EV (and low-CO<sub>2</sub>) market development and to support the emerging EV manufacturing base.
- While is not possible to *directly* attribute the extensive public and private investment of over £7 billion already announced to support the UK's EV skills and manufacturing base, industry analysis suggests that this funding will secure at least 30,000 jobs within the UK automotive sector and ensure that it will be well placed to capitalise on the global market shift to electric powertrains, so ensuring a good supply of EVs in the UK.
- Innovative leasing and new ownership models have potential to address the capital cost premium of EVs (and the high discounting rates of consumers) with the added benefits of removing consumer concern regarding component degradation and the resale issue. New vehicle ownership and financing models for EVs should therefore be supported, e.g. through smart and targeted taxation. This is supported by the modelling of long term (8-12 year) battery leases that indicates such plans would significantly decrease the level of equivalent value support required to meet the uptake targets.
- **Consumer awareness:** Generic and EV-specific evidence suggests that, to achieving 100% EV awareness among UK car buyers by 2021 will require large scale, coordinated and sustained campaigns which draw on the experience of large scale marketing campaigns that go well beyond solely providing information. This supports the UK Government's planned EV promotional campaign is to work with at least six major manufacturers on a public communication programme due to launch in late 2013/2014.
- Regarding industry-led EV promotion, the authors recommend that OEMs: increase spend on model-specific EV marketing, develop real-world EV performance metrics, provide fleet-specific EV information and tools, prepare dealerships to support and inform prospective buyers, and increase opportunities for EV test drives and demonstrations.
- A key finding to emerge from global EV trials is the positive role played by test drives in increasing consumer acceptance of EVs. Building on previous success of trials in raising the profile of EVs, the government and industry should support further opportunities for mainstream consumers to gain direct experience of EVs to promote and improve awareness.
- The country case studies suggest that local government also has an important role to play in promoting local financial and non-financial incentives (including charging infrastructure), public procurement of EV to lead-by-example, and through existing channels of communication with local residential and business communities.
- The level of success (or otherwise) of future awareness campaigns could be tracked relatively easily through existing surveys such as the 'Public attitudes tracking survey' that is run several times a year by DECC and the National Travel Survey that is run bi-annually by the Department of Transport.

*Continued...*



**Summary of Section 6 (continued)**

- **Charging infrastructure:** Based on projected OLEV spend and an assumption that the level of private investment will continue to increase, the authors forecast a combined domestic and workplace network of around 160,000 by 2020. Given that the high uptake EV pathway sees 680,000 EVs on the road by 2020, it suggests a steep acceleration in CP installation (and promotion) will be required to support the EV pathway.
- Before the end of the allocated OLEV budget in 2015, therefore, the authors would recommend an evaluation be conducted to determine if the expected private sector investment will be enough to deliver the scale of network required by 2020.
- As installing charge points in new builds and refurbishments is the most cost-effective way to increase home and workplace infrastructure coverage (due to low CP unit and installation costs), it is recommended that local authorities adopt planning conditions that require all parking spaces in new developments to be 'EV-ready' i.e. fitted with an dedicated EV socket.
- Given the key role identified for the rapid charging network in EV market development, the report recommends that Government should actively support the development of new rapid charging services to ensure adequate roll-out of rapid charging facilities across the UK.
- There is already evidence that the private sector is installing fast and rapid chargers for public access and fleet use, suggesting the deployment of such a network will not have to rely on public funds alone. There will however be a continuing role for a central organisation to coordinate stakeholders (at the EU and UK levels) so that an agreement is reached on the key issues (such as interoperability, connector type, payment systems) that will ensure the installed rapid CPs form a coherent and visible network.
- **Equivalent value support** could be provided through a range of financial and/or non-financial measures. Were capital incentives to be used, the scale of support potentially required to achieve the high EV pathway to 2030 would present a challenge to a future UK administration, even with long term battery leases to reduce upfront costs of EVs, suggesting alternative policy options will be needed.
- The analysis conducted for this project would suggest that reinstatement of the Enhanced Capital Allowance (ECA), or an equivalent capital support, for leased and rental fleets, would be highly advantageous to supporting the future EV market in the UK.
- One alternative to providing capital grants is the use of technology-neutral 'feebates', which combine an system of 'fees' for the most polluting vehicles, with purchase 'rebates' for EVs. Self-financing feebate schemes offer the possibility of supporting market transformation over the longer-term. Given the extent and quality of the evidence, this report recommends that feebates should be further explored for future application in the UK.
- One of the key lessons from the country case studies is that EV sales can be promoted successfully through the provision of non-financial benefits (e.g. preferential parking and road access) which can provide high value benefits to end users at relatively low cost. Local authorities (and national government) are recommended therefore to introduce non-financial incentives to support the EV market.
- Given that annual procurement of public sector vehicles is worth over £400 million (2009), government at all levels should commit wherever possible to the purchase of EVs to support UK market development. Noting the purchase power of public fleets, the IPPR recommend that, by 2020, the Government Buying Standards (GBS) for Transport threshold should be reduced from to 95 gCO<sub>2</sub>/km for cars and 147 gCO<sub>2</sub>/km for vans (in line with EU targets).

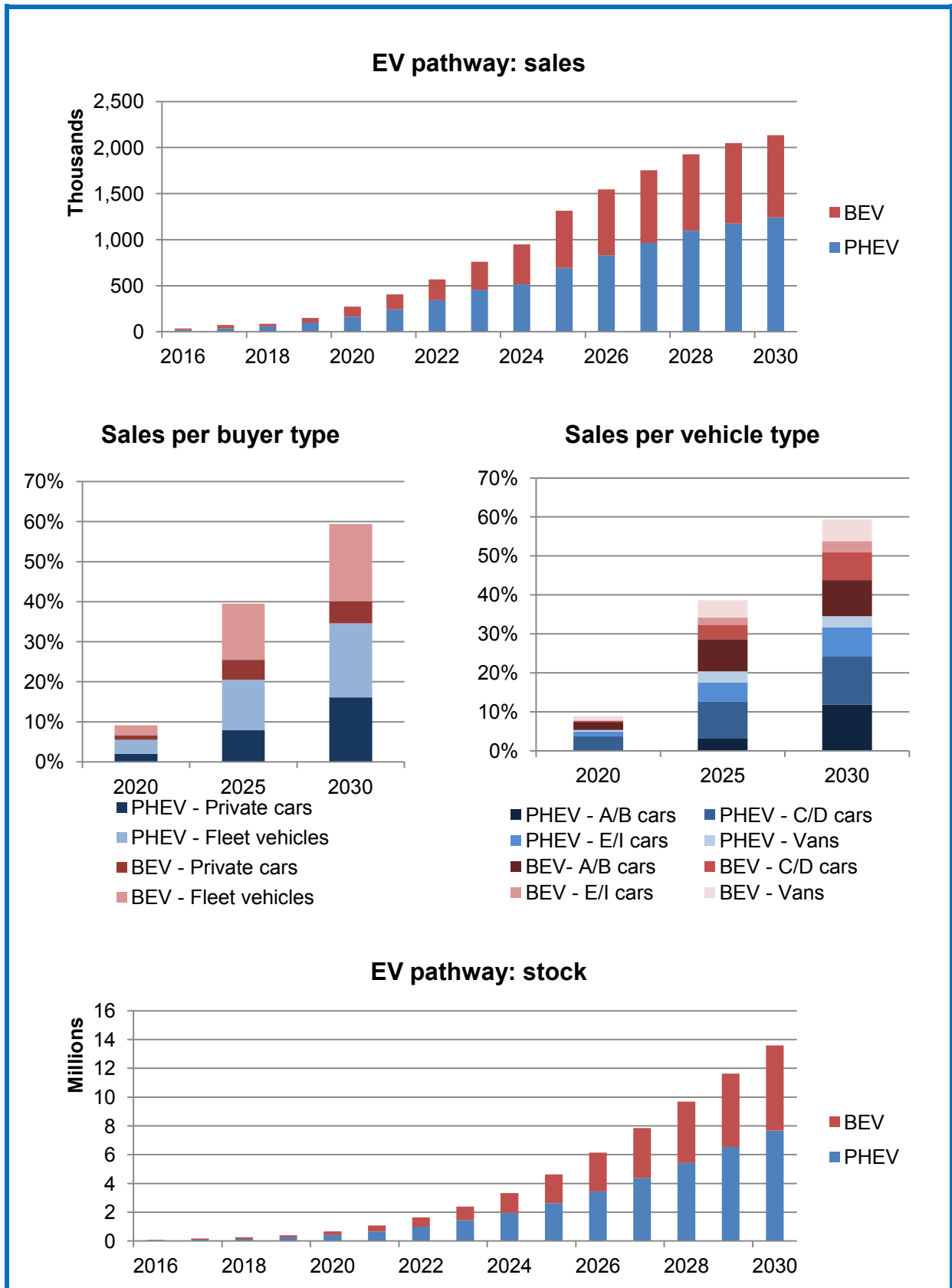


Figure 54 Summary of pathway to high uptake of EVs: UK sales and stock of EVs

## 7 Prospect for hydrogen fuel cell vehicles

This section is dedicated to the case of fuel cell vehicles (FCVs). It presents the barriers to uptake and current UK landscape before concluding on the possible level of uptake. It draws on Element Energy’s extensive work in the area as well as the findings from literature, most notably from the recent UKH<sub>2</sub>Mobility initiative to provide a succinct summary of the FCV case.

This study

### 7.1 Supply of Fuel Cell Vehicles

To date there is no large volume manufacture of FCVs by OEMs. Both Honda and (currently) Hyundai are demonstrating limited series production run vehicles, but no manufacturer has yet begun production on the tens of thousands of units per year, the level associated with conventional vehicle manufacturing plant. In 2012 there were 650 FCVs in operation worldwide, which includes 200 buses, and approximately 200 hydrogen refuelling stations<sup>337</sup>.

However, OEMs are clearly committed to development of FCVs, this is demonstrated by recent announcements of manufacturing alliances by leading OEMs<sup>338</sup> and participation in programs to develop national refuelling infrastructures such as the UK H<sub>2</sub>Mobility initiative. This program aims to set out the roadmap for deployment of FCVs and associated refuelling infrastructure from 2015. The project brings together partners from utility, industrial gas, fuel retail and car manufacturing sectors alongside three UK government departments<sup>339</sup>, to work together to resolve and de-risk the shared challenges of implementing a hydrogen roll out for the UK. The OEM partners in UK H<sub>2</sub>Mobility are Daimler, Hyundai, Nissan, and Toyota.

Several OEMs have made past statements regarding future production volumes. For example in a 2009 Letter of Intent Daimler, Ford, General Motors/Opel, Renault, Nissan, Hyundai-Kia, Honda and Toyota publicly stated their expectation to produce hydrogen cars in volumes of the order of 100,000 units by 2015<sup>340</sup>. The table below sets out more recent announcements by OEMs. Taken together, these announcements imply that progress is somewhat slower than anticipated by the 2009 Letter of Intent, but manufacturers do appear to be scaling up for volume manufacture from 2015, with at least 5 manufacturers having announced plans to begin mass manufacture by 2017 (see Table 15 below).

**Table 15 OEM announcements on Fuel Cell Vehicle production**

OEM	FCV production announcement
Toyota	Commercial vehicle planned for launch in 2015 <sup>341</sup> . 10,000’s of sales by 2020 <sup>342</sup>
Hyundai	In Feb 2013 production of ix35 fuel cell model began. Production of 1,000 units expected by 2015 <sup>343</sup> .
Daimler, Nissan and Ford	In 2013 they signed a collaborative agreement to accelerate the commercialisation of FCV technology, with the goal of series production by 2017 <sup>344</sup> .

<sup>337</sup> Market development for green cars, 2012, OECD

<sup>338</sup> For example Nissan, Daimler and Ford have announced an alliance aimed at large volume manufacture from 2017, Toyota and BMW have made a similar commitment to working together towards a 2020 vehicle.

<sup>339</sup> UK H<sub>2</sub>Mobility Phase 1 Report: <https://www.gov.uk/government/publications/uk-h2mmobility-potential-for-hydrogen-fuel-cell-electric-vehicles-phase-1-results>

<sup>340</sup> <http://www.hydrogenlink.net/download/LoU-fuelcell-cars.pdf>

<sup>341</sup> [http://www.fuelcelltoday.com/news-events/news-archive/2013/may/toyota-fuel-cell-car-to-be-sold-in-the-usa-from-2015-for-under-\\$100,000](http://www.fuelcelltoday.com/news-events/news-archive/2013/may/toyota-fuel-cell-car-to-be-sold-in-the-usa-from-2015-for-under-$100,000)

<sup>342</sup> <http://www.autonews.com/apps/pbcs.dll/article?AID=/20120307/OEM05/303079774#axzz2WYsey9FS>

<sup>343</sup> [http://www.hyundai.co.uk/aboutus/news\\_and\\_events/latest\\_news\\_stories/first\\_assembly\\_line\\_production\\_of\\_ix35\\_fuel\\_cell](http://www.hyundai.co.uk/aboutus/news_and_events/latest_news_stories/first_assembly_line_production_of_ix35_fuel_cell)

<sup>344</sup> [http://media.ford.com/article\\_display.cfm?article\\_id=37631](http://media.ford.com/article_display.cfm?article_id=37631)

Honda	FX Clarity is available for lease in Japan and the US (limited pilot programs). In 2012 Honda reconfirmed 2015 launch date for a new FCV model in Japan, US and Europe <sup>345</sup> .
BMW	Potential market release in 2020 <sup>346</sup>

## 7.2 Barriers to uptake of fuel cell vehicles

This section presents the barriers to the adoption of fuel cell vehicles. Contrary to the case of BEVs, there are no range barriers to the adoption of FCVs, as the typical range (> 400km) is comparable to conventional ICE vehicles. Similarly, there is no recharging time barrier, as it takes only a few minutes to refill the car with hydrogen. The barrier categories presented below are common to plug-in vehicles: supply, cost, access to infrastructure and consumer acceptance.

### 7.2.1 Supply

Supply, both in terms of volume and brand/model diversity, is a significant barrier to uptake of a new technology, as observed in the case of plug-in vehicles. The previous section presented the case of fuel cell vehicles and showed that, while there is currently no large scale production of FCVs, several major OEMs are committed to release series models (between 2015 and 2020) and will be able to increase production to meet demand as the market develops.

In terms of the market segment OEMs are likely to focus on, FCV technology is most likely to be deployed in C/D and E/H segments where margins are higher, buyers are less price sensitive and battery based vehicles struggle to offer a plausible range due to vehicle weight. Whilst some UK SME's are developing small FCVs<sup>347</sup>, none of the large OEMs involved in the UK H<sub>2</sub>Mobility program have publicly stated plans to manufacture a small FCV.

As yet, there are no announcements of fuel cell vans being commercially available before the mid-2020s. This reflects a trend of manufacturers to not introduce a new technology into the van segment due to the low margins and small market size, not a technological barrier to FC vans. In the pathway to 100% Zero Emission Vehicles, FC vans would be able to address the share of the market that is not compatible with BEV range.

### 7.2.2 Cost

The fuel cell system is the key cost component in a FCV, and there is significant uncertainty about the future costs. This cost uncertainty stems from a range of parameters (for example materials development), but is also highly dependent on volume assumptions. Current costs for a one-off automotive fuel cell system (e.g. for a bus stack), are over \$1000/kW. Projections for 2030 based on high volumes range from \$36/kW<sup>379</sup> (target for ICEV competitiveness, achieved through large volume and technology step change) to \$110/kW<sup>348</sup> (upper bound, EE 2010). Estimates for the price premium over ICEVs and payback periods for different fuel cell costs are given in Table 16.

<sup>345</sup> <http://www.fuelcelltoday.com/news-events/news-archive/2012/september/honda-confirms-2015-fuel-cell-vehicle-launch-reveals-residential-fuel-cell-plans>

<sup>346</sup> <http://www.thedetroitbureau.com/2013/01/toyota-bmw-expected-to-sign-fuel-cell-agreement/>

<sup>347</sup> For example Microcab

<sup>348</sup> Upper bound of fuel cell stack cost in 'Influences on the Low Carbon Car market 2020-2030', Element Energy for the Low Carbon Vehicle Partnership

Table 16 Impact of fuel cell costs in 2030, medium car

Fuel cell cost assumptions	Price premium over ICEV*	Payback, years*
\$84/kW – Mid-value of (EE, 2010) <sup>349</sup>	£6.3k	5
\$55/kW – Powertrains for EU study (McKinsey, 2010) <sup>350</sup>	£3.5k	2.5
\$36/kW (techno step change case) – Carbon Trust (2012) <sup>379</sup>	£1.6k	1.2

\* based on vehicle and energy costs as per CCC model. No policy applied. Payback calculated based on energy prices as of given year (kept constant), 14,000km/year assumed. Hydrogen cost as per (McKinsey, 2010)

Recent OEM announcements of FCV commercialisation that suggest competitive pricing may be possible **before 2020**, indicating that OEMs must expect fuel cell system prices below that of the upper range of estimates given above. OEM announcements include:

- Daimler: annual production will need to reach 100,000 units to be considered commercially viable, and vehicle prices could be comparable to “premium” gasoline cars by around 2015<sup>351</sup>.
- Toyota: when the first commercial models are released in 2015, Toyota will set prices from 5 to 10 million yen per vehicle (£32-64k), on par with pricing for its luxury models<sup>352</sup>.

The UK H<sub>2</sub>Mobility Phase 1 findings are based on recent OEM cost and supply data (as well as consumer preferences), and therefore is the most robust dataset on which to base costs and sales. The results suggest that TCO parity between diesel ICEV and FCV is expected to be reached before 2030 (see Figure 55).

The H<sub>2</sub> price in the study provided lower fuel costs per km than from a diesel vehicle<sup>353</sup>. This was based on market research which revealed that consumers will expect hydrogen prices to be lower than the equivalent diesel price. Initially the infrastructure network will therefore require investment in capital equipment and initial operating losses, before achieving a positive cash flow in the 2020s (investment levels are discussed in the next section). By 2030 the H<sub>2</sub> price reflects the production costs from an established and competitive market.<sup>354</sup>

<sup>349</sup> ‘Influences on the Low Carbon Car market 2020-2030’, Element Energy for the Low Carbon Vehicle Partnership

<sup>350</sup> A portfolio of powertrains for Europe: a fact-based analysis, 2011, McKinsey & Company.

<sup>351</sup> <http://www.ihs.com/products/global-insight/industry-economic-report.aspx?id=1065975694>

<sup>352</sup> <http://the-japan-news.com/news/article/0000173672>

<sup>353</sup> Based on the assumption of continued fuel duty on diesel and fuel duty being levied on hydrogen used as a road fuel.

<sup>354</sup> The production mix changes over time and by 2030 consists of 51% water electrolysis, 47% steam methane reforming and 2% existing capacities, resulting in a carbon intensity of 35g CO<sub>2</sub>/km for a mid-size car.

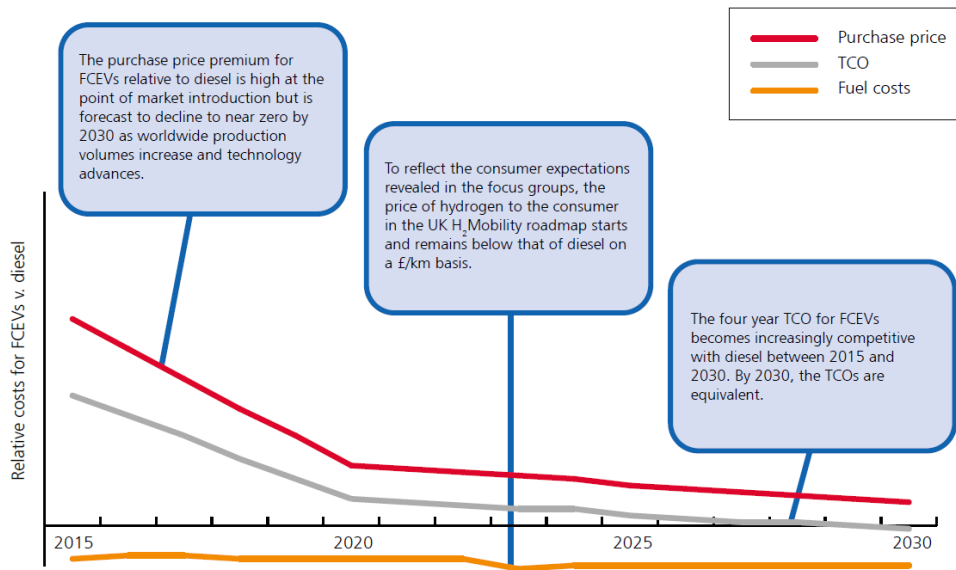


Figure 55 Average purchase price premium, relative fuel costs, and relative TCO for FCVs compared to equivalent diesel vehicles. Source: UK H<sub>2</sub>Mobility Phase 1 report.

### 7.2.3 Access to infrastructure

The UK H<sub>2</sub>Mobility study asked drivers about their willingness to drive to find a hydrogen refuelling station (HRS), and found that c. 80% of most consumer groups are willing to drive 7 minutes or less<sup>339</sup>. This is consistent with results of research undertaken in California, and adopted by the California Fuel Cell Partnership, which indicate that in the US, a six minute drive from the home or office is the maximum acceptable travel time<sup>355</sup>. UK H<sub>2</sub>Mobility also found that limited early availability of HRS is a source of concern for potential FCV buyers, and that consumers are more receptive to FCVs if they have access to more than one HRS locally.

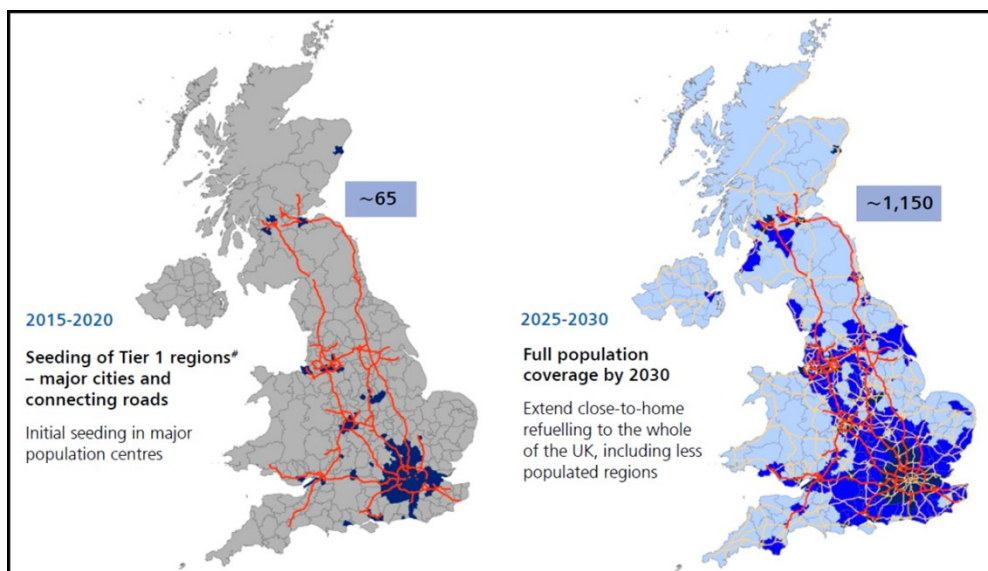


Figure 56 HRS network, 2015-2020 and 2025-2030. Source: UK H<sub>2</sub>Mobility

<sup>355</sup> Stephens-Romero, Kang, Brown, Recker, Samuelsen, (2010). Systematic Planning to Optimize Investments in Hydrogen Infrastructure Deployment. International Journal of Hydrogen Energy



The UKH<sub>2</sub>Mobility study also looked at the minimum initial rollout required to encourage deployment of FCVs by early adopters. The optimum strategy chosen to achieve this was to target selected localities where there would be at least two HRS per Local Authority District, and additional national coverage on major roads to enable long distance journeys, based on an analysis of UK traffic flows. This strategy was chosen as it would ensure high population coverage and make long journeys possible, balanced against the need for minimum upfront investment. The study concluded that 65 initial HRS would fulfil this requirement, located in urban centres and key points on the road network. These initial stations could all be relatively small (>80 kg per day, or 16 FCV fills/day). FCV uptake numbers from demand modelling indicated that around 330 HRS would be needed by 2025, which would mean that 50% of the UK population would have close-to-home refuelling. A proportion of these stations would have a larger capacity, up to 400 kg/day or 80 FCV fills per day. With further growth in demand the HRS network would expand to 1,150 by 2030, by which point all UK Local Authority Districts<sup>356</sup> would have at least 1 HRS. By 2030 the study expected that the initial small stations would be upgraded to increase their capacity, and new stations would be built with a larger capacity, so that the majority of HRS would have a capacity up to 400 kg/day, and some would be larger, up to 1000 kg/day or 200 FCV fills/day.

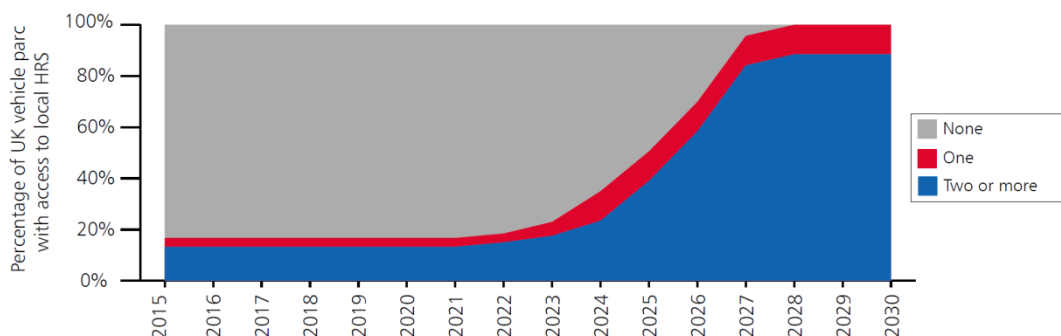
In the early stages of development of the HRS network (2015-2020), capital costs are high, and revenues are low because the number of FCVs on the roads is low. After 2020, revenues increase as the utilisation of HRS increases, but capital investment is still required to develop the network. The financing need required before the HRS network becomes fully self-sustaining was quantified in the UK H<sub>2</sub>Mobility report as the sum of all undiscounted net cash flows from the first HRS investment to the point at which the annual cash flows turn positive. This financing need is around £420 million, of which around £60 million is required before 2020. This figure includes the capital costs of the expanding network, hence part of the post-2020 financing need could be covered by conventional debt finance repaid out of the annual station revenues. A range of stakeholders would need to be involved in HRS rollout, including industrial gas companies, fuel retailers, OEMs, as well as local authorities and Government Departments.

#### 7.2.4 Consumer acceptance

At present, the general public has had less exposure to FCVs than to EVs. The German project HyTrust is a research project designed to understand public attitudes to hydrogen and FCVs. They have conducted a survey which shows that 26% respondents had never heard of FCVs, compared to 5% for plug-in vehicles. Respondents did however hold no safety concerns about FCVs, assuming that if the vehicles were officially sold, then they are safe. The same survey showed that the majority of respondents (77%) would be no more worried about living next to a hydrogen refuelling station than a conventional petrol station.

As set out in the UK H<sub>2</sub>Mobility study, convenient and accessible HRS are critical to the FCV consumer proposition. The consumer analysis shows that the availability of hydrogen and cost of ownership are their primary concerns. Consumers are unlikely to consider buying an FCV if they do not have local access to an HRS. Figure 57 below shows how the percentage of the UK vehicle parc with access to an HRS increases over time according to the UK H<sub>2</sub>Mobility HRS rollout scenario.

<sup>356</sup> Local Authority Districts are a level of sub-national division used for the purposes of local government. The structure and names of the districts varies between the four countries of the United Kingdom. There are 326 in England, 32 in Scotland, 22 in Wales, and 26 in Northern Ireland.



**Figure 57** The development of local HRS network coverage in terms of the proportion of UK vehicle parc with access to zero, one and two or more HRS in their local district. Source: UK H<sub>2</sub>Mobility.

### 7.3 The current landscape for fuel cell vehicles in the UK

As well as the UK H<sub>2</sub>Mobility initiative, there is significant activity in the UK on hydrogen fuelled vehicles. The previous sections have focussed on fuel cell vehicles, given that they are likely to dominate hydrogen fuelled vehicles in the long-term. However in the short-term there is significant UK activity on hydrogen ICE vehicles<sup>357</sup>. This section sets out the key regions for hydrogen activity, and then describes the current infrastructure landscape, and current incentive landscape. This is then compared with the incentive landscape in other leading countries and regions.

#### Key UK regions

In terms of regional hydrogen vehicle activity, London is a key area. The London Hydrogen Partnership was set up in 2002<sup>358</sup> and aims to develop a network of stakeholders and develop hydrogen and fuel cell technologies. The Hydrogen London Action Plan commits to making London a global early adopter market<sup>359</sup>.

There is current interest in a number of other regions in the UK, indicating that new clusters could emerge. Key areas are Scotland, where electrolytic hydrogen generation is viewed as a way to accommodate the local renewable energy potential and balance the network, and the Midlands, as part of the strategy to help diversify the local auto manufacturing sector.

Hydrogen partnerships have been developing in other areas, for example the Greater Manchester Hydrogen Partnership was set up in 2012, to develop a network and to help to create a lower carbon economy and a secure a stable grid.

#### Infrastructure deployment trends

The development of refuelling infrastructure in the UK to date reflects the fact that hydrogen vehicles are not yet commercially available, and are mainly deployed through demonstration projects, with associated hydrogen refuelling stations (HRS). As of May 2013 there are 12 HRS operational in the UK, 8 of which are publicly accessible by appointment. There are 7 further HRS currently being developed (see Figure 58).

Most of these HRS have been publicly funded from sources such as EU R&D funding, regional funding and UK R&D funding. The majority of stations are used for fleet vehicles only, for example the TfL station in East London, which is being used by hydrogen buses.

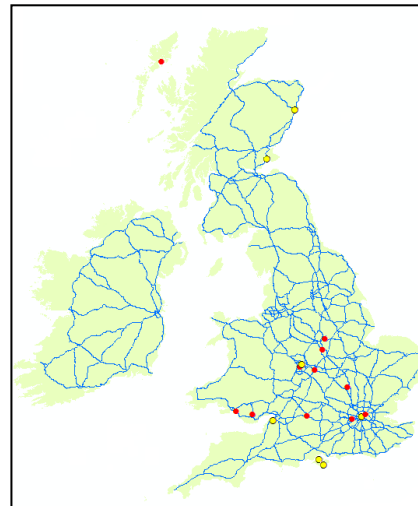
<sup>357</sup> For example Revolve

<sup>358</sup> <http://www.london.gov.uk/lhp/about/index.jsp>

<sup>359</sup> Hydrogen London Action Plan 2012-2016, London Hydrogen Partnership

The current stations do not compare yet with the HRS rollout identified by the UK H<sub>2</sub>Mobility initiative, for five main reasons:

- Most of the existing HRS are small in capacity, at around 20kg/day (~ 4 cars a day) This is significantly smaller than the “small” stations identified in the UK H<sub>2</sub>Mobility initiative, which are up to 80 kg/day.
- Many of the current stations are demonstration projects and/or dedicated to a fleet and not necessarily sited in the optimum locations for private drivers
- They tend to be sited on low cost public land as opposed to premium fuel retailing locations.
- None of the stations are integrated into a conventional fuel retailing environment.
- Stations tend to be located behind security fences requiring access by appointment, or special access keys.



**Figure 58 Existing (red) and planned (yellow) HRS in the UK. Source: H2stations.org, Element Energy**

However the current and planned roll-out, and the variety of stakeholders involved, suggests the UK has a good industry base for scale-up of hydrogen infrastructure.

### Summary of UK incentive landscape

The table below sets out the current UK landscape with respect to each of the barriers explored in Section 7.2.

**Table 17 Summary of UK landscape in relation to barriers to FCV uptake**

Barrier	UK measures
Supply	<ul style="list-style-type: none"> <li>• UK is potentially well placed, as an early adopter, as one of the leading countries who are bringing stakeholders together to resolve the roll-out challenges, including 4 OEMs, through the UK H<sub>2</sub>Mobility initiative.</li> </ul>
Cost (capital and running cost)	<ul style="list-style-type: none"> <li>• If current incentives for ULEVs continue, then tax incentives and possibly purchase incentives for FCVs can be expected<sup>360</sup></li> <li>• Price of hydrogen: no fuel duty is applied at present but no clarity over taxation yet in mid to long term.</li> </ul>
Infrastructure	<ul style="list-style-type: none"> <li>• 12 HRS in 2013, 8 of which are publicly accessible but mostly dedicated to special uses, i.e. do not compare with network required for FCV roll-out</li> <li>• UK H<sub>2</sub>Mobility Phase 2 (2013) is working on the business case for FCVs and infrastructure.</li> </ul>
Consumer awareness	<ul style="list-style-type: none"> <li>• Consumer awareness is increasing through several high profile demonstration projects, e.g. TfL has 8 hydrogen buses running on a Central London route. A fleet of 5 fuel cell-powered London taxis was introduced by Intelligent Energy and London Taxi Company to carry passengers during the 2012 London Olympics.</li> <li>• However, more work will be required to target early adopters of FCVs as a part of any roll-out.</li> <li>• The (relatively) slow speed of the expected ramp-up also creates political</li> </ul>

<sup>360</sup> Note that some of the incentives for ULEVs have not been confirmed beyond 2015.

	and communication challenges, as press reports might be negative while growth remains slow.
Technology acceptance	<ul style="list-style-type: none"> <li>• New technology with less exposure but also fewer preconceptions than for EVs</li> </ul>

### Comparison with leading regions

There are a number of countries or regions who are aiming to drive the uptake of FCVs, including, Germany, California, Japan and South Korea. In this section the examples of Germany and California are compared to the UK incentive landscape. The table below outlines the key programs and measures in both Germany and California.

In Germany, the approach to the cost and supply barriers has been to focus significant investment on R&D, whereas in California, there are direct incentives for OEMs to sell zero emission vehicles, including FCVs. The UK has incentives for ULEVs which would be applicable to FCVs when production models are available. However California has placed direct incentives on OEMs to produce fuel cell vehicles. In the UK the R&D budget for hydrogen and fuel cells is significantly less than for Germany<sup>361</sup>. This implies that the UK could go further in addressing the cost and supply barriers.

In all of the countries which are trying to promote the uptake of FCVs, the main focus is on infrastructure, and in the UK this is also the case. The UK is well-placed, but there will be a significant challenge in securing public or private investment for HRS to take forward the roll-out of HRS infrastructure.

**Table 18 Summary of key initiatives in Germany and California**

	Germany	California
<b>Strategy</b>	<ul style="list-style-type: none"> <li>• H2 R&amp;D budget of €1.4 billion<sup>362</sup> (2007-2016)</li> <li>• H<sub>2</sub>Mobility Germany first national initiative (launched 2009, 17 partners as of 2011) coordinating roll-out of FCVs and infrastructure<sup>363</sup>.</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on infrastructure - funding for stations (\$29.7 million<sup>364</sup>), and mandate that in the future importers of conventional fuel have to install new HRS to keep pace with the growing FCV parc</li> <li>• State law requires 33% of hydrogen to be produced from renewable resources once annual volumes reach a pre-defined threshold</li> </ul>

<sup>361</sup> Under £30m for 2007-12 in the UK against a budget of €1.4 bn for 2007-16 in Germany, for a vehicle parc of comparable size <http://www.publications.parliament.uk/pa/cm201314/cmselect/cmenvaud/writev/61/m6101.htm>

<sup>362</sup> <http://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/Smarter-business/Smart-energy/germanys-energy-concept.did=547320.html>

<sup>363</sup> Analysis of a Business Plan developing a hydrogen refuelling infrastructure in Germany, H<sub>2</sub>Mobility, 2012, communication document.

<sup>364</sup> California Fuel Cell Partnership, [http://cafcp.org/hydrogen\\_station\\_funding\\_available](http://cafcp.org/hydrogen_station_funding_available)

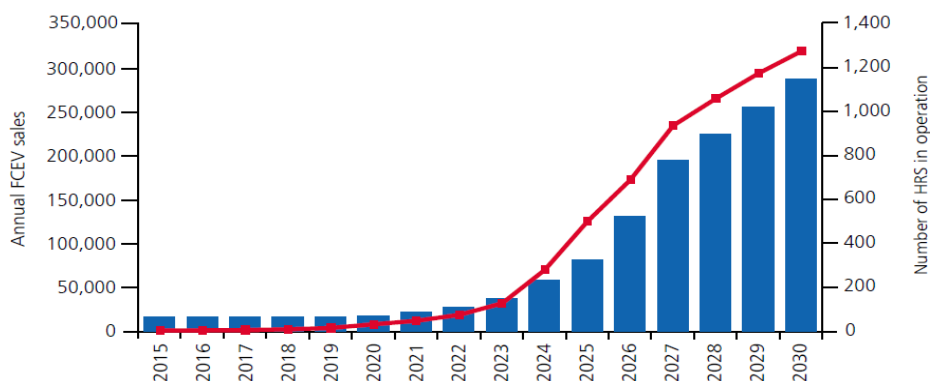
<b>FCV deployment</b>	<ul style="list-style-type: none"> <li>The Clean Energy Partnership (CEP) has trialled FCVs since 2011, by the end of 2013 more than 100 FCVs will be in trials<sup>365</sup></li> <li>CEP runs 6 FC buses<sup>366</sup></li> </ul>	<ul style="list-style-type: none"> <li>Three transit agencies run FC buses<sup>367</sup></li> <li>Pilot lease programs of FCVs, by Mercedes-Benz<sup>368</sup> and Honda<sup>369</sup>. Large deployments for real-world testing by GM<sup>370</sup>, and smaller demonstrations by Toyota<sup>371</sup> and Hyundai<sup>372</sup>.</li> </ul>
<b>Refuelling stations</b>	<ul style="list-style-type: none"> <li>15 HRS in 2013<sup>373</sup></li> </ul>	<ul style="list-style-type: none"> <li>24 HRS in 2013, 9 of which are publicly accessible<sup>374</sup></li> </ul>
<b>Future plans</b>	<ul style="list-style-type: none"> <li>By 2015, a network of at least 50 public refuelling stations is planned<sup>373</sup> (Government, gas company, OEM and fuel retailer initiative).</li> </ul>	<ul style="list-style-type: none"> <li>68 stations required by 2016, located in 5 in clusters, to enable early commercial market of 10-30,000 FCVs<sup>375</sup>.</li> </ul>
<b>Incentives</b>	<ul style="list-style-type: none"> <li>Currently there are no specific incentives beyond the CO<sub>2</sub> based annual tax</li> </ul>	<ul style="list-style-type: none"> <li>FCVs are currently incentivised along with BEVs and PHEVs through credits to OEMs<sup>376</sup></li> <li>There are both federal<sup>377</sup> and state-wide<sup>378</sup> incentives for the purchase of FCVs.</li> </ul>

### Market potential

As the market is at an earlier stage of development, there exist fewer sales projections for FCVs than for plug-in vehicles. Projections vary due to uncertainty in the rate of development and fuel cell cost reduction, and will depend on the type and strength of and future policy interventions. Nevertheless, there are some projections, most notably for the UK those from the UK H2Mobility program.<sup>339</sup>

The UK H2 Mobility study, based on OEM supply and cost data and a representation of consumers' preferences, foresees a 10% market share for FCV by 2030 in the UK. This equates to annual sales of 300,000 vehicles (see Figure 59, with a total of 1.6 million FCVS on the road in 2030). They identify "early adopters" who could generate sales of c. 10,000 p.a. by 2020, and forecast an initial uptake of 13,000 vehicles between 2015 and 2020. Uptake during this time period is limited by the cost of the vehicle. The study assumes no subsidy for FCV purchase (other than a VED incentive). Although the developed consumer segmentation was for FCVs, that are some characteristics similar to the segmentation observed for EVs: the potential early adopters of FCVs, as for EVs, value low running costs and are willing to pay a premium for owning new technology. At the other end of the spectrum, the 'Uninterested rejecters' identified by the UK H<sub>2</sub>Mobility study show a heavy focus on capital cost, like the 'Resistor' group.

<sup>365</sup> [http://www.cleanenergypartnership.de/uploads/tx\\_cepdownloadsv2/ENG\\_Druck\\_CEP\\_Leporello.pdf](http://www.cleanenergypartnership.de/uploads/tx_cepdownloadsv2/ENG_Druck_CEP_Leporello.pdf)  
<sup>366</sup> [http://www.linde-gas.com/internet.global.lindegas.global/en/images/CEP-TOTAL%20hydrogen%20fuelling%20stations%20at%20Heerstrasse,%20Berlin,%20Germany.17\\_15299.pdf](http://www.linde-gas.com/internet.global.lindegas.global/en/images/CEP-TOTAL%20hydrogen%20fuelling%20stations%20at%20Heerstrasse,%20Berlin,%20Germany.17_15299.pdf)  
<sup>367</sup> [http://www1.eere.energy.gov/hydrogenandfuelcells/tech\\_validation/ca\\_transit\\_agencies.html](http://www1.eere.energy.gov/hydrogenandfuelcells/tech_validation/ca_transit_agencies.html)  
<sup>368</sup> [http://www.mbusa.com/mercedes/benz/green/electric\\_car](http://www.mbusa.com/mercedes/benz/green/electric_car)  
<sup>369</sup> <http://automobiles.honda.com/fcx-clarity/>  
<sup>370</sup> <http://www.caranddriver.com/news/gms-fuel-cell-vehicle-development-plan-car-news>  
<sup>371</sup> <http://green.autoblog.com/2010/01/13/toyota-to-deploy-100-fuel-cell-vehicles-in-us-demonstration-prog/>  
<sup>372</sup> <http://green.autoblog.com/2013/06/14/hyundai-on-hydrogen-fuel-cells/>  
<sup>373</sup> <http://media.daimler.com/deeplink?cci=2183345>  
<sup>374</sup> California Fuel Cell Partnership <http://cafcp.org/stationmap>  
<sup>375</sup> <http://cafcp.org/carsandbuses/caroadmap>  
<sup>376</sup> California Air Resources Board [http://www.arb.ca.gov/msprog/clean\\_cars/acc%20summary-final.pdf](http://www.arb.ca.gov/msprog/clean_cars/acc%20summary-final.pdf)  
<sup>377</sup> Alternative Fuels Data Center <http://www.afdc.energy.gov/fuels/laws/3255/US>  
<sup>378</sup> California Air Resources Board [http://www.arb.ca.gov/msprog/zevprog/factsheets/clean\\_vehicle\\_incentives.pdf](http://www.arb.ca.gov/msprog/zevprog/factsheets/clean_vehicle_incentives.pdf)



**Figure 59 UK FCV sales and H2 Refilling Station (HRS) network Source: UK H<sub>2</sub>Mobility Phase 1 report**

To contrast this against results from other studies, a 2012 study by the Carbon Trust predicts that FCVs could achieve between 25% and 34% share of medium car sales by 2050.<sup>379</sup> The upper projection of 34% depends on a step change bringing fuel cell cost down to level of competitiveness with ICEV, i.e. through advances in polymer fuel cell technology that the Carbon Trust assessed as feasible. In the US, California has sales projections for each type of low emission vehicle. The projections for FCVs are that there will be 10,600 sales in 2020 (representing <1% of sales – which is similar to the UK H<sub>2</sub>Mobility projections) rising to 43,600 sales in 2025<sup>380</sup> (representing <2% of sales – which is lower than the UK H<sub>2</sub>Mobility results of ca. 3%). These projections are based on meeting the California Zero Emissions Vehicle Target of 1.5 million vehicles by 2025.<sup>381</sup>

The UK sales projections discussed above look out to 2030 and beyond. Beyond 2030, cost projections suggest FCVs will be of comparable cost than BEVs (based on the CCC cost modelling); access to infrastructure will therefore become a key differentiator.

One study indicates that after 2030, FCVs will have a TCO advantage over BEVs and PHEVs for large cars, due to the associated longer trips that tend to be taken by these vehicles, and therefore greater importance of running cost benefits.<sup>382</sup> The authors concluded that FCVs are the most cost effective solution for zero/low carbon medium and large cars in 2040-2050.

The results presented in Section 5 are based on meeting a target of 60% plug-in vehicles by 2030, in the context of plug-in vehicles being in competition with conventional vehicles. However it is also important to consider the prospect for FCVs. As discussed, the UK H<sub>2</sub>Mobility study projects that FCVs could take 10% of light duty vehicles sales by 2030 in the UK, and quantifies the scale of investment in refuelling infrastructure.

### Competition between fuel cell vehicles and plug-in vehicles

It is unlikely that OEMs would make the three technologies (PHEVs, BEVs and FCVs) compete by offering them in all vehicle segments. Instead OEMs might identify the vehicle segments where the technical specification and cost premium of each technology fit best, to optimize their investment and limit risk. For instance Toyota has published its view on the future mobility portfolio: BEVs would be confined to the small size, low mileage vehicle segments while FCVs, at the other end of the spectrum

<sup>379</sup> Based on Monte Carlo analysis of market share, based on consumers making their choice on 3 year TCO and some technology attributes. No technology preference assumed. Polymer Fuel Cells – Cost reduction and market potential – Carbon Trust, 2012

<sup>380</sup> California Air Resources Board, 2011, <http://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf>

<sup>381</sup> California 2013 Zero Emission Vehicle Action Plan

<sup>382</sup> A portfolio of powertrains for Europe: a fact-based analysis, 2010, McKinsey & Company.



would serve the high premium, large and high mileage cars (and larger vehicles); hybrid and PHEVs would serve the medium to large size car segments<sup>383</sup>.

Other studies have concluded on the good fit of FCVs for high mileage premium segments<sup>384</sup>. Figure 60 shows the market share of BEVs within each vehicle segment in 2030, in the high uptake pathway. This shows the large car segment (E/H) is indeed the hardest segment to address with BEVs, mostly due to the large batteries that create a cost premium over other technologies. Fully electrifying vans also pose a challenge: based on the cost projections, BEVs are very competitive in the van segment (smaller batteries than for the E/H cars) and capture 40% of the market by 2030; however their uptake will not grow further without addressing the range barrier. A significant share of vans need a long driving range: an analysis of van trip dataset shows 30% of vans have a daily distance that exceeds 300km<sup>385</sup>. Although a rapid charging network can help extend the range of BEVs, in the case of company owned vans, the lost value of the time spent charging means that this solution will not be acceptable for most businesses.<sup>386</sup> FCVs could therefore address this portion of the market not readily accessible to pure electric vans.

The competition between FCVs and EVs could therefore be mostly between FCVs and PHEVs, the two technologies offering the long driving range. OEMs (and consumers) will make their choice about which technology to support based on the extent of the hydrogen infrastructure in place along with other factors.

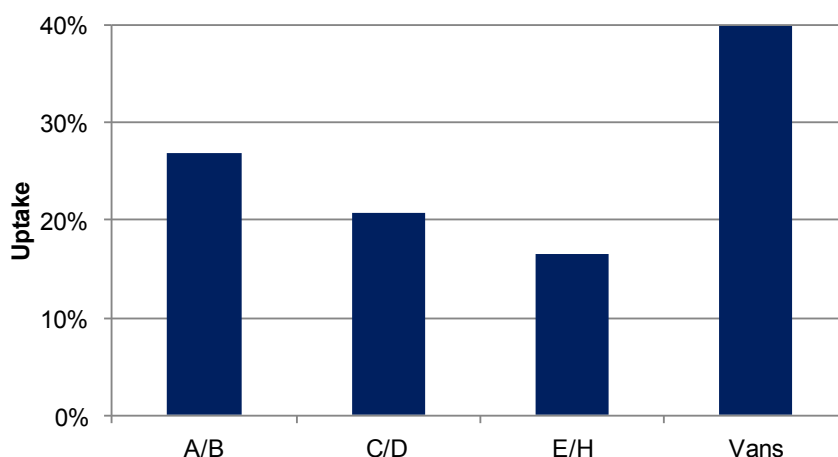


Figure 60 Market share of BEVs in 2030 within each vehicle segment

### FCVs’ contribution to the 60% target in 2030

The choice model analysis was run for a target of 50% EVs uptake in 2030, assuming an uptake of 10% FCVs in 2030, based on the UK H<sub>2</sub>Mobility initiative projections (which assumed no financial support other than preferential VED). It shows that reducing the EV target to 50% reduces the equivalent value support by about half.

However this result must be interpreted with caution as FCVs were not part of the choice model so this simplified approach implicitly assumes that the supply and sales of FCVs could be incentivised to address the vehicle segments hardest to address with EVs so as to minimise competition with EVs. That is, the results assume that the costs and supply of EVs and FCVs are independent of each

<sup>383</sup> Toyota’s Perspective of Sustainable Mobility, BATTERIES 2012 conference, Sept 2012

<sup>384</sup> A portfolio of powertrains for Europe: a fact-based analysis, 2010, McKinsey & Company.

<sup>385</sup> Based on EE analysis of maximum daily distance of 8,000 van sample, over 31 consecutive days

<sup>386</sup> Fleet operators interviewed for the UK H<sub>2</sub>Mobility study stated the need for “low emission, long range, fast refuelling vehicles”; this is also consistent with Element Energy interview of fleet managers for the Dft in 2011.

other. This can be a reasonable assumption for the case of BEVs, but it is not true for PHEVs as they can address the same vehicle segments, as discussed above.

The significant reduction in equivalent value support required seems to suggest a successful FCV market could potentially significantly decrease the challenge of achieving a high uptake of zero or ultra low emission vehicles. However there are two important caveats that may act against this, so that the FCV market may not help, and may even hinder the development of the EV market and thus the overall equivalent value support of deploying ultra emission vehicles might either decrease or increase:

- Supply

FCVs and EVs are likely to compete in certain vehicle segments, and therefore a successful FCV market might mean less demand for EVs. This will likely to impact on OEMs production plans and lead to a reduced supply of EVs, placing a barrier to meeting EV market share targets.

- Infrastructure

The success of the FCV market greatly depends on the deployment of a network of refuelling stations. The success of the EV market also depends – to a lesser extent – on the coordinated deployment of infrastructure (rapid charging network). The EV and FCV markets could therefore effectively compete for government support in terms of infrastructure.

The UK H<sub>2</sub>Mobility analysis estimates the financing needed for the network of filling stations would be £420 million, after which the fuelling stations would become self-sustaining. The study noted that ca. £60 million of financing is required before 2020, meaning the level of contribution of FCVs to the 60% target will depend on investment decisions taking place in *the next few years*. A delayed refuelling network is likely to mean a lower market share than 10% in 2030 as extra incentive support such as cost support would not replace the need for refuelling infrastructure.

It is worth noting that government support to the charging infrastructure has successfully stimulated private investment so far (see section 3.3), suggesting the EV market may be less dependent than FCVs on direct public support for the infrastructure network – although the private sector will have the confidence to invest only if the government shows commitment to the success of the EV market.

This reliance on support, either direct from the government or indirect to stimulate private investment, suggests that some (non technology neutral) choices will have to be made in the next few years and committed to for a sustained period.

In summary, the FCVs may be the most cost competitive zero emission technology in larger vehicle segments, but their contribution to the 60% target in 2030 is difficult to assess on a cost effectiveness of support basis because of the interdependencies of the EV and FCV markets described above. The benefit of the FCV option is clearer under the post-2030 target (of 100% market share for Zero Emission Vehicles) as FCVs could offer a valuable complement to BEVs to address the challenges of relying solely on BEVs. The post-2030 trajectory to 100% market share for ZEVs is discussed in the next section.

**Summary of Section 7**

- The cost premium, supply of FCVs, and challenges of initiating a nationwide refuelling infrastructure are the greatest barriers to uptake. However the UK is well placed in terms of infrastructure deployment and supply, due to the strong industry engagement. Consumer awareness of FCVs is currently very low and will need to be raised, as in the case of plug-in vehicles.
- There is a near-term supply focus on medium to large cars but there is no technological barrier to the production of FC vans or smaller cars. Vans are expected by mid to late 2020s and their long range could address the share of van market that is not compatible with BEV range.
- The UK H2Mobility findings provide the most credible projections of sales (based on OEMs cost and supply data and consumer choice model) as well as projecting the cost and scale of accompanying infrastructure to 2030: up to 10% car market share (300,000 sales p.a.) and 1,150 hydrogen refuelling stations will be needed by 2030.
- The financing need required before the HRS network becomes fully self-sustaining is £420 million, of which £62 million is required before 2020. Conventional debt financing is likely to be available for new stations during the 2020s assuming demand is growing. Post-2030, cost projections suggest FCVs will be of comparable cost to BEVs; access to infrastructure will therefore become a key differentiator.
- A successful FCV market could contribute to the 60% ZEV target with a share of 10%, reducing the target for plug-in vehicles to 50% by 2030. The model does not capture the inter-dependencies of plug-in vehicles and FCVs markets, nor does it quantify the support required for a successful FCVs market.
- The findings of the UK H2 Mobility analysis indicates the success of the FCV market depends on investment decisions taking place in the next few years to deliver a refuelling network, and investment is also needed for the EV charging network. A further inter-dependency between EVs and FCVs concerns supply: the two technologies will compete in certain vehicle segments, meaning a successful FCV market might be at a cost of reduced EV supply, leading to lower EV uptake than would otherwise be the case.

## 8 Electric vehicles post-2030: towards 100% market share

For the period after 2030, the target is for Zero Emission Vehicles (ZEVs) to increase until they account for 100% of sales in 2040 such that, taking the stock turnover into account, the vehicle fleet is almost entirely zero emission by 2050. The post-2030 pathway to 100% ZEVs is now discussed.

### 8.1 Cost landscape post 2030

In the pathway to 2030, the infrastructure action targets are traded against the equivalent value support needed to achieve the 60% market share target, and to ensure that BEVs represent a significant share of the EV market (25%) (to be consistent with the 2040 target of 100% ZEV market share). Increasing the market share of BEVs from 25% in 2030 to 50-100% in 2040 (depending on FCVs contribution to the ZEV target – see below) does however represent a very fast transformation of the market.

As reported in Section 7.2.2., projections for the cost of a fuel cell stack in 2030 vary widely, in part due to varying assumptions on production volume, manufacturing progress and technology improvement. The cost of batteries post-2030 is uncertain for the same reasons. The cost modelling developed for the CCC suggests that after 2030, BEVs and FCVs will still have a higher capital cost than ICEVs and PHEVs. Even excluding the battery or fuel cell, the BEV or FCV capital cost is either close to or greater than the capital cost of an ICEV, so no matter how great the actual battery or fuel cell cost reduction, ZEVs will remain more expensive than ICEVs.<sup>387</sup>

It is, however, expected that the purchase and use of non-ZEVs will be increasingly discouraged (in urban centres at least) through emission-based regulations (e.g. restricted access, ultra-low emission zones, procurement rules, higher company BIK rates, increased fuel duty or high taxes on ICEs). This position is clearly apparent in the European Commission's Transport 2050 Strategy<sup>388</sup> which sets the following goals for transport:

- CO<sub>2</sub>-free city logistics in major urban centres by 2030;
- Halving the use of conventionally fuelled cars in urban transport by 2030;
- Phasing out conventionally fuelled cars in cities by 2050.

The view of the EC is therefore that large cities will be instrumental in the phasing out of non-ZEVs. Indeed, the Mayor of London has already instigated the design and development of a London ULEZ due for implementation in 2020.<sup>389</sup> Stockholm has also pledged to be wholly independent of fossil fuels by 2050<sup>390</sup> and progress on this policy is likely to be of interest to several UK cities.

In the longer term, the cost proposition of BEVs could also be improved through end users providing services to the grid. According to a recent study<sup>391</sup>, controlled charging of EVs could provide revenue to EV drivers. Rather than relying on vehicle-to-grid technology, controlled charging would preferentially enable EV charging at times favourable for the grid in order to minimise peak and/or capture variable renewable energy. The study estimates that, in a context of an electricity grid with high penetration of renewable energy, revenue to drivers could be in the order of half of the annual cost of vehicle charging.

<sup>387</sup> AEA, A review of the efficiency and cost assumptions for road transport vehicles to 2050, 2012

<sup>388</sup> Transport White Paper 2011

<sup>389</sup> <http://www.bbc.co.uk/news/uk-england-london-21443439>; <http://www.nextgreencar.com/news/6167/London-to-get-Ultra-Low-Emission-Zone>

<sup>390</sup> <http://ec.europa.eu/environment/europeangreencapital/stockholm-fossil-fuel-free/>

<sup>391</sup> Fuelling Europe's Future: How auto innovation leads to EU jobs, June 2013, Cambridge Econometrics for the European Climate Foundation

An alternative way to deliver ultra-low road transport emissions is to combine high blend (low carbon) biofuels with PHEVs.<sup>392</sup> However, as the use of biofuels in light-duty vehicles is not in accord with the CCC's vision for the use of bioenergy resources in the long term, it is therefore excluded from the post-2030 pathway in this project. That said, the authors acknowledge that as PHEVs have a capital cost advantage over BEVs and FCVs, as well as a driving range advantage over BEVs, the use of biofuels in PHEVs may become an attractive option to some stakeholders in the future. Should this be the case, in order to deliver the CCC vision on the use of bioenergy resources, policies would, therefore, need to be introduced to discourage the use of biofuels in light-duty vehicles.

## 8.2 Infrastructure need and options post-2030

One of the greatest challenges to reaching a market share of 100% BEVs post-2030 will be to provide sufficient access to charging infrastructure.

BEVs sold post-2030 are likely to have a longer driving range than today's models; consumers may therefore not need have access to a 'personal' charging point before considering purchase of a BEV. However, regardless of the progress on battery energy density and BEV range, drivers will still require a reliable and accessible charging infrastructure. The following discussion analyses the scale of the challenge, along with the potential options for delivering a sufficient network.

The starting point of the analysis is the pathway to 2030, where it is assumed that most EV charging is conducted overnight, with a UK-wide network of rapid network providing all BEVs with a reliable day charging option.

By 2030, the high EV pathway forecasts around 14 million plug-in vehicles (cars and vans) in the UK (representing around 30% of the parc) with around half of these being BEVs. An analysis of UK households suggests that 14 million EVs equates to the saturation of households with access to a garage, but not of households with other off-street parking – see Table 19. This means that, providing measures are in place to support charging in residential off-street car parking area, the majority of the 2030 EV parc would be able to access low cost overnight charging.

Closer to 2050 with its associated ambition of a 100% ZEV parc, the number of plug-in vehicles means that providing access to overnight charging is no longer straightforward. As shown in Table 19, around 10 million cars are expected to park on-street by 2050. This suggests that, if the entire fleet is composed of plug-in vehicles, either large scale deployment of on-street chargers will be necessary, or sufficient day charging will be required to provide certainty of access for BEVs. Despite the high costs of on-street CPs, they may therefore become a necessity at very high levels of EV market penetration.

One approach to lower the cost of building a sufficient CP network is to increase the provision of off-street charging facilities through the use of planning regulations. The London Plan, for example, stipulates that for residential parking, 20% of all car spaces must be 'EV-ready' i.e. fitted with a charging point. As discussed in Section 6.3, Westminster City Council has gone further by setting the target at 100% for all new planning permits (including new builds as well as retrofits or change in use). As the cost of domestic units is relatively low, developers have accepted the policy and internalised the costs of sockets.<sup>393</sup> (Anecdotal evidence also suggests that EV charging facilities can be used to differentiate properties when marketing new developments.)<sup>394</sup>

Table 19 also shows that, without increased planning requirements, the projected number of households with access to off-street parking will be 26 million by 2050. In a scenario where planning

<sup>392</sup> An affordable transition to sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2013.

<sup>393</sup> All car spaces must be fitted with a socket or be 'socket ready' i.e. the cables must be in place for an easy socket installation in future if demand requires it. Source: Westminster City Planning

<sup>394</sup> Based on author's discussions with private developer.

regulations made it mandatory for all new builds to provide off-street parking (from 2020), the number of households with off-road access in 2050 would increase to 29 million. This scenario is, of course, unlikely, and only used to highlight the ‘housing stock inertia’; even in 2050 the housing stock will still be dominated by houses built before 1990 (approx. 66%).<sup>395</sup>

For EV owners without access to off-street parking, there will, however, need to be provision of a reliable charging infrastructure. A number of options are available to develop this infrastructure - presented in Table 20. In practice, a mix of these options might be the most likely scenario to reflect the different local resources and transport needs of different UK regions (e.g. urban/sub-urban/rural). It is worth noting that, for all on-street options, user pricing would have to be low enough to attract car buyers that do not have off-street parking. The risk is that BEV drivers with overnight charging are encouraged to charge on-street during the day, increasing competition for available posts and adding to electricity demand during the day (adding loads to local distribution networks). Differential pricing for EV owners without off-street parking may have to be developed.

**Table 19 Projection of number of households in the UK (millions)**

Number of UK households (millions)	2030	2040	2050	Comments
<b>Total</b>	33	35	38	Based on CCC projections
<b>Access to garage</b>	13	14	15	Based on 40% of households as per 2010 DCLG analysis
<b>Access to garage or other off-street parking</b>	23	25	26	Based on 70% of households as per 2010 DCLG analysis
<i>Upper limit</i>	24	27	29	<i>If all new builds from 2020 required to provide off street parking</i>
<b>With at least one car</b>	24	26	28	Based on current ratio of 75% of households
<b>Cars parked on-street overnight (millions)</b>	7-11	8-12	8-12	Based on CCC parc size projections (see Appendix 10.4) and current estimates of 20-30% cars parked on-street (see Table 27)

### Large deployment of Fuel Cell Vehicles

One alternative to promoting high levels of BEV adoption is to instead rely on FCVs to make up for the saturation in overnight charging thereby using a combination of FCVs and BEVs to achieve the 100% uptake target. As was discussed previously, successful market development of FCVs could see their market share reach 10% in 2030; their specifications would particularly match the large car segments and vans with high duty cycles (both more problematic for BEVs).

Economic analysis of hydrogen stations shows that, at this level of uptake, the provision of refuelling stations would become self-sustaining. This suggests that the private market alone could grow the hydrogen refuelling infrastructure to accommodate the growing demand post-2030. Under these conditions, an alternative to the target of 100% market share for BEVs in 2040 could be a 70% / 30% split between BEVs and FCVs; 70% being roughly the proportion of vehicle buyers with access to off-street overnight charging facilities for BEVs.

<sup>395</sup> See Figure 77 in Appendix for household projections



Table 20 Comparison of the different infrastructure options to accommodate 100% uptake of BEVs

Options	Sub-option	Advantage	Challenge	Scale
Large scale installation of on-street charging outside homes		<ul style="list-style-type: none"> <li>Overnight charging does not require extra electricity grid investment</li> </ul>	<ul style="list-style-type: none"> <li>Daytime charging would also be required to meet the needs of high daily mileage drivers</li> </ul>	Between 4 and 10 million on-street sockets* will be needed by 2050 <sup>396</sup> .
Wide-scale public charging infrastructure for daytime use to cater for drivers without access to overnight charging	Quick recharge based upon ultra-rapid charging (120 kW or above)	<ul style="list-style-type: none"> <li>Restricted network can cover UK</li> <li>Provide for high daily mileage applications</li> </ul>	<ul style="list-style-type: none"> <li>Battery technology needs to be compatible with high charging rates</li> <li>Electricity networks reinforcement<sup>397</sup></li> </ul>	Restricted network (<2,000 sites) can cover UK
	Quick recharge based around battery swapping stations (BSS)	<ul style="list-style-type: none"> <li>Restricted network can cover UK; provide for high daily mileage applications</li> <li>BSS could develop around large commercial vehicle fleet before expanding to the more diverse and demanding private car market</li> </ul>	<ul style="list-style-type: none"> <li>Rely partly on OEMs standardising vehicles and battery packs</li> </ul>	
	Widespread network of normal (3-7 kW) CPs for daytime charging			<ul style="list-style-type: none"> <li>Does not provide for high daily mileage applications, the provision of such a network would not remove the need for faster day charging (ultra rapid or battery swapping)</li> </ul>

\*Sockets' could be wireless pads instead – this does not change the number of charging places needed.

<sup>396</sup> Based on estimates of the number of vehicles parked on-street at c. 10 million, presented above. Even under ambitious assumptions about new-build properties providing off-street parking, at least 7 million households would need to be provided for. If one socket could be shared between two BEV owners, it would take in the order of four million on-street sockets (or 2 million twin socket post). If drivers need to have one socket per vehicle, to have confidence in the BEV option (as observed today); this would mean 7 to 10 million on-street sockets are needed by 2050 to provide national overnight charging.

<sup>397</sup> A parallel study commissioned by the CCC is investigating the cost related to network reinforcement corresponding to the increase in electricity demand as well as the specific impact of a charging network used during day time.

<sup>398</sup> See analysis page 38

**Conclusions and summary of Section 8**

- Moving towards a 100% ZEV uptake will require further infrastructure investment and choices, as not all vehicles can park off-street overnight: around 10 million cars are expected to park on-street by 2050.
- All options to provide for these vehicles (on-street CP outside homes, wide deployment at work / public car parks, ultra-fast charging network, battery swapping, and hydrogen network) entail large investments in infrastructure. A mix of these options is more likely to develop than one option alone, as different regions have different needs and will develop at different speeds. An ultra-fast charging network might be a plausible option post-2030, although advances in charging technologies means that it is difficult to accurately forecast the likely charge rate and costs. Although due to the required standardisation and costs, battery swapping is very unlikely in the short to medium term, in the longer term there may be a case for a battery swapping station network which first develops to serve the commercial vehicle market, before then supporting BEV uptake.
- A ZEV target which includes BEVs and FCVs would allow for the BEV fleet to be able to rely on relatively cheap overnight charging, and a successful FCV market would help address the most difficult vehicle segments to electrify, in particular high duty cycle vans and high mileage business cars. As noted in Section 7 , the strength of the FCV market in 2030 depends in part on infrastructure investment decisions to be made in the next few years.
- The cost and technical uncertainties of the aforementioned challenges to full scale deployment of BEVs (charging infrastructure, high mileage vehicles), suggest that continued work on FCVs is required to keep this option open.
- The 100% ZEV vision will require strong non-technology neutral policies, in particular if PHEVs (even fuelled with advanced biofuels) are to be excluded. Capital cost projections, and the high value consumers place on these costs, suggests reaching a 100% ZEV market share by 2040 will require regulations that phase out non-ZEVs. Such action could be direct (procurement rules, emission zones) or indirect (for example a penalty on OEMs to encourage them to cross subsidise ZEVs by making ICEVs more expensive, in the UK, or potentially in other markets once the EV market share is close to 100%). Cities are likely to be an instrumental stakeholder, as suggested by the EC Transport Strategy, as well as the recent UK move to Local Authorities being in charge of air quality health issues.

## 9 Implications of the report

This section discusses the implications regarding the main issues arising from the project analysis for the four action targets identified as necessary to deliver the high EV uptake pathway: vehicle supply, consumer awareness and acceptance, the provision of charging infrastructure and equivalent value support for the consumer.

### Challenges of the high uptake pathway

The objective of this report is to identify possible pathways to achieve high penetration of light-duty electric vehicles (car and vans, battery, plug-in hybrid and fuel cell electric vehicles) in the UK needed to meet emission reductions in the transport sector consistent with the 2050 UK GHG reduction targets, as identified by the Committee on Climate Change.

As defined by the CCC, the target for 2030 is a 60% market share for plug-in vehicles (BEVs and PHEVs) with a potential contribution from fuel cell vehicles (FCVs). Post-2030, the uptake pathway target of zero emission vehicles (BEVs and FCVs) increases to 100% by 2040 such that the UK fleet is fully decarbonised by 2050.

These targets are clearly very ambitious and represent a speed of technological adoption which is unprecedented in the UK automotive sector. As highlighted in the analysis, whereas the 2030 EV pathway target is for a 60% market share only 20 years after their market introduction, diesel cars (representing a less radical technological shift) took 40 years to reach 50% share of new car sales.

Whilst the high EV uptake pathway poses a huge challenge, the analysis in this report suggests a feasible pathway towards achieving this target. The evidence presented also underlines the fact that the high EV uptake pathway can only be achieved if there are sustained efforts to address both vehicle supply and consumer demand issues, a position that informs the modelling which couples and analyses both of these aspects.

On the supply side, the automotive industry EV production capacity has been assessed at the global and regional level to gauge the ability of the sector to deliver EVs in sufficient numbers across all vehicle segments. On the demand side, a choice modelling methodology has been used to assess consumers' willingness to pay across multiple dimensions, allowing quantification of vehicle attributes in terms of utility to the driver and calculates the market share based on choice probability.

The project modelling identified that, to achieve the 2030 high uptake target for the UK market, the following key action targets would have to be implemented:

- Continuing and sustained improvements in the supply of EV models;
- Almost total consumer awareness and acceptance of EVs by 2021;
- High levels of utilisation of all available off-street parking for overnight charging;
- A nationwide day charging infrastructure (based on 'rapid' chargers) to extend BEV range;
- A level of equivalent value support (financial or otherwise) of the order of £2,500 per EV (noting that this is sensitive to capital cost), sustained until 2030.

### Electric vehicle supply

In terms of vehicle supply, there are two aspects to consider: the OEM's production capacity (volume) and the vehicle segments (and brands) across which an EV option is available. The choice of segment is related to the consumer requirements of size, comfort and practicality, whereas the brand choice reflects more emotional factors such as brand attachment (loyalty), perceived reliability and the buyer's identity construct.

Based on existing OEM announcements collated by the project authors, the annual global production capacity of EVs, currently standing at approx. 500,000 units, is projected to increase to 1.5 million by 2015 (representing a 50% annual growth from 2012). To meet the ambitious national EV targets set

by several countries (also collated), the analysis finds EV annual production capacity will need to increase by an additional 30% per annum post-2015 to reach a capacity of 5.6 million by 2020.

In parallel with a strong vehicle supply, and considering the current low market base, a significant increase in demand will also be needed in order to support the expansion in production volumes consistent with the high uptake pathway developed in this study. However, given sufficient demand, the authors estimate that production growth rates required by the high uptake pathway are credible. As an illustration, in 2020, the projected global EV production capacity would still represent less than 7% of the current total light-duty vehicle production. Consistent with these overall volume increases, the analysis shows that the supply across each vehicle segment and across brands will also need to continue to improve; a key finding being that OEMs must continue to release new EV models in the UK market at least at the current rate of over 10 new EV models per year.

While the UK can continue to stimulate supply through support of innovation and the manufacturing base, and by provision of effective demand side incentives, European CO<sub>2</sub> legislation provides a significant market driver (in the form of emission standards and mandates). To be consistent with the high uptake pathway, the UK must therefore continue to engage in the debate at the levels of the European Commission and Parliament to support a trajectory of decreasing emission targets on cars and vans, as these targets (and the measures to implement them) are likely to be decisive in determining the level of electrification of the fleet and the rate of EV adoption. This report also provides evidence that cities and local government can influence the supply side, through the use of low-cost, high-consumer value measures which advantage EV use, as well as more conventional actions that focus on air quality such as emission zones.

In addition to product supply, the report highlights that OEMs have another important role to play in nurturing the EV market through the development of new ownership and financing models that address two key market barriers: the capital cost premium and consumer uncertainty of EVs. In addition to using existing financial instruments, the most proactive companies are likely to expand the range of finance products for EVs, as has already occurred in the highly competitive mobile phone sector. A related but more radical innovation, and one supported by the project's authors with respect to EV support, is the emergence of new mobility services (such as car clubs).

### Consumer awareness and acceptance of EVs

A key finding of the project is that, as a pre-condition of the high uptake pathway, consumer awareness and acceptance of EVs must be increased significantly from current levels (only around 20% of UK drivers declare being 'very familiar' with the technology and only 25% are aware of the Plug-In Car Grant). Reaching the target of 100% awareness by the early 2020s will require clear and effective messaging regarding the advantages of EVs, so that the mass market actively considers them as a viable vehicle choice.

Given that costs and performance factors rank high in car buyers' purchase criteria, these should remain the principal focus of awareness campaigns (rather than environmental issues) as should new aspects of EV ownership and use such as high levels of internet connectivity and the advantage of being able to home charge. Consumer purchase behaviour and research in product promotion shows that a dedicated EV campaign will need to adopt a marketing approach going well beyond solely providing information and focus on issues that matter to consumers (including cost savings, performance, practicality, social status, safety, and reliability).

While OEMs are the most experienced stakeholders with regards to marketing and advertising, given the scale and complexity of the technological challenge, it may not be sufficient to rely solely on OEMs for EV promotion. Instead, the coordination of messages from all involved stakeholders (central and local government, OEM trade associations, energy companies, the charging infrastructure industry and agencies currently providing information or advice on vehicles such as EST, Cenex, LowCVP) will be needed to sufficiently raise awareness (and therefore demand) before 2020.

Beyond awareness of EVs, the report cites extensive EV trials that show that consumer *acceptance* (i.e. not rejecting EVs on the basis of performance perceptions, concern over new technologies or identity issues linked to EV symbolism) can be fostered through direct consumer exposure to the vehicles. As such, government and industry should support further opportunities for mainstream consumers to gain direct experience of EVs through test-drives and short-term hire. Shifting attitudes of the most resistive consumer segments will however require a long time horizon; as these segments will become receptive to EVs only once EVs have become a visible part of the fleet.

Another approach with which to create a platform for large scale consumer exposure to EVs (and incentivise supply) should involve the support of businesses procuring vehicles for new mobility services (e.g. EV taxi fleets, vehicle rental and car clubs). Incentivising all forms of vehicle leasing (and reinstating tax breaks recently withdrawn) would therefore support opportunities to experience an EV without the long-term commitment of ownership; incentives that have already proven effective in other countries such as the Netherlands in supporting the early EV market.

### Access to charging infrastructure

Counter to initial approaches to EV promotion, this report cites robust evidence which shows that providing large scale access to a national public charging infrastructure is *not* required for *early* EV adoption in terms of actual need (although a public network does provide some degree of psychological incentive). The reason underlying this finding, as identified by the analysis, is that the majority (70%) of new car buyers in the UK already have access to a garage or off-street parking, the highly preferred location for EV charging.

In order that the EV market can grow, however, the authors note that this opportunity to provide low-cost 'overnight' charging facilities must be progressed quickly, the analysis indicating that, by 2020, all car owning households with off-street parking should have either installed a dedicated EV charging unit, or should be aware of the process of having one installed. This will require increased levels of communication to inform prospective EV buyers of the opportunity and the provision for tenants to have the right to install a home charger unit. Support will also be required to install charging facilities for fleet vehicles to enable overnight charging, either at depots or at employees' places of residence.

Based on the current UK best-practice, the report also highlights the installation of charge points in new builds and refurbishments as the most cost-effective way to increase new residential and workplace infrastructure coverage and recommends that local authorities adopt planning conditions that require all parking spaces in new developments to be made 'EV-ready'; a policy already been adopted by Westminster City Council which has a 100% target for all new planning permits.

In the longer term, however, to support high levels of BEV uptake, a national network of publically accessible charging points will be necessary. While government funding has successfully stimulated charging infrastructure development, the majority of chargers are either standard (3kW) or fast rate (7-21kW), with most networks not being highly visible or interoperable. A key finding of the report is that a charging network that meets EV user requirements is best delivered through a national deployment of *rapid* chargers (across around 500 sites by 2020, increasing to 2,100 sites by 2030). Based on 50kW DC units (currently the highest rate that is commercially available and compatible with most BEVs), such a network could cost between £300 and £550 million in cumulative installation costs by 2030 (based on a high utilisation rate by BEVs).

While the analysis recommends that, by 2020, the rapid charging network should provide coverage for 20% of drivers, increasing to 60% by 2025 and 100% by 2030, the key issue here is that a national rapid network both complements the overnight charging network and provides a level of charging service that will increasingly be demanded by EV users wanting to shorten charging times and lengthen possible journeys.

In support of the development of a rapid network, the authors cite recent private sector announcements including the launch by Tesla of a U.S. and European ‘supercharger’ (120 kW) network for Model S owners. In the same way that EV sales can be supported through the use of new models of ownership, funding a national rapid network is likely to require significant private sector investment using new revenue generating business models.

### Policy and equivalent value support

The policy implications of the high uptake pathway is that significant and sustained commitment will be required from the government and industry until at least 2030. It is also unlikely that the pathway targets will be achieved without strong public-private coordination.

Even with vehicle supply, consumer awareness and charging infrastructure actions targets met, the choice model reveals that, to reach the pathway targets, EVs are still expected to need a significant equivalent value support (in financial or other forms) to address their higher capital cost and compensate for the loss of utility associated with reduced range and longer charging times.

Of the identified barriers, the most significant restraint on mass EV adoption is the capital cost premium over ICE vehicles. Not only are consumers highly sensitive to vehicle price, lower running costs have limited potential to reduce the total cost of ownership (for private car buyers at least), due to the way in which consumers discount future spending. Even for fleets, where whole life costs are acted on more readily, financial incentives that address the cost premium of EVs will be required well into the 2020s if EV sales are to increase beyond niche markets.

Based on current cost projections, and assumptions associated with the main pathway scenario, the project modelling quantifies the equivalent value support required to be around £3,000 per EV (2015-2020) and £2,500 per EV (2020-2030). However, the sensitivity modelling shows that the level of support required is highly dependent on the vehicle cost inputs assumed; according to the model, a fall in EV production costs of only 12% by 2030 (compared to projections) would remove the need for equivalent value support post-2020. Estimates of equivalent support should therefore be reviewed by 2020, to reflect any change in cost differential between EVs and non-EVs.

Given the likelihood that equivalent value support will be required into the medium- and long-term, the authors draw attention to important research from the International Council for Clean Transportation that highlights the use of self-financing ‘feebates’ (in place of existing purchase grants and differential circulation taxes) as an affordable driver of market change; an approach to market support that can be sustained over an extended period.

A key finding of this project is the importance of local incentives that compliment national policy. As the country case studies analysed by the report clearly show, delivering equivalent value support in non-financial forms (such as preferential parking and road access) is a cost-effective way to drive the EV market. It also has the advantage of supporting the used as well as new EV market. Local authorities have a particular role to play in delivering these low-cost high-value incentives and, through the use of existing statutory instruments, are likely to become more involved in EV promotion. One key issue yet to address, however, is the need to coordinate and standardise such local measures across the UK.

While capital subsidies, tax differentials, feebate schemes and local incentives could all be used to address the EV cost premium, the scale of the challenge may also call for market delivered solutions and the effective phasing out of ICEVs through emission based regulations – as has already been proposed by the European Commission whose Transport 2050 Strategy sees cities as instrumental in creating strong value added to EVs, with goals for transport that include CO<sub>2</sub>-free city logistics in major urban centres by 2030 and phasing out conventionally fuelled cars in cities by 2050. Given the success to date of the London Congestion Charge in supporting EV sales in the South East, the



authors support the proposed London Ultra Low Emission Zones as a policy to promote the EV market in the UK.

In summary, however, the ambitious EV sales targets will call for actions that are beyond the reach of a single city or country (for instance to stimulate vehicle supply); as such the UK should work more closely with other countries to coordinate EV targets and support measures, as well as influence decisions made at the EU level to help accelerate the market transition to electric vehicles.

### **Role of fuel cell vehicles and 100% ZEV market pathway**

One key issue addressed throughout the study is the relative importance (in terms of market share) of three technologies: battery electric vehicles (BEVs), PHEVs (plug-in hybrid vehicles; including range-extended EVs), and fuel cell vehicles (FCVs).

The report notes findings from a recent study by a consortium of government, OEMs and other industries (utility, gas, fuel retail) which indicates that FCVs could reach 10% market share by 2030, and therefore contribute to the 60% EV adoption target. This level of uptake is highly dependent on the roll-out of hydrogen refuelling stations that will require an estimated total financing of £420 million before becoming self-sustaining, of which £62 million is required before 2020.

Whilst FCVs would contribute to the high uptake pathway of ultra-low emission vehicles by 2030, the full implications in terms of supply of vehicles and competition for infrastructure investment have not been evaluated. It is not clear whether OEMs have sufficient resources or can generate sufficient revenues to deliver all three technologies simultaneously (PHEVs, BEVs and FCVs). FCVs and EVs will compete in certain vehicle segments, meaning a successful FCV market could come at a cost of a reduced EV supply.

Beyond 2030, the CCC target is for BEVs and FCVs to dominate new car sales, reaching 100% market share by 2040. The saturation of households with access to off-street parking implies that further deployment of electric charging infrastructure would be required, ideally converging towards very rapid charging times to provide the level of mobility demanded by drivers. A successful FCV market would reduce this electric charging challenge, in particular in addressing the high mileage segments.

Considering the cost and technical uncertainties of the aforementioned challenges to full scale deployment of BEVs (charging infrastructure, high mileage vehicles), the recommendation is therefore that the efforts to bring the FCV technology closer to commercialisation are continued.

### **Commitment over the longer term**

The overarching implication of the findings is that reaching the high uptake pathway targets is achievable but will require a long term commitment to the support of electric powertrains which may go against a historical policy approach which has tended to be technology neutral.

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## 10 Appendix

### 10.1 Detailed country case studies

Detailed below are the cases of two successful European markets, Norway and the Netherlands. Both countries have addressed the cost barrier of purchasing an EV through grants or purchase tax incentives, as well as providing other benefits that contribute to making EVs a competitive and appealing proposition.

#### 10.1.1 Norway

Norway is the leading country for EV sales as a percentage of total vehicle sales. In 2012, 3,950 EVs were sold, which is 3.3% of all vehicle sales. As of April 2013 there were over 12,000 EVs on the roads in Norway. The country has a relatively long history in terms of EV supply and incentives, with some incentives for EVs being in place for nearly 20 years.

##### Sales of EVs

Passenger EVs have been available in Norway since the early 1990s. Norwegian companies, notably Buddy Electric and Th!nk Global, produced small car models for sale in the early 1990s and 2000s respectively. Despite this early supply and the early existence of EV incentives, sales only began to increase significantly with the introduction of larger models by car manufacturers with stronger brands (see graph below)<sup>399</sup>. The Norwegian EV Association<sup>400</sup> links this to the demand for 4 and 5-seater models, which were not produced by Buddy or Th!nk, as well as perceived safety concerns with these smaller models. This correlates with findings from Argonne National Laboratory which shows that a lack of brand and model choice is a barrier to technology uptake<sup>401</sup>.

In April 2013, the Nissan Leaf was the second-best selling car in Norway, with 455 sales.

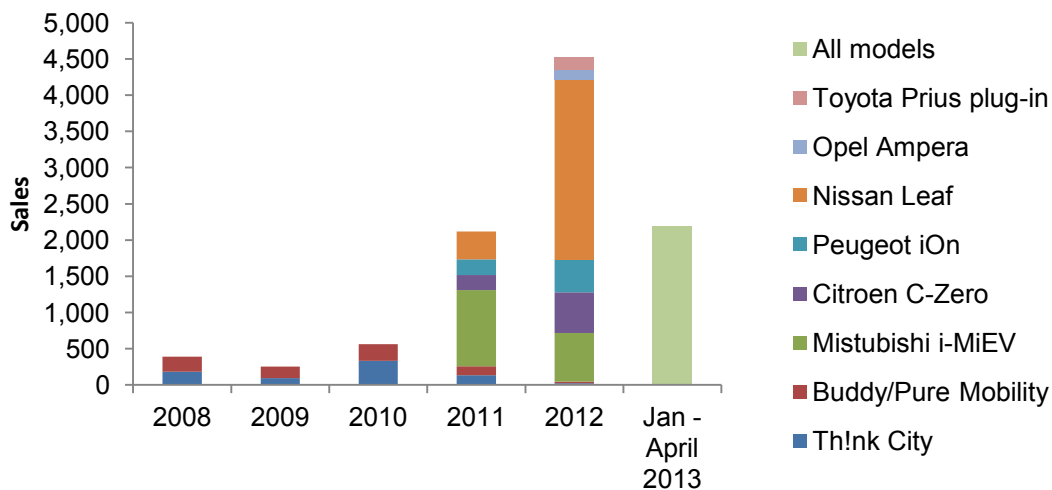


Figure 61 Sales of the main EV models in Norway<sup>402</sup>. Data for 2013 covers the four months from January to April, and all models of EVs.

<sup>399</sup> New models are also providing better performance thanks to the use of lithium-ion batteries while Buddy vehicles use lead-acid batteries and think used molten salt batteries before changing to lithium ion.

<sup>400</sup> Personal communication.

<sup>401</sup> Stephens, T., 2013, Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies, Argonne National Laboratory

<sup>402</sup> Source: Grønn Bil

### Incentives in place to address barriers

The table below sets out the key measures in place to address the cost barriers. There are measures which address the running costs as well as the capital costs of EV purchase. Recognising the greater environmental benefits of BEVs, in terms of CO<sub>2</sub> emissions but also air quality, and also the greater acceptance barriers for BEVs in terms of cost and range/charging time, the Norwegian Government decided to focus incentives on BEVs. The majority of these incentives apply only to BEVs, the only exception being free parking and charging which has also been available to PHEVs.

**Table 21 Measures to address barriers to EV uptake in Norway**

Barrier	Measure	Approximate value, based on comparison with an average C segment ICEV	Type of buyer
Cost – capital cost	1. VAT exemption (25%) on EV purchase, although note that VAT is still chargeable on an EV lease car service.	€8,500	Private, company
	2. Registration tax exemption. Registration tax is based on weight, CO <sub>2</sub> and NO <sub>x</sub> emissions.	€6,000 <sup>403</sup>	Private, company
Cost – running cost	3. Company car tax exemption. Value of relief varies depending on marginal tax rate	€2,820 per year	Company
	4. Road tax exemption	€480 per year	Private, company
	5. Exemption from road tolls and ferry tolls. Tolls vary depending on location.	€4-40 per trip, and up to €910 per year <sup>404</sup>	Private, company
	6. Free parking and free charging	€624 <sup>405</sup> per year for free parking	Private, company

The purchase tax incentives are a significant measure which brings the price of an EV much closer to the price of an ICEV, with a cost premium of c. €1,000<sup>406</sup>. Purchase incentives have been confirmed as being in place until 2018 or until there are 50,000 zero-emission vehicles on the Norwegian roads<sup>407</sup>.

In terms of the running costs the table above shows the significant savings that can be made from toll exemptions and free parking. On top of this, there is a significant difference in the energy cost, with

<sup>403</sup> Note that even without a registration tax exemption, registration taxes on EVs would be very low due to the strong link to emissions.

<sup>404</sup> Source: Grønn Bil 2013 <http://www.gronnbil.no/nyheter/highly-misleading-figures-regarding-norwegian-ev-benefits-in-reuters-article-article326-239.html>

<sup>405</sup> Ibid.

<sup>406</sup> Source: Norwegian electric car user experiences, Petter Haugneland and Hans Håvard Kvisle, 2013.

<sup>407</sup> <http://www.aveve.org/www/newsMgr.php?action=view&frmNewsId=611&section=&type=&SGLSESSID=mi3nr04brhkq4qi69nqjcd61>



electricity in Norway costing 10 euro cents/kWh, and petrol €2/litre; this translates into 1.5 euro cents/km for a BEV compared to 12 euro cents/km for an average car<sup>408</sup>.

### Access to infrastructure

As of June 2013 there were 4,029 charging points in Norway, of which 127 are fast charging points<sup>409</sup>. As yet, there is no national strategy on infrastructure, although the Government agency Transnova is in the process of developing a strategy. In 2009, the Norwegian Government set up a 50 million NOK (c. £5.6 million) fund, where municipalities and companies could apply for grants to cover the installation costs up to 30,000 NOK (£3,380) per charging point. This resulted in 1800 charging points<sup>410</sup>. The City of Oslo has been particularly active, installing 400 charging points between 2009 and 2011, and aiming to install 300 more over 2012 and 2013<sup>411</sup>. The locations of the charging points within the city have largely been determined by requests from EV drivers. The City has also funded CPs for shared apartment buildings and businesses. Across Norway, public CPs are free to use and are easily accessible, being accessed by the same key which is provided by the Norwegian Electric Vehicle Association.

Fast charging is being developed by private companies, although there has been some level of public investment in this. Originally fast charging was free, but most providers now charge a subscription fee. As yet the different providers do not facilitate access to each other's stations. However the national government has mandated that fast charging providers must provide reasonably priced charging to any non-member who requires it.

### Non-financial incentives and consumer acceptance

One of the most important measures has been providing access to bus lanes for EVs, significantly cutting journey times for people who commute into Oslo. This is shown by the significant number of registrations in the suburbs around Oslo. Akershus, to the west of Oslo, is the county with the highest number of EVs registered, at 3245. A local newspaper recently organised a "race" between a conventional car and an EV using the bus lanes. On a typical commute taking 1.5 hours, the EV arrived 45 minutes earlier than the conventional car<sup>412</sup>.

For over 20 years Norway has had a strong and active user association, the Norwegian Electric Vehicle Association, who work on behalf of their members, and with governments, NGOs and industry, to promote EVs.

It is also worth noting that the very severe winters in Norway mean that drivers are accustomed to plugging in cars – a heater is plugged in overnight to keep the engine from freezing, to ensure that it can start in the morning. This familiarity with plugging in cars may aid the consumer acceptance of EVs.

### Supply – measures

The City of Oslo's procurement framework now only allows for replacement of municipal vehicles with electric vehicles. The City has a target that its car fleet will be zero emission by 2015, and has concluded a purchasing agreement for 1,000 vehicles<sup>413</sup>.

<sup>408</sup> Based on 0.15kWh/km for BEV and 6 litre/100 km for an ICE.

<sup>409</sup> Grønn Bil, Norway,

<http://www.gronnbil.no/elbiluniverset/kart.php#zoom=4&tr=72.14173187862764,56.444476074218755&bl=55.70293210778397,-30.567242675781245&m=2&reg=0>

<sup>410</sup> Norwegian Electric Vehicle Association, personal communication.

<sup>411</sup> Electric Vehicles in Urban Europe project, Oslo case study. <http://urbact.eu/en/projects/low-carbon-urban-environments/evue/our-outputs/>

<sup>412</sup> [http://www.osloby.no/nyheter/Sa-tregt-herregud\\_-sa-tregt-7052177.html#\\_Ubh7Af17ly4](http://www.osloby.no/nyheter/Sa-tregt-herregud_-sa-tregt-7052177.html#_Ubh7Af17ly4)

<sup>413</sup> <http://c40.org/blog/driving-action-oslos-electric-vehicle-strategy-leading-the-way>

### Summary

Norway has focussed on incentivising the sales and use of BEVs over PHEVs, and this has resulted in BEVs comprising the majority of EVs sold. Significant purchase tax incentives, bringing the cost premium to around €1,000 more than a conventional car, act as a precondition to EV sales. Surveys undertaken by the Norwegian Electric Vehicle Association demonstrate the importance of local measures which affect the daily driving experience. The most important benefits according to EV drivers are the lack of charges on toll roads, purchase tax incentives, and access to bus lanes. However, even with these measures in place for a number of years, sales did not increase until more conventional models from well-known manufacturers were available.

### 10.1.2 The Netherlands

In 2012, electric car registrations increased by c. 5,100, the equivalent of 1.02% of all passenger car sales<sup>414</sup>. As in Norway, the Netherlands achieves this high uptake through a significant range of measures addressing EV barriers.

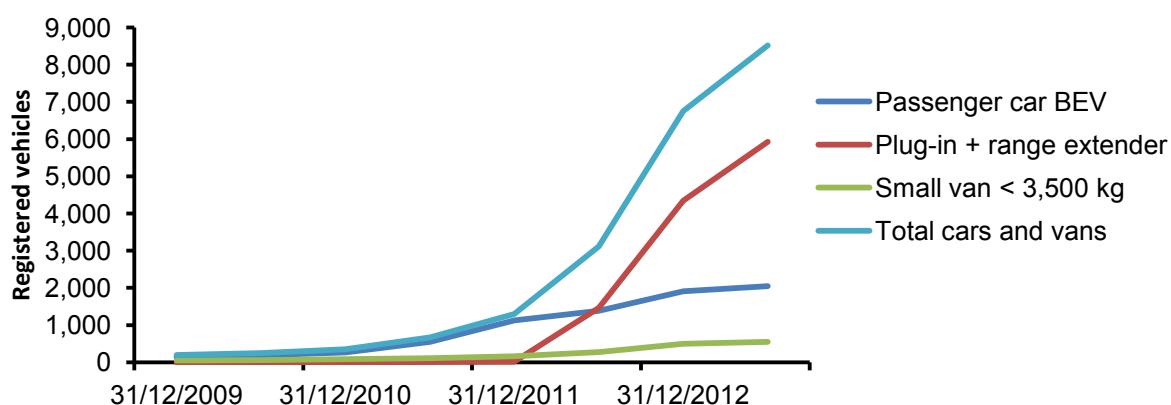


Figure 62 Total number of EVs registered in the Netherlands between Dec 2009 and April 2013. Source: Agentschap NL

### Sales of EVs

EV uptake in the Netherlands has been dominated by sales of PHEVs and RE-EVs (both referred to as PHEVs for simplicity) – see Table 22 below. The dominance of PHEVs is likely to be due to the lack of range limitation for PHEVs coupled with the fact that they attract the same incentives as for BEVs.

Table 22 EV registration in the Netherlands. Source: Agentschap NL

Model	Number of registrations as of April 2013
Opel Ampera (REEV)	3205
Toyota Prius Plug-in (PHEV)	1868
Nissan Leaf (BEV)	650
Chevrolet Volt (REEV)	433
Renault Kangoo Express ZE (BEV)	332

<sup>414</sup> Agentschap NL

**Incentives in place to address barriers**

The table below sets out the key measures in place to address the cost barriers. The measures in place address the running costs, as well as the capital costs of EV purchase, and apply to both PHEVs and BEVs. The tax exemptions have been confirmed to be in place until 2018<sup>415</sup>.

**Table 23 Measures to address barriers to EV uptake in the Netherlands**

Barrier	Measure	Approximate value, based on comparison with an average C segment ICEV	Type of buyer
Cost – capital cost	1. Exemption from purchase tax for EV purchase. Rates vary, but can be up to 45% of the list price.	€5-8,000	Private, lease, company
	2. Company car tax exemptions. Value of relief varies	€4,300	Company
	3. National grant of €3,000 for purchase of taxis and vans	€3,000	Purchase of taxi and van
	4. Local grant of €2,000 for purchase of taxis or vans in cities and regions with air quality issues, including Amsterdam, Rotterdam, Utrecht, the Hague, Arnhem.	€2,000	Company
Cost – running cost	5. Exemption from additional income tax implications for leased cars. For a conventional vehicle, up to 20% of the value of a leased car is added to income each year.	Up to €2,300 per year	Lease
	6. Road tax exemption (MRB)	€250	Private, lease, company
	7. Free parking and charging in Amsterdam (ended Jan 2013), Rotterdam (ended Jan 2013), and Utrecht (ends Jan 2014)	€5-6/hour	Private, lease, company

The measures in place bring the cost premium of an EV down, but they have more impact on company cars and lease cars than for private purchasers. The cost of an average BEV is €11,000 more than a standard segment C ICEV<sup>416</sup> before incentives are taken into account. The incentives in place are worth up to €8,000 for a private purchaser, and significantly more for a company purchase or lease car.

The incentives for companies and lease cars are an important factor in driving sales of EVs to date. According to one survey<sup>417</sup>, half of the EVs on the road are lease cars, in contrast to the car fleet as a whole, where 7% of the vehicles registered are lease cars<sup>418</sup>. Measure 5 in the table above has had particular significance in terms of this market. Lease cars are seen as a benefit, and this benefit is

<sup>415</sup> Electric Mobility Gets Up to Speed, Action Plan 2011-2015, Agentschap NL.

<sup>416</sup> Based on Nissan Leaf and VW Golf Trendline 1.2L. Prices has quoted in <http://www.volkswagen.nl/modellen/golf/uitvoeringen> and <http://www.nissan-global.com/EN/NEWS/2010/STORY/100517-01-e.html>

<sup>417</sup> Elektrische auto op 1!, Accenture, 2012.

<sup>418</sup> Vehicle Leasing Market Key Figures 2011. VNA, the Association of Dutch Vehicle Leasing Companies, June 2012.

therefore added to the user's income tax liability. Exemption from this liability is a significant saving compared to leasing an ICEV. The popularity of EVs as lease cars may also be due in part to driver not having responsibility for the battery and not taking the risk of the battery life/EV resale value.

### Access to infrastructure

The E-Laad Foundation was set-up in 2009 with the objective to install 10,000 public charging points in the Netherlands<sup>419</sup>. The Foundation is funded by the Dutch electricity grid operators. Members of the public could ask for public charging points to be installed at particular (public) locations, but in August 2012 they were no longer able to take requests as the three year trial period and corresponding budget had run out. The Foundation will continue to maintain existing charging points and collect data, and is working on future financing for more charging points. As of May 2013 the E-Laad Foundation have installed 2,500 charging points, and there is an average of 480 transactions per day on these charging points<sup>419</sup>.

However the E-Laad Foundation is not the only installer of charging points. Agentschap NL estimates that there are 3067 public charging points in total (comprising the E-Laad points and points installed by local municipalities), with a further 1445 semi-public (installed by private companies on private locations but available for the public to use), and 89 fast to rapid charging points in the Netherlands<sup>420</sup>. Of these fast to rapid chargers, there are at least 36 rapid 50kW DC chargers<sup>421</sup>.

One key feature of the Dutch infrastructure is that it is easy for all EV drivers to access the public infrastructure. The market has developed so that there are infrastructure providers (who install and operate the equipment) and service providers (who provide subscriptions to the users of charging points). All of these bodies, as well as E-Laad Foundation and the national government have worked together to ensure the interoperability of the infrastructure, so that any subscriber of any service provider can use any charging point.

Home charging has also been supported, with some local municipalities giving grants of up to €1,000 towards the installation of home charging points<sup>422</sup>. Furthermore, some EVs were sold with one or more charging stations included, mostly free of charge including installation at home or office locations.

### Non-financial incentives and consumer acceptance

In Amsterdam EV owners are able to jump the queue for a parking permit. In some areas of Amsterdam, the waiting time for a parking permit can be up to 4 years<sup>423</sup>. The City will also grant up to €1,000 towards the cost of a charging point in a public parking space<sup>424</sup>. In Rotterdam, a parking permit is free for 1 year, and EV drivers can request a charging point to be installed in a public place for free<sup>425</sup>.

In Amsterdam an EV-only car rental club "Car2Go" was launched in November 2011, with 300 Daimler SmartforTwo BEVs. There is no subscription fee to pay, instead, members pay only for the time they have used the vehicle for. EV charging is free to members and members are incentivised to plug the vehicle in, as they receive free minutes. By March 2013, more than 7,000 people had registered, and there are as many as 5,000 separate rentals a week<sup>426</sup>.

<sup>419</sup> [www.e-laad.nl](http://www.e-laad.nl)

<sup>420</sup> <http://www.agentschapnl.nl/onderwerp/cijfers-elektrisch-rijden>. Data as of end of April 2013.

<sup>421</sup> <http://www.essent.nl/content/particulier/producten/elektrisch-rijden/laadpuntenkaart/index.html>

<sup>422</sup> Lode Messemaker, Innovation Manager, Rotterdam Electric, City of Rotterdam

<sup>423</sup> [http://www.citizen.nl/main.php?obj\\_id=442832490](http://www.citizen.nl/main.php?obj_id=442832490)

<sup>424</sup> <http://www.amsterdam.nl/parkeren-verkeer/amsterdam-elektrisch-opladen/subsidie/>

<sup>425</sup> <http://www.rotterdam.nl/product:oplaadpuntoopenbareruimte>

<sup>426</sup> Eltis, the Urban Mobility Portal [http://www.eltis.org/index.php?id=13&study\\_id=3720](http://www.eltis.org/index.php?id=13&study_id=3720)

In Rotterdam there is a Centre for EVs (Elektrisch Vervoer Centrum), financed by a consortium of public and private bodies. The aim of the centre is to target fleet managers, but the public and businesses can also test drive EVs. The centre also provides information about the range of EV models, infrastructure and grants available. Since it opened at the beginning of 2012, the centre has held 5,000 test drives of EVs, and provided information to 1,500 companies<sup>427</sup>.

### Supply - measures

In 2009 a consortium of public and private partners came together with the intention of launching a national procurement ahead of the release of series models<sup>428</sup>. However, specialised vehicle requirements and legal tender differences between partners delayed the process. As several series models were released onto the market before the consortium had finalised the tender, the procurement was eventually cancelled.

Local and national government bodies have put in place targets for the number of EVs as part of the fleet. For example Rijkswaterstaat (the Government agency for public works and water management) have purchased 24 full electric vehicles and plug-in hybrid vehicles, and have a target that one quarter of its fleet should be electric by 2015<sup>429</sup>.

### Summary

Incentives in the Netherlands have been particularly favourable for lease cars. It is possible that the uptake of EVs has been driven by a combination of these incentives and the low perceived risk for a driver of using an EV as a lease car as opposed to buying an EV outright and owning the battery (with the concern of battery degradation). PHEVs and BEVs are equally incentivised, and so PHEVs have dominated the uptake due to the convenience brought by the lack of a range restriction. The available infrastructure is easily accessible to all EV drivers, although this is not likely to have had a large impact on uptake so far as sales are dominated by PHEVs.

<sup>427</sup> [elektrisch-vervoer-centrum.nl](http://elektrisch-vervoer-centrum.nl), personal communication

<sup>428</sup> <http://www.greencarcongress.com/2009/09/new-dutch-purchasing-consortium-launches-tender-for-almost-3000-evs-.html>

<sup>429</sup> [http://www.rijkswaterstaat.nl/en/images/Rijkswaterstaat%20Annual%20Review%202011\\_tcm224-321458.pdf](http://www.rijkswaterstaat.nl/en/images/Rijkswaterstaat%20Annual%20Review%202011_tcm224-321458.pdf)

## 10.2 The UK car and van market

This section introduces the UK vehicle buyers as well as the segmentation of vehicles.

### 10.2.1 Car buyers

#### Private car buyers

In the UK, the private car market accounts for around 45% of new car sales (0.93 million sales in 2012).<sup>430</sup>

New (conventional) car buyers in the UK tend to be male (62%), well educated (50% have a degree or higher qualification), affluent (with over 40% being in the AB socio-economic groups) and older (the majority being 45+ years).<sup>431,432</sup> These trends are expected to become increasingly important for new car sales with the continuing growth of the AB group and over 45s. New car owners are also more likely to be in multiple car households (with an average of 1.7 cars per new car household).

Private car purchase buyers have been presented in more detail in terms of purchase decision process in section 3.1.

#### Fleet car buyers

In the UK, the fleet and business car market accounts for around 55% of new car sales (1.12 million sales in 2012).<sup>433</sup> As such, fleet sales play a crucial role in the new vehicle market.

Non-private car purchases fall into two categories: 'business cars' within fleets of less than 25 vehicles, and 'fleet cars' of 25 vehicles or more. 'Fleet cars' form the great majority of company vehicles, representing over 90% annual non-private sales. With a typical replacement cycle of 3-5 years for cars, fleets are an important channel by which conventional and new technology vehicles reach the used car market.

To a greater extent than for private buyers, fleet managers consider the total cost of ownership (TCO) during vehicle procurement and are sensitive to both financial incentives and regulation.<sup>434</sup> Fleet buyers are also more concerned with vehicle reliability and maintenance issues, but are less concerned with image, viewing vehicles from a more functional perspective. Fleet managers also take what action they can to reduce (economic and other) risks and look for high degrees of certainty regarding future policy signals (from government and internally).

Fleet and business car purchases become more complex in cases where vehicles are provided for non-company use, the main example being 'company cars' which are provided to employees as a benefit-in-kind (BIK). In these situations, fleet managers may also be influenced by the purchasing priorities of employees who aim to maximise the vehicle's specification while also minimising the level of company car tax (payable on BIK). Based on HMRC data,<sup>435</sup> and including all employee provided cars, the authors estimate that the proportion of 'user choosers' represents around 40% of company fleets.<sup>436</sup>

In contrast to company cars, depot-based 'captive fleets' represent fleet vehicles used solely for business use. These vehicles are exempt from VAT (where no private use can be proven) and are not

<sup>430</sup> SMMT industry data, 2013.

<sup>431</sup> Purchasing of New and Second-hand Cars, Market Intelligence, Mintel, 2009.

<sup>432</sup> The Role of the Internet in New Car Purchases, Netpop Research, 2011.

<sup>433</sup> SMMT industry data, 2013.

<sup>434</sup> Consumer attitudes to low carbon and fuel-efficient passenger cars. Ecolane on behalf of the Low Carbon Vehicle Partnership, March 2005.

<sup>435</sup> Benefits in Kind Statistics, HMRC, July 2012

<sup>436</sup> For more details about the proportion of company cars, see section 10.2.3



liable for company car tax. In these cases, vehicles are selected by the company primarily to match the application (and method of financing), the majority being chosen from a restricted list.

As a result of the higher importance given to functionality and TCO, fleet buyers have historically been one of the first market groups to accept and adopt new vehicle powertrains. The next figure shows that – with the exception of hybrid vehicles (HEV) in medium segments – fleet car buyers buy proportionality more technologies that have a higher capex but lower fuel consumption. Hybrid vehicles are less attractive to fleets because fuel saving benefit is captured in urban cycle.

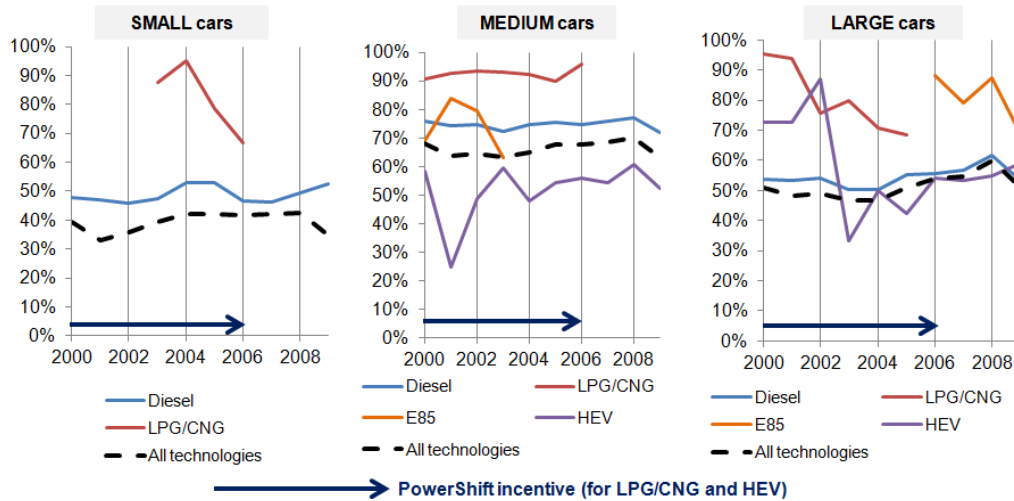


Figure 63 Company owned car shares of new sales. Source: SMMT

Businesses are also more likely than private buyers to pay a premium for cleaner vehicles if their use enhances the company’s brand, environmental policy or CSR position,<sup>437</sup> especially in cases where this can be quantified.

This is supported by figures supplied by the Department for Transport which shows that, analysing new EV registrations between 2010 Q1 and 2012 Q4, UK fleets represented 76% of all EV sales (24% private)<sup>438</sup>. Disaggregating EV types, fleets showed a preference for BEVs with company registrations representing 81% BEV sales and 61% PHEV sales.<sup>439</sup>

Regarding the cost and financing considerations related to fleet purchase, it is also important to note the multiplicity of vehicle acquisition methods available. Of the total fleet and business car sales, around 60% of car ownership resides with corporate finance agencies, with vehicles being leased or hired to end user companies through contracts (the most popular being contract hire), or supplied to the rental fleet.<sup>440</sup> Of the remainder, fewer than 30% are purchased outright<sup>441</sup>. The issue here is that each acquisition method has different capital allowance and tax implications which in turn impacts on TCO. The method of acquisition method is therefore an important consideration for fleet purchase.

<sup>437</sup> CSR: Corporate Social Responsibility.

<sup>438</sup> Department for Transport (2013)

<sup>439</sup> The company/private split is defined as whether the vehicle is registered to a company or private individual, and is not determined by its end use. For instance, a dealership may register the vehicle before selling it on, a vehicle could be registered to a mobility company and then leased to its user, or a vehicle could be registered to a company such as a sole trader and then used for private as well as business purposes.

<sup>440</sup> Authors’ estimate based on data supplied by the BVRLA, FLA and SMMT – see section 10.2.3

<sup>441</sup> The remainder 10% are demonstrator or stock vehicles for car dealers.

Car segments

Table 24 SMMT vehicle segmentation. Source: SMMT

Segment	Full name	Example
A	Mini (City Car)	Smart
B	Supermini	Nissan Micra
C	Lower medium (small family)	Vauxhall Astra
D	Upper medium (large family)	Ford Mondeo
E	Executive	BMW 5 series
F	Luxury saloon	Rolls Royce
G	Specialist Sports	Porsche 911
H	Sport Utility Vehicle / Dual purpose	Range Rover
I	Multi Purpose Vehicle	Renault Espace

10.2.2 Van buyers

In the UK, the fleet van market accounts for around 90% of new van sales (approx. 240 thousand LCV <3.5t sales in 2012).<sup>442</sup> Of the new vans company registered, around 50% are bought outright, the rest being acquired using finance contracts. While the majority of new vans are purchased or leased directly for business use, rental fleets account for around 20% of the new van market.

As part of a study on ultra-low carbon vans conducted for the Department for Transport in 2011, Element Energy conducted a survey of 20 UK fleet van buyers.<sup>443</sup> The sample included both public and private organisations, and a wide range of vehicle applications and fleet sizes (1 to 30,000 vehicles). The sample also included three of the leading vehicle lease companies in the UK, which collectively lease and manage over 100,000 commercial vehicles under 3.5t GVW.

From the detailed interviews, a list of purchase criteria emerged - the main issues are summarised in Table 25. Overriding all other factors is ‘fitness for purpose’, conceptualised as sufficient payload and/or cubic capacity. Van buyers also prioritise a total cost of ownership (TCO) approach when comparing technologies. Regarding the time period over which TCO is assessed, leasing companies and other stakeholders report a recent trend in the lengthening of the hire or ownership period from 3-4 years to 5-6 years.

Around half of those interviewed reported to be willing to pay a small TCO premium for an ultra-low carbon vans (assuming fit for purpose). More recent work with fleet managers by Element Energy suggests a smaller proportion, of the order of 20%, with all interviewees stating they would need TCO parity to buy volumes beyond trials.<sup>444</sup> Reasons given for willingness to pay a premium include corporate CO<sub>2</sub> targets as well as, for some companies, a desire to be ahead of policy and brand image enhancement (linked to CSR policy).

<sup>442</sup> SMMT industry data, 2013.

<sup>443</sup> Ultra Low Emission Vans study, January 2012, Element Energy for the DfT

<sup>444</sup> Element Energy research




Table 25 Van purchase priorities in order of importance. Source: Element Energy




<b>Fitness for purpose</b>	Sufficient payload and cubic capacity
<b>Total cost of ownership</b>	Purchase price or lease fee, fuel, maintenance, depreciation
<b>Reliability</b>	As distinct from repair costs in the TCO, it concerns value of downtime
<b>Brand</b>	Some consumers were willing to pay more for ‘premium brands’, or required compatibility with existing racking equipment
<b>Safety</b>	Many procurement tenders stipulated safety equipment e.g. airbags
<b>Emissions (Euro Standard)</b>	Several public sector fleet managers required Euro 5 vehicles before being legally mandated

Van segmentation

The van market can be segmented into six vehicle types, based on a combination of body type and gross weight. Descriptions and illustrative payload and mass data are given in the next tables.

Table 26 light commercial vehicle segmentation. Source: Element Energy for the DfT

Segment	Small car-derived	Small van	Standard panel van
			
Description	Based on small passenger hatchbacks	Includes larger car-derived vans and small panel vans e.g. Transit Connect	‘Standard’ panel van, short/medium wheelbase, low roof
Payload volume (m <sup>3</sup> )	1	3	6
Payload mass (kg)	500	750	900
Gross weight (t)	1.6	2.1	2.6 (+ up to 3.4t)
Examples	Corsavan, Fiesta van,	Citroen Berlingo, Ford Transit Connect	Ford Transit, Vauxhall Vivaro

Segment	Large panel van	Tipper/drop-side/Luton/box van	Pick-up truck
			
Description	Larger than standard panel van, though can be LWB, high roof variants of same models	Either specialist conversions or factory-fitted. Often with dual rear axle	4WD pick-up trucks. Double cab variants are best-selling models
Payload volume (m <sup>3</sup> )	13	15-20 (Luton van)	N/A
Payload mass (kg)	1300	1000-1300	1000
Gross weight (t)	3.5	3.5	3
Examples	LWB Sprinter, Iveco Daily, VW Crafter	Ford Transit, Vauxhall Movano	Toyota Hilux, Mitsubishi L200

### 10.2.3 Purchase methods / supply pathway

Based on data from SMMT, BVRLA, HMRC, ACFO (organisation for fleet decision-makers in charge of cars and light commercial vehicles) and the Finance & Leasing Association, a breakdown of acquisition methods for new cars and vans (fleet only) was derived, they are shown in the figures below. The most important sub-markets and methods of acquisition/financing are highlighted.

Kind findings include:

- 70% of cars are financed (both private and fleet); 50% of fleet vans are financed;
- 80% of employee cars 'see' the BIK signal;
- 30% fleet cars receive the Enhanced Capital Allowance, 50% for fleet vans;
- 40% of company-owned cars are chosen by the employees themselves ('user-choosers')

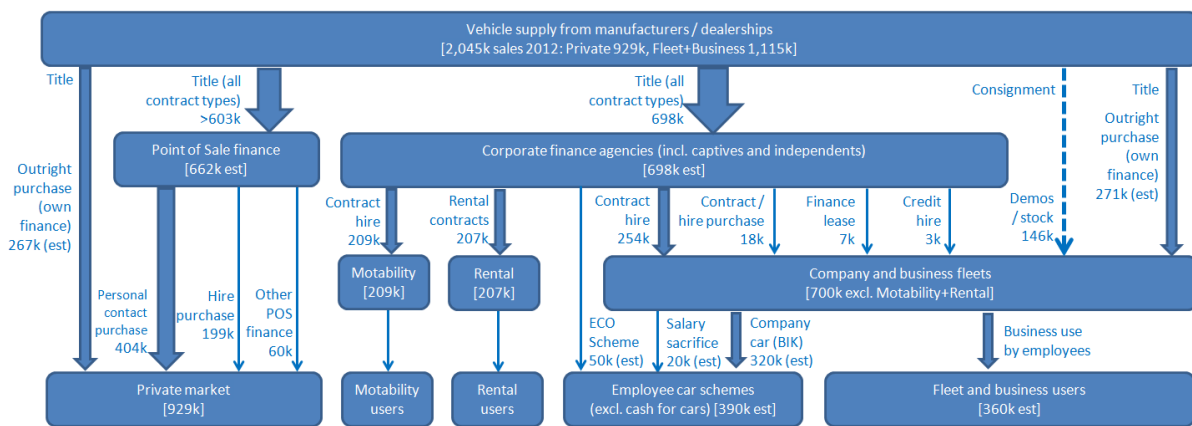


Figure 64 Acquisition methods, new car sales, 2012

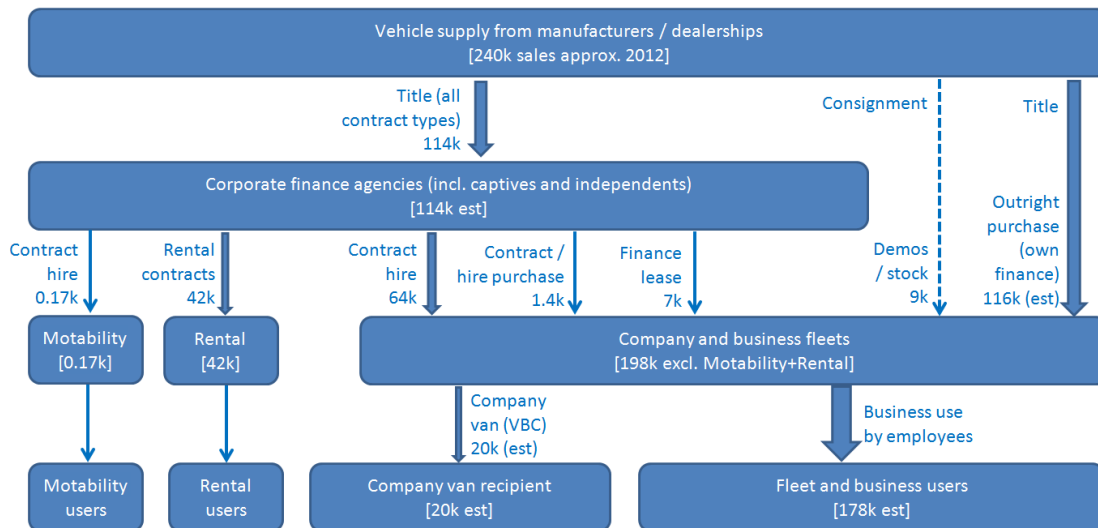


Figure 65 Acquisition methods, new van sales, 2012

### 10.2.4 Access to overnight off-street parking

The level of access to off-street parking is high in the UK: around 40% of all households have access to a garage (including those not owning a car) and a further 26% have an alternative off-street parking space. Even in London, around 60% of cars are parked off-street.<sup>445</sup>

The Department for Transport Omnibus survey (2008) on the use of cars looks more specifically at households that own at least one car and differentiates between parking locations households have access to and those locations actually used.<sup>446</sup> The survey shows that although 55% of the sampled households have a garage, only 23% are used for parking a car (the main reason being that it is used as storage), with the main location used described as 'other off-street parking' (a drive way in most cases). The survey also reveals that, while fewer than 20% of households *only* have access to on-street parking, this location is used by 20-30% of households.

A survey by Element Energy of new car buyers conducted in 2010 also reveals that while 80% of the sample had access to a garage or other off-street parking space, the share of buyers with parking locations close enough to the house to allow for overnight charging was reduced to 70%.<sup>447</sup> Table 27 summarises the survey findings regarding the breakdown of overnight locations for the UK car stock.

**Table 27 Overnight parking location of cars (excluding depot based vehicles). Estimates based on DCLG analysis as reported by RAC Foundation 2012 and Dft/Omnibus Survey 2008**

Parking location	Access to*	Used
Garage or off-street	80%	60-70%
On-street	60%	20-30%
Resident car park	15%	10%

\*Total exceeds 100% as drivers have access to several options

For company owned cars, it is estimated that 15% return 'back to base' (i.e. they are parked at the depot or workplace overnight).<sup>448</sup> Among the remaining 85% parked at home by users, it is assumed that 70% of the fleet have access to a location that allows for overnight charging, as detailed above.

Most vans also spend the night at a base location that allows access to an electric supply. The analysis of the Survey of Company Owned Vans reveals that 25% of vans spend the night at a central location where they can be plugged in (defined as 'warehouse', 'retailing', 'transport and utilities' or 'offices') while only 10% are at locations without an accessible socket (such as a 'construction site' or 'minerals and landfill').<sup>449</sup>

The remaining 65% of vans are parked overnight in residential areas. Assuming that 50% of these have access to a socket (reduced from 70% to account for small vans not fitting in some garages, and the possibility of a car competing for a limited garage/ driveway space), the overall access to overnight charging facilities for vans is estimated at about 60%.

Based on the figures described and assuming drivers take advantage of their off-street parking, the level of overnight charging access is :

- 70% for private cars
- 75% for fleet cars [60% at home, 15% at depot/ work place]
- ca. 60% for vans [ca.35% at home, 25% at depot/ work place]

<sup>445</sup> RAC Foundation report, Spaced out, perspectives on parking policy, 2012

<sup>446</sup> DfT/ONS Omnibus Survey 2008

<sup>447</sup> Consumer Research by Element Energy for the ETI Transport programme

<sup>448</sup> New Vehicle Purchase Market Transformation Model, 2007, Element Energy for the Energy Saving Trust

<sup>449</sup> Survey conducted in 2005 on 8,400 van owners, covering 44,300 journeys. Element Energy analysis.

### 10.3 Targets for electric vehicle uptake in selected countries

Country	Target for EV stock in 2020	Source
<b>China</b>	5,000,000	<a href="http://www.cars21.com/news/view/425">http://www.cars21.com/news/view/425</a>
<b>Japan</b>	800,000	IEA, EV city casebook, target is 20% of all vehicles sold. The IEA estimate that this means 800,000 vehicles
<b>India</b>	2,000,000	Government target of 6 million, 4 million of which are two-wheelers, <a href="http://www.cars21.com/news/view/4910">http://www.cars21.com/news/view/4910</a>
<b>South Korea</b>	1,000,000	Government plan that EVs are 10% of all light duty vehicle sales by 2020. Initial target of one million vehicles. <a href="http://english.peopledaily.com.cn/90001/90778/90858/90863/6923060.html">http://english.peopledaily.com.cn/90001/90778/90858/90863/6923060.html</a>
<b>United States</b>	2,488,320	Government target of 1 million EVs by 2015. President Obama, State of the Union 2011. This number is then projected to 2020 using a compound annual growth rate of 20% (Source for calculation EVI Global Outlook 2013)
<b>Canada</b>	500,000	Government roadmap published in 2010, <a href="http://canmetenergy.nrcan.gc.ca/sites/canmetenergy.nrcan.gc.ca/files/pdf/fichier/81890/ElectricVehicleTechnologyRoadmap_e.pdf">http://canmetenergy.nrcan.gc.ca/sites/canmetenergy.nrcan.gc.ca/files/pdf/fichier/81890/ElectricVehicleTechnologyRoadmap_e.pdf</a>
<b>Spain</b>	2,500,000	<a href="http://europa.eu/rapid/press-release_MEMO-13-24_en.htm#footnote-14">http://europa.eu/rapid/press-release_MEMO-13-24_en.htm#footnote-14</a>
<b>France</b>	2,000,000	Government target, <a href="http://www.ieahev.org/by-country/france/">http://www.ieahev.org/by-country/france/</a>
<b>Germany</b>	1,000,000	Government target, <a href="http://www.upi.com/Science_News/Resource-Wars/2010/05/04/Germany-launches-electric-car-initiative/UPI-55231273005809/?loc=interstitialskip">http://www.upi.com/Science_News/Resource-Wars/2010/05/04/Germany-launches-electric-car-initiative/UPI-55231273005809/?loc=interstitialskip</a>
<b>Netherlands</b>	200,000	Government target, <a href="http://dc.the-netherlands.org/key-topics/energy--climate/building-a-green-economy.html">http://dc.the-netherlands.org/key-topics/energy--climate/building-a-green-economy.html</a>
<b>Portugal</b>	200,000	Government target <a href="http://www.mobieurope.eu/the-project/ongoing-initiatives/mobi-e/">http://www.mobieurope.eu/the-project/ongoing-initiatives/mobi-e/</a>
<b>Ireland</b>	230,000	Government target <a href="http://www.dcenr.gov.ie/Corporate+Units/Press+Room/Speeches/2012/Speech+by+Minister+Rabbitte+at+International+Electric+Vehicles+Summit.htm">http://www.dcenr.gov.ie/Corporate+Units/Press+Room/Speeches/2012/Speech+by+Minister+Rabbitte+at+International+Electric+Vehicles+Summit.htm</a>
<b>Austria</b>	250,000	Government target <a href="http://www.ieahev.org/by-country/austria-on-the-road-and-deployments/">http://www.ieahev.org/by-country/austria-on-the-road-and-deployments/</a>
<b>Other Europe</b>	184,000	Includes: Italy, Luxembourg and Slovenia <a href="http://europa.eu/rapid/press-release_MEMO-13-24_en.htm#footnote-14">http://europa.eu/rapid/press-release_MEMO-13-24_en.htm#footnote-14</a>



## 10.4 Model inputs and assumptions

The overall methodology is presented in section 4 . This Appendix section details the inputs and assumptions used in the modelling of the uptake of electric vehicles. It is divided in three sections:

- The choice model section describes the inputs and assumptions regarding consumer purchase behaviour and value of vehicle attributes.
- The vehicle costs and characteristics section reports on the vehicle inputs, as developed by the CCC.
- The other inputs section contains all other inputs, such as energy costs and housing stock projections

### 10.4.1 Choice model inputs

#### Purchase and running cost

The price coefficient is set as 0.00035, in line with the price elasticity reported in the Eftec study<sup>450</sup> and the running cost coefficients are set to reproduce the willingness to pay (WTP) for running cost savings (Table 28). This varies from a WTP £7 upfront to save £1 annual for Enthusiasts to a WTP of only £2 for Resistors. This can be interpreted as ‘payback time horizon’: for a vehicle with a capital cost premium over the incumbent (ICEV), the running costs savings must offset the premium over 7 years for Enthusiasts (for the market share to reach 50% in the case of a comparison between two technologies). This time period is reduced to 2 years for Resistors.

Another way to interpret the WTP for running cost savings is to translate them into discounting rates: the range is 7% for Enthusiasts to 48% for Resistors. The overall weighted average discounting rate of private buyers is 25%, which is in line with other studies<sup>451</sup>.

This relatively high discount rate reflects the cost of finance of capital purchases, opportunity costs and the risk that the product may not deliver the claimed on-going savings. This is also seen in the domestic energy efficiency market, where consumers choose not to install measures with payback periods beyond 2-3 years, despite the product lifetime of over 20 years.

**Table 28 Running cost weighting<sup>452</sup>**

Segment	Willingness to pay for £1 in running cost savings
Enthusiasts	£7
Aspirers	£5
Mass market	£5
Resistors	£2
User Choosers	£4

For private buyers, the utility equation contains the vehicle price, running cost, access to infrastructure, charging time, driving range and supply – as laid out in 4.2 and Figure 26.

For fleet managers (35% of new car sales, 100% vans), a simpler approach is used to reproduce the reported TCO and technology suitability approach (illustrated Figure 27). The utility equation contains

<sup>450</sup> Demand for car and their attributes, 2008, Eftec for the Department of Transport. Page 46

<sup>451</sup> Private discount rates of around 30% are cited in Brand C, Anable J, Tran M, *Accelerating the transformation to a low carbon passenger transport system: The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK*, Transportation Research, 2013

<sup>452</sup> Consumer Research by Element Energy for the ETI Transport programme

only a 4 year TCO and supply penalty. The price coefficients are derived from the elasticity in demand as per Greene (2004)<sup>453</sup>.

Table 29 shows the fleet manager price coefficients for each vehicle segment as well as values used to derive them. The elasticity is based on the willingness to pay data of fleet manager as collected during primary research conducted by Element Energy. Vans are modelled based on one type of van (the standard panel van). The TCO calculation is based on resale value rates, discount rates and financing rates as developed in previous work by Element Energy<sup>454</sup>.

The lower discount rates used by businesses (10%) bring the overall average UK buyer discount rate to c. 20%.

**Table 29 Price coefficients for the ‘fleet manager’ consumer segments**

	A/B car	C/D car	E-I car	Van
ICEV TCO in 2012	£14,433	£22,461	£33,397	£23,877
Number of makes/models	75	98	255	13
Elasticity	-15.7	-15.7	-15.7	-12.4
Implied price coefficient	0.00110	0.00070	0.00047	0.00056

**Lack of access penalty (overnight charging)**

As the certainty of access to charging facilities is a key decision factor for potential BEV owners, it is assumed that only consumers with such access will consider purchasing a BEV. Without the provision of extensive public infrastructure, only overnight charging can provide this certainty of access<sup>455</sup>. The assumptions regarding the share of consumer with such access are as shown in Figure 20, and as described in Section 10.2.4.

For PHEVs, while access to recharging equipment is necessary to realise running cost savings, it is not essential for mobility. Therefore all private car buyers (privately registered cars and 40% of cars registered as company cars) are assumed in the model to be able to consider purchasing PHEVs. However, for the portion without access to infrastructure, the perceived running costs are based on the use of conventional fuel only, and an associated penalty equivalent to the loss of four years of fuel savings (four years being the average ownership period of new cars).

Given their motivation to reduce costs, it is assumed that fleet managers consider PHEVs only if they have certainty of access to charging facilities, as this provides the only route to fuel cost reduction.

**Lack of access penalty (day charging)**

Even for private car buyers (and company car ‘user choosers’) with access to home charging, the lack of opportunity to charge in the day translates into a disutility for BEVs (commonly referred to as ‘range anxiety’). Lin and Greene (2010) value the corresponding penalty, based on observed U.S. travel patterns, to be worth up to £4,000 (for the lowest mileage drivers, the figure is estimated at around £1,000)<sup>456</sup>.

<sup>453</sup> Greene , D. L. 2004, Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market  
<sup>454</sup> Influences on low carbon car market from 2020-2030, Element Energy for the LowCVP, July 2011 for cars and Ultra Low Emission Vans study, January 2012, Element Energy for the DfT for vans  
<sup>455</sup> Work place charging involves some competition for the charging socket; furthermore it is not accessible 7 days a week. Also note that 50% of cars do not commute (Dft data).  
<sup>456</sup> USD converted to GBP based on 1GBP = 1.2 US; Lin, Z., Greene D. L., 2010, “Rethinking FCV/BEV Vehicle Range: A Consumer Value Trade-off Perspective,” EVS-25, The 25th World Battery, Hybrid and Fuel Cell Electric Vehicle Symposium & Exhibition, China

For this project, the model uses a lower value of £2,000, in line with the findings from the choice experiment conducted on UK new car buyers.<sup>457</sup> However, based on observed UK purchase behaviour,<sup>458</sup> the modelling assumes that the ‘Enthusiast’ segment does not perceive a penalty related to any lack of day infrastructure. For PHEVs, as in the case of access to overnight charging, the perceived running costs reflect the level of access to recharging; not having access to recharging is, therefore, set at the equivalent of four years of fuel savings.

Being depot/work based, it is assumed that fleet managers only they consider BEVs if they have access to overnight charging<sup>459</sup> and their vehicle application operation is compatible with the vehicle’s range. Therefore access to a (rapid) network increases the share of fleet managers who can consider BEVs, but any lack of public day charging infrastructure does not represent a penalty for fleet managers. In the particular case of vans, available data on range indicates that improvements in battery cost and energy density will result in EV range being compatible with 40% of ICE vans in 2020 and 50% in 2030, increasing from 34% today<sup>460</sup>. For fleet cars, as data on usage pattern is not readily available,<sup>461</sup> it is assumed that there is more variety in usage; as a result, range compatibility (before provision of day infrastructure) is set lower than for vans (30% in 2020 and 40% in 2030).

### Driving range and charging time penalty

As data related to the value of range or recharging time has not yet been revealed by market trends<sup>462</sup>, the penalty assumed by the model relies on findings from recent choice experiments, as detailed below.

#### Driving range

In a meta-analysis of 31 surveys spanning different years and countries, Dimitropoulos *et al.* (2011), report an average value for EV range of £30/km<sup>463</sup>. This means consumers would be willing to pay £3,000 to add 100 km to the driving range of a BEV. Alternatively, if the maximum range of a BEV is 100 km less than the ideal range consumers would like, the range penalty is valued as £3,000. The value of driving range has also been tested over different scales (for example, the value of adding range when starting from a 100 km or 200km maximum). Such experiments reveal that the incremental value of range decreases as the maximum range increases<sup>464</sup>. In the model used for this study, this decrease in penalty is reproduced (from £30/km at 150 km), and assumes that the ‘ideal range’ of 370 km (discussed in section 3.3) is the limit over which no more penalty is perceived (i.e. value of adding range over 370 km is zero).

Figure 66 shows the resulting penalty as a function of driving range. A range of 200 km represents an approx. £2,000 penalty whereas a range above 250km entails a small penalty (under £1,000).

<sup>457</sup> Consumer Research by Element Energy for the ETI Transport programme

<sup>458</sup> Research conducted by TRL for the DfT, due for publication in September 2013

<sup>459</sup> Vehicle operations would not want to rely solely on publically accessible infrastructure (loss of time entailed for finding the post and/or queuing).

<sup>460</sup> Based on EE analysis of maximum daily distance of 8,000 van sample over 31 consecutive days. 80% factor used to account for loading effect and/or wanted margin. Range assumptions presented in next section

<sup>461</sup> Although the National Travel Survey captures some company car data, the high mileages quoted indicate they are more likely to correspond to ‘user choosers’ than fleet vehicles.

<sup>462</sup> Although Tesla offers various driving range options, the purchase choice is skewed by different charger types and power options. Nissan also offers three different trims for the LEAF in the U.S., with different charging speed options (soon to be available in the UK); while a sales breakdown of the three trim options could give an indication of the value of recharging time, this data is not yet in the public domain

<sup>463</sup> Dimitropoulos A. *et al.*, 2011, Consumer Valuation of Driving Range: A Meta-Analysis, Tinbergen Institute Discussion Paper.

<sup>464</sup> For example, Hidrue, 2011, Willingness to pay for electric vehicles and their attributes, Resource Energy Econ. as well as Consumer Research by Element Energy for the ETI Transport programme

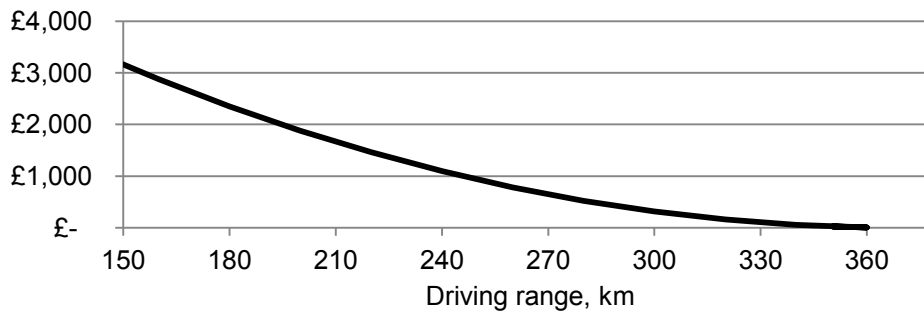


Figure 66 Range penalty as a function of BEV driving range

### Charging time

Results reported in the literature report a high charging time penalty; the findings also reveal a non-linearity in the value of one hour reduction in charging time, suggesting a particularly high penalty for the first hour. The results vary widely, from £300 to £600 per hour in the 10h-5h and 5h-1h range, to £1,000 to £3,000 per hour for the initial hour<sup>465</sup>. This decrease in penalty per hour with increase total time is intuitive: as the charging time increases, adding an hour adds decreasing levels of additional inconvenience.

The authors note that these high values of waiting time contrast with the values based on the average salary of UK car buyers, which are less than £100 per hour.

The model used for this project uses a value for charging time of £250/h is lower than that suggested in the aforementioned literature in order to be consistent with the assumption that the majority of BEV drivers have access to overnight charging. Furthermore, a review of work in this area suggests the high penalty associated with the first hour is accounted for in more general technology acceptance/rejection factors (discussed in the next section) and the value for charging time reduction should therefore be based on the lower end of reported range<sup>466</sup>.

### Supply penalty

Based on the methodology developed by David Greene from Oak Ridge laboratory, and used in the U.S. Transitional Alternative Fuels Vehicle Model, the disutility corresponding to a low supply of brands and models can be expressed as function of the percentage of models available on the market:<sup>467</sup>

$$\text{Disutility}_{\text{powetrain } i} = 2/3 * \ln (\text{Number of models}_{\text{powetrain } i} / \text{Total number of models})$$

This disutility can be expressed as a monetised value (in this case negative, and therefore a penalty) to the consumer. Figure 67 shows the penalty of the 'low model availability' for electric vehicles in the UK, based on the number of models available as presented in Section 2.3.2. The highest disutility is observed in the large car segment; this meta-segment offers the highest choice of models to consumers (60% of car models on the market) while only representing 20% of sales. Despite the limited number of electric models available, the van segment sees the lowest penalty, as the number of conventional van models is also small (approx. 40).

<sup>465</sup> Hidrue, 2011, Willingness to pay for electric vehicles and their attributes, Resource Energy Econ., Stephens, T. (March 2013). Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies. Transportation Energy Futures Series. Prepared for the U.S. Department of Energy by Argonne National Laboratory, Argonne, IL. DOE/GO-102013-3709 as well as Daimler conjoint analysis <http://www.ev-charging-infrastructure.com/media/downloads/inline/brian-mcbeth-daimler.1291372915.pdf>

<sup>466</sup> Stephens, T. (March 2013). Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies. Transportation Energy Futures Series. Prepared for the U.S. Department of Energy by Argonne National Laboratory, Argonne, IL. DOE/GO-102013-3709.

<sup>467</sup> Greene, D.L. 2001, TAFV Alternative Fuels and Vehicles Choice Model Documentation, ORNL/TM-2001/134, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July.

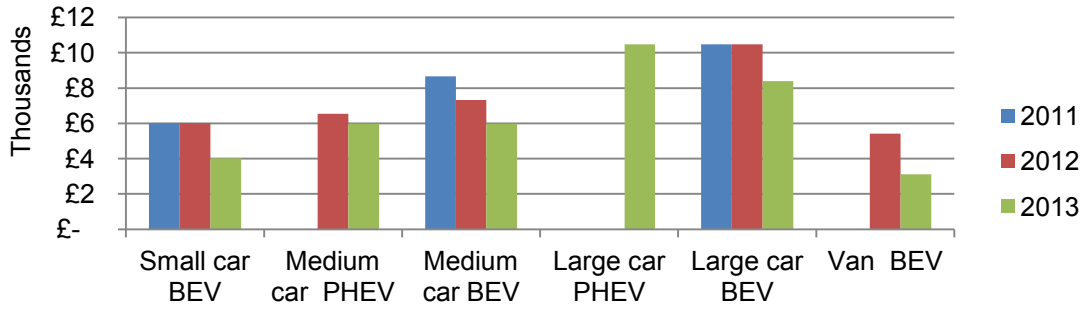


Figure 67 Penalty value related to the low number of EV models and brands

For the pathway to high uptake, the supply of models is assumed to continue as per the announced releases (presented in 2.3.2) and accelerate post-2020. The corresponding supply per segment is detailed in section 5.3, from page 61, while the corresponding penalty is presented in the figure below.

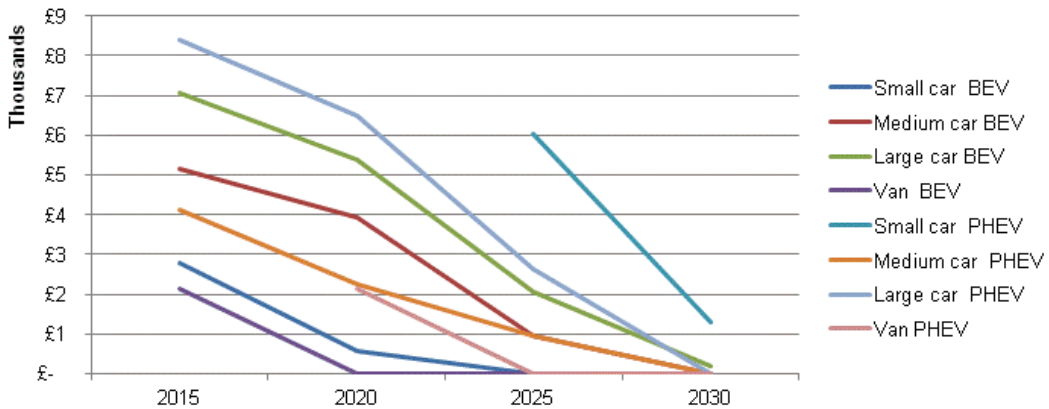


Figure 68 Supply penalty scenario for the high uptake pathway, based on observed trends (announcements of models to 2015) and acceleration of model release post 2020

If the announced EV model release do not reach production and the growth in EV models remains slow, the supply penalty would not decrease as rapidly. The next figure illustrates a case where growth in EV models remains slow (one new release per year per segment, no small PHEV model).

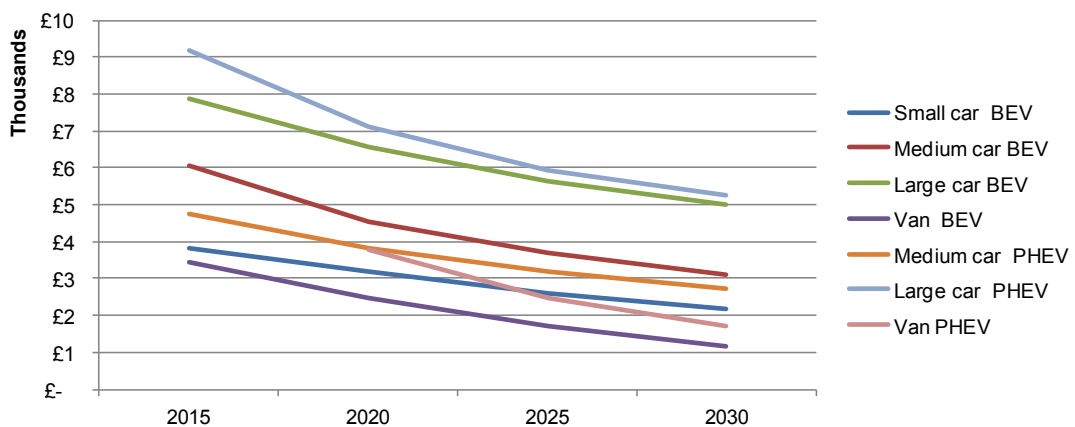


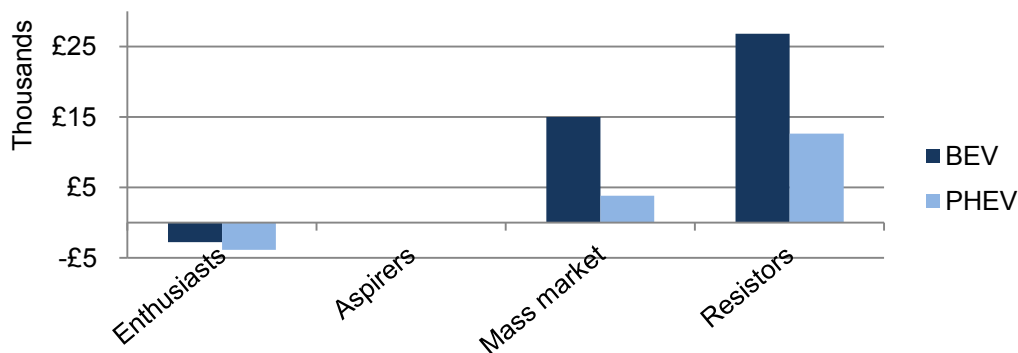
Figure 69 Low supply case: possible supply penalty if EV models do not spread to the majority of brands

**Consumer awareness and consumer acceptance penalty**

In the model, the lack of consumer awareness is represented by setting the share of consumers who consider EVs in their choice set to 20% in 2013 (based on evidence presented in section 3 ) and increasing this to 100% (by 2021 in the pathway to high uptake).

The penalty associated with consumer acceptance (or rejection) is captured through the *Alternative Specific Constant (ASC)*. This constant represents the value equivalent of the loss of utility as perceived by consumers due to the new technology alone, i.e. if all other attributes were equal to the non-EV option (e.g. vehicle price, driving range etc).<sup>468</sup>

Figure 70 shows the values of the ASC relating to BEVs and PHEVs for each consumer segment, based on literature findings<sup>469</sup>. In the case of Resistors, for example, the high value for BEVs indicates a very strong rejection of this technology. More positively, at the other extreme, a negative ASC indicates that ‘Enthusiasts’ are willing to pay a premium for EVs. Note that in all cases, the ASC is markedly lower for PHEVs than for BEVs.



**Figure 70 Starting value for the Alternative Specific Constant**

These values shown in Figure 70 are derived from recently conducted choice experiments, when the uptake of and thus exposure to EVs was very low. It is intuitively accepted (and consistent with theories of technology diffusion) that technology awareness and acceptance increases with sales. However the ‘speed of change’ cannot be easily measured or observed for technologies as new as plug-in vehicles.

Axsen *et al.* (2009) has attempted to measure the change in technology acceptance that comes with the ‘neighbour effect’, i.e. a technology becoming more desirable as its adoption becomes more widespread. The approach used is of particular interest as it uses a mix of stated and revealed preference (based on hybrid vehicle markets in Canada and California, where hybrid sales level were 0.17% and 3% respectively), providing an empirical basis for the theory of technology preference dynamics<sup>470</sup>. The paper’s findings confirms that the consumer acceptance penalty decreases with sales, and suggests that the penalty reduces to zero when sales reach 10% of the market share.

<sup>468</sup> Note that this value should not be interpreted as the level of financial subsidy required for consumer adoption – rather it is a measure of the perceived loss of value of the new technology as compared to the ICE baseline.

<sup>469</sup> In particular Hidrue, 2011, Willingness to pay for electric vehicles and their attributes, Resource Energy Econ. ;Hoen, 2012, Driving on electricity, hydrogen or biofuels, what does the motorist want?, Planbureau voor de Leefomgeving; New Vehicle Purchase Market Transformation Model, 2007, Element Energy for the Energy Saving Trust and An affordable transition to sustainable and secure energy for light vehicles in the UK, Energy Technologies Institute, June 2013

<sup>470</sup> Axsen J. et al., 2009, Combining stated and revealed choice research to simulate the neighbor effect: The case of hybrid-electric vehicles Resource and Energy Economics 31 221-238



A study of diffusion and competition among alternative fuel vehicles by Struben and Sterman (2007)<sup>471</sup> found that favourable conditions for diffusion (such as a marketing campaign and exposure to the technology) are necessary for the market share to increase to a self-sustaining level and that, due to slow vehicle parc turnover in the EU and U.S., the marketing campaign would have to be sustained for twenty years.

For the purposes of this project, the decrease in penalty with sales (to zero at 10% sales) is implemented in the model used, for Mass market and Resistor segments. However, in line with the findings on the ‘diffusion challenge’, for this decrease in penalty to be realised, it would need to be strongly supported in the pathways to high EV uptake by a range of promotional measures which are deployed over a significant timescale.

As fleet managers are assumed to be more rational than private car buyers (i.e. compare vehicles on TCO and suitability basis, and have no technology preference in the model), the fleet ASC is effectively zero. This assumption is supported in the pathway by measures that favour fleet managers’ knowledge and understanding of plug-in vehicles. The impact and implications of this assumption is discussed in Section 5.7 from page 68.

**Sensitivity to choice coefficients**

The sensitivity of results to the choice coefficient has been tested under a ‘baseline’ case, where no cost support is provided beyond existing grant and tax differentials, there is no intervention on infrastructure but supply of EVs improves, fleet managers have no technology preferences and acceptance of EVs by private consumer increases with sales. The table below shows the results of this baseline case.

**Table 30 Market share of EVs under the baseline used for sensitivity testing**

	2020	2025	2030
<b>All EVs</b>	2%	10%	26%
<b>PHEVs</b>	1%	6%	20%
<b>BEVs</b>	1%	3%	6%

The tornado graphs in the next pages show the sensitivity of these baseline uptake results to a +/- 20% variation in the choice coefficients. The X-axis shows the relative change in market share (of all EVs in Figure 71, for PHEVs in Figure 72 and BEVs in Figure 73). For example, Figure 71 shows that in 2030, the estimated uptake of EVs varies by ca. +/-15% (i.e. becomes 22% or 30% instead of the baseline 26%) when varying the price coefficient.

The impacts are not symmetric because the change in relative vehicle utility is not symmetric, i.e. the relative attractiveness of each vehicle choice is not changed in a symmetric way – this is especially apparent in the graphs relative to PHEVs and BEVs.

A +/-20% testing range is wider than the uncertainty range for price and running cost coefficients and the fleet managers’ TCO horizon as these are calibrated on revealed data. A wide testing range is however adequate to test the other parameters (supply penalty, access to day charging, driving range, charging time and starting value for the ASC) as coefficients for these are based primarily on stated preferences and thus are more uncertain.

<sup>471</sup> Struben J., Sterman J, Transition challenges for alternative fuel vehicle and transportation systems, 2007, MIT Sloan School of Management, Cambridge MA 02142

Overall, the results show that, based on the baseline inputs for vehicle cost and performance, the price, running costs and TCO horizon are the most influential parameters in the calculation of market share. The impact differs between PHEVs and BEVs: a more favourable price coefficient has a greater impact on PHEVs sales than BEVs. This is because PHEVs cost less than BEVs and more drivers can consider them (because overnight charging is not a pre-requisite for private buyers to buy PHEVs). Changing the TCO time horizon of fleet managers has however a greater impact on BEVs than PHEVs, as access to overnight charging is a pre-requisite for both EVs for fleet managers (who do not consider range and charging time penalties), and a longer time horizon favour BEVs more than PHEVs (as BEVs have lower running costs).

These sensitivity tests indicate that the *weighting* of non-financial attributes such as driving range, charging time and access to day charging is secondary to the weighting of financial attributes, under baseline inputs. Under scenarios where the cost differential between EVs and non-EVs is addressed, the impact of non-financial attributes will increase. The sensitivity tests on *attribute values* (i.e. vehicle cost and performance inputs) are shown in Section 10.5.

It should also be noted that the impact of the share of drivers assumed to have overnight access is not shown on these graphs as overnight access is not attributed a penalty but is a pre-requisite condition for sale<sup>472</sup> – this impact is studied next.

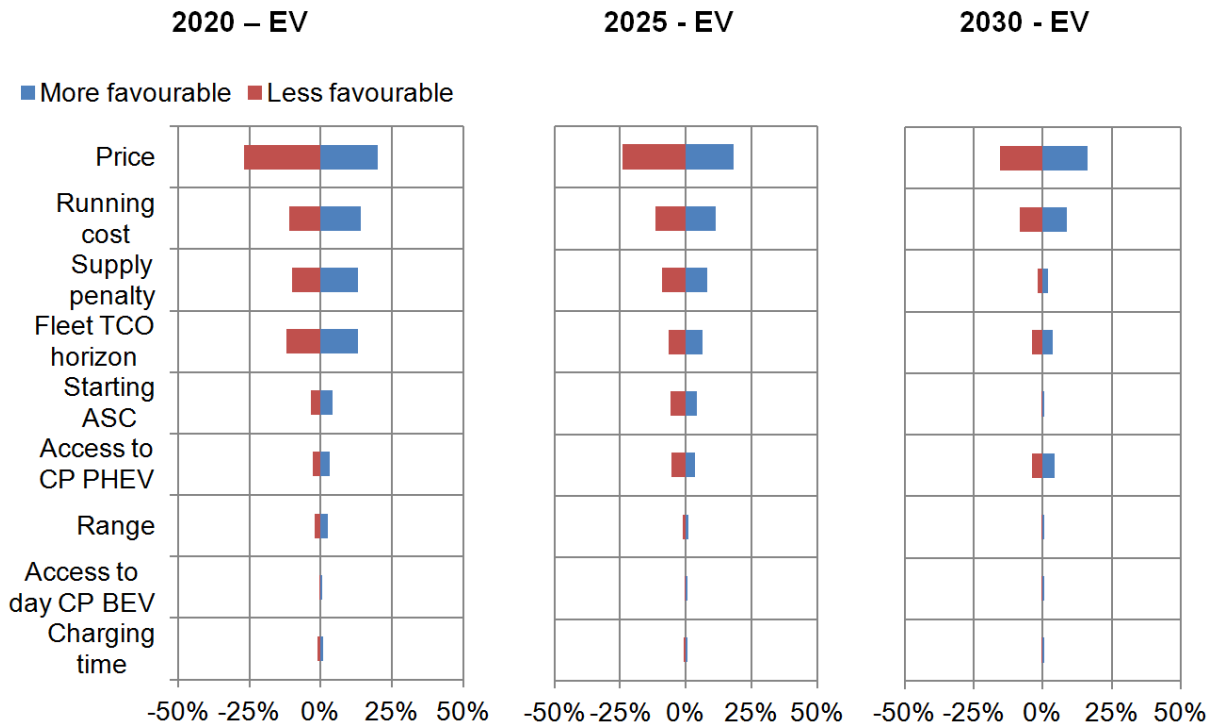


Figure 71 Sensitivity to choice coefficients, supply penalty, fleet TCO horizon and ASC values for the case of EVs

<sup>472</sup> With the exception of PHEVs for private buyers

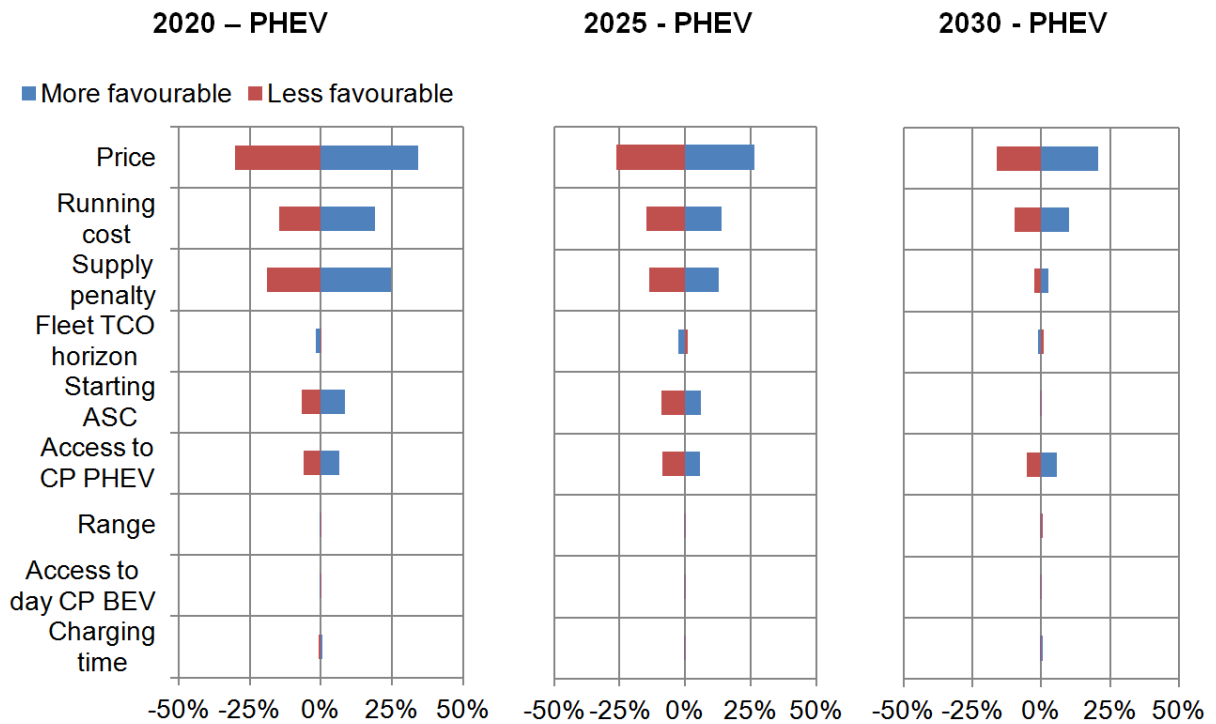


Figure 72 Sensitivity to choice coefficients, supply penalty, fleet TCO horizon and ASC values for the case of PHEVs

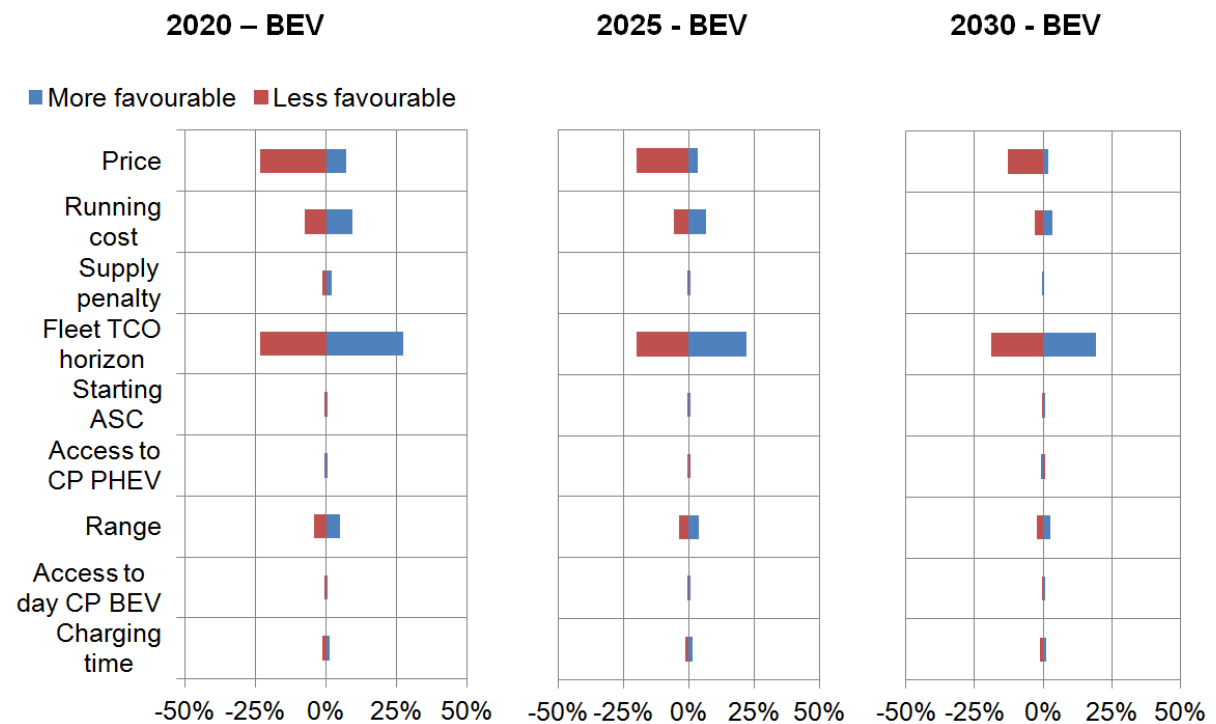


Figure 73 Sensitivity to choice coefficients, supply penalty, fleet TCO horizon and ASC values for the case of BEVs

**Sensitivity to other assumptions**

This section comments on the impact of other choice model assumptions; it uses the same baseline as above and the tornado graphs (next pages) follow the same format than above. Five parameters have been tested, with the levels as described in the table below.

**Table 31 Variations used for the sensitivity analysis around the current trajectory**

	Base	More favourable	Less favourable
<b>Fleet manager ASC</b>	0	As base	As mass market consumers
<b>REEV or PHEV input</b>	PHEV	As base	REEV
<b>ASC change over time</b>	Decreases to 0 when sales reach 10%	threshold 5%	threshold 15%
<b>Fleet range compatibility 2020-30</b>	30% in 2020, increasing to 40% by 2030	40%-60%	20%-30%
<b>Overnight charging access</b>	70% for households	80%	60%

Results show that the assumption that fleet managers do not have technology preferences (modelled by setting their ASC to 0) has a very significant impact on EVs sales. The implications of this assumption have therefore been studied further and are discussed in Section 5.7 from page 68. It should be noted that, while the base assumption of ‘no preferences’ must be supported by awareness and dissemination campaigns, setting the preference ‘as Mass Market consumers’ is extreme, in view of the current high share of company registered cars among EVs.<sup>473</sup>

The model uses PHEV cost and performance inputs for the ‘PHEV’ segment; using the inputs relative to the more expensive Range Extender powertrains results in a markedly lower EV uptake – which is consistent with the impact of vehicle cost discussed in the previous section.

It is assumed that the ASC of private buyers (positive for Mass Market and Resistors) decreases with sales of EVs and reaches 0 when a 10% market share is reached (applied separately to PHEVs and BEVs). Thresholds of 5% and 15% have been tested. In the baseline case, results show a slower decrease (i.e. a slower change in acceptance of EVs) does not significantly impact the sales’ estimates and a faster decrease has only a modest impact.

This is however *under the baseline case*, when sales are commanded mostly by the financial attributes. Under the EV pathway, when the cost premium of EVs is reduced through a cost support, the impact of the ASC becomes more significant – this is detailed in Section 10.5. This is also true for the other tested parameters: the assumptions on fleet vehicle driving range compatibility with BEVs and share of drivers with overnight access.

<sup>473</sup> UK fleets represented 76% of all EV sales among new EV registrations between 2010 Q1 and 2012 Q4 (versus a typical share of ca. 50% across all powertrains) - DfT data

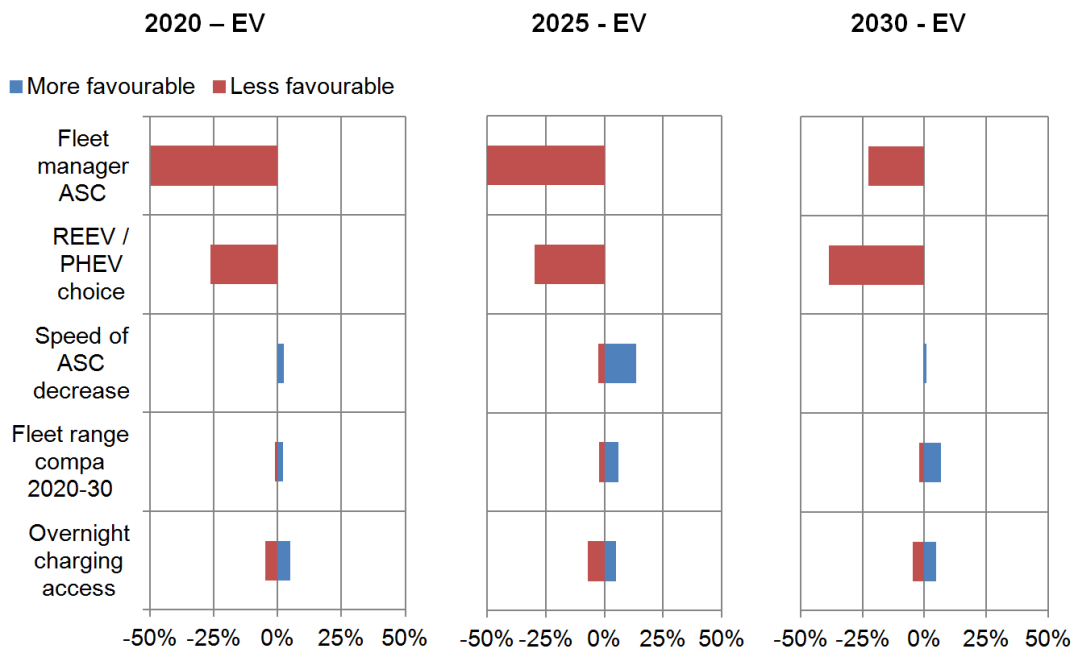


Figure 74 Sensitivity to other choice model assumptions for the case of EVs

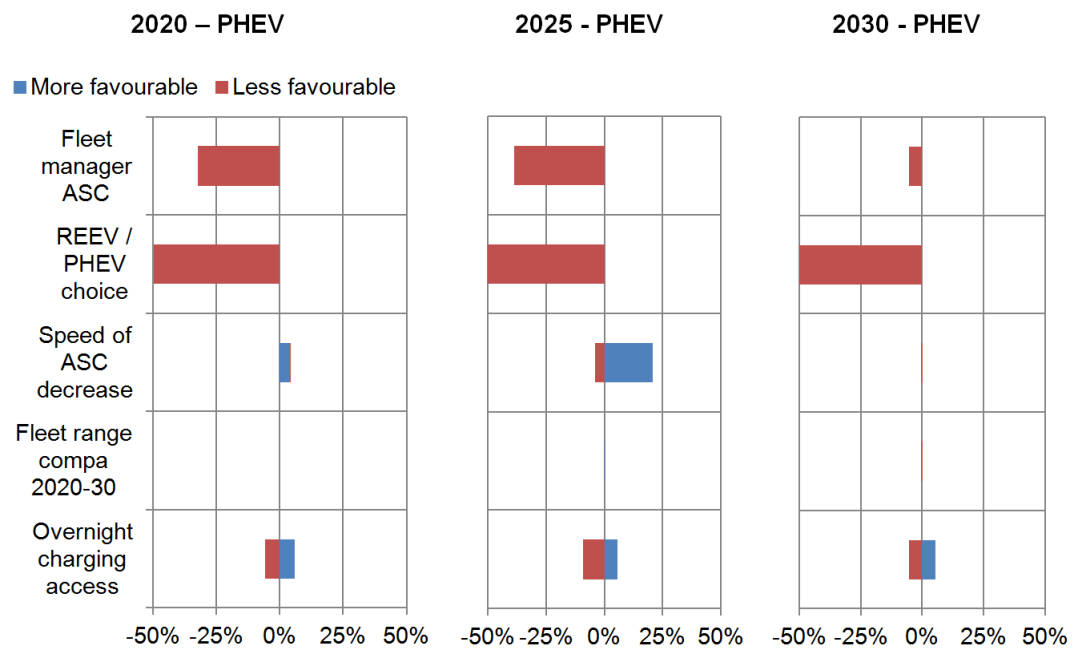


Figure 75 Sensitivity to other choice model assumptions for the case of PHEVs

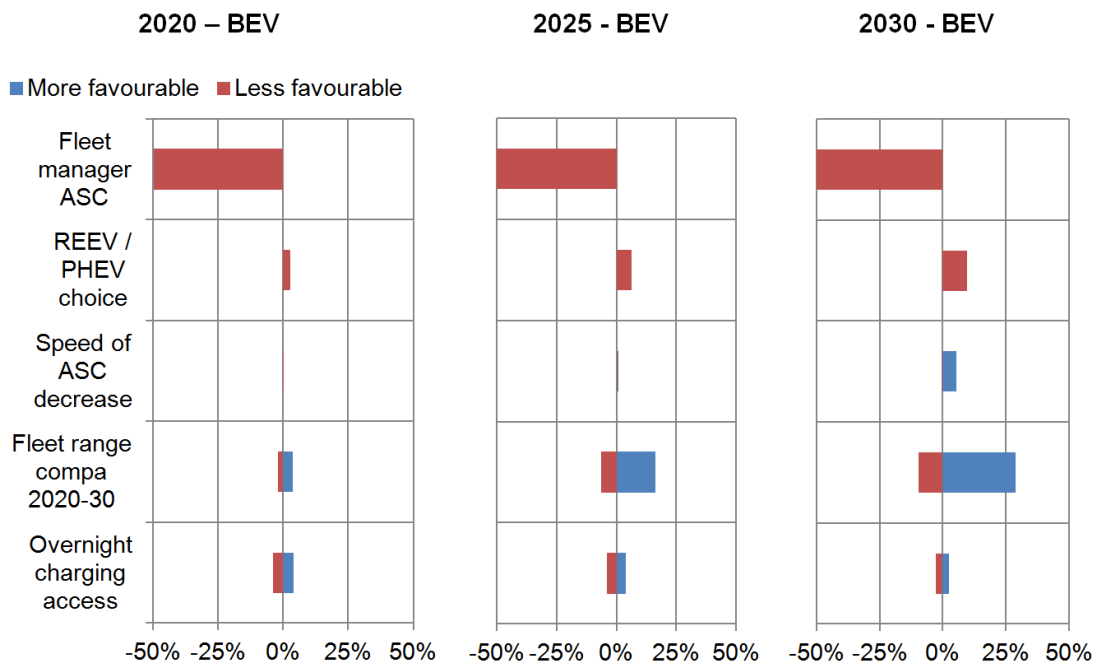


Figure 76 Sensitivity to other choice model assumptions for the case of BEVs



### Summary

- The choice model includes for the attributes identified as critical to the purchase decision of electric vehicles: capital and running cost, access to infrastructure, range, charging time and supply. Consumer preferences are also accounted for through a segmentation of buyers.
- Certainty of access to charging is considered a pre-requisite for considering BEV purchase and only overnight charging (home, depot) can currently provides this. Although day charging (public places, workplace) is not crucial for market adoption, the lack of availability translates into a consumer penalty for BEVs (valued at £2,000). Fewer restrictions are applied to PHEV purchase, although the perceived fuel cost reflects the perceived access to recharging.
- Although current BEVs can deliver the range required for most trips for the large majority of drivers, car buyers consider a maximum range based on this (150 km) as insufficient. Research suggests that a range of 370 km would remove this adoption barrier and this is reproduced in the model. The penalty value of charging time as reported in the literature varies widely but is overall significantly greater than the value of time as based on drivers' income.
- The low number of EV models and brands currently available translates into a significant barrier to uptake, representing a penalty between £3,000 and £10,000 (varying across vehicle segments).
- Technology acceptance is a key differentiator between consumer segments, with a spectrum of attitudes going from Resistors, who reject EVs, to Enthusiasts who display a preference and are effectively willing to pay a premium for EVs.
- Sensitivity of results to the choice model coefficients (which stay constant over the years) and assumptions related to the purchase decision process show the financial attributes have the greatest impact on market share, under the baseline inputs. An exception is the assumption that fleet managers do not display technology preferences. In the extreme case where their bias against EVs is set identical to the Mass Market buyers, sales estimates are reduced by up to 50% by 2030.

### 10.4.2 Vehicle costs and characteristics

This section lays out the vehicle cost and characteristics as used in the model. The data comes from a CCC model, which itself rests mainly on two reports that were commissioned by the CCC in 2012: “A review of the efficiency and cost assumptions for road transport vehicles to 2050” by Ricardo-AEA and “Cost and performance of EV batteries” by Element Energy.

In all cases, annual values are obtained by linear interpolation between 2015, 2020 and 2030. The vehicle cost has been converted into a price, based on a 24% margin<sup>474</sup>. The Value Added Tax at 20% is added for privately used vehicles but not on vans as it is reclaimable by business users.

Although data on both PHEVs and REEVs is available, given their relative similarity, the model was run with only one of these technologies at a time. PHEVs achieve a greater uptake, a result of their lower capital cost. For PHEVs, the electric range is 30km, representing 49% of the car mileage and 10% of van mileage. For REEVs, the electric range is 60km, representing 70% of the car mileage and 30% of van mileage<sup>475</sup>.

The ‘perceived’ energy consumption is used in the model as it is the one that is available to consumers, through the regulation of car labelling; it is based on test cycle performance. For the electric driving distance of BEVs, the real world value is used, to reflect the observed trends of OEMs communicating a range of values, as opposed to communicating only a distance based on a test cycle. The impact of this methodology choice is minimal: using a 15% higher range would change the baseline results by ca. 3% (relative) for the BEV uptake and less than 0.5% for overall EV uptake. The results are more sensitive to the energy consumption figures – as commented in Section 10.5.

In the case of small cars, the range (i.e. battery size) is not increased with time to keep BEVs cost low in this vehicle segment where vehicle prices are very competitive, and in consistence with the lower mileage of smaller cars.

**Table 32 Vehicle price before VAT, £.**

		2015	2020	2030
ICEV	A/B	10,050	10,802	11,442
	C/D	18,660	19,481	20,109
	E+	29,902	30,761	31,381
	Van	15,742	16,520	17,109
PHEV	A/B	15,920	14,503	13,360
	C/D	25,236	23,663	22,220
	E+	37,402	35,588	33,774
	Van	20,155	19,700	18,721
REEV	A/B	20,839	17,055	14,628
	C/D	31,233	26,700	23,642
	E+	44,811	39,283	35,436
	Van	23,747	21,619	19,610
BEV	A/B	21,272	16,479	13,056
	C/D	28,170	27,122	24,021
	E+	47,530	41,570	38,087
	Van	28,366	24,376	21,565

<sup>474</sup> Excludes component supplier margin, includes OEM, dealer and logistic and marketing margins. ‘Influences on the Low Carbon Car market 2020-2030’, Element Energy for the Low Carbon Vehicle Partnership, 2011

<sup>475</sup> Based on CCC analysis of National Travel Survey for cars and Element Energy analysis of van trip dataset for vans.

**Table 33 Fuel consumption, MJ/km (PHEV/REEV: pure fuel mode). Medium: perceived (test cycle), High: real world**

		2015		2020		2030	
		medium	high	medium	high	medium	high
ICEV	A/B	1.60	1.92	1.36	1.65	1.10	1.35
	C/D	1.80	2.16	1.56	1.88	1.27	1.55
	E+	2.33	2.79	2.04	2.45	1.68	2.03
	Van	2.25	2.70	2.08	2.49	1.83	2.20
PHEV	A/B	1.26	1.54	1.13	1.39	1.00	1.24
	C/D	1.47	1.79	1.34	1.64	1.19	1.47
	E+	1.89	2.31	1.75	2.13	1.57	1.93
	Van	1.90	2.32	1.81	2.20	1.70	2.07
REEV	A/B	1.26	1.54	1.13	1.39	1.00	1.24
	C/D	1.47	1.79	1.34	1.64	1.19	1.47
	E+	1.89	2.31	1.75	2.13	1.57	1.93
	Van	1.90	2.32	1.81	2.20	1.70	2.07

**Table 34 Electricity consumption, MJ/km (PHEV/REEV: pure electric mode). Medium: perceived (test cycle), High: real world**

		2015		2020		2030	
		medium	high	medium	high	medium	high
PHEV	A/B	0.43	0.54	0.41	0.51	0.37	0.47
	C/D	0.53	0.66	0.50	0.63	0.46	0.58
	E+	0.66	0.82	0.63	0.78	0.57	0.72
	Van	0.55	0.68	0.53	0.66	0.49	0.62
REEV	A/B	0.43	0.54	0.41	0.51	0.37	0.47
	C/D	0.53	0.66	0.50	0.63	0.46	0.58
	E+	0.66	0.82	0.63	0.78	0.57	0.72
	Van	0.55	0.68	0.53	0.66	0.49	0.62
BEV	A/B	0.43	0.54	0.41	0.51	0.37	0.47
	C/D	0.53	0.66	0.50	0.63	0.46	0.58
	E+	0.66	0.82	0.63	0.78	0.57	0.72
	Van	0.55	0.68	0.53	0.66	0.49	0.62

**Table 35 BEV 'real world' range assumptions, km**

Segment	2015	2020	2030
A/B	150	150	150
C/D	155	200	240
E+	205	230	300
Van	180	200	240

**Table 36 Total battery capacity (kWh)**

		2015	2020	2030
PHEV	A/B	6	6	5
	C/D	8	8	6
	E+	10	9	7
	Van	8	8	6
REEV	A/B	13	12	10
	C/D	16	15	12
	E+	20	19	15
	Van	16	16	13
BEV	A/B	28	27	24
	C/D	34	44	48
	E+	58	63	75
	Van	43	46	52

### 10.4.3 Other inputs

Other inputs of the model include energy prices, parc size, sales volume and breakdown per vehicle segments and mileage assumptions.

Energy prices are based on DECC projections for petrol and diesel, while the price of electricity is based on CCC modelling. It is worth noting that electricity prices are lower than those forecast by the DECC Updated Energy Projections, which has 2030 prices of 13.4p/kWh for electricity to the service sector, and 19p/kWh for electricity supplied to residential properties. The price projected by the CCC assumes an off-peak tariff. While not all the charging will occur off-peak, the majority is charging will happen overnight and access of overnight charging is a pre-requisite to BEV purchase (as well as to PHEV purchase for fleet managers).

The sales breakdown per segment and ownership is kept constant to 2030. The annual mileage is assumed to be 13,835km for cars and 21,450 for vans. Private car mileage is adjusted for each vehicle segment (Table 41), based on the NTS dataset. Mileage of ‘user choosers’ (company-owned cars chosen by individuals) is set higher than for private cars, with a ratio of 1.76; for the other fleet cars, the ratio is 1.17.

**Table 37 Energy prices, including VAT. Source: DECC projections and CCC modelling**

	2015	2020	2030
Petrol p/litre,	135.3	147.7	160.4
Diesel p/litre,	140.4	155.4	168.8
Electricity, p/kWh	7.67	9.49	10.27

**Table 38 UK car and van parc in selected years. Source: CCC modelling**

	2015	2020	2030
Cars	31,676,025	33,609,996	37,442,671
Vans	3,815,895	4,218,311	5,251,233

Table 39 UK car and van sales in selected years. Source: CCC modelling

	2015	2020	2030
Cars	2,787,129	2,667,306	3,099,956
Vans	386,254	384,939	498,194

Table 40 Assumption on car sales breakdown by segment. Based on SMMT data

Sector	% of total sales	Segment	% of total sales
Overall sales		A/B	40%
		C/D	40%
		E/H	20%
Private	44%	A/B	55%
		C/D	28%
		E/H	17%
Fleet	56%	A/B	28%
		C/D	50%
		E/H	22%

Table 41 Mileage ratio applied to national mileage for private cars. Source: NTS analysis

Mileage ratio	
A/B	0.76
C/D	0.93
E/H	1.10

Table 42 Cost of installing a charging point perceived by fleet managers (cars and vans). Based on observed current cost for wall mounted solutions (see section 3.3) and authors' projections

2015	2020	2030
£950	£700	£500

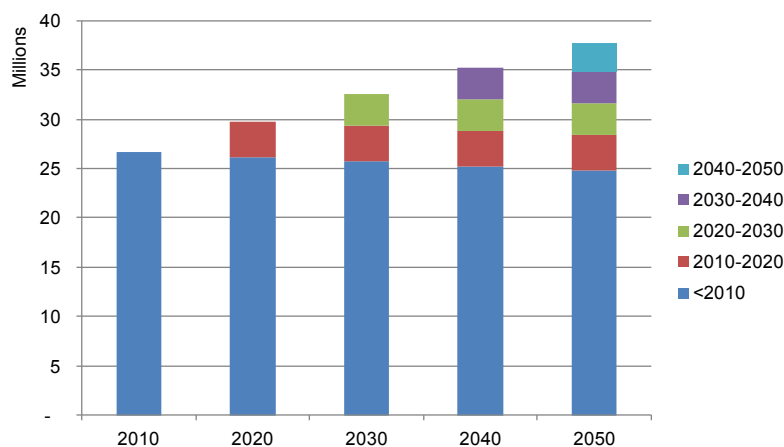


Figure 77 Number of households in the UK per year of build. Source: CCC modelling

## 10.5 Model sensitivity

Sensitivities to inputs that *do not* change over years (choice coefficients) were commented on in the section dedicated to choice coefficient (Section 10.4.1); here are reported more detailed sensitivity analysis to individual inputs or assumptions that vary with years, e.g. vehicle costs, charging time. This section also comments on alternative scenarios – or variations around the pathway.

### 10.5.1 Sensitivity to individual inputs

The sensitivity of results to model inputs has been tested under a ‘baseline’ case (no intervention case, as presented in Table 30 page 152) as well as under the EV pathway (interventions to reach action targets in order to meet the 60% EV uptake target in 2030).

#### Settings

Main inputs include: the vehicle supply assumptions, costs (vehicle, energy related such as energy consumption and energy prices), charging infrastructure inputs (access to, power rate and fleet vehicle compatibility with BEV driving range) and consumers’ awareness and acceptance of EVs. As vehicle capital cost is one of the most influential parameter, the analysis also includes the time horizon considered by vehicle buyers when comparing options.<sup>476</sup>

The value ranges used in the analysis are shown in Table 43 (variations around baseline) and Table 46 (variations around EV pathway). The variation applied to prices increases over time, for example the ‘+10% by 2030’ applied to EVs costs means 0% change is applied in 2016, increasing to 3.33% in 2020 and 10% in 2030. The fuel price variation is set at +/-19% to reproduce the variation between the central, low and high DECC projections. The variation between DECC electricity price projections is lower, at around +/-10%.

**Table 43 Variations used for the sensitivity analysis around the baseline trajectory**

	Base	More favourable	Less favourable
<b>Model/brand supply</b>	Projection from 2012-2014 trends; see Section 5.3	As base	Slower supply scenario, see 10.4.1
<b>Capital cost EVs</b>	CCC model – see 10.4.2	-10% by 2030	+10% by 2030
<b>Fuel price</b>	CCC model – see 10.4.3	+19% by 2030	-19% by 2030
<b>Electricity price</b>	CCC model – see 10.4.3	-10% by 2030	+10% by 2030
<b>Vehicles energy consumption</b>	Perceived MJ/km, CCC model – see 10.4.2	Real MJ/km – see 10.4.2	As base
<b>Time horizon considered by buyers</b>	From 2 years for Resisters to 7 years for Enthusiasts and 4 years for Fleet managers.	+20% for all buyers	-20% for all buyers
<b>Overnight charging access</b>	70% for households	80%	60%
<b>Day charging access</b>	0% drivers perceiving day access	20%	0%
<b>Fleet car range compatibility 2020-30</b>	30% in 2020, increasing to 40% by 2030	40%-60%	20%-30%
<b>Power rate perceived</b>	3kW increasing to 7kW in 2020	14kW from 2020	3kW until 2030
<b>Level of awareness</b>	100% in 2026	100% in 2021	As base
<b>ASC change over time</b>	Decreases to 0 when sales reach 10%	threshold 5%	threshold 15%

<sup>476</sup> Reminder: a 4 year time horizon means two technologies will take 50% share each if their TCO is equal over 4 years.



Table 44 Variations used for the sensitivity analysis around the high EV pathway

	EV pathway	More favourable	Less favourable
<b>Model/brand supply</b>	Projection from 2012-2014 trends; see Section 5.3	As base	Slower supply scenario, see 10.4.1
<b>Capital cost EVs</b>	CCC model – see section 10.4.2 (+ value support)	-10% by 2030 (+ value support)	+10% by 2030 (+ value support)
<b>Fuel price</b>	CCC model – see 10.4.3	+19% by 2030	-19% by 2030
<b>Electricity price</b>	CCC model – see 10.4.3	-10% by 2030	+10% by 2030
<b>Vehicles energy consumption</b>	Perceived MJ/km, CCC model – see 10.4.2	Real MJ/km – see 10.4.2	As base
<b>Time horizon considered by buyers</b>	From 2 years for Resistors to 7 years for Enthusiasts and 4 years for Fleet managers.	+10% for all buyers	-10% for all buyers
<b>Overnight charging access</b>	70% for households	80%	60%
<b>Day charging access</b>	20% in 2020 60% in 2025 and 100% in 2030 for BEVs; 60% of these for PHEVs	40% /100% /100% for BEVs	10% /30% /50% for BEVs
<b>Fleet car range compatibility 2020-30</b>	30% in 2020, increasing to 100% by 2030 (thanks to rapid CP network)	As base	30%-40% (assume no impact of rapid CP network)
<b>Threshold for rapid CP to extend range of van fleet BEV</b>	50%	30%	70%
<b>Power rate perceived</b>	7 /30 /50kW in 2020/2025/2030 (max 7kW for PHEV)	10 / 50 / 70 kW	3 / 20 / 30 kW
<b>Level of awareness</b>	100% in 2021	As base	100% in 2026
<b>ASC change over time</b>	Decreases to 0 when sales reach 10%	threshold 5%	threshold 15%

**Results**

Results are presented in tornado graphs, where the X-axis shows the relative change in market share of all EVs (Figure 78), for PHEVs (Figure 79) and BEVs (in Figure 80).

Overall comparing the results under pathway with the results under baseline shows that the pathway developed addresses the most influential purchase criteria. For example, results are less sensitive to changes in vehicle prices under the pathway, as the equivalent value support partly bridges the price differential between EVs and non-EVs.

The assumptions on the level of awareness influence the short term uptake in particular, as over time inputs converge towards 100% awareness and acceptance (decrease of ASC to 0).

Some variations are more favourable to BEVs than PHEVs. The vehicle energy consumption is an example: if the ‘real world’ MJ/km is used – as opposed to announced MJ/km based on test cycle – the BEV uptake is increased by 10% to 25% in 2030 whereas the uptake of PHEVs slightly decreases. The utility of BEVs increases more than the utility of PHEVs (relative to non-EVs) and thus BEVs take some market share away from PHEVs. This is because BEVs become even more cost efficient in £/km for energy spending than other powertrains, when accounting for the real world uplift.

The assumptions on access to infrastructure impact the uptake of BEVs more than PHEVs; this is expected as access to charging is a pre-requisite for all vehicle buyers for BEVs.

The graphs show results are predominantly sensitive to the assumptions on supply and capital costs – these are therefore discussed more at length within the main report along with consequences on necessary change in interventions to reach the target uptake of 60% by 2030.

In the next section, alternative input scenarios are tested, based on variation of the most influential inputs overall in 2030: cost, supply, charging attributes.

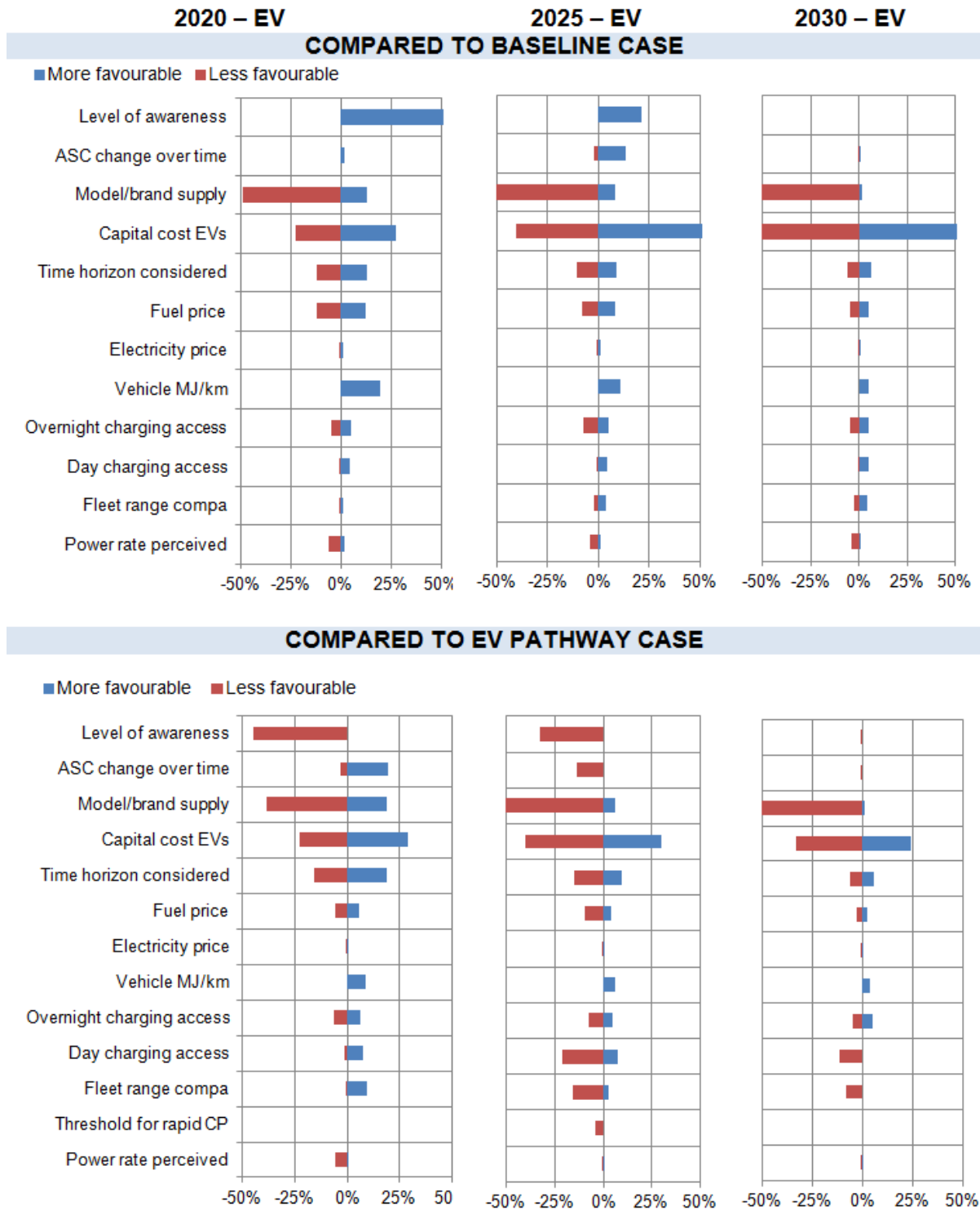


Figure 78 Sensitivity of uptake of EVs (BEVs and PHEVs) to inputs. The X axis shows a change in uptake relative to a baseline case (top graphs) and to the EV pathway case (bottom graphs).

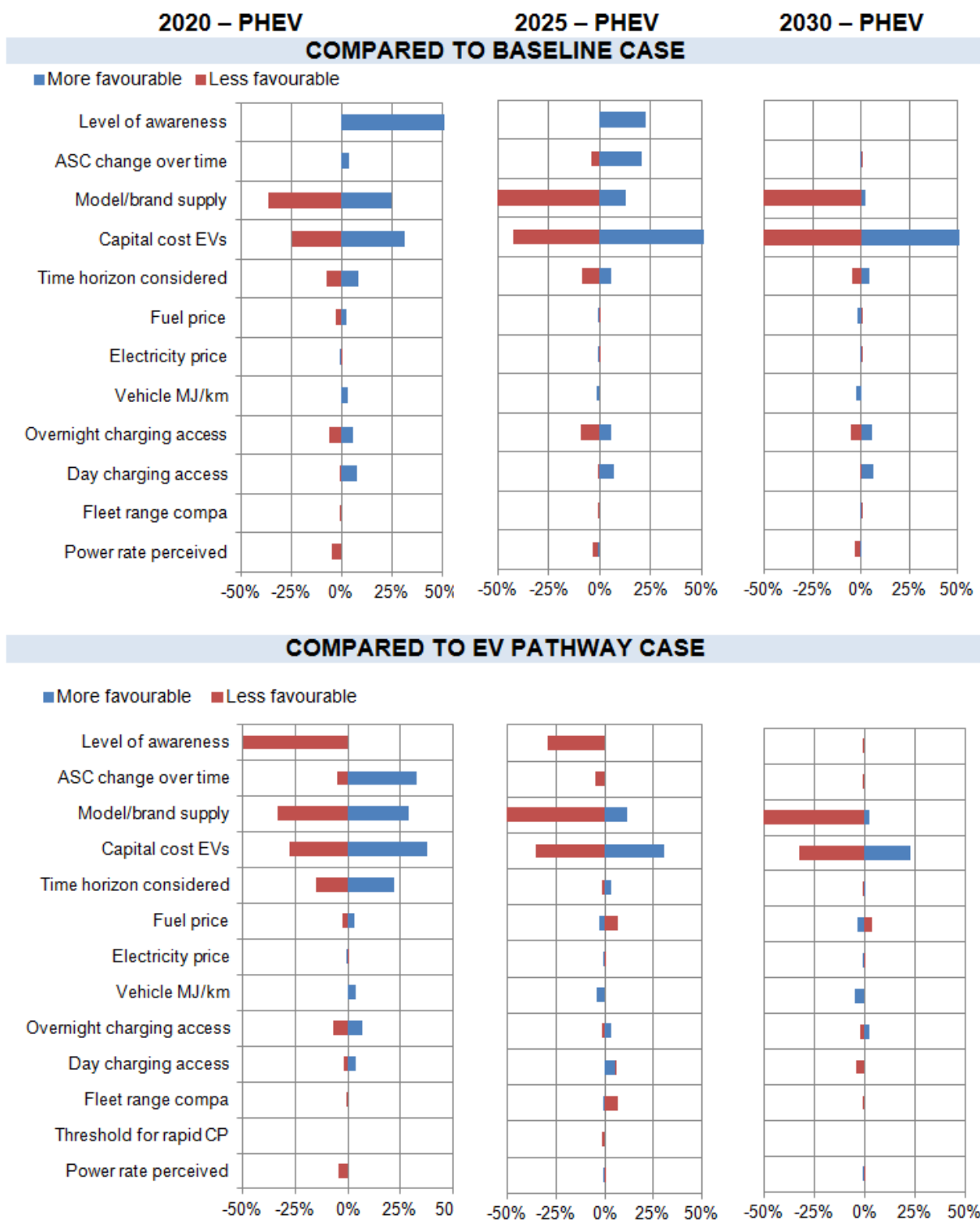


Figure 79 Sensitivity of uptake of PHEVs to inputs. The X axis shows a change in uptake relative to a baseline case (top graphs) and to the EV pathway case (bottom graphs).

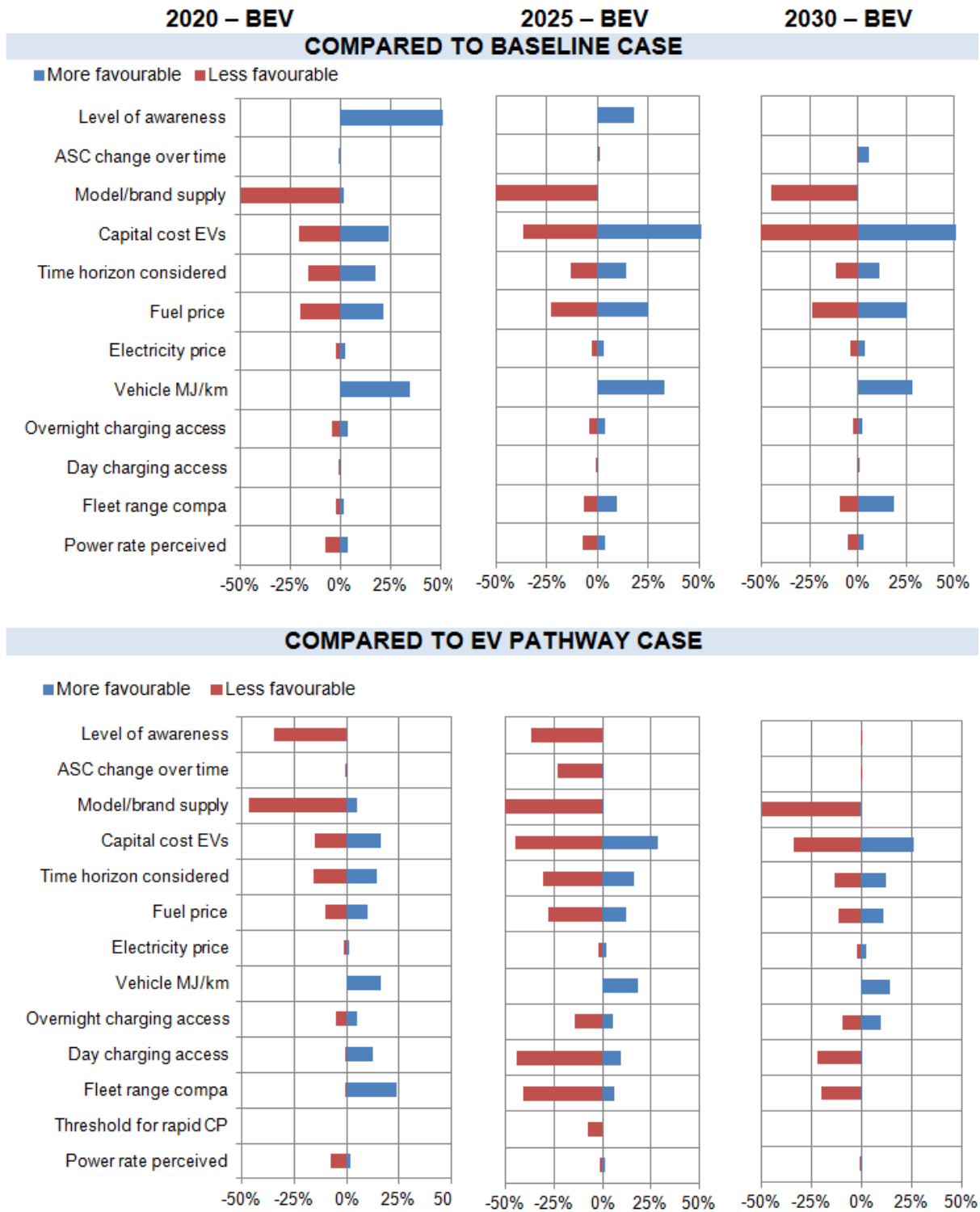


Figure 80 Sensitivity of uptake of BEVs to inputs. The X axis shows a change in uptake relative to a baseline case (top graphs) and to the EV pathway case (bottom graphs).

### 10.5.2 Alternative scenarios

The previous section has shown the cost inputs (vehicle price and fuel price), model supply and access to charging are the most influential inputs in terms of EV uptake. In this section, the impact of varying several assumptions is explored ; firstly non-financial attributes and then cost attributes. The case of REEVs is also reported, along with the impact of a battery repayment scheme on their uptake and required equivalent value support.

#### Variation around overnight charging access and value of non-financial attributes

The figure below compares the EV pathway (i.e. all action targets met and hence uptake target met) with two cases: for ‘harder’ or ‘easier’ conditions for EV uptake.

The series in red shows the results for a case when the awareness and acceptance of EVs is delayed<sup>477</sup> and only 50% of households have access to overnight charging (instead of 70%) – reasons could include tenants not given rights to install dedicated sockets. The overall impact is a 2030 uptake reduced from 60% to ca. 50%; despite the equivalent value support and deployment of a national rapid charging network.

On the contrary, the series in green shows a case where assumptions are more favourable to the uptake of EVs. It is assumed that, from 2025, EV attributes are generally more accepted and thus generate less disutility in the eye of buyers: the penalty for access to day charging is divided by two and penalties for range and charging time are removed entirely. The range compatibility of fleet cars is also increased: from 30% (proportion of the fleet with a duty cycle compatible with the BEV at that time) and 40% in 2020 and 2030 respectively to 50% and 70%. In both cases (value placed on range, charging time etc. and share of fleet cars with cycle duty compatible with BEV range), there is uncertainty over future values. The overall impact of these changes is modest, with an uptake of 63% in 2030. This is to be expected as range and charging time are not dominant barriers (presented in previous sections) and, while the access to day charging and range compatibility of fleet cars are influential parameters, the wide rapid charging network addresses these issues.

Under the less favourable conditions for uptake, the equivalent value support would need to increase to £3k per EVs in 2021-2024 and £3.8k per EVs from 2025 to reproduce the EV pathway trajectory. Under the more favourable conditions for uptake, the equivalent value support would decrease (from £2.5k in the baseline EV pathway) to £2k per EVs.

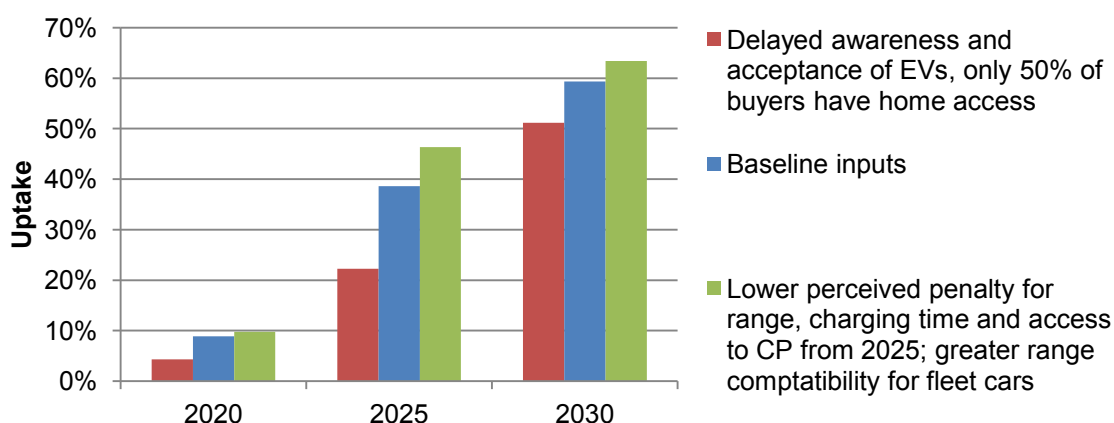


Figure 81 Comparison of the baseline EV pathway results with alternative input scenarios

<sup>477</sup> This is represented as follow in the model: 100% awareness reached in 2026 instead of 2021 and the technology bias against EVs displayed by some private consumers disappear only when sales reach 20% share (instead of 10%).

### Impact of different cost landscapes

The figure below compares the EV pathway (i.e. all action targets met and hence uptake target met) with two alternative 'cost landscapes'.

The series in red shows the results for a case when EV capital costs are 5% higher than the baseline inputs by 2030 and energy prices (fuel and electricity) are 10% lower. The overall impact is a 2030 uptake reduced from 60% to just under 50%.

The series in green shows the results for a change in cost input favourable to EV uptake: -5% on EV capital costs and +10% in energy prices. This brings the uptake to almost 70% by 2030.

Under the higher EV costs, the equivalent value support would need to increase to £3.5k per EVs in 2021-2024 and £4k per EVs from 2025 to reproduce the EV pathway trajectory. Under the lower EV costs, the equivalent value support would decrease (from £2.5k in the baseline EV pathway) to £1.6k per EVs.

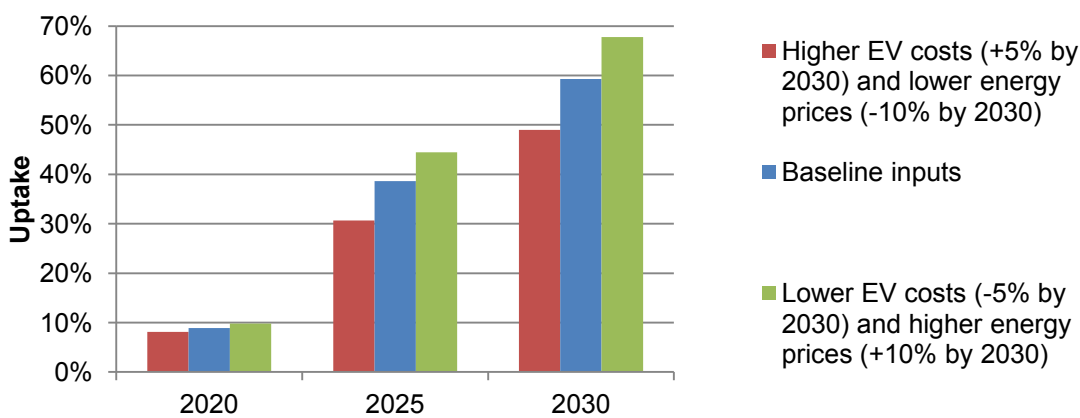


Figure 82 Comparison of the baseline EV pathway results with alternative input scenarios

### The case of REEVs under extended lease purchase agreement

The choice model has been run with ICE, PHEVs and BEVs. Replacing the PHEV offer with the REEV reduces the uptake of EVs as REEVs are larger batteries and hence higher cost – see detailed inputs in Section 10.4.2.

Table 45 shows the results of replacing PHEVs with REEVs in the model and also modelling two extended leasing periods (8 and 12 years); it compares the equivalent value support required to deliver the high EV pathway. Under the extended lease period, the capital cost premium of EVs over the ICEV is removed and instead repaid on a monthly basis, based on a 3.5% interest rate.

The results show that, assuming the previously defined action targets are met in full (vehicle supply, consumer awareness and acceptance, and charging infrastructure), when REEVs are modelled the equivalent value support needed to reach the 60% uptake target is greater than in the case of PHEVs.

The results also show that a repayment scheme significantly decrease the perceived support needed to reproduce the high EV pathway: a 12 year repayment period could reduce the equivalent value support by 50%.



**Table 45 Comparison of equivalent value support required to reach the uptake targets, with and without a repayment scheme in place – REEVs for sale instead of PHEVs**

Case	Equivalent value support per EV		
	2016-2020	2021-2025	2026-2030
High EV uptake pathway with PHEVs	£3,000	£2,500	£2,500
High EV uptake pathway with REEVs – <i>achieves 51% uptake in 2030 instead of 60% target</i>	£3,000	£2,500	£2,500
High EV uptake pathway with REEVs – equivalent value support revised for target	£3,500	£5,500	£5,500
Repayment scheme for REEVs and BEVs – 8 years	£2,000	£2,500	£2,500
Repayment scheme for REEVs and BEVs – 12 years	£1,000	£1,500	£1,500

### 10.6 Detailed results

This section provides results in tables and shows the results broken down by vehicle type (cars and vans) and consumer segment.

#### Cars and vans

The table below shows the sales and stock of EVs under the EV pathway developed to reach the CCC targets. Note the sales of vans should be seen as an upper estimate as they are based on the panel van characteristics. Other van segments are likely to be slower to come to the market and might show an increased cost differential to the ICEV, in particular large panel vans and pick-ups, which will also require more expensive charging solutions (typically 400V three-phase).

**Table 46 Sales and stock of plug-in vehicles in the EV pathway to 60% uptake by 2030**

		Sales, %			Stock, %		
		2020	2025	2030	2020	2025	2030
<b>Cars and vans</b>	All EVs	9%	39%	59%	1.9%	13%	37%
	PHEVs	5%	20%	35%	1.1%	7%	21%
	BEVs	4%	18%	25%	0.7%	5%	16%
<b>Cars</b>	All EVs	9%	36%	59%	1.6%	11%	31%
	PHEVs	6%	20%	37%	1.1%	7%	18%
	BEVs	3%	16%	22%	0.4%	4%	12%
<b>Vans</b>	All EVs	12%	54%	60%	3.3%	16%	38%
	PHEVs	3%	21%	20%	0.8%	6%	14%
	BEVs	9%	33%	40%	2.5%	11%	24%
		Sales, thousands			Stock, millions		
<b>Cars and vans</b>	All EVs	272	1315	2134	0.68	4.63	13.60
	PHEVs	163	693	1243	0.41	2.64	7.68
	BEVs	109	622	892	0.26	1.99	5.91
<b>Cars</b>	All EVs	227	1069	1834	0.53	3.77	11.42
	PHEVs	151	597	1141	0.38	2.34	6.90
	BEVs	76	472	693	0.15	1.44	4.52
<b>Vans</b>	All EVs	45	246	300	0.15	0.86	2.17
	PHEVs	11	96	102	0.04	0.30	0.78
	BEVs	33	150	199	0.12	0.56	1.40

#### Consumer segments

Figure 83 shows the EV market share within each consumer segment, under the EV pathway (action targets of infrastructure, equivalent support etc. met). As expected, the EV market share is highest among the Enthusiast segment (over 30% in 2020 and over 80% by 2030) and lowest among the Resistor group, with virtually no EV sales in 2020 and 40% in 2030.

All consumer segments favour PHEVs over BEVs except fleet managers. This is a reflection of the TCO approach that does not put a penalty on range and charging attributes if the EV is considered as suitable for the fleet operations, and the lower running costs of BEVs.

The total EV uptake is higher among company-owned vehicles than private vehicles, but the overall difference is small: 61% vs. 57% in 2030 – see Table 47. Different consumer segments show different uptake of PHEVs and BEVs, as explained on the following page.

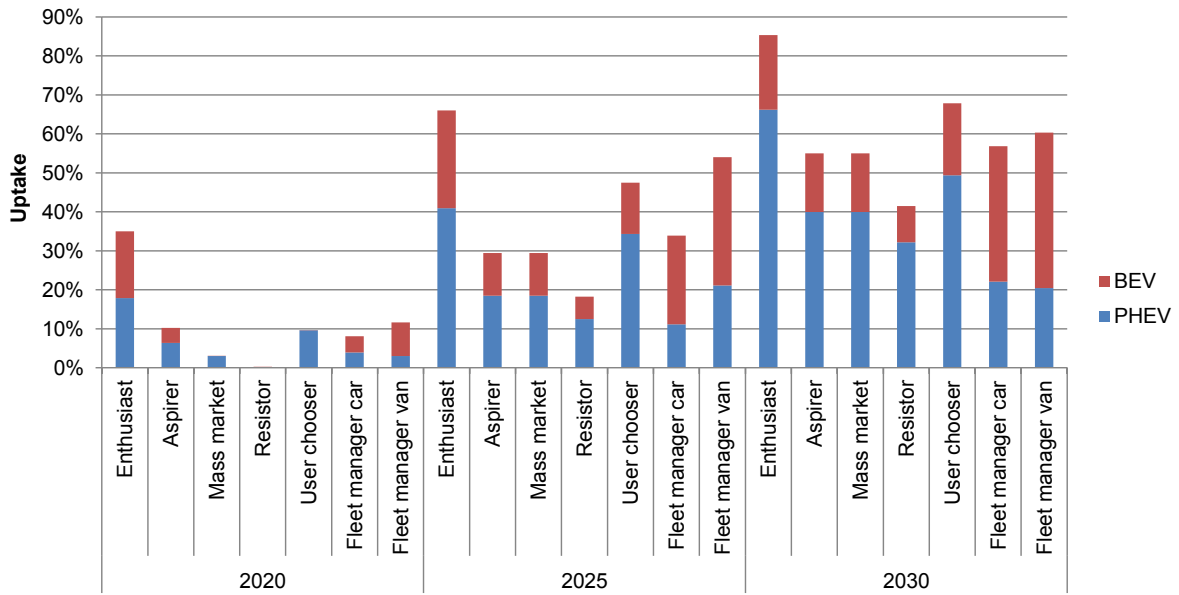


Figure 83 EV pathway: EV uptake within each consumer segment

Table 47 EV pathway: EV uptake by vehicle ownership

		PHEV	BEV	All EVs
2020	Private cars	5%	3%	8%
	Fleet vehicles	5%	4%	9%
2025	Private cars	21%	12%	33%
	Fleet vehicles	20%	22%	42%
2030	Private cars	42%	15%	57%
	Fleet vehicles	30%	31%	61%

The graphs and table above report the uptake within a consumer segment or vehicle class. However consumer segments do not all contribute equally to sales. The graphs in Figure 84 (data shown in Table 48) show how much each consumer segment contributes to the EV uptake. Because the Enthusiast segment represents 15% of the car buyers, the high EV uptake within that segment does not contribute significantly to the 60% in 2030. As fleet vehicles represent 62% of all vehicle sales (cars and vans), they contribute more to the total EV uptake.

The graphs show that two thirds of the 2030 EV uptake is by fleet vehicles (User chooser and fleet manager segments). Sales of BEVs are higher for fleet sales than for other consumer segments, and fleet sales represent 80% of the BEVs uptake in 2030.

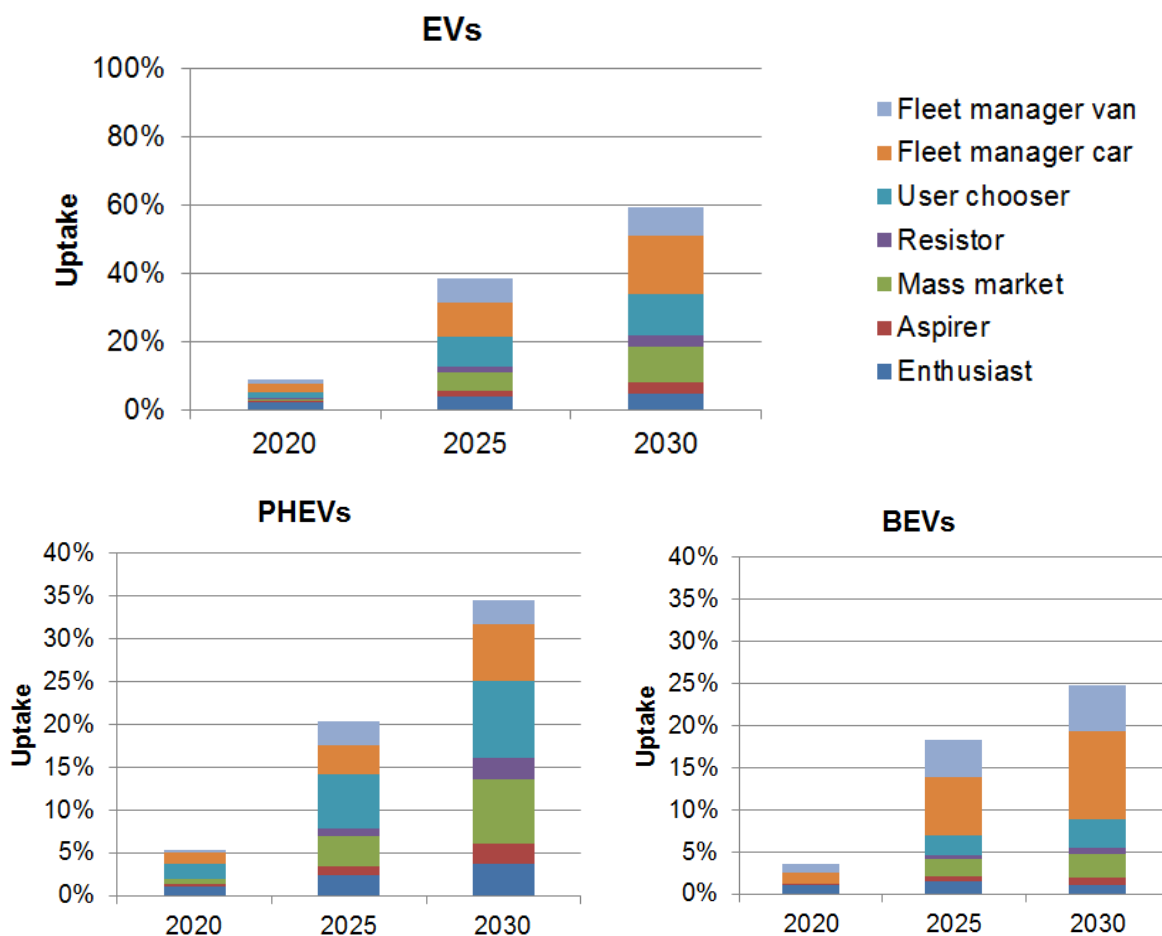


Figure 84 EV pathway: EV uptake broken down by consumer segments

Table 48 EV pathway: EV uptake broken down by consumer segment

		2020	2025	2030
<b>PHEVs</b>	Enthusiast	1%	2%	4%
	Aspirer	0%	1%	2%
	Mass market	1%	4%	8%
	Resistor	0%	1%	2%
	User chooser	2%	6%	9%
	Fleet manager car	1%	3%	7%
	Fleet manager van	0%	3%	3%
<b>BEVs</b>	Enthusiast	1%	1%	1%
	Aspirer	0%	1%	1%
	Mass market	0%	2%	3%
	Resistor	0%	0%	1%
	User chooser	0%	2%	3%
	Fleet manager car	1%	7%	10%
	Fleet manager van	1%	4%	6%
<b>All EVs</b>	Enthusiast	2%	4%	5%

	Aspirer	1%	2%	3%
	Mass market	1%	6%	10%
	Resistor	0%	1%	3%
	User chooser	2%	9%	12%
	Fleet manager car	2%	10%	17%
	Fleet manager van	1%	7%	8%
<b>All EVs</b>	Private cars	3%	12%	22%
	Fleet cars and vans	6%	26%	38%

### Vehicle segments

The graph and table below show the EV pathway results detailed at car segment level. BEVs are more successful in the small car segment (A/B) because the cost differential between ICEVs and BEVs is more advantageous for small BEVs as the battery pack is kept 'small', i.e. the A/B BEVs are not sized for a 200+km driving range. PHEVs, once introduced in the A/B segment (assumed in 2025), are equally successful across vehicle segments.

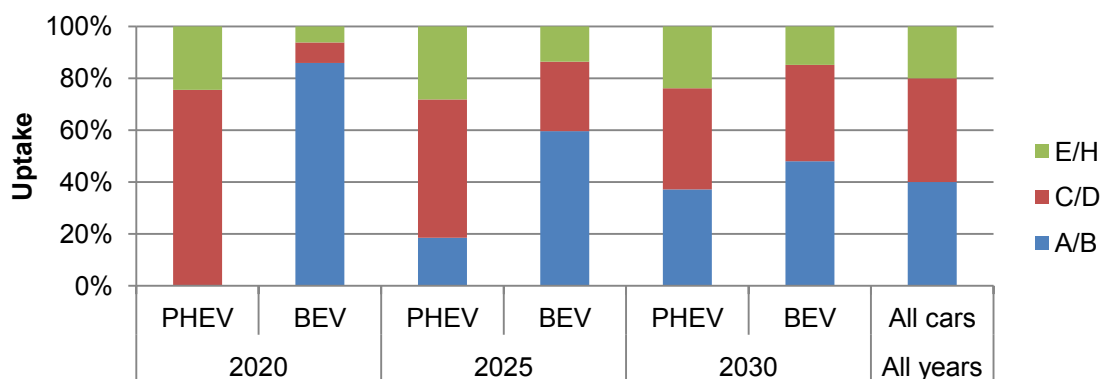


Figure 85 EV pathway: EV uptake for cars broken down by car segments

Table 49 EV pathway: EV uptake for cars broken down by car segment

		A/B	C/D	E/H
<b>2020</b>	PHEV	0%	4%	1%
	BEV	2%	0%	0%
<b>2025</b>	PHEV	4%	11%	6%
	BEV	10%	4%	2%
<b>2030</b>	PHEV	14%	14%	9%
	BEV	11%	8%	3%
<b>All years</b>	All cars	40%	40%	20%