WWF

WATT CAR?

The role of electric vehicles in Scotland's low carbon future

For more information contact:

WWF Scotland
Little Dunkeld
Dunkeld
Perthshire PH8 0AD
t: 01350 728200
f: 01350 728201

With thanks to Scottish Power and SEPA.
Based on an original analysis by Element Energy Ltd
for WWF Scotland www.element-energy.co.uk

Designed by Ian Kirkwood Design
www.ik-design.co.uk

Printed by Woods of Perth on recycled paper

Front cover photo: © Nissan. Inserts from top: © BMW AG, WWF Scotland, istockphoto, Paul Weller/WWF Scotland. Back cover © Nissan.

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WWF Scotland is working to create solutions to the most serious environmental challenges facing our planet, for a future where people and nature thrive. WWF Scotland has produced this report to outline the role electric vehicles could play in ensuring the Scottish transport sector makes its full contribution to tackling climate change.

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Executive Summary

- This report describes the number of battery and plug-in hybrid vehicles according to three scenarios of future electric vehicle use in Scotland for 2020 and 2030. In addition, it provides an indication of the likely CO_2 savings under these scenarios, assuming both a growth in car km driven and a stabilisation in car km. The report offers an introduction to the potential impacts on urban air quality, the associated infrastructure required to support electric vehicles and the resulting additional energy demands and storage capacity resulting from their use.

- CO_2 emissions associated with an electric vehicle (EV) powered by electricity from today's grid are approximately 50% less than from the average internal combustion-engined car. This figure should improve to approximately 80% less by 2030 as the power sector is progressively decarbonised.

- For the transport sector to make a proportionate contribution towards Scotland's 2020 target of at least a 42% reduction in emissions, we will need at least 290,000 EVs on the roads of Scotland by this date (around 11% of the Scottish car fleet). However, if we fail to halt the projected growth in number of km driven by cars in Scotland, we will need vastly more EVs.

- Urban homes in Aberdeen, Glasgow and Edinburgh are less likely to have adequate off-street parking to allow for home charging of EVs than the rest of Scotland. Between 22% and 46% of houses have access to off-street parking that would allow home charging in these three cities. This means greater emphasis will have to be given to public charging infrastructure to allow on-street charging at home.

- Great care must be taken in encouraging the roll out of electric vehicles so that they are seen as the low carbon replacement to necessary car travel and not an additional mode of transport that replaces existing bus and walking or cycling.

- The increased electricity demand resulting from a new fleet of EVs is relatively modest at just a 1% increase from today by 2020 and 5% by 2030. If backed up with a smart grid, only a fraction of this new demand would actually be additional; instead demand is able to follow supply availability rather than adding to existing peak demand and in turn driving supply. The storage capacity of this new electrified transport system presents a significant opportunity to transform the public's role as electricity consumers and make cars an important component in an efficient electricity supply chain.

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1 Introduction

In August 2009, the Climate Change (Scotland) Act 2009 came into force and immediately placed Scotland on a steep trajectory towards a 2020 target of a 42% reduction in greenhouse gases (GHG) and on to an 80% reduction by 2050.[1] In order to meet these targets every sector of the Scottish economy, from farming to transport, will have to contribute its full emissions savings potential.

Road transport has a particularly important role to play. In 2007, it overtook industry and the domestic sector as the largest source of CO_2 in Scotland. Indeed, road transport emissions have increased by 12% since 1990, while many other sectors have declined.[2] Tackling the emissions from road transport requires a policy package that reduces the number of vehicle km driven in Scotland and increases the efficiency of the remaining vehicles. Although increased investment in public transport and active travel is critically important, the dominance of the private car means that there is a vital role for low carbon vehicles and, in particular, the electric vehicle (EV) in a decarbonised transport sector.

The long history of EV development, dating back as far as the 1890s, is currently being renewed in response to steadily increasing fuel prices, binding climate change targets, increased regulation of car emissions and growing investment in emerging low carbon technologies. Such is the current momentum behind the EV industry that investment analysts McKinsey are saying "it's a safe bet that consumers will eventually swap their gas powered cars and trucks for rechargeable models. Electrified transport, in some form, would seem to be in our future."[3]

> **"In order to meet these targets every sector of the Scottish economy...will have to contribute its full emissions savings potential."**

1. See the full Climate Change Act here http://www.opsi.gov.uk/legislation/scotland/acts2009/pdf/asp_20090012_en.pdf
2. See the full NAEI 2007 report here http://www.airquality.co.uk/reports/cat07/0911120930_DA_End_Users_Report_2007_Issue_1.pdf
3. See http://www.mckinseyquarterly.com/Electrifying_cars_How_three_industries_will_evolve_2370

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1.1 Introducing the technology

This report considers both plug-in hybrid electric vehicles (PHEV) and full battery electric vehicles (BEV). Although there are currently very few real world examples of PHEVs, they are the subject of increasing attention by car manufactures with Toyota, Ford, General Motors, Volkswagen and Hyundai all showing intended production PHEVs.

1.1.1 Plug-in hybrid electric vehicles (PHEVs)

PHEVs use a combination of an electric motor and batteries along with an internal combustion engine. PHEVs come in two main types: parallel and series. In series hybrids the sole source of motive power to the wheels comes from the electric motor(s). The motor is supplied with electricity from a battery or directly from a generator (driven by an internal combustion engine). When the engine is running, any excess charge is used to recharge the battery. Parallel hybrids differ from series in that they can transmit power to drive the wheels from two separate sources, such as an internal combustion engine (ICE) and battery-powered electric motors. PHEV are initially likely to have an important role in the move towards EVs but may, in the long-term, prove to be a transitional technology as the public acceptance of full BEVs increases.

1.1.2 Battery electric vehicles (BEVs)

BEVs use an electric motor, or a number of electric motors to propel the vehicle. The energy supplied is from batteries within the vehicle. A BEV's range is limited by the storage capacity of the battery. Instead of filling up at a petrol station, the battery must be recharged from an external source.

2 The role of electric vehicles in Scotland's future transport system

Based on analysis provided by Element Energy for WWF Scotland,[4] this report provides an initial assessment of EVs' potential role in Scotland's future transport sector[5], including a description of emissions savings, infrastructure demands, air quality impacts and energy demand implications of EVs. It also highlights the critical areas that must be addressed if we are to achieve this transformation of road transport.

2.1 Four future scenarios of electric vehicle use by 2020 and 2030

The research describes four scenarios of the possible number of BEVs and PHEVs on the roads of Scotland by 2020 and 2030. The four scenarios are:

1. Business as usual (BAU)
2. The upper scenario
3. Stretch target with traffic growth
4. Stretch target with traffic stabilisation

2.1.1 The Business as Usual Scenario (BAU)[6]

The Business as Usual scenario represents the level of EV uptake with existing and announced policies in place, such as capital grants of up to £5,000 for electric cars from 2011. In this scenario, internal combustion engine vehicles (ICEVs) remain the preferred purchasing choice through the 2020s and EV uptake levels remain relatively low, for example limited to congestion zones (where charging exemption provides a specific incentive) and early adopters ('green' consumers). Without specific EV support policies, the BAU scenario shows very low uptake in 2020. The ratio of PHEVs to BEVs reflects the fact that without appropriate support, BEVs will remain niche (whereas PHEVs could find a wider market due to their higher utility).

2.1.2 The Upper Scenario

This scenario represents an upper bound of EV uptake assuming proactive support measures for EVs are implemented. Under this scenario support for EVs is sufficient for whole-life costs of EVs to be comparable to ICEVs by 2015. Realisation of this level of EV uptake would require significant intervention to encourage EV sales, widely available battery leasing opportunities, and widespread charging infrastructure in urban and sub-urban areas.[7]

> **"Without specific EV support policies, the BAU scenario shows very low uptake in 2020."**

In this scenario, support policies through the 2010s drive demand for EVs, particularly BEVs in urban areas, for example where policies such as congestion charge derogation can be applied. Given sufficient support, and the fact that BEV development is slightly more advanced than PHEV development (i.e. there are currently no PHEVs available to the UK market whereas BEVs have been available for some time) a higher number of BEVs relative to PHEVs may be expected in 2020. However, in the longer term PHEVs may find a larger market since they can be used as a direct replacement for ICEVs.

4. Link to EE report here on our website wwfscotland.org.uk/evs
5. The focus of this study is the passenger car market, which is the largest market for electric vehicles, and accounted for 62% of CO_2 emissions in the road transport sector in Scotland in 2007.
6. The BAU and Upper Scenarios were defined based on scenarios derived in a study by Arup and Cenex for BERR (*Investigation into the scope for the transport sector to switch to electric vehicles and plug-in hybrid vehicles*, Arup/Cenex for BERR, October 2008).
7. Ibid.

TABLE 1 **Four future scenarios of electric vehicle use Percentage breakdown of Scottish car stock**

Scenario	Vehicle	2006	2020	2030
Business as usual scenario	BEVs	0%	0.2%	1.4%
	PHEVs	0%	0.6%	7.1%
	ICEVs	100%	99.2%	91.4%
Upper scenario	BEVs	0%	3.7%	9.4%
	PHEVs	0%	1.1%	22.6%
	ICEVs	100%	95.2%	68%
Stretch: traffic growth scenario	BEVs	0%	27.6%	29.4%
	PHEVs	0%	31.9%	70.6%
	ICEVs	100%	40.4%	0%
Stretch: traffic stabilisation scenario	BEVs	0%	8.8%	17.9%
	PHEVs	0%	2.5%	42.9%
	ICEVs	100%	88.7%	39.3%

2.1.3 The Stretch: traffic growth scenario

Unlike the 'bottom up' analysis behind the BAU and Upper scenarios described above, the Stretch scenario is target-driven, i.e. it describes the number of EVs required in order to achieve the required emissions reduction from the transport sector described by the Climate Change Delivery Plan (CCDP).[8] The CCDP sets a target CO_2 saving of 27% by 2020 for transport relative to 1990 emission levels, but with no specific targets for each component of the transport sector. However, road transport is expected to make the bulk of the savings and in this study it has been assumed that the savings from the road transport sector alone must be sufficient for the transport sector as a whole to meet the 27% reduction target. This equates to reductions from road transport of 43% by 2020 relative to 1990 emission levels.

Given that total emissions from passenger cars in Scotland depend on total car km driven this scenario investigates the contribution that EVs would have to make to meeting the 2020 and 2030 CO_2 reduction targets with officially-projected traffic growth to 2020 (with stabilisation thereafter).[9]

In this scenario very high uptake levels of EVs are required by 2020. For the purpose of demonstration this dominance of EVs in new car sales has been continued through the 2020s, leading to total replacement of ICEVs in the stock by 2030.

2.1.4 The Stretch: traffic stabilisation scenario

This final scenario describes the uptake of both BEVs and PHEVs needed to achieve the 2020 target assuming car km have been stabilised at 2001 levels by 2021.[10] This scenario highlights the sensitivity of emissions from passenger cars to total car km and fits with the 'Smarter Choices (low)' scenario set out by the UK Committee on Climate Change, which shows a reduction in total vehicle-km in the UK from now to 2020.[11] Reducing car km is the recognised low cost first step to tackling transport emissions and as such it is important to frame future EV uptake in this context.[12]

Under this scenario the proportion of EVs in the stock is comparable with the 'Extreme Range' in the Arup/ Cenex study (which shows 8.1% BEVs and 1.6% PHEVs in 2020 and 16.5% BEVs and 42.3% PHEVs in 2030) and with the UK uptake rates predicted by the UK Committee on Climate Change for electric vehicles by 2020.

8. The target CO_2 reduction from cars for 2020 was derived based on emission reduction targets set out in Scotland's Climate Change Delivery Plan (CCDP). Further detail behind the derivation of this figure is given in the full report by Element Energy to WWF Scotland. In the absence of any clear carbon saving target for 2030, a target of 70% relative to 1990 emission levels has been taken for the passenger car sector. This figure has been selected for the purposes of demonstration and is based on consideration of CO_2 saving projections from 2020 to 2030.

9. Increase in total car km taken from LATIS model results (See Element Energy Report).

10. Traffic stabilisation is in line with achieving key National Performance Indicators on reducing Ecological Footprint and reducing traffic congestion (see http://www.scotland.gov.uk/About/scotPerforms/indicators) Note also that overall vehicle-km is one of the key Indicators used in the *Strategic Transport Projects Review: Environmental Report* http://www.transportscotland.gov.uk/reports/road/j10194b-003.htm#24t.

11. *Meeting Carbon Budgets – the need for a step change*, p.229, Committee on Climate Change (October 2009).

12. A recent and comprehensive study carried our by Atkins and University of Aberdeen for the Scottish Government describe car demand management as 'having the greatest potential to reduce CO_2 emissions'. See p3.http://www.scotland.gov.uk/Resource/Doc/282791/0085548.pdf

2.2 Building up the fleet

A simple stock model developed by Element Energy[13] provides an indication of the EV sales required to achieve the uptake rates under each scenario. The results of this model show that:

- the level of EV uptake in the BAU scenario could be achieved with steady annual growth in EV sales such that BEVs and PHEVs together represent around 1.5% and 15% of total new car sales in 2020 and 2030 respectively;
- in the Upper scenario a more rapid increase in EV sales penetration is required, with EVs accounting for around 9% of sales in 2020 and 54% in 2030;
- the Stretch: traffic stabilisation scenario would require an increase in EV sales to achieve 20% of the new car sales market by 2020. Under this scenario EV sales begin to dominate new car sales through the 2020s and nearly all new cars sold are EVs by 2030;
- under the Stretch: traffic growth scenario ICE car sales cease by 2020.

13. See p59 of the Element Energy report.

"the Stretch: traffic stabilisation scenario would require an increase in EV sales to achieve 20% of the new car sales market by 2020."

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3 Greenhouse gas emission reductions

This section describes the potential CO_2 emission reductions associated with different levels of electric vehicle uptake. Two sets of results are presented:

- Traffic stabilisation: CO_2 emissions resulting from the levels of EV uptake in each scenario under an assumption that current traffic growth is stabilised.
- Traffic growth: CO_2 emissions resulting from EV uptake in each scenario assuming continued traffic growth.

A full description of the assumptions behind this analysis is provided in the report by Element Energy to WWF. These assumptions include charging efficiency, battery to wheel energy demands and range utilisation. The analysis is based on predicted carbon intensity of the grid of 193gCO_2/kWh by 2020 and 80gCO_2/kWh by 2030.[14]

3.1 Traffic stabilisation

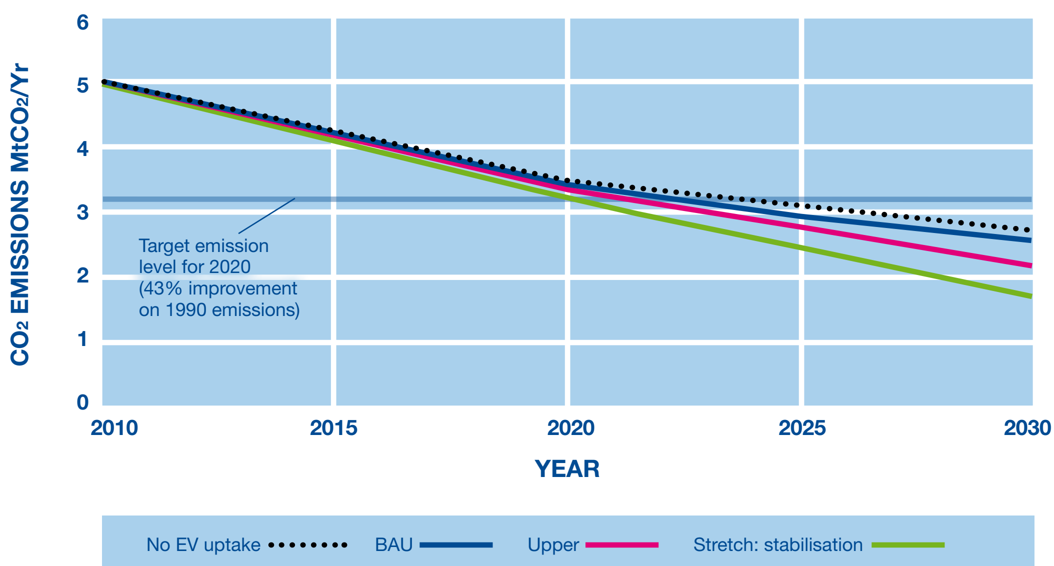
The following graph shows the predicted CO_2 emissions from cars in Scotland out to 2030 assuming car km are stabilised.

The emissions resulting from no BEV or PHEV uptake at all are also plotted (the 'No EV uptake' series). With no EV uptake all reductions are due to reduced distance driven (overall car km), improvements in ICE efficiency, and non-powertrain measures (see report by Element Energy for full description of emissions reduction potential with no EV contribution).

The key observations from these results are:

- The Business as Usual scenario leads to CO_2 savings in 2020 of around 40% relative to 1990 levels. This suggests that if a goal of stabilising total car km at 2001 levels from 2021 is attained, and ICE efficiencies improve to the extent that the UK Committee on Climate Change forecasts, then the additional savings required from EVs are small.
- The CO_2 savings in 2030 equate to 55%, 62% and 70% reductions relative to 1990 levels in the BAU, Upper and Stretch: stabilisation scenarios respectively. These savings depend on total car km reducing by around 7% from 2008 levels by 2020, with zero growth thereafter.[15]

FIGURE 1 **Forecast CO_2 emissions from cars in Scotland: traffic stabilisation**



14. Explanation of these figures is provided in the Element Energy report and a taken from: *The future of electricity generation in Scotland*, Wood Mackenzie (December 2008); also *Meeting Carbon Budgets – the need for a step change*, p.107, Committee on Climate Change (October 2009).

15. The ICE car fleet is considered to be all cars excluding plug-in vehicles (BEVs and PHEVs) and therefore includes technology such as stop-start, mild hybrids etc. The figures of 107gCO_2/km and 85gCO_2/km include adjustment for non-drivetrain measures. For the full derivation and justification of these figures, see full Element Energy report.

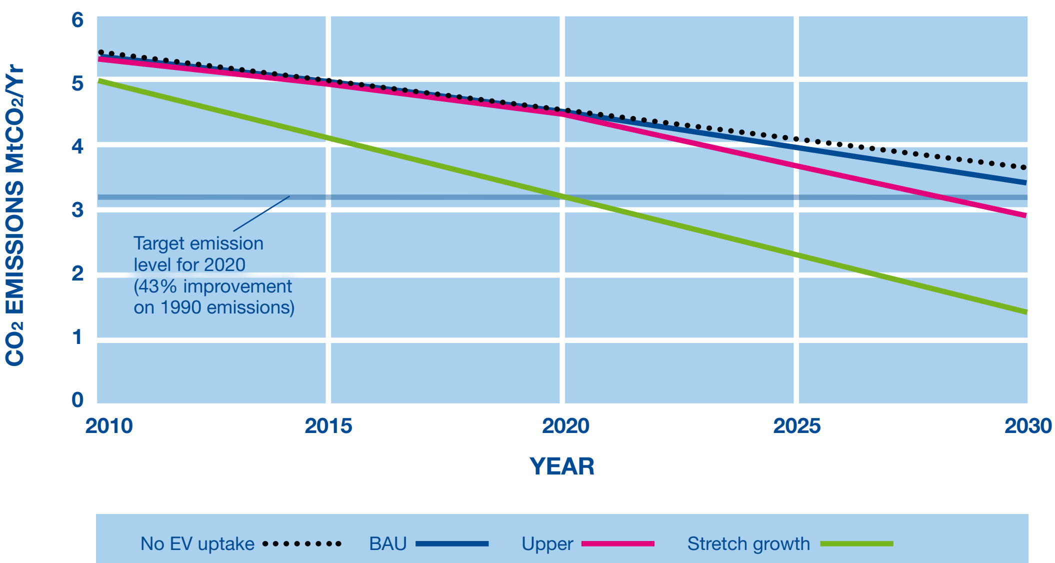
3.2 Traffic growth

This section presents the results from a scenario in which total car km increase by 24% from 2008 levels by 2020 this reflects historical trends in traffic growth and is based on the latest outputs from the Land Use and Transport Integration in Scotland LATIS model.[16] However, in recent years the growth in car km has slowed down considerably, this more recent trend raises possible questions as to the accuracy of the LATIS model projection.[17]

The only change compared to the results presented in Figure 1 is that the total car km in 2020 and 2030 are increased in this scenario. This therefore impacts on the numbers of BEVs and PHEVs in 2020 and 2030 in the Stretch scenario since it is target-driven. Compared to the traffic stabilisation results, the data plotted in Figure 2 show significantly higher CO_2 emissions under the BAU and Upper scenarios. For example, while emissions from cars in 2020 total 3.40MtCO_2/yr under BAU in the traffic stabilisation scenario, the equivalent figure under the traffic growth scenario is 4.55MtCO_2/yr. Specific points of interest from these results include:

- The CO_2 savings in 2020 under BAU correspond to a 20% reduction relative to 1990 levels (compared to 40% in the traffic stabilisation scenario).
- The Upper scenario leads to savings in 2020 of around 21.5% relative to 1990 levels, around half the saving required to meet the 43% 2020 target.
- Being target-driven, the Stretch: traffic growth scenario meets the 2020 emission reduction ambition. However, the levels of EV uptake required to accomplish this under the traffic growth scenario are beyond what could be realistically envisaged.
- These results highlight the importance of curbing demand for car travel. In a scenario where total car km continue to rise broadly in line with historical trends, meeting an ambitious CO_2 emission reduction target in 2020 is well beyond realistic expectations of EV market growth (even with significant support and relatively ambitious uptake levels).

FIGURE 2 **Forecast CO_2 emissions from cars in Scotland: traffic growth**



16. The LATIS model takes Local Authority planning policy data, demographic and economic forecasts, and predicted changes in transport infrastructure as inputs. From these inputs it forecasts changes in traffic and travel patterns over time. The car-km figure in the traffic growth scenario in this work is based on the growth predicted by the LATIS model, which in turn is a result of the input assumptions. These include growth in population and employment levels in Scotland over the medium to long term http://www.latis.org.uk/index.html
17. See the relevant statistics here http://www.scotland.gov.uk/Resource/Doc/933/0092536.pdf

3.3 Impact of traffic growth assumptions on the number of EVs required to meet the 2020 target

The results presented above relate to two alternative futures: one in which an ambitious target for reducing demand for car travel is met and one in which the total car km figure grows by 24% from current levels to 2020. In reality, demand for car travel in 2020 is likely to lie between these two values. The following graph shows the total number of EVs required to meet the 2020 CO_2 reduction target against total annual car km in 2020.

“ In a scenario where total car km continue to rise broadly in line with historical trends, meeting an ambitious CO_2 emission reduction target in 2020 is well beyond realistic expectations of EV market growth.”

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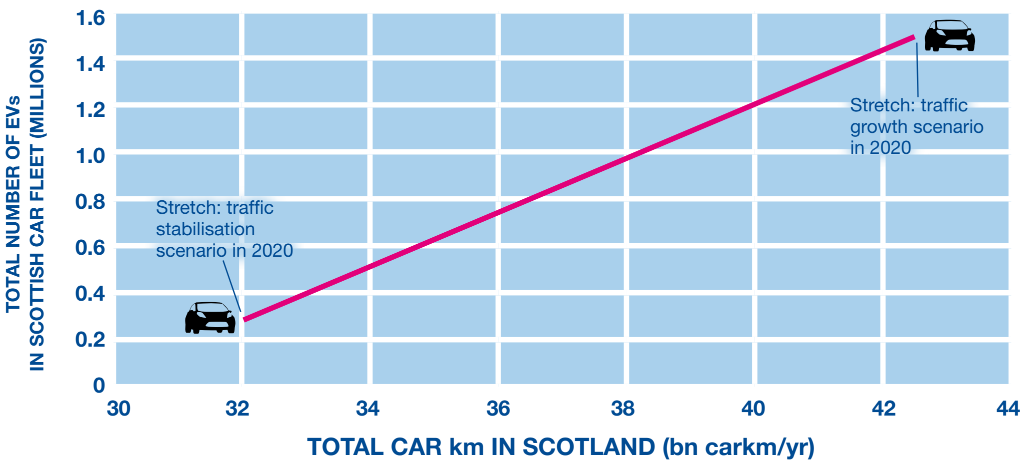
FIGURE 3 **Number of EVs required to meet 2020 CO_2 emission reduction target as a function of car usage**



4 Recharging infrastructure requirements

The necessary rapid roll out of electric vehicles requires a supporting infrastructure of charging points. This section describes the infrastructure requirements to support the levels of EV uptake defined in each scenario.

4.1 Recharging infrastructure: general considerations

Electric vehicle recharging infrastructure includes charge points located in a variety of locations, including at people's homes, workplaces, in public and private car parks (e.g. supermarket car parks) and on street. These charging points can be one of two types, providing either slow or fast charge to EVs.

Contrary to the view that widespread dense, publicly available recharging infrastructure must be in place to encourage EV adoption, a recent report for the UK Committee on Climate Change demonstrated that domestic charging alone could go a long way towards electrification of car km in the UK.[18] This work highlighted the fact that publicly available charging points represent an expensive solution (on the basis of £/kWh of electricity delivered), and that while visible public charge points have a role to play in sending signals to potential end users, infrastructure solutions offer better value when targeted at specific locations. Key conclusions from this work include:

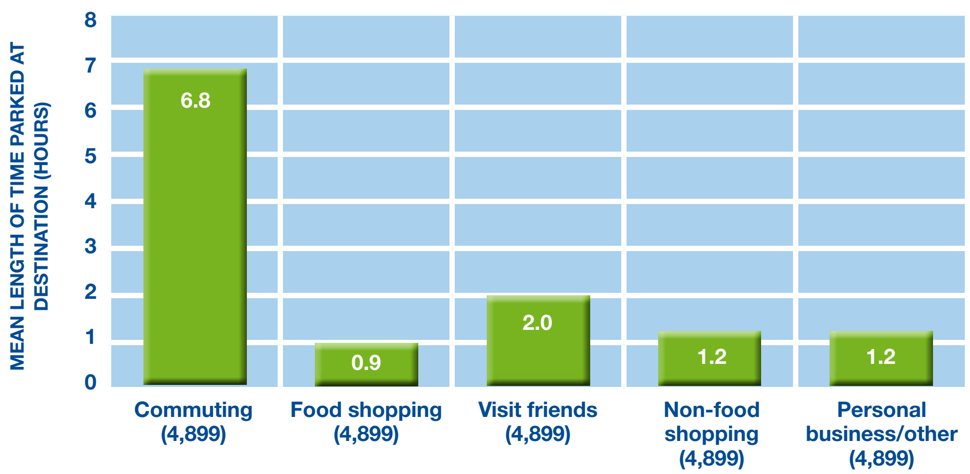
- slow-charge may have relatively low utility in public recharging points because of the short duration that cars are typically parked;
- fast-charge points can be effective in increasing the proportion of an EV's technical range that drivers are willing to use.

4.1.1 Trips and mileage by purpose and distance

An analysis of the driving patterns of Scottish drivers was completed based on National Travel Survey Scotland-specific data from 2004–2006. Figure 4 shows the length of stay by trip purpose.[19] These eight most frequent trip purposes accounted for 78% of all trips in the sample analysed.

An analysis of the data[20] shows that a high proportion of trips are in the lower distance bands. For example, 64% of all commuting journeys were less than 16km, which suggests that around 64% of commuters who drive to work complete round trip commutes of less than 32km. Commutes of this length are well within the usable range of today's BEVs.

FIGURE 4 **Time parked at destination for a selection of common journey purposes* in Scotland** * Based on Scotland-specific NTS data (2004-2006).



Numbers in brackets indicate the total number of journeys from which the mean value is calculated

18. *Strategies for the uptake of electric vehicles and associated infrastructure implications*, Element Energy for the Committee on Climate Change (October 2009).

19. These results are based on an analysis of a total of around 39,000 journeys in Scotland.

20. See the full Element Energy report to WWF for this analysis.

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4.1.2 Length of stay by trip purpose

Time to recharge is often cited as an issue that could negatively impact EV uptake. Any infrastructure deployment should take full account of the habits of drivers, for example how long people typically spend parked at potential electric charging point sites.

These results (fig 4) suggest that slow charge points could be of use to EV drivers if located at workplaces. However, provision of workplace charging points should be seen as part of a package of travel plans designed to reduce single occupancy private car commuting. In addition it is also important to note that the utility of slow-charge points in other locations may be relatively limited given the low mean residence times while the addition of fast-charge points can have a significant impact.[21]

> **"Provision of workplace charging points should be seen as part of a package of travel plans designed to reduce single occupancy private car commuting."**

4.2 Recharging infrastructure: scenario-specific results

4.2.1 Infrastructure limits

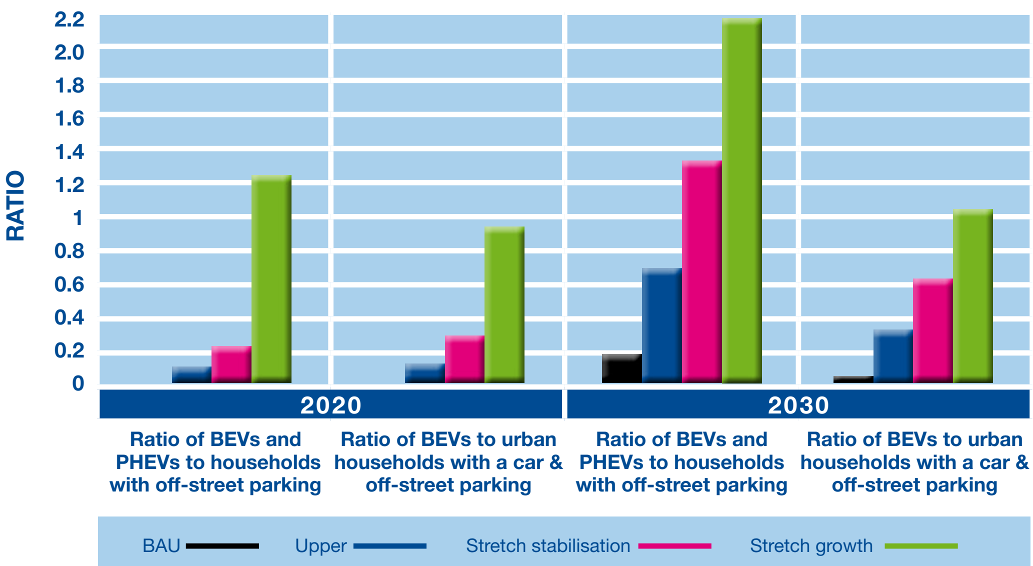
In this section the total numbers of plug-in vehicles (EVs) under each scenario are compared to other relevant data such as number of households in Scotland with access to off-street parking. The aim of this analysis is to identify any urgent infrastructure requirements for each scenario (such as the need to provide on-street home charge facilities for EV owners) and to make recommendations as to appropriate infrastructure solutions.

The ratio of plug-in vehicles to households with off-street parking is well below one in all cases except the Stretch: traffic growth scenario. The implications of this ratio exceeding one are that on-street recharging points will be required outside the homes of EV owners unless:

1. Some households with access to off-street parking own more than one plug-in car.
2. The driving patterns of a proportion of EV users mean that domestic charging is not required for all EVs in the stock (e.g. if the EV is used predominately for commuting and is mainly charged at work).

FIGURE 5 **Ratio of number of EVs to households with off-street parking and number of BEVs to urban car-owning households with off-street parking***

* Data sources: proportion of households with off-street parking and proportion of all households in urban areas with a car and off-street parking from SHCS (2007) (assumed no change over time), household growth projections from: http://www.gro-scotland.gov.uk/files1/stats/high-level-summary-of-statistics-population-and-migration/j1068518.htm.



21. Based on data from a Tepco trial in Japan, as reported in: *Strategies for the uptake of electric vehicles and associated infrastructure implications*, Element Energy for the Committee on Climate Change, p.19-20, (October 2009).

The second ratio considered in Figure 5 compares the total number of BEVs in the stock with the number of car-owning households in urban areas with access to off-street parking.[22] This is more relevant in 2020, when BEV uptake is expected to be mainly in urban areas. These results suggest that the total number of BEVs in Scotland does not exceed the number of car-owning urban households with access to off-street parking in 2020 under any scenario.

4.2.2 Infrastructure requirements: home and workplace

The following tables summarise the base level domestic infrastructure requirements under each scenario in 2020 and 2030.

It is assumed that every household that owns an EV will require a domestic charging point (see Element Energy report for details of domestic charging points). These tables also include estimated workplace charge point requirements, which are based on the total number of BEVs in the stock.

These results suggest that if EVs are adopted by households with access to off-street parking, domestic charging will pose no problems (in terms of adequate parking to facilitate such charging) in the BAU or Upper scenarios. However, the number of plug-in vehicles in the stock exceeds the projected number of households with off-street parking under the Stretch: traffic growth scenario in 2020 (and 2030) and under the Stretch: traffic stabilisation in 2030.

TABLE 2 **Number of plug-in cars and domestic and workplace charge points required in Scotland under each scenario in 2020**

	BAU	Upper	Stretch: stabilisation	Stretch: growth
Number of plug-in cars & number of charge points	21,400	122,700	286,250	1,509,200
Number as % of households with off-street parking	2%	10%	23%	123%
Number of workplace charge points required (upper bound – based on number of BEVs in stock)*	5,550	95,000	221,900	700,000

* To put these figures in context, approximately 1.1 million people in Scotland commute to work by driving a private car. This figure is based on 2001 Census data, which shows there are around 1.85 million commuters in Scotland, and NTS statistics, which suggest that 60% of commuters drive to work.

TABLE 3 **Number of plug-in cars and domestic and workplace charge points required in Scotland under each scenario in 2030**

	BAU	Upper	Stretch: stabilisation	Stretch: growth
Number of plug-in cars & number of charge points	239,900	895,600	1,700,000	2,798,650
Number as % of households with off-street parking	19%	69%	131%	216%
Number of workplace charge points required (upper bound – based on number of BEVs in stock)	40,000	263,900	500,000	823,150

22. 'Urban' in this context refers to 'Large Urban Areas' and 'Other Urban Areas' as defined by the Scottish House Condition Survey (SHCS). Large Urban Areas are defined as settlements of over 125,000 people and Other Urban Areas are settlements of 10,000-125,000 people.

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This suggests that charge points on the public street outside the homes of EV owners may be required by 2020 or 2030 to support the levels of EV uptake needed to meet the emission reductions targets although timing depends on traffic growth.

While there may be sufficient off-street parking at the national level for domestic charging of all EVs under the BAU and Upper scenarios, a further consideration is the ability of local distribution networks to meet the additional electricity demands resulting from the connection of EVs. Domestic slow charging places less severe strains on the distribution system than fast charging, however, connection of a large number of EVs in a localised area may necessitate infrastructure reinforcement. Having said this, increased demand for domestic recharging of EVs is a relatively containable issue which can be managed within the overall programme of electricity grid upgrades. The vehicle to grid opportunity presented by hundreds of thousands of mobile batteries will be an equally important consideration in future proofing the distribution networks to ensure we realise the full benefits of EVs.

4.2.3 City-specific considerations

In the previous section the number of plug-in cars under each scenario was compared with the total number of households in Scotland with access to off-street parking. Given that uptake of EVs (particularly BEVs) is expected to be predominately in urban areas (at least initially), consideration of parking availability in cities is important. The following table presents data relating to parking availability by local authorities from the Scottish House Condition Survey.

In this table 'adequate off-street parking' refers to properties with one or more of the following: an integral garage, a garage on the plot, or space on the plot. These figures highlight a potential challenge to large scale EV uptake in that whilst BEVs are purportedly best-suited to urban environments, households in urban areas are on average less likely to have access to off-street parking facilities. This is a reflection of the relatively high proportion of dwellings such as tenement housing in Scottish cities, which have little or no dedicated off-street parking facilities.

TABLE 4 Number of households and off-street parking availability in Aberdeen, Edinburgh and Glasgow*

	Aberdeen	Edinburgh	Glasgow
Total number of households in the city	101,000	211,000	276,000
% of households with adequate off-street parking	46%	32%	22%
Number of households with adequate off-street parking	45,988	67,144	61,597

* Source: SHCS (2004-2007).

5 Impacts on urban air quality

This study provides a high-level assessment of the implications of replacing ICEVs with BEVs on urban air quality. The approach taken in this study involves providing an assessment of the potential of EVs to reduce total annual emissions of certain pollutants. The pollutants considered are: carbon monoxide (CO), oxides of nitrogen (NOx), sulphur dioxide (SO_2), volatile organic compounds (VOC) and particulate matter below 10µm in diameter (PM10).

5.1 Effect of EVs on pollutant emissions

An estimation of the contribution that ICEVs make to total emissions was made based on specific pollutant emissions and traffic flow data. These results suggest that cars are responsible for up to around 45% of pollutant emissions in the cities of interest, depending on pollutants.[23]

To determine how emissions will change as a result of BEVs and PHEVs the contribution of each car type to the total car km in each city must be calculated. The approach taken considers 68% of the distance driven by PHEVs is done in electric (based on the analysis which shows that 68% of total mileage could be done in electric mode for series PHEVs that are recharged overnight).

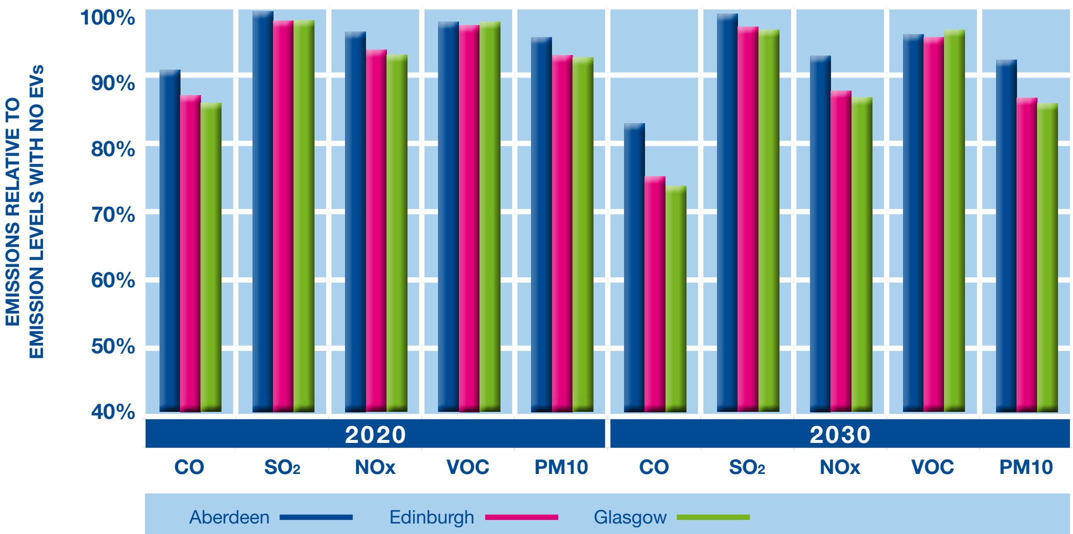
The results presented in this section relate to the Stretch: traffic growth scenario and therefore give an indication of the maximum potential impact of EVs on pollutant emissions.

The impact of the shift towards EVs in terms of change in total emissions is shown in the following graph. The percentage figure illustrates the emissions as a proportion of total emissions in the cities with no EVs on the road.

5.2 Key points

- This analysis suggests that cars account for c.10% or less of SO_2 and VOC emissions, 10–20% of PM10 and NOx emissions and up to around 30–45% of CO emissions. For significant reductions in emissions of pollutants such as NOx and PM10, efforts should be made to reduce emissions from other (larger) vehicles such as heavy goods vehicles and buses.
- Substitution of ICE cars with EVs is therefore expected to have a relatively limited effect in terms of reducing emissions in cities. However, the benefit of EVs in terms of improved urban air quality may be important in areas that are at the margins of air quality management designation.
- EVs could have a greater benefit on local air quality in terms of pollutant concentrations.

FIGURE 6 **Change in pollutant emissions in cities as a result of EV uptake under the Stretch: traffic growth scenario with 68% of PHEV-km in electric mode**



23. See Element Energy report for full analysis behind these figures.

6 Electricity demand and renewable electricity generation implications

When it comes to the electricity grid, EVs offer challenges and opportunities. For example, EVs place additional demands on the grid and significant EV uptake could exacerbate the current spikes in electricity demand (e.g. adding to the evening peak). However, EVs, in conjunction with Smart Grid and Meters, could have a positive impact by matching demand to supply and filling the night time 'demand valleys' with previously unused wind capacity.

The same technology interaction with a Smart Grid could also allow the stored capacity in the batteries of an EV fleet to be used to 'shave' the carbon intensive peaks of electricity demand.

This section considers the additional electricity demands arising from the levels of EV uptake associated with each scenario and the extent to which this additional demand could be met by electricity from renewables. The total energy storage capacity of EVs is also considered.

6.1 Future electricity production in Scotland

The WWF Scotland report *The Power of Scotland Renewed* shows that total electricity demand in Scotland is expected to be around 33,600 GWh[24] in 2020 and 31,100 GWh in 2030.[25] These figures are used to contextualise the additional demands from EVs in the following section.

6.2 Additional electricity demand

Additional electricity demands due to EVs in 2020 and 2030 are calculated from the total car km travelled in electric mode and the overall vehicle efficiency (including charging efficiency).[26]

EV uptake levels in the BAU and Upper scenarios lead to small increases in annual electricity demands, with a maximum increase of c.3.5% by 2030 under the Upper scenario. Under the stretch: traffic stabilisation scenario the additional electricity generation required is under 6%. How this projected additional demand is incorporated onto the grid will be critical in determining the extent to which it can be met by expected generation or require additional capacity.

24. This figure compares to a total electricity demand figure of 43,935 GWh presented in the Scottish Energy Study Volume 5. See http://www.scotland.gov.uk/Resource/Doc/245369/0069126.pdf for this report. This figure does not include an equivalent level of demand reduction to that applied to the Power of Scotland Renewed report.
25. See http://assets.wwf.org.uk/downloads/powerofscotland_renewed.pdf for the full report. These figures are based on achieving a 20% reduction in demand by 2020 and 26% by 2030.
26. See Element Energy report for full details of technical assumptions.

6.3 Storage capacity offered

A potential benefit of plug-in vehicles is the concept of 'vehicle-to-grid' (V2G). This involves communication between plug-in vehicles and the electricity grid such that EVs can be used to aid in load balancing ('valley filling' and 'peak shaving'). Vehicle-to-grid has a potential role in stabilising the variability of renewables such as wind power by providing a storage medium for times of high generation (if generation exceeds demand) and feeding power back to grid during periods of high demand.

The following table shows the total storage capacity of all plug-in vehicles in the Scottish car fleet under each scenario.

By 2030, the theoretical storage capacity of EVs is over double the storage capacity of the Ben Cruachan[27] hydro power station in the Stretch: traffic stabilisation scenario. The table shows the maximum technical storage capacity of all EVs in the stock. However, the useful storage potential in any V2G application would be significantly lower since at any point in time some EVs will not be grid-connected and those that are will be at various states of charge.

Many other issues must be considered and resolved before V2G becomes viable. For example, EV owners (and vehicle manufacturers) could have concerns over the impact of V2G on battery charge cycling and hence battery life. There are also technical and commercial issues to be addressed.[28]

6.4 Key points

- Additional electricity demand from EVs has been estimated at c.1,100GWh/yr by 2030 under the Upper scenario. This corresponds to around 3.5% of the total anticipated annual electricity demand in Scotland.
- The maximum increase in electricity demand occurs under the Stretch: traffic growth scenario and equates to around 12% of total annual electricity demand in Scotland by 2030.

TABLE 5 **Additional electricity demands from EVs under each scenario***

Scenario	Year	Total electricity demands of EVs in stock (GWh/yr)	Percent of total Scottish electricity demand
Business as usual scenario	2020	31.5	0.09%
	2030	294	0.94%
Upper scenario	2020	138	0.41%
	2030	1,100	3.53%
Stretch: traffic stabilisation scenario	2020	297	0.88%
	2030	1,706	5.4%
Stretch: traffic growth scenario	2020	2,315	6.8%
	2030	3,798	12.2%

* Values for the BAU and Upper scenarios correspond to the traffic growth future and therefore represent the upper bound.

TABLE 6 **Total technical storage capacity of all EVs in Scotland under each scenario**

Scenario	Year	Total electricity storage capacity of EVs (GWh)
Business as usual scenario	2020	0.3
	2030	2.2
Upper scenario	2020	2.4
	2030	10.3
Stretch: traffic stabilisation scenario	2020	5.7
	2030	19.5
Stretch: traffic growth scenario	2020	22.7
	2030	32.1

27. Ben Cruachan is the largest pumped water storage facility in Scotland, giving approximately 9GWh of storage capacity.
28. For further details of V2G technology and on-going research in this area see http://www.udel.edu/V2G/index.html.

7 Making the electric avenue a reality

Although the electric car is the subject of much renewed global attention and is repeatedly described as providing the transformative step to a low carbon road transport system, it would be wrong to think the electric avenue of the future is inevitable and will be rolled out across the country in the next five years. Instead it will require new and innovative collaborations between the public and private sector, between utilities, car manufactures and government if it is to be realised.

Such partnerships are beginning to emerge as across the world there are numerous pilot projects underway and support schemes being rolled out to both trial the technology and jump-start the revolution. We need to ensure we share the learning from these efforts and avoid any risk of reinventing the wheel.

7.1 Pilot projects

From Hawaii to Sweden and in at least ten other countries worldwide, there has been a rapid rise in the number of pilot projects testing electric vehicles. Across Europe alone at least sixteen EV fleet tests have been announced, the majority of which have received significant public financial support. For instance, in Paris, an agreement between the state energy company EDF and Renault-Nissan will trial over 100 electric cars and vans. At the same time Paris city authorities plan to launch a 4,000 electric vehicle car sharing scheme and put in place 1,400 charging points. The French are by no means alone in their enthusiasm for EVs, the Spanish aim to have over 2,000 EVs and over 500 charging points in place by 2011. Some countries have made clear commitments to developing the supporting infrastructure; the Danes intend to build some 500,000 charging points in a partnership between Dong Energy and the Better Place company. A similar partnership between the Israeli Government and Better Place will mean a total of 100,000 electric vehicles on the road by 2016. Across the UK, there are pilot EV programmes taking place in major cities. In Scotland, Glasgow City Council has joined forces with partners including Scottish Power, Allied Vehicles and Axeon Batteries to trial 40 EVs and supporting infrastructure in 2010.

7.2 Driving demand for electric vehicles

Supporting pilot projects and investing in infrastructure must also be matched by a commitment to stimulate demand in electric vehicles. The normal market penetration rate for a new technology is simply too slow and requires direct intervention if it is to be accelerated to meet the necessary emissions reduction trajectory. Regulation, subsidies and fiscal measures, infrastructure provision, behaviour change measures and standardisation are all being deployed to varying extents by different countries to accelerate the take-up of electric vehicles.

The following examples (Table 10) from across the EU and beyond provide an introduction to the different measures employed to increase sales of electric vehicles.

“ In Scotland, Glasgow City Council has joined forces with partners including Scottish Power, Allied Vehicles and Axeon Batteries to trial 40 EVs and supporting infrastructure in 2010.”

© Allied Vehicles

TABLE 7 **Examples of different public investment support for EVs across the EU and beyond**

Support mechanism	Countries
Tax exemption (e.g. car registration tax or VAT)	Denmark, Norway, Sweden, Portugal, Czech Republic, Austria
Car tax based on CO_2 emissions	UK, France, Japan
Congestion charge and parking fee exemption	Norway, Denmark, London
Scrapage scheme designed to increase sales of LCVs	Italy, Czech Republic
State subsidies for electric vehicle purchase	UK, France, Sweden
Public sector procurement	Belgium, Scotland
Tax credit	USA
Required infrastructure provision e.g. local government required to provide charging points in new development	France, Spain
Investment in infrastructure	Spain, UK, France, Israel, Denmark, Netherlands Germany, Portugal

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7.3 Establishing cost comparability across technologies

To ensure the electric vehicle becomes established on Scottish roads in the time we have available, it will be necessary to pursue a twin-track approach that commits to pilot/demonstration projects and at the same time strives to establish cost comparability between ICEVs and EVs. The latter must combine both subsidies to reduce the absolute cost of EVs and steps to reduce the relative cost of the EV in comparison to that of the ICEV. This last point highlights the need to build an integrated road policy framework that provides such opportunities through for instance, derogation of congestion charges or road charging.

Analysis carried out by the UK Committee on Climate Change suggests that the current proposed UK support package of between £2,000 and £5,000 per electric vehicle to be introduced from 2011 is only likely to be sufficient if consumers fully value the operating cost savings of electric cars.[29] Given that this seems unlikely, the Committee's higher figure, of approximately £10,000 per vehicle for the first 25,000 vehicles, would seem to provide a more accurate reflection of the level of support required. What is clear is that the financial support package cannot be divorced from the wider promotion and piloting investment as this will be critical in shaping consumer attitudes and in turn the level of purchase support needed to kick start demand and help to bring down costs.

7.4 Emerging business models to support electric vehicle use

The key differences between electric vehicles and conventional cars have stimulated the emergence of new business models to support their uptake. Faced with three key barriers: initial price premium, infrastructure provision and a constrained driving range, new partnerships are required to support the transition to electric vehicle use.

29. See p210 – 211 of *Meeting Carbon Budgets – the need for a step change*. http://hmccc.s3.amazonaws.com/docs/21667%20CCC%20Report%20Chapter%206%20to%20the%20end.pdf

WATT CAR?

The role of electric vehicles in Scotland's low carbon future

Battery leasing[30] potentially offers an approach that reduces the financial risk to the consumer and when the battery is owned by a utility company, provides for possible vehicle to grid energy provision. The 'Think City' electric vehicle is already offered on the basis of a battery leasing concept by the Norwegian company Think Global AS and the UK CCC indicates that the soon-to-be launched Nissan Leaf may be available on a similar basis.

The subscription model is based around the established mobile phone contract customers have with their service provider. The contract, or subscription, would give you a package that included access to charging points and battery exchange stations. This model is being promoted by the Better Place Company and is intended to tackle the upfront capital costs, the infrastructure provision and remove range anxiety by providing fast battery exchange points. The downside to this model is that it requires a high degree of standardisation across car manufactures.

Vehicle leasing extends the battery leasing model to the whole car and removes the first time buyers' risk associated with purchasing new technology. The UK CCC describes Mitsubishi as pursuing this model for its first EV, the i-MiEV.

Car clubs provide another potential means of introducing large numbers of people to a new technology while keeping them insulated from the initial high price and perceived risks of battery driven mobility. However, the high price remains a potential barrier as it has just been shifted from the individual to the car club, itself often backed by the public sector.

30. See p201 of *Meeting Carbon Budgets – the need for a step change* http://hmccc.s3.amazonaws.com/docs/21667%20CCC%20Report%20Chapter%206%20to%20the%20end.pdf

7.5 Integrated transport and energy policy

The relationship between electric vehicles and the power sector and their role in contributing to a low carbon transport network, demands they are considered in the context of the wider changes needed to both our energy system and private car use. The emissions savings they offer are a product of the carbon intensity of the electricity grid and the number of car km driven; both have to be significantly decreased if this new technology is to offer a significant carbon return on the investment needed. Road transport policy must be designed to discourage private car use and promote active travel and public transport use. Only if the necessary investment in these transport modes is forthcoming will the real emissions reduction potential of electric vehicles be realised. Great care must be taken in encouraging the roll out of electric vehicles so that they are seen as the low carbon replacement to necessary car travel and not an additional mode of transport that replaces existing bus and walking or cycling.

On the energy provision side, the right framework of incentives and technology has to be established to ensure EVs deliver on their potential to smooth the peaks and troughs of the daily electricity demand cycle. This means EVs cannot be taken in isolation, they have to be seen in the context of their potential role in driving a renewables-rich grid.

7.6 Future work

This report has provided an overview of the significant contribution electric vehicles could make to achieving the requirements of the Scottish Climate Change Act. In doing so, it has also raised two critical questions that should frame future work:

1. How to secure the necessary reduction in car km while establishing the role EVs have to play in private transport?
2. What does the fully integrated electrified vehicle system look like in a high-renewable power sector and in particular how does the emerging interface between consumer and electricity provider need to evolve?

More specifically, immediate attention should be given to describing:

- The package of possible fiscal incentive mechanisms and car ownership models and their likely impact in accelerating the up-take of EVs. This should include possible future electricity tariffs as these could provide a significant incentive as consumers acknowledge the reduced lifetime costs of the electric car.
- The expected consumer behaviour response to the electric vehicle and the projected impact this might have on the use of this new technology and, in turn, the effect on possible emissions savings. This should include an assessment of possible solutions to 'range anxiety' – the fear that the battery will run out long before it actually will.
- How an emerging EV fleet can be fully integrated into a renewables-rich electricity grid so as to ensure they make the greatest possible emissions reduction contribution and, in particular, how their potential as distributed electricity storage can be fully realised.
- The economic opportunities for Scotland resulting from the EV market penetration described by this report as necessary to ensure the 2020 target is achieved. This should include full supply chain analysis and the necessary new investment in both providing the charging infrastructure and the supporting technical maintenance.
- The public sector's role in being a market leader and how an electrified transport system should be incorporated into strategic planning across local authority areas.
- A more detailed study of the role electric vehicles could play in air quality management areas.

The answers to these questions and many others must not hold up the electrification of our transport system, instead they should feed into its design and development.

"What does the fully integrated electrified vehicle system look like in a high-renewable power sector and in particular how does the emerging interface between consumer and electricity provider need to evolve?"

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The role of electric vehicles in Scotland's low carbon future

8 Conclusions

1 EVs have an important role to play in Scotland's future transport sector if we are to achieve the 2020 target of at least 42% emissions reduction and the 2050 target of at least 80%. Emissions are approximately 50% lower for an EV powered from the current UK grid than from the average ICE car. This figure should improve to more than 80% less by 2030 as the power sector is decarbonised.

2 For the transport sector to make a proportionate contribution towards Scotland's 2020 target of at least a 42% reduction in emissions we will need to see at least 290,000 EVs on the roads of Scotland by this date (around 11% of the Scottish car fleet). To meet this goal, EV sales must achieve 20% of the new car sales market by 2020. If we fail to stabilise car km, the total number of electric vehicles required to meet the target shoots up to over 1.5 million cars by the same date.

3 In order that EVs make the greatest impact towards the 2020 targets, they must be seen as part of an overall package to stabilise road traffic levels and almost decarbonise the power sector by 2030.

4 Urban homes in Aberdeen, Glasgow and Edinburgh are less likely to have adequate off-street parking to allow for home charging of EVs than the rest of Scotland. Between just 22% and 46% of houses have access to off-street parking that would allow home charging.

5 Charging infrastructure must be targeted so as to ensure it has the greatest possible utility and therefore the lowest associated cost and most significant impact on driving distances of EVs.

6 The increased electricity demand resulting from a new fleet of EVs is relatively modest. However, this new demand must be fully integrated into a smart energy system that ensures demand follows supply availability rather than adding to existing peak demand and in turn driving supply. This new electrified transport system presents a significant opportunity to transform our role as electricity consumers and place us as an important component in an efficient electricity supply chain.


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