WWF

REPORT 2011

Conservation | Sustainability | Climate Change

Electric avenues

Driving home the case for electric vehicles in the UK

March 2011

LIST OF ACRONYMS AND INITIALS

BAU	Business as usual
BEV	Battery electric vehicle
CCC	The Committee on Climate Change
GHG	Greenhouse gas
GWh	Gigawatt hour (unit of energy) 1GWh = 10^6kWh
EV	Electric vehicle (used as a generic term to refer to BEVs and PHEVs)
ICEV	Internal combustion engine vehicle (used to refer to traditional cars)
kt	Kilo tonne (one thousand tonnes)
kWh	Kilowatt hour (unit of energy)
Mt	Megatonne (one million tonnes)
MW	Megawatt (unit of power)
NTS	National Travel Survey
OEM	Original equipment manufacturer
OLEV	Office for Low Emission Vehicles
ONS	Office for National Statistics
PHEV	Plug-in hybrid electric vehicle
SMMT	Society of Motor Manufacturers and Traders
R&D	Research and development
UNFCCC	United Nations Framework Convention on Climate Change
US ABC	United States Advanced Battery Consortium
V2G	Vehicle to grid
VED	Vehicle excise duty

- All UK figures include Northern Ireland.
- 'Britain' or 'Great Britain' refers to England, Scotland and Wales.
- Please also note that, unless otherwise stated, percentage emission reductions are relative to 1990 emission levels.

ACKNOWLEDGEMENTS

This report is based on research commissioned by WWF-UK and prepared by Element Energy Ltd. It includes the main findings of the consultants' research and presents our view of what these findings mean. The consultants' research report can be downloaded from *wwf.org.uk/electricvehicles*. A separate summary of this report is also available in hard copy or to download, as above.

We'd especially like to thank Shane Slater and Michael Dolman of Element Energy for devising the three different scenarios to estimate the UK carbon savings potential of EVs and their grid impacts, and for writing the research report. We're also grateful to Dr Jillian Anable of the Centre for Transport Research, University of Aberdeen, and Keith Buchan of the Metropolitan Transport Research Unit for acting as peer reviewers, providing their expertise and advice at all stages of this project.

100% RENEWABLES BY 2050

WWF has a vision of a world that is powered by 100% renewable resources by the middle of this century. Unless we make this transition, the world is most unlikely to avoid predicted escalating impacts of climate change.

See *wwf.org.uk/energyreport* for more information

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KEY MESSAGES

- Electric vehicles (EVs) have an important role to play in decarbonising road transport and reducing the UK's dependency on oil. They'll also be essential in delivering the level of reduction in emissions from cars that's necessary to achieve the targets required under the UK Climate Change Act.
- EVs have strategic importance to the UK economy: thousands of future jobs are expected in this industry. The development of a strong domestic market will help to attract future investment. The UK is already a leader in commercial EVs and battery technology and, with the announcement of the Nissan Leaf manufacturing facility in Sunderland, can expect to play a leading role in the international EV market.
- WWF-UK supports the rapid introduction of EVs to replace petrol/diesel vehicles. However, the full value of EVs to a low-carbon economy will be dependent on decarbonising the power sector and reducing the amount we drive.

1.7 MILLION

AT LEAST 1.7 MILLION EVS WILL BE NEEDED BY 2020 AND 6.4 MILLION BY 2030

- This study shows that at least 1.7 million EVs will be needed by 2020 and 6.4 million by 2030 in order to achieve the UK's climate change targets. EVs would then represent 6% of all UK cars in 2020 and 18% in 2030. Capital grants and other incentives to encourage an increase in numbers of EVs will be essential to stimulate the market.
- A combination of high EV uptake, improvements in the efficiency of internal combustion engine vehicles (ICEVs), and demand management measures to reduce the amount people drive could potentially deliver a 75% reduction in car emissions by 2030. EVs could provide nearly a third of this emissions reduction.

£5 BILLION

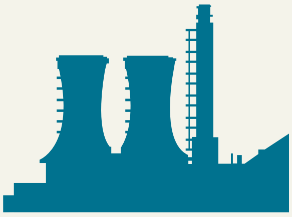
EVS COULD ACCOUNT FOR NEARLY A THIRD OF THE REDUCTION IN FUEL DEMAND, REPRESENTING OVER £5 BILLION A YEAR IN AVOIDED OIL IMPORTS BY 2030

- This same combination of factors could also reduce UK fuel demand for cars by nearly 80% by 2030. EVs could account for nearly a third of the reduction in UK fuel demand, representing over £5 billion a year in avoided oil imports by 2030.
- Grid impacts of EVs are manageable and within National Grid forecasts in terms of additional load and peak electricity demand, even with high levels of EV uptake. However, EVs could overload current local distribution systems and transformers, so these may need upgrading as the number of EVs increases.
- EVs support the rapid growth of renewable energy. They can help balance the grid by charging late at night, using renewable power when electricity demand is otherwise low. Using renewables to recharge EVs also reduces their carbon impact. Once technical issues are resolved, there's also potential for EVs to feed power back into the grid at times of high demand.
- To ensure EVs deliver significant carbon savings in the 2020s, the UK needs to become 'EV ready' now. Early actions needed include the roll-out of charging infrastructure, encouragement of delayed charging, and development of 'smart grids' that include intelligent monitoring, control and communications technologies to optimise EV charging for grid stability and at times of lowest carbon intensity.
- Other priorities for innovation and investment are reducing the cost and improving the performance of EV batteries, and decarbonising the grid. A Europe-wide approach to grid infrastructure will also be needed if EVs are to be powered by a decarbonised European grid, in order to deliver maximum carbon savings both in the UK and on the continent.

EXECUTIVE SUMMARY

Electric vehicles (EVs) have an important role to play in decarbonising road transport.

To ensure they realise their full emissions-saving potential, we also need to decarbonise the power sector by 2030 and deliver demand management measures that will reduce the amount people drive.



Burning liquid hydrocarbon fuels made from oil is responsible for around 30% of global CO2 emissions contributing to climate change

Why EVs are an important issue for WWF

Climate change is one of the greatest threats to the natural world and the people who depend on it. As the primary cause of climate change is the burning of fossil fuels (coal, oil and gas), reducing humanity's carbon footprint must be a priority if the rise in global temperatures is to be kept below dangerous levels. This will require aggressive action to improve energy efficiency in all sectors of the economy. In the transport sector, it will require a reduction in the demand for oil-derived fuels.

WWF's Living Planet Report 2010 shows that, globally, we're currently using natural resources at a rate that's 50% higher than the planet can replenish each year. If everyone lived as we do in the UK, we'd need 2.75 planets of resources. This overshoot is largely due to our carbon footprint. We believe that a move towards transportation systems powered by renewable electricity, together with improvements in conventional vehicle efficiency and a reduction in the amount people drive, can play a major role in reducing our reliance on oil and other fossil fuels, thereby cutting carbon emissions significantly.

Helping to reduce our oil dependency

The world is running out of cheap and easily accessible sources of oil[1]. This reduction in affordable supply should focus our efforts on developing alternatives – yet we continue to seek increasingly risky and more polluting sources of oil in the Arctic, deep waters such as the Mexican Gulf and the tar sands of Canada.

Burning liquid hydrocarbon fuels made from oil is responsible for around 30% of global CO2 emissions contributing to climate change.[2] We need to wean ourselves off oil and decarbonise our economies in order to ensure that average global temperatures rise by no more than 1.5°C compared to pre-industrial levels. This is necessary if we want to ensure the safety, sustainability and prosperity of people, places and wildlife.

In its recent report[3], the Industry Taskforce on Peak Oil and Energy Security warned that Britain was unprepared for oil price shocks which could happen in the next five years, placing the UK economy at risk. Taskforce member Jeremy Leggett says: "Only two things are standing in the way: a collective sense of urgency consistent with peak-oil risk, and effective yoking of industry and government in strategic harness."

1 The UK Energy Research Centre (UKERC) *Global Oil Depletion* report (October 2009) states that there is significant risk of peak oil occurring before 2020; also that large resources of conventional oil are 'unlikely to be accessed quickly', pp ix-x.
2 http://cdiac.ornl.gov/trends/emis/tre_glob.html, 2007 data (June 2010).
3 Industry Taskforce on Peak Oil and Energy Security, *The Oil Crunch: a wake-up call for the British economy*, February 2010.

The growing danger of dirty oil

Energy companies are increasingly looking to meet continuing growth in energy demand by exploiting risky and highly polluting sources of oil and gas, such as deep-water oil and unconventional oils like tar sands. But these come at an enormous cost, economically and environmentally, at a time when we should be investing in renewables. Many oil reserves are located in pristine places that are vital for biodiversity – including tropical rainforests and the Arctic. Extracting them is difficult and dangerous, and further disasters like the Deepwater Horizon oil spill in the Gulf of Mexico are inevitable.

Closer to home, there are now moves to license deep-sea drilling for oil near the Shetland Islands and off the west coast of Scotland – vulnerable areas where environmental damage would be difficult to contain in the event of a blow out.

We've recently highlighted an obscure legality in Crown Estate leases that shows a clear institutional bias towards offshore oil and gas exploration to the detriment of renewables. But if the use of EVs and renewables were expanded, this would help to reduce fuel demand, meaning there would be less need to rely on increasingly risky sources of oil and gas.

"Be it oil and coal or flights and car kilometres, people need to consume and travel less – and more intelligently – if the UK is to meet its climate change targets. We need to make the right set of choices to bring about fundamental change if we're to reduce our oil dependency and make the transition to a low-carbon economy"

Keith Allott, Head of Climate Change, WWF-UK

We believe there's a way forward. Our vision is for a low-carbon future based on renewable energy, energy efficiency and demand reduction, where fossil fuel-dependent cars are increasingly replaced by EVs.

This is a big challenge, but there's no reason why the UK cannot plan for such a future. A recent report from the European Climate Foundation (ECF)[4] shows that Europe does not need to rely on nuclear energy or fossil fuels to meet ambitious carbon targets or energy security objectives – and that an electricity system based on 100% renewable energy sources is affordable and achievable. Moreover, the ECF report found that this could be achieved alongside very substantial electrification of road transport.

The UK's Committee on Climate Change has also repeatedly called for near decarbonisation of the power sector by 2030 as a critical milestone to achieving the Climate Change Act target of a reduction in the UK's greenhouse gas emissions of at least 80% by 2050.[5] In order to achieve this target, they recommend a strong focus on efficiency and demand reduction, a decarbonised power sector, and the electrification of transport.

In our view, EVs only make sense in the context of a new, more sustainable approach to transport which accepts the need to reduce our reliance on fossil fuels, manage demand, and promote alternatives to travel. As Keith Allott, WWF-UK's Head of Climate Change explains: " Be it oil and coal or flights and car kilometres, people need to consume and travel less – and more intelligently – if the UK is to meet its climate change targets. Business as usual (BAU) practices and an overreliance on technology improvements will not be enough. We need to make the right set of choices to bring about fundamental change if we're to reduce our oil dependency and make the transition to a low-carbon economy."

4 *Roadmap 2050: a practical guide to a prosperous, low-carbon Europe*, European Climate Foundation, April 2010.
5 For example in the Committee on Climate Change letter from Adair Turner to Chris Huhne, 9 September 2010, regarding the level of renewable energy ambition to 2020.

Energy companies are increasingly looking to meet continuing growth in energy demand by exploiting risky and highly polluting sources of oil and gas, such as deep-water oil and unconventional oils like tar sands.

EVs are also more energy efficient, with 75% efficiency compared to the 20% efficiency of fossil fuel-powered cars

EVs as part of the solution, not a panacea

If we're serious about reducing our oil dependency, then EVs have to be an important part of the solution as they are a much lower carbon alternative to conventional cars, which produce 14% of CO2 emissions in the UK[6]. EVs are also more energy efficient, with 75% efficiency compared to the 20% efficiency of fossil fuel-powered cars[7]. But EVs are not carbon free. Ultimately, the scale of the contribution they could make to a low-carbon transport sector depends on the carbon intensity of the electricity that powers them. That's why EVs need to go hand in hand with decarbonisation of the grid.

It is also important that EVs are used to drive less, not more – which will be a challenge as EVs have lower operating costs. If EVs contribute to a rise in car kilometres, we'll need far more of them to achieve the same result as driving less in terms of reducing fuel demand and car emissions. Greater support for walking and cycling, car sharing and more attractive public transport options would all help to bring down car kilometres by reducing the need for private car travel. Other measures such as road and congestion charges or higher parking charges would also help to curb demand.

Even without EVs, there is significant potential to reduce car emissions and oil consumption by improving ICEV engine efficiency. Pressing for stronger EU legislation to reduce average fleet emissions from ICEVs[8] needs to be a continuing priority, especially before 2020 while EVs are in their infancy and the grid is still substantially powered with fossil fuels. Tighter emissions targets will be critical in driving the widespread investment in research and development (R&D) that will bring down EV costs and make them commonplace on the roads.

EVs offer a promising way of reducing our oil dependency and improving our ability to meet climate change targets. At high levels of uptake and together with ICEV efficiency improvements and demand management, EVs could deliver a reduction of nearly 80% in fossil fuel demand from cars by 2030, and at the same time deliver a 75% reduction in carbon emissions from cars.

Replacing the need for biofuels

Another low-carbon alternative to EVs would be to opt for high levels of biofuel use in conventional cars. Although we believe that bioenergy could play an important role in meeting the world's energy needs in future, it's important to realise that it is a finite resource with numerous potential impacts on land use, food and water security and biodiversity.

Biofuels should therefore be considered a last resort for sectors where at present there are no practical alternatives to fossil fuels – such as aviation, shipping and heavy goods transport. In contrast, an attractive and feasible alternative – electrification – is available for passenger cars, so the use of biofuels for this sector should not be considered a high priority.

6 Committee on Climate Change, www.theccc.org.uk/sectors/transport
7 See pp 82-83 of WWF's *Plugged In* report for an efficiency comparison of electrical versus mechanical powertrains. The energy efficiency of EVs is heavily dependent on the 'generation mix' of the electricity used to power them. Using coal or gas-fired plant to generate the electricity used for charging EVs significantly reduces their overall energy efficiency and, worst case, can put them nearly on a par with ICEVs, as discussed in p95 of Element Energy's research report.
8 The European Parliament passed new car CO2 legislation that sets an emissions cap of 130gCO2/km averaged over all new vehicles produced by each manufacturer by 2015. Reaching this goal will be phased in over three years, from 2012. An extended target is set to be an average of 95gCO2/km/km by 2020.

A rapid rise in EV numbers is needed

EVs could start delivering substantial carbon savings by 2020. But we need lots of them – at least 1.7 million EVs by 2020 and 6.4 million by 2030 – if they are to make a serious dent on car emissions. This will require a high level of policy intervention by the government to both invest in the conditions and infrastructure that are needed for EVs to succeed and to help 'normalise' their acceptance by consumers, and provide incentives for their purchase, in order to ensure a rapid rise in EV numbers that will be needed for them to make a difference.

There are three main reasons for taking early action on EVs. Support now for UK manufacturers will help to establish a market-leading EV industry and create green jobs. A continuation of the capital grant scheme, and an increase in the total funds available, will help to stimulate early purchases of EVs. And planning now for grid improvements and rolling out new charging infrastructure will ensure that these are ready in time to accommodate high levels of EVs.

Supporting the rapid growth in renewables

EVS CAN HELP TO SUPPORT THE TRANSITION TO RENEWABLES BY CHARGING AT TIMES OF LOW OVERALL DEMAND ON THE GRID, USING POWER FROM RENEWABLE SOURCES WHEN IT MIGHT OTHERWISE NOT BE USED

We're convinced that a future where people share the world's natural resources more sustainably is within our grasp, based on much greater use of renewable energy sources. A significant increase in electricity from renewables is required if the UK is to meet the government's renewable energy target of 15% by 2020, and if we are to achieve a 100% renewable energy future by 2050. EVs can help to support this transition by charging at times of low overall demand on the grid, using power from renewable sources when it might otherwise not be used. Charging at times when the CO2 intensity of the grid is low also helps to reduce the carbon impact of EVs.

It is encouraging that, even at high levels of uptake, EVs' impact on the grid is not as great as perhaps feared. At a national level, their impact can be contained within the range of National Grid forecasts. Longer term, EVs also have the potential to feed power back to the grid at times of peak demand. But such vehicle to grid (V2G) applications must first overcome significant technical and economic challenges if this aspect of EV potential is to be realised.

The importance of investing now to ensure the UK is 'EV ready'

In order for people to want to drive EVs, they need to get used to seeing them, perhaps initially in government or corporate car fleets or car sharing clubs. They also need plenty of encouragement, from free parking spaces to exemption from congestion charging and Vehicle Excise Duty (VED). But capital grants will be most important in order to reduce the high upfront cost of EVs relative to ICEVs. This government funding for EVs needs to continue well beyond 2012, once the economy improves, in order to boost sales. In addition, new models of ownership, such as leasing schemes, may be needed that shift the cost of EV ownership over many years.

A flexible charging network is also required, involving charge delay devices and smart grids, so that EVs can be charged at times of low electricity demand and when the carbon intensity of the grid is low. The UK government's support for integrated smart grids and standardised charging points and compatible charging technology across Europe will be important if EVs are to provide more than a localised solution to reducing transport emissions. Doing this early will help to shape and develop the future market for EVs and provide a consistent model for EV charging across the UK and Europe.

Most charging points will be needed at home, with delayed overnight charging to put less pressure on the grid. Workplace charging points will also be required, although travel to work by private car needs to reduce. Charging points at other high visibility locations such as supermarkets or in front of town halls will also be important.

There is also a pressing requirement for R&D investment to improve EV cost and performance. In particular, reducing battery costs and increasing their storage capacity and range would make EVs more attractive to consumers.

Much market learning is still needed for new business models to succeed, such as EV car sharing instead of ownership or (borrowing from the mobile phone business model) battery leasing and swapping, perhaps at petrol station forecourts, to help reduce the cost of EVs and increase their uptake.

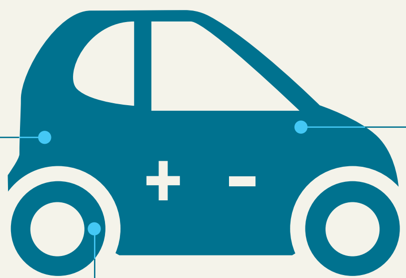
Insights not forecasts

This report presents the feasibility, opportunities and challenges of moving away from oil-dependent car travel. It sets out three different scenarios for EV uptake: a Business as usual scenario (BAU) representing low levels of EVs (1.7 million EVs by 2030); an Extended scenario with medium EV levels (6.4 million EVs by 2030); and a Stretch scenario which stress tests a future with very high EV uptake (26.3 million EVs by 2030).

Our research builds on two other WWF reports: *Plugged In*, which looked at the importance of EVs in relation to declining oil resources, and *Watt Car*, which examined the role for EVs in Scotland. This report, our first to focus on the UK potential for EVs in 2020 and 2030, uses a similar methodology to that used by *Watt Car* to estimate CO2 savings and grid impacts from EVs.

It is important to note that these scenarios are intended to provide insights, not forecasts. They aim to provide a better understanding of the role EVs could play, as well as what has to happen in order for EVs to realise their potential. The future is likely to lie somewhere between the scenarios that this report describes. However, it is clear that at least 1.7 million EVs will be needed by 2020 and 6.4 million by 2030 in order to achieve the level of ambition that we need.

We need to wean ourselves off oil and decarbonise our economies in order to ensure that average global temperatures rise by no more than 1.5C compared to pre-industrial levels



EVs are a much lower carbon alternative to conventional cars, which produce 14% of CO2 emissions in the UK

We need at least 1.7 million EVs by 2020 and 6.4 million by 2030 if they are to make a serious dent on car emissions

1. INTRODUCTION

EVs are needed to reduce car emissions to levels which are in line with UK climate change targets. EVs have many advantages over conventional cars and the UK already has a strong presence in this market.

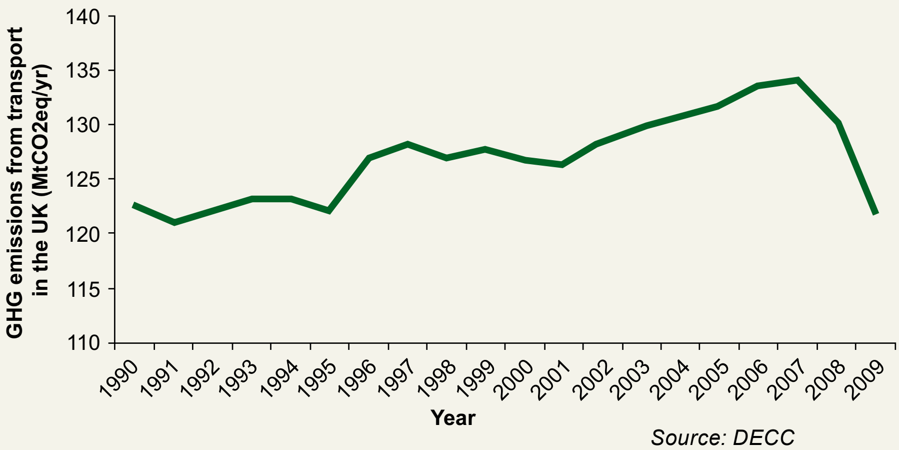
EMISSIONS FROM THE TRANSPORT SECTOR HAVE BEEN ON AN UPWARD PATH FOR MOST OF THE LAST TWO DECADES

1.1 Meeting UK climate change obligations

The UK is legally committed to reduce its greenhouse gas emissions by at least 80% by 2050, from 1990 levels, under the Climate Change Act. The government has accepted an interim reduction target of 34% for 2020 as the UK's contribution towards achieving an EU-wide emissions reduction target of 20%. However, the Committee on Climate Change (CCC) has recommended an 'intended' target for 2020 of 42% – which is in line with a more ambitious 30% target in Europe. WWF is also supporting a UK emissions reduction target of 42% by 2020, which we believe can and must be achieved through domestic action rather than offsetting.

The transport sector currently accounts for a quarter of UK CO2 emissions, of which 55% come from passenger cars.[9] Emissions from the transport sector have been on an upward path for most of the last two decades. Until the recession, transport was the only sector of the economy whose emissions were continuing to grow. Emissions from UK transport are shown below.

Figure 1: Historical emissions from the UK transport sector from 1990



Source: DECC

1.2 CCC indicative figures for reducing car emissions

In its October 2009 report to Parliament[10], the CCC prepared an indicative set of figures for a reduction in car emissions by vehicle type, in line with the 34% UK target. These figures represent the best available data from which target savings from cars can be derived. The CCC's figures are for different years (2012, 2018 and 2022) than those of interest in this study, and linear interpolation based on the CCC figures has been used to derive the figures for 2020 and 2030. They suggest that car emissions would need to reduce by 26% by 2020 and by 47% by 2030.

9 Committee on Climate Change, www.theccc.org.uk/sectors/transport
10 *Meeting Carbon Budgets – the need for a step change*, Progress Report to Parliament by the CCC, table 3.4, p240 (October 2009).

We then asked Element Energy to take the figures described above and adjust them to be in line with a more ambitious 42% reduction target by 2020, which we believe will give the UK a better chance of meeting its 80% reduction target for 2050. This means that car emissions would need to come down by 32% by 2020 and, using linear interpolation, by 51% in 2030.[11] These higher ambition figures have been used as the emissions milestones shown in Chapter 3 of this report. We have looked at the ability of each of our three EV scenarios to meet these emissions milestones.

Looking beyond 2030, the CCC's indicative figures for the reduction of car emissions suggest that car emissions will need to fall by 90% by 2050 in order to meet the overall 80% emissions reduction target.

-32%

CAR EMISSIONS NEED TO COME DOWN BY 32% BY 2020 AND 51% BY 2030

The main types of EVs

Battery electric vehicles (BEVs)

BEVs such as the Nissan Leaf 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.

Plug-in hybrid electric vehicles (PHEVs)

PHEVs such as the Vauxhall Ampera use a combination of an electric motor and batteries along with an internal combustion engine (ICE). 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 ICE and battery-powered electric motors. Some manufacturers are developing series-parallel hybrids, which are able to operate in either series or parallel mode.

Hybrid Electric Vehicles (HEVs), such as the Toyota Prius, differ from PHEVs in that they cannot plug in to recharge, although both HEVs and PHEVs are primarily powered by petrol or diesel.

In this report, only BEVs and PHEVs are included in the figures for EVs, with our scenarios assuming an equal split between the two. HEVs are included in the figures for Internal Combustion Engine Vehicles (ICEVs).

Hybrid Electric Vehicles (HEVs) such as the Toyota Prius are different from PHEVs in that they do not require charging from the grid and use motive energy, largely supplied through an ICE, to recharge the battery.

WWF has used the term EVs generically to include BEVs and PHEVs only.

11 A more detailed description of the methodology used to adjust the CCC's figures can be found in Appendix 8.3.1 to Element Energy's research report. Following additional analysis by the CCC on the impacts of the recession, their Fourth Carbon Budget (December 2010) shows that the achievement of the 42% target (in the Extended Ambition scenario) is looking more likely, at least in the non-traded sector (including transport).

EVS NOT ONLY HELP TO REDUCE OUR OIL DEPENDENCY AND THE CLIMATE CHANGE IMPACTS OF CONVENTIONAL CARS, THEY CAN ALSO REDUCE AIR POLLUTION ASSOCIATED WITH EMISSIONS

1.3 The advantages of EVs

The main advantages of EVs over conventional cars are that they are less oil dependent and are considerably more energy efficient. The internal combustion engine is incredibly inefficient, wasting over three-quarters of fuel energy, whereas BEVs achieve around 75% efficiency.[12] The fuel efficiency of PHEVs is also better than ICEVs, although less good than BEVs.

Compared to the average ICEV, EVs also offer carbon savings even with today's largely fossil-fuel powered energy grid. For example, the average emissions performance of all new cars sold in the first half of 2010 was 145gCO_2/km.[13] This compares to just over 100gCO_2/km for a BEV charged with grid electricity.[14] As the electricity sector is steadily decarbonised, which is a prerequisite for achieving our UK climate change targets, EVs will generate even lower emissions compared to ICEVs.

EVs reduce or eliminate many of the issues associated with conventional cars, including:

- Long-term sustainability issues – as fossil fuel supplies are limited and the environmental impact of extracting these fuels from increasingly risky sources can be severe.
- Carbon impact – the combustion of fossil fuels releases CO_2 into the atmosphere, contributing to climate change.
- Price volatility – traditional transportation fuel prices are linked to the price of oil, which is highly volatile and expected to increase in the medium to long term as supplies diminish.
- Security of fuel supply – the world's oil reserves are concentrated in a relatively small number of countries.
- Air quality issues – the burning of petrol and diesel contributes to air pollution, especially in cities, with significant health impacts.

EVs can therefore not only help to reduce our oil dependency and the climate change impacts of conventional cars, they can also reduce air pollution associated with emissions. Air pollution is associated with respiratory and cardiac diseases, which are major contributors to sickness and mortality. Air quality improvements through greater use of EVs, tougher emissions legislation, and demand reduction measures would benefit the health of the UK population and contribute to health care savings.

1.4 The emerging EV market

EV manufacturers

Analysis by Frost and Sullivan[15] suggests that over 47 manufacturers are expected to compete in the global EV market with over 75 models by 2015. Chinese original equipment manufacturers (OEMs) are expected to launch 35 EV models in the next three to five years. This emerging EV market will, to start with at least, remain dominated by traditional OEMs. Manufacturers such as Toyota, Ford, Volvo, BMW, VW, Nissan, Renault, GM, Tata and Smart all have models coming to the market in the near future.

12 WWF, *Plugged In*: the end of the oil age, pp 79-83 (2008)
13 Data from SMMT: www.smmt.co.uk
14 Emissions from EVs based on typical grid to wheel efficiency of 02.kWh/km and an average grid CO_2 intensity of 517gCO_2 kWH, which is the figure used in the government's latest tool for assessing the carbon impact of new dwellings.
15 Frost and Sullivan, *Electric Vehicles: Market Opportunities and New Business Models for Industry Stakeholders*, MaRS Market Insights, 20 September 2010.

In the UK, the Nissan Leaf, Mitsubishi i-MiEV and new plug-in Toyata Prius will all go on sale in 2011. Renault-Nissan has announced a £420 million investment both to produce the Leaf and to build a new battery plant at Sunderland, Tyne and Wear, where 50,000 EVs will be produced initially as from 2013. Some 2,250 people will be employed at Nissan and across the UK supply chain. Toyota's Auris hybrid is manufactured in Burnaston, Derbyshire. The Vauxhall Ampera (sister EV to the US Chevrolet Volt) may also be manufactured in Ellesmere Port, Merseyside. In addition, three UK companies – Smith Electric Vehicles, Allied Vehicles, and Modec – are well established electric commercial vehicle manufacturers.

UK manufacturers therefore have a head start in EV manufacture which should give them a competitive advantage in the future, as the market grows.

Current number of EVs

The EV market is still in its infancy. According to the latest figures, there are currently 61,000 HEVs and 1,400 BEVs licensed in Great Britain.[16] There are currently no PHEVs on the market.

Sales of BEVs in 2009 were tiny, with only 55 new cars registered, in comparison to 397 in 2007. Most of these were G-Wiz cars, manufactured in India. This sharp drop in sales has been interpreted as due to the recession or because people are waiting for government grants to arrive before purchasing an EV. Certainly UK EV manufacturers are bullish, as is the DfT which expects 8,600 EVs to be sold in 2011 once capital grants for EVs are available.

To move from thousands to millions of EVs in future will clearly be an enormous task, requiring substantial investment and government support. Challenges and opportunities for growing the EV market are discussed further in Chapter 5.

16 DfT 2009 figures for BEVs and PHEVs. This concurs with the government's response to the Second Annual Progress Report of the Committee on Climate Change, p35, which shows 1,453 EVs registered in 2009.

2. THREE SCENARIOS FOR EVS

In order to examine the feasibility, opportunities and challenges of moving away from oil-dependent car travel, three different scenarios have been prepared – Business as usual (BAU), Extended and Stretch – based on low, medium and high levels of EV uptake. These show a range of possible futures for EVs.

2.1 What's behind the scenarios

A basic comparison of the three scenarios is shown below, including the main assumptions for each one:

Table 1: Comparing the three scenarios

Scenario	EV support policies	EV contribution to UK CO2 target	Demand for car travel	EV cost	EV range
BAU	Existing and announced	Minimal	Growth	Medium	Medium
Extended	Some additional support	Medium	Stabilisation	Medium	Medium
Stretch	Very high support and investment	High	Stabilisation	High[17]	High

For more detailed information about the assumptions and parameters used for each scenario, please see Appendix A in this report or refer to Element Energy's research report at *wwf.org.uk/electricvehicles*

It's important to note that these scenarios are indicative only (representing different levels of EV uptake and a range of alternative futures) and do not attempt to forecast consumer demand for EVs. The number of EVs needed for each of the three scenarios is shown below.

Table 2: EV numbers needed for each of the three scenarios

EVs	BAU 2020	BAU 2030	Extended 2020	Extended 2030	Stretch 2020	Stretch 2030
Number of EVs needed	160,000	1.7m	1.7m	6.4m	4.2m	26.3m
EVs as % of new car sales	1%	8%	15%	20%	44%	80%
EVs as % of all UK cars	0.5%	5%	6%	18%	13%	74%

A 50/50 split between BEVs and PHEVs has been assumed in all three scenarios for purposes of simplicity, as it is not the intention of the scenarios to provide forecasts by type of EV.

All three scenarios assume near decarbonisation of the grid by 2030.

17 The cost is high due to the assumption that BEVs have a high range (250km) in the Stretch scenario, which means larger capacity batteries, resulting in higher cost. There is a debate to be had around the impact of any battery cost reductions in future – i.e. the extent to which they will feed through into lower cost EVs versus higher cost EVs with greater range.

2.2 Purpose of the scenarios

The main purpose of the scenarios is to examine the impact of EVs on UK carbon emissions, as well as fuel and electricity demand. The Stretch scenario is the only one that's been designed to meet the higher 42% carbon reduction target for 2020, which we support. However, we've examined the ability of all three scenarios to meet this more ambitious target.

The scenarios look at passenger cars only. They include assumptions on the demand for car travel, emission reductions through measures such as eco-driving[18] and speed limit enforcement, and the speed at which the market for EVs takes off in future years. We've made other assumptions on the efficiency of all car types, EV range, and the carbon intensity of the grid.

A description of each scenario follows.

2.3 The business as usual (bau) scenario

The BAU scenario is a realistic one if current policies and behaviours remain unchanged. Under this scenario, EVs will have minimal impact in reducing UK carbon emissions.

This scenario shows the level of EV uptake assuming that existing and announced policies remain in place, with no further support for EVs. These include the DfT's 'Plugged-in Places' scheme to install charging points in key UK cities, which was recently extended from three to eight cities and regions[19] as part of its £400 million funding for low-carbon vehicles, announced in the Comprehensive Spending Review. This funding also includes £43 million in capital grants as from 1 January 2011 to support the uptake of EVs, with subsidies of up to £5,000 per vehicle[20]. A review of this funding will take place in January 2012. If no further funding is made available as a result of public spending cuts, the level of EV uptake in the BAU scenario would be even smaller than that shown here.

In a BAU future, EVs only account for a small percentage of new car sales and UK cars. They remain a niche product for at least a decade and provide little in the way of carbon savings.

The BAU scenario assumes that ICEVs will remain the predominant vehicle and that their efficiency will improve in line with EU legislation, i.e. 130gCO2/km by 2015, with a further a target of 95gCO2/km proposed for 2020. These improvements mean that ICEVs will help to reduce car emissions, even without many EVs on the road. But they will be insufficient on their own to hit the emissions milestones in line with a 42% target, and still leave UK car travel very dependent on oil.

Under this scenario, the carbon intensity of grid electricity remains high until 2020, but by 2030 this will have reduced markedly as a result of less polluting sources of energy coming on-stream, in line with the CCC's recommendations.

18 According to a 2010 DfT consultation on eco-driving training, the definition of eco-driving includes driving at efficient speeds, fuel efficiency and choice of gear, best practice for acceleration and braking and anticipation for traffic and driving conditions.
19 London, Milton Keynes, the North East, Midlands, Greater Manchester, east England, Scotland and Northern Ireland.
20 The £43 million of funding, which was announced by the Secretary of State for Transport in July 2010 to subsidise EV purchases, at £5,000 per vehicle, between 2011 and 2012 and confirmed in the Comprehensive Spending Review in October 2010, is a good deal less than the £230 million allocated by the previous government. In December 2010, the government announced the nine BEVs and PHEVs that will initially be eligible for this grant: the Nissan Leaf, Mitsubishi i-MiEV, Smart fortwo electric drive, Peugeot iOn, Tata Vista, Citroen CZero, Vauxhall Ampera, Toyota Prius Plug-in Hybrid and Chevrolet Volt.

2.4 The extended scenario

In this scenario, we've assumed medium levels of EV uptake, and that carbon savings from EVs start to be realised.

EV uptake under the Extended scenario is significantly above that of the BAU scenario, with a relatively high increase in production capacity and demand within the next decade. In this scenario, EVs are estimated to account for around 15% of new car sales by 2020, and 20% by 2030, corresponding to 6% of all UK cars by 2020, and 18% by 2030. Ramping up EV penetration to this level requires additional policy support from government, such as additional funding for low carbon vehicles and a continuation of the £5,000 per vehicle subsidy well beyond 2012.

In this scenario, there are 1.7 million EVs by 2020. This figure matches the CCC's recommended level of EV penetration in line with the UK achieving a 34% carbon reduction target by 2020.

The Extended scenario assumes stabilisation in traffic growth at 2010 levels, improvements in ICEV efficiency, and CO2 savings from eco-driving and speed limit enforcement. We assume the same carbon intensity of the grid as in the BAU scenario.

2.5 The stretch scenario

The Stretch scenario is in line with the emissions reduction that we expect the car sector to contribute in order to achieve a 42% carbon reduction target by 2020. It assumes the very highest level of EV uptake in order to indicate EVs' maximum carbon savings potential and 'stress tests' the impact of extremely high EV levels on the grid. It assumes a rapid increase in EV numbers over the next decade and beyond, with traffic stabilised at today's levels. It's the only one of the three scenarios that's based on meeting a 42% emissions reduction target by 2020.

This is not to say that the only way a 42% target can be achieved is by meeting the Stretch scenario. But if car emissions do not fall to the level needed to meet this target, then other sectors will have to decarbonise more.

In order to achieve this level of EV uptake, a rapid increase in EV production volumes is needed to keep up with demand. Continuing subsidies to reduce the cost of EVs and performance improvements to extend their range, as well as additional policy support, are required if this level of demand is to be realised.

Sales of EVs start from a low base in the Stretch scenario but then follow a rapid growth trajectory[21] which is typical of new car technologies such as the Toyota Prius. According to this very ambitious scenario, EVs account for 44% of new car sales by 2020 and 80% by 2030, far outselling ICEVs. They also represent the majority of the UK's car stock by 2030.

2.6 Scope

The focus of this study is on passenger cars as this is the main market for EVs in the UK and the main source of road transport emissions. All sections pertaining to UK emissions savings and reduction in fuel demand from EVs include Northern Ireland. However, grid impacts and infrastructure analysis are focussed on Great Britain (including England, Wales and Scotland). This is because Northern Ireland and the Republic of Ireland both share a separate grid from the rest of Great Britain. We do, however, refer to grid impacts for Northern Ireland and the Republic of Ireland in the text.

21 For further information about growth trajectory assumptions, see Appendix 8.2.4 in Element Energy's research report.

3. THE ROLE OF EVS IN REDUCING CARBON EMISSIONS

EVs can make a significant contribution to helping the UK meet its emissions reduction targets and to reducing our oil dependency.

3.1 EVs and CO2 reduction

The importance of EVs in reducing emissions

If cars are to play their part in helping the UK to achieve a reduction in carbon emissions of 42% by 2020 and at least 80% by 2050, then car emissions need to fall by about a third by 2020 and by half by 2030. There is clearly a big task ahead of us.

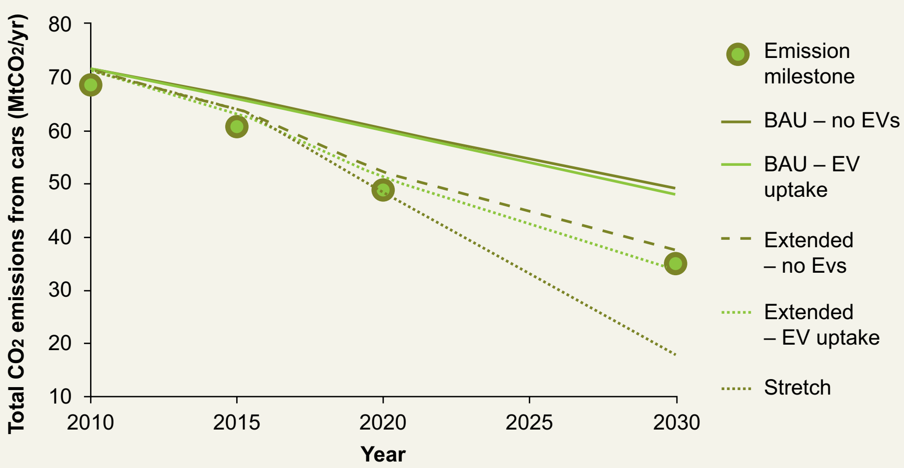
High levels of EV uptake can result in significant emissions savings, but:

- the electricity used to power EVs must be substantially decarbonised; and
- the amount we drive must not grow from current levels and should decline.

For purposes of illustration, Figure 2 shows what would happen if there was no EV uptake in either the BAU or Extended scenarios. This is in contrast to the base case for these scenarios, as described in Sections 2.3 and 2.4, which assume low and medium EV uptake, respectively.

Figure 2: Emissions projections under each scenario for cars in the UK (emissions are calculated for 2020 and 2030, with the dashed lines indicating the trajectories)

Projected emissions from cars to 2030: UK



-17%

THIS FIGURE DEMONSTRATES THAT, EVEN IN A BAU SCENARIO WITH NO EVS, WE CAN REDUCE CAR EMISSIONS BY 17% BY 2020, AND OVER 30% BY 2030 , THROUGH EFFECTIVE EU POLICIES THAT RESULT IN REDUCED GCO2/KM FOR ICEVS.

This figure demonstrates that, even in a BAU scenario with no EVs, we can reduce car emissions by 17% by 2020, and over 30% by 2030[22], through effective EU policies that result in reduced gCO2/km for ICEVs. But this still leaves car travel woefully dependent on oil, with few prospects of further improvement beyond 2030 – when emission constraints and the depletion of global oil supplies will really be biting hard.

22 Relative to 1990 levels.

28%

HIGH NUMBERS OF EVS, AS PER THE STRETCH SCENARIO, COULD REDUCE CAR EMISSIONS BY 28% BY 2030

The emission milestones shown in Figure 2 indicate the trajectory needed if car emissions are to fall in line with a UK emissions reduction target of 42% by 2020 and make their recommended contribution towards meeting the 80% reduction target by 2050. These milestones are based on the CCC's indicative figures for car emissions reduction assuming a 34% reduction target but adjusted upwards to meet an 'intended' 42% target[23].

Figure 2 shows that the Stretch scenario is the only one to hit or exceed emissions milestones in line with a 42% reduction trajectory in 2020 and 2030. The Extended scenario isn't far off though. It does achieve the trajectory for 2030 and misses the 2020 emissions milestone by less than 5 MtCO2/year – roughly equivalent to the emissions output of one coal-fired power station. Reducing the amount we drive by just 4% from today's levels would make up this shortfall.

The point is that it's still possible for the UK to meet an overall 42% reduction target even if car emissions fail to come down to the indicative emission milestone used in this report. But other sectors will have to decarbonise more to make up the shortfall. Ultimately, to deliver on the UK's Climate Change Act targets, it is important to have a credible plan to reduce our reliance on fossil fuels – and EVs can play a critical role.

As the following table demonstrates, a combination of EVs, ICEV improvements and demand management measures could deliver a 75% reduction in car emissions by 2030. High levels of EVs could provide 28% of this emissions reduction.

Table 3: Scenario emissions savings in the UK in 2020 and 2030

Scenario	**CO2 emission reduction from 1990 levels due to EVs and other measures (MtCO2/yr)**							
	2020				**2030**			
	EVs	Other	Total	%	EVs	Other	Total	%
BAU	0.1	11.5	11.6	16.3%	1.2	22.1	23.3	32.6%
Extended	1.1	19.3	20.4	28.6%	3.7	34.0	37.7	52.7%
Stretch	3.3	19.3	22.6	31.7%	19.8	34.0	53.8	75.3%

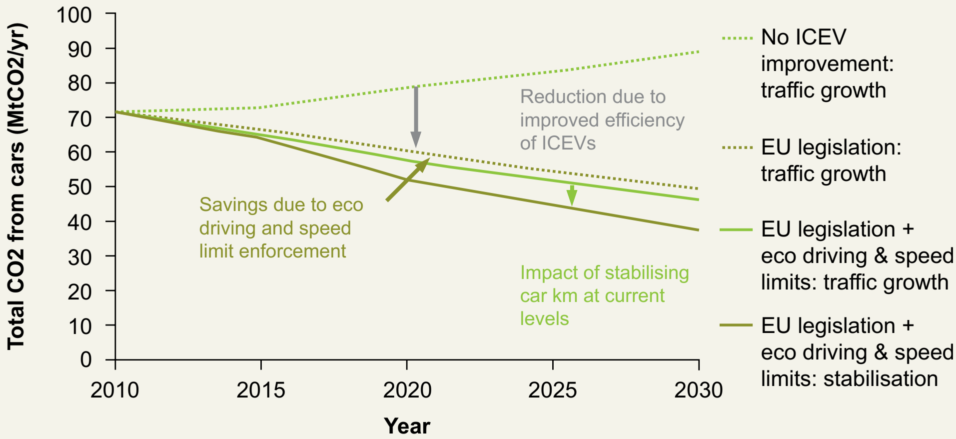
23 For a further description of the methodology used to derive the emissions milestones consistent with a 42% target, please see Section 1.2 in this report and Appendix 8.3.1 in Element Energy's research report.

The importance of other measures to reduce car emissions

A key conclusion of this report is that much can be done to reduce the carbon impact of car travel even without EVs. The importance of each non-EV measure to reduce emissions is shown in Figure 3.

Figure 3: Impact of improvements in ICEVs, non-drivetrain measures[24] and demand management on total emissions from cars, no EVs

Impact of baseline assumptions on emissions trajectory for cars: UK



IMPROVING ICEV EFFICIENCY MUST BE AN EARLY PRIORITY FOR ACTION

These results show the huge importance of EU legislation that's set to reduce average fleet emissions for new cars to 130gCO2/km by 2015, with a future target of 95gCO2/km by 2020. Of course, this EU legislation needs to be fully supported by domestic UK policies on, for example, fuel taxation and VED. Even lower levels of emissions are desirable to improve ICEV efficiency and would drive investment in EVs because they bring down average emissions for new cars across each manufacturer's entire fleet, which is the basis for meeting EU legislation These efficiency improvements can even compensate for rising emissions associated with a moderate increase in car travel[25]. But without these efficiency savings, and if the demand for car travel continues to rise, car emissions will keep on growing.

Clearly, improving ICEV efficiency must be an early priority for action to reduce car emissions, especially before 2020 when there will be relatively few EVs on the road and the grid is not fully decarbonised. But ICEV improvements, as important as they are, will never be enough to wean us off our dependency on oil – or to reduce car emissions to the level needed by 2030 and beyond. They need to go hand in hand with EVs and managing travel demand in order to make the biggest carbon savings

3.2 The importance of managing travel demand

EVs should be used as a lower carbon alternative to conventional cars where driving is necessary. They should not be used to simply replicate or exacerbate existing driving patterns.

24 The system in a motor vehicle that connects the transmission to the drive axles.
25 EU legislation plus traffic growth in Figure 3 assumes an 8% increase in total car kms by 2020 and a 13% increase by 2030.

EVEN IF WE KEEP CAR KILOMETRES PER CAPITA STABLE, POPULATION GROWTH ALONE WILL DRIVE UP TOTAL DEMAND. THEREFORE WE NEED A REDUCTION IN PER CAPITA CAR KILOMETRES TO ACHIEVE STABILISATION.

Managing travel demand is especially important as EVs are cheaper to operate than conventional cars, as they tend to have relatively low operating costs.[26] There is thus a possible 'rebound effect' – that EVs could be driven more than conventional cars. An increase in total car kilometres as a result of EVs would not be either desirable or sustainable. This is because the more that EVs are driven, the more often they need charging, which produces emissions and increases total energy demand. An increase in EV driving could also generate pressure for new road building or discourage people from using public transport, which would add further environmental costs.

Even if we keep car kilometres per capita stable, population growth alone will drive up total demand. The UK population is expected to grow at about 0.7% per annum.[27] Therefore we need a reduction in per capita car kilometres to achieve stabilisation.

Demand reduction will require significant changes in consumer behaviour and a reversal of historical trends to decouple traffic growth from economic growth. But to reduce car kilometres still further will require a sustained effort and a strong set of government policy measures.

The good news is that demand reduction is less difficult to achieve than often assumed[28]:

- Since the mid-1990s, the rate of passenger traffic growth in the UK has halved even though economic growth was (until recently) 50% higher – so there has already been some decoupling.
- Bayliss et al. (2008)[29] identify that actual traffic levels (up to 2006) have been well below the mid-range forecasts provided by both the 1989 and 1997 National Road Traffic Forecasts.
- The average annual traffic growth rate from 2003-08 was only 0.1%.
- Total distance travelled per capita by all modes has levelled off since 1999 and the share of private trips by car is falling.
- Recently, the number of trips by car has started to fall.
- Although car ownership has continued to grow, annual mileage per car fell by 10% during the last decade.

As suggested in *A low carbon transport policy for the UK*[30], such measures could include:

- Additional rail capacity, reopening of closed lines and local line support.
- Increasing VED for less energy efficient cars.
- A moratorium on the construction of major roads.
- Higher parking charges.
- Road and congestion charging.

26 According to the AA, a Ford Focus costs about 14p per mile to operate compared to 0.3p per mile for a Nissan Leaf.
27 Office for National Statistics.
28 Source: Dr Jillian Anable, Centre for Transport Research, University of Aberdeen
29 David Baylis, *Travel demand and its causes*, Royal Automobile Club Foundation, July 2008.
30 Keith Buchan, Metropolitan Transport Research Unit (MTRU), November 2008; www.transportclimate.org. See Table 1, p18 for proposed low carbon transport policies.

- Government backing for smarter travel choices[31], including greater use of public transport, car sharing, cycling and walking.
- Limits on parking in new developments and workplaces.
- Planning of new developments closer to public transport links.

The UK Energy Research Centre (UKERC) stresses the importance of a future 'lifecycle scenario' in reducing emissions from transport[32], where carbon emissions reduction is not delivered merely through public policy, price and technical change, but also through socially led change – i.e. through individuals and communities choosing to live in a way that has lower environmental impact. According to this view of the future, shared car ownership would be encouraged, which is correlated with lower car use. There would also be an increase in active travel, with more walking and cycling, as a consequence of more people working, shopping and relaxing closer to home. Teleworking and videoconferencing would be used more often to replace long distance commuting or business travel.

Reducing travel demand through fewer car kilometres would also mean we don't need as many EVs on the road to achieve the same result in terms of carbon savings. Demand reduction is also cheaper and doesn't require the investment in infrastructure necessary for EVs.

WE FOUND THAT A REDUCTION IN DEMAND AT LOWER LEVELS OF EV UPTAKE MAKES THE GREATEST IMPACT ON REDUCING CAR EMISSION, IN PERCENTAGE TERMS

The impact of reducing car kilometres

To test the difference that reducing travel demand could make to carbon savings, Element Energy ran a sensitivity analysis to see what would happen to car emissions in our three baseline scenarios if:

1) car kilometres were reduced by 16% by 2020 and stayed the same in 2030; or

2) car kilometres were reduced by 23% by 2020 and 37% by 2030, relative to 2010 levels.

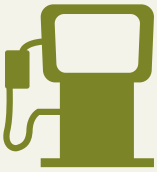
We found that a reduction in demand at lower levels of EV uptake makes the greatest impact on reducing car emission, in percentage terms. For example, in the BAU scenario with low levels of EVs (160,000 by 2020 and 1.7 million by 2030), a moderate level of demand reduction as per 1) reduces car emissions from 16 to 36% by 2020 and from 33 to 55% by 2030. But in the Extended scenario with medium levels of EVs (1.7 million by 2020 and 6.4 million by 2030), a moderate level of demand reduction would reduce car emissions from 29 to 40% by 2020 and from 53 to 61% by 2030.

More ambitious demand reduction in the BAU scenario as per 2) above would reduce car emissions from 16 to 41% by 2020 and from 33 to 66% by 2030. Greater demand reduction in the Extended scenario would reduce car emissions from 29 to 45% by 2020 and from 53 to 71% by 2030. This higher level of demand reduction would allow us to meet the emission milestones consistent with a 42% reduction trajectory without any EVs at all (assuming that ICEV efficiency improvements are realised in line with EU legislation). Only 4% fewer car kilometres are needed from 2010 levels to ensure that 1.7 million EVs by 2020, as per the CCC's recommendation to achieve a 34% reduction in emissions, would also be enough to hit the 42% target.

For further information about this sensitivity analysis, please see Section 8.6.2 in Element Energy's research report.

31 For more information about the DfT's support for Smarter Choices regarding travel, see http://www.dft.gov.uk/pgr/sustainable/smarterchoices/
32 UKERC, *Making the transition to a secure and low-carbon energy system*, Chapter 6.

30%



HIGH NUMBERS OF EVS COULD ALSO PROVIDE 30% OF THE REDUCTION IN FUEL DEMAND FROM CARS BY 2030

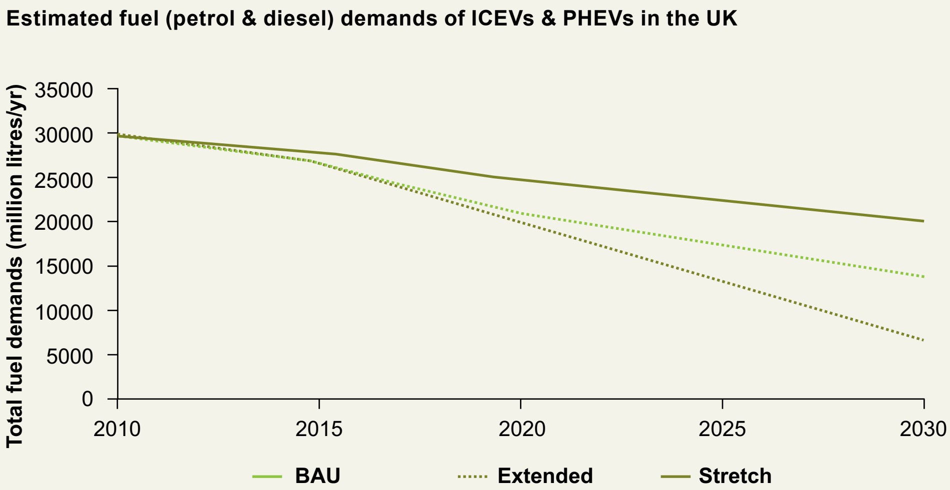
3.3 EVs' impact on fuel demand

Road transport is the largest consumer of petroleum products in the UK[33]. Our cars and other road vehicles currently consume 29,650 million litres a year in petrol and diesel. With oil a declining and increasingly expensive resource, alternative and more sustainable energy supplies are urgently needed for both environmental and energy security reasons. Lower volumes of oil imports will also improve the UK's trade deficit.

EVs can definitely help to reduce the demand for petroleum fuels – especially after 2020 when there are more of them. Before 2020, our priority should be on improving ICEV efficiency and reducing car kilometres to lessen the fuel demand for cars.

Figure 4 shows that EVs, in combination with other measures, have the ability to reduce fuel demand in the car sector significantly.

Figure 4: Projected fossil fuel demands from the passenger car sector in the UK



Supporting figures for this graph are shown in the following table. They indicate that we could reduce the fuel demand from UK cars by more than half in 2030 by achieving the Extended scenario. These figures take into account a reduction in fuel demand due to improved ICEV efficiency and other measures such as eco-driving and speed limits (in all three scenarios), as well as stabilisation in the demand for car travel (in the Extended and Stretch scenarios only). This would make a big difference in reducing our oil dependency. If we were able to achieve the ambitious Stretch scenario, we would be able to reduce fuel demand from cars by nearly 80%. This level of reduction would allow us to reduce our oil dependency to a significant extent.

33 Road transport accounts for 40% of petroleum products according to the Digest of UK energy statistics (DUKES), Chapter 3, p62 (2009). www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Table 4: UK fuel reduction scenarios in 2020 and 2030

Scenario	Fuel (petrol & diesel) reduction from 2010 levels due to EVs and other measures (millions of litres/yr)							
	2020				2030			
	EVs	Other	Total	%	EVs	Other	Total	%
BAU	72	4,741	4,813	16.2%	571	9,124	9,695	32.7%
Extended	704	7,971	8,675	29.3%	1,702	14,076	15,779	53.2%
Stretch	1,933	7,971	9,905	33.4%	8,992	14,076	23,068	77.8%

Even in the BAU scenario with low levels of EV uptake, we could reduce our fuel demand from cars by a third by 2030, by relying primarily on improvements in ICEV efficiencies. However efficiency improvements, although desirable, will still leave the car sector very dependent on petroleum fuels. EVs are needed to maximise the fuel demand savings that are possible.

THE HIGHER THE LEVEL OF UPTAKE, THE GREATER THE DIFFERENCE EVS CAN MAKE TO REDUCING FUEL DEMAND – AND HENCE OUR OIL DEPENDENCY

According to this table, EVs could account for 30% of the reduction in fuel demand by 2030 in the Stretch scenario and 6% of the reduction in fuel demand in the Extended scenario, compared to 2010 levels. Clearly, the higher the level of uptake, the greater the difference EVs can make to reducing fuel demand – and hence our oil dependency.

Because EVs are more energy efficient than ICEVs, they are clearly a much better way to achieve mobility. Even at high levels of EV uptake, where EVs outnumber ICEVs by three to one, as in the Stretch scenario, they would only require around one-third of the total energy demand for cars in 2030.[34]

Reducing the cost of oil imports

The UK's declining oil reserves mean that we're increasingly exposed to a high and volatile global oil price. The current complete dependence of the road transport sector on this single fuel means it is especially vulnerable to the impacts of price spikes and sustained high prices. As well as reducing our energy demand, electric vehicles have an important role to play both in divorcing our transport sector from the projected high costs of oil and limiting our trade deficit by reducing our dependence on imported fuel.

In its 2010 annual energy statement, DECC describes how the "country's energy security is heavily dependent on international developments". It also states that by 2020 our "oil import dependence is likely to be in the region of 45-60%", compared to the 8% it is today. DECC's figures show that if we secure the number of EVs needed to ensure the transport sector plays its full part in achieving a 42% reduction in greenhouse gases by 2020, then even assuming its conservative central price forecast, the UK economy could save over £5 billion in avoided fuel imports per year by 2030 and as much as £8.5 billion under higher price forecasts. EVs make sense not only as the credible transport technology to reduce emissions but also as part of a strategy to reduce our dependence on expensive oil imports over which we have very limited control.

For further information about these calculations, please see Appendix C in this report.

34 See Section 3.3.2, Figure 6, p22 in Element Energy's research report for further information about changes in UK energy demand for cars.

EVs make sense not only as the credible transport technology to reduce emissions but also as part of a strategy to reduce our dependence on expensive oil imports over which we have very limited control.

4. THE IMPACT OF EVS ON THE GRID

EVs can play an important role in helping to balance the grid, which will encourage a greater use of renewables. The impact of EVs on the grid is generally less than feared, but delayed charging will be important to spread peak demand from EVs.

4.1 Charging EVs

The most important locations for charging EVs will be at homes and workplaces since these are where EVs are likely to be parked for the longest periods of time, as indicated by the National Travel Survey (NTS)[35]. Most owners are likely to want to charge their EVs overnight using a charging point at home, perhaps next to their property.

WWF's research has found that, while off-street charge points are likely to be the norm for the next two decades, on-street charge points will increasingly be needed if EVs become the dominant vehicle type in the passenger car market.

Public charge points should be considered a lower priority than home or workplace charging as they are likely to be used less often and cost more to install, especially if they are fast charging. But they do have a value in helping to increase the public profile of EVs, encourage their use, and extend their range. Good locations for public charge points would include special EV parking and charging areas within congestion zones, or EV parking spaces with charge points close to shop entrances.

As cars are also parked for longer at home or at work, this suggests that slow charge points could be sufficient for charging EVs in their primary locations. However, faster charging points are more likely to be needed in public locations so that EV drivers can recharge quickly when they are out and about.

4.2 Grid impacts

Because EVs will be charged from the national grid, their impact on the grid must consider:

- Additional annual electricity demands from EVs.
- The impact of EVs on peak electricity demand.

The impacts that EVs will have on the grid have to be understood at both a national and local level. Simultaneous demands on the grid can add to peak loads, and generation capacity must be planned accordingly. But localised peaks in demand for power also have an impact on local distribution systems and transformers, which are smaller scale and lower specification than national level transmission systems and therefore less able to handle surges in demand.

Any extra demands that EVs place on the grid must also be compatible with greater electrification of other sectors, such as heat pumps for domestic housing and rail electrification – which are also increasingly relying on their energy from a decarbonised electricity grid.

35 According to the NTS, a continuous survey for the DfT, vehicles spend 61% of time parked at home, 35% at work and 4% in other places. For further information, see: www.dft.gov.uk/pgr/statistics/datatablespublications/personal/mtehodlolgoy/ntstechreports/

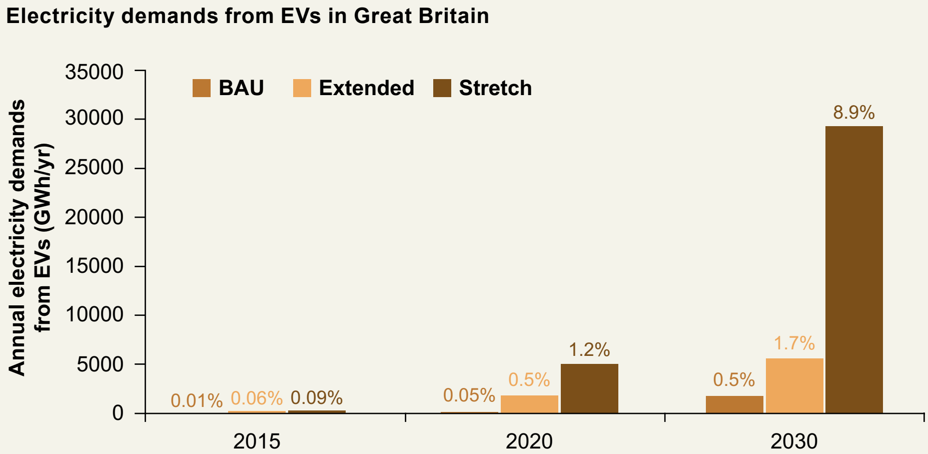
9%

IN THE MOST AMBITIOUS STRETCH SCENARIO WITH VERY HIGH EV UPTAKE, EVS WOULD ONLY ADD A MAXIMUM ADDITIONAL LOAD OF 29,000GWH/YR IN 2030, OR 9% OF TOTAL FORECAST DEMANDS FOR ALL END USES

Additional loads from EVs

In terms of additional annual electricity demand, EVs will not place too much extra demand on the grid in Great Britain, which covers all areas of the UK except Northern Ireland. By 2020, EVs only add an extra 1.5% demand because their uptake is limited. But even in the most ambitious Stretch scenario with very high EV uptake, EVs would only add a maximum additional load of 29,000GWh/yr in 2030, or 9% of total forecast demands for all end uses.

Figure 5: Average annual electricity demands from EVs in Great Britain under each scenario in years of interest



Modelling of the BAU, Extended and Stretch scenarios separately for Northern Ireland and the Republic of Ireland produces a similar picture to that of Great Britain.

Additional average annual electricity demands are expected to be around 1% of total forecast demand by 2020 with medium to high levels of EV uptake. Even in the Stretch scenario with very high levels of EVs, additional demands due to EVs are less than 10% of forecast total electricity demand for Northern Ireland and the Republic of Ireland.

However, it is important to stress that these results relate to aggregate demand over the year. The timing of electricity delivery from the grid to recharge EVs is what is really important to understand the grid's ability to cope with peak demand from EVs. Peak demand from EVs is likely to occur in the evening once drivers return home from work. This is what we have assumed in the following section to estimate the additional peak demand due to EVs.

Peak demand from EVs

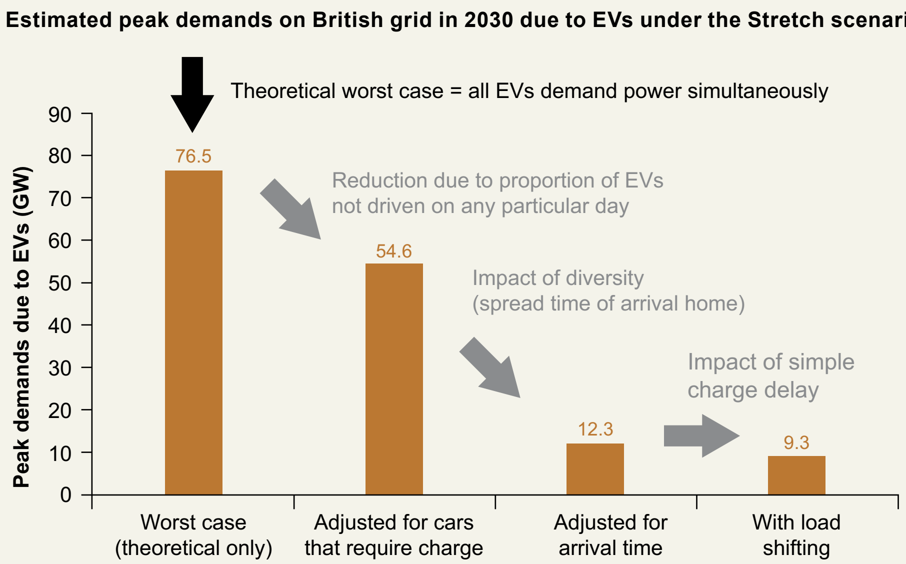
Even if there was uncontrolled charging of EVs, which assumes that most people will want to start charging their EVs once they come home from work, the realistic peak demand on the British grid due to EVs in 2020 would only be around 1.1GW, according to the Extended scenario.

Given that electricity demands on the British grid currently range from around 25-40GW, an extra 1.1GW from EVs doesn't seem too onerous. However, it would clearly be an advantage to defer EV charging until after 8pm or 9pm, once people have cooked their evening meals and when demand starts to decline.

The use of charge delay devices would help to smooth out the spikes of peak demand by pushing back the time when EVs are charged, ideally to late at night when demands on the grid are low. In concept, they are not dissimilar to using storage heaters, as both consume and store cheaper electricity for delayed use.

Even under the Stretch scenario in 2030, where EVs make up 75% of all UK cars, a realistic worst case peak demand due to EVs is still below 10GW, which is within the range of National Grid forecasts of load growth[36]. The worst case scenario represents all EVs demanding power at the same time. But this is never likely to happen as not all EVs are driven each day and there are different arrival times home. Charge delay devices can also help to reduce peak demand due to EVs, as shown in Figure 6[37].

Figure 6: Peak demands on the electricity grid in Great Britain with 25.5 million EVs in stock (Stretch scenario in 2030) based on average charging rate of 3kW per EV

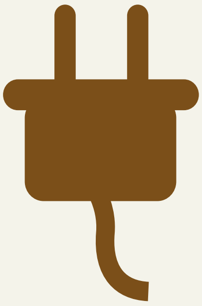


EVS CAN PLAY AN IMPORTANT ROLE IN HELPING TO BALANCE THE GRID, WHICH WILL ENCOURAGE A GREATER USE OF RENEWABLES

Widespread use of charge delay devices would also reduce potential strain on local distribution networks and transformers, which are less able to cope with peaks in demand than the national grid, given their lower voltage and thermal rating.[38]

Smart electricity grids that include intelligent monitoring, control and communications technologies could also help to minimise the impact that EVs have on the grid by helping to determine optimum charging times, at the lowest carbon intensity. The use of smart grids could, for example, shift EV charging to the middle of the night, when the overall demand for energy is lower and therefore renewable energy sources are more likely to provide most of the electricity needed to charge EVs, at a lower grid CO_2 intensity. By contrast, charging EVs at times of peak demand is more likely to involve high carbon 'peaking plant' (generators that come on line for short periods to meet surges in electricity demand, which are usually powered by coal or gas). This would reduce the potential CO_2 savings of EVs.

36 Based on forward extrapolation of medium term projections from the National Grid. See Section 5.3.4 in Element Energy's research report for further information.
37 For further information about how the realistic worst case peak demand due to EVs was derived, see Section 5.3.4 in Element Energy's research report.
38 In *Strategies for the uptake of electric vehicles and associated infrastructure implications*, prepared by Element Energy for the CCC (2009), it was estimated that local distribution networks could accommodate reasonable levels of EV uptake (up to a third of households owning EVs). Upgrading the local distribution systems at the same time as the national grid to maximise synergies would also help to reduce local impacts.



Although smart grids are not likely to be widespread in the short term, neither are EVs. This gives time for further investment and research, which needs to happen now if smart grids are to be in use by the time there are millions of EVs.

Flexible charging of EVs using charge delay devices and smart grids will clearly become more important as other sectors also electrify and place greater demands on the national grid and local distribution systems. The cumulative impacts of all these additional demands must be borne in mind in planning and upgrading future infrastructure.

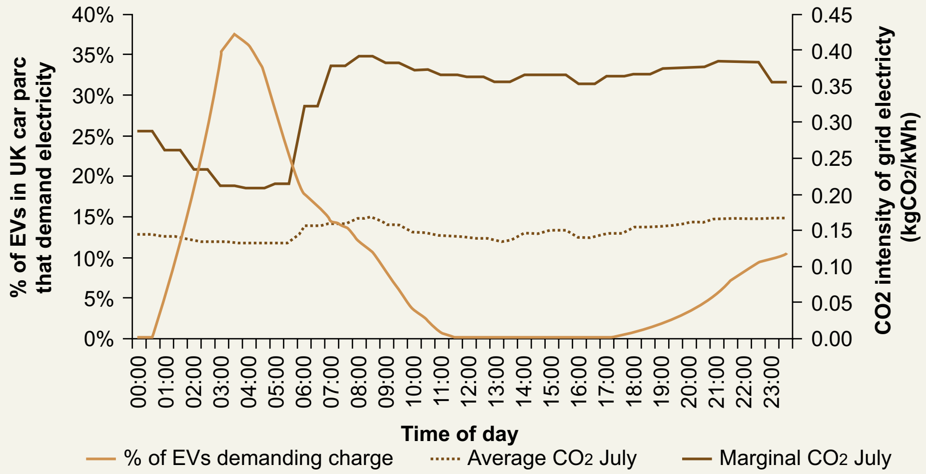
The best time for EVs to be recharging would be around 4am when the CO2 intensity of the grid is at its lowest

Optimum timing of EV charging

The best time for EVs to be recharging would be around 4am when the CO_2 intensity of the grid is at its lowest, as illustrated below. Early evening would be the worst time for recharging EVs because of peak demand for electricity and high CO_2 intensity of the grid. As renewables are likely to be supplying a higher proportion of the 'generation mix' when electricity demand is low, shifting EV recharging to the middle of the night would help to minimise their carbon impact.

Figure 7: Grid CO_2 intensity profile against proportion of EVs that demand charge for a typical weekday in summer, with charge delay

Charge demand and grid CO_2 intensity profiles for a typical weekday in 2030: nine hour charge delay



+23 TO 41%

THESE FIGURES SUGGEST THAT MANAGING THE TIMING OF EV CHARGING, TO UTILISE LOWEST GRID CO2 INTENSITY, WOULD INCREASE THE CARBON SAVINGS OF EVS FROM 23% TO 41% IN COMPARISON TO ICEVS BY 2030.

These figures suggest that managing the timing of EV charging, to utilise lowest grid CO_2 intensity, would increase the carbon savings of EVs from 23% to 41% in comparison to ICEVs by 2030.[39]

If grid impacts from EVs are incorporated into future capacity planning, there's a greater likelihood that EVs can be charged at average grid CO_2 intensity instead of the higher marginal CO_2 intensity when peaking plant is in use.

39 This figure quantifies the carbon impact of EV travel relative to anticipated average ICEV performance in 2030 for a sample of 1,000 ICEVs travelling an average of 37km daily, based on marginal grid CO_2 intensity. See Section 8.6.3 in the appendix to the Element Energy research report for further information.

IN FUTURE, HIGH LEVELS OF EVS COULD POTENTIALLY STORE ELECTRICITY WHEN DEMAND IS LOW AND THEN FEED IT BACK TO THE GRID WHEN DEMAND IS HIGH

Storage potential of EVs

In future, high levels of EVs could potentially store electricity when demand is low and then feed it back to the grid when demand is high. However, further research is needed to improve both battery and smart grid technologies. Significant investment will therefore be required if this potential is to be realised.

Driver acceptability is also an issue, as some individuals will want to have access to their EVs at all times. Smart charging tariffs that reward drivers who are prepared to surrender some of their battery capacity would help to encourage the storage potential of EVs.

The total storage capacity of EVs, according to the Extended scenario, is equivalent to around 30 minutes of the average national electricity demand by 2020. In Great Britain, the maximum storage capacity of EVs in the 2030 Stretch scenario would be 417GWh, based on 90% of EVs being parked and plugged into the grid at any one time[40]. This is equivalent to 46 times the UK's largest pumped hydro storage facility.

In Northern Ireland and the Republic of Ireland, the maximum storage capacity of EVs in the Stretch scenario would be 41GWh, based on 90% of EVs being parked and plugged into the grid at any one time. This is equivalent to 26 times the energy available from the Republic of Ireland's only pumped hydro storage facility at Turlough Hill.

Grid balancing and vehicle to grid (V2G) applications

Grid balancing refers to matching the amount of electricity that's generated at any point in time with the simultaneous demand for power from the grid. Vehicle to grid (or V2G) is a concept that's still in its infancy. It involves providing power to the grid from the batteries of grid-connected EVs at times of high overall electricity demand, when the price of electricity is also high. The batteries can then be charged during periods of lower demand, such as late at night when electricity should be cheaper.

Using V2G could potentially reduce the need for high carbon peaking plant by feeding back power to the grid at times of peak demand. But faster battery charging will be needed, as well as smart grids to help shift demand when EVs are better able to help balance the grid. These technologies are not likely to be available for some time.

Another significant barrier to V2G is the cost of EV batteries. This will determine the point at which it makes economic sense to provide electricity back to the grid from EVs, especially as feeding power back to the grid reduces battery life. Our research suggests that, at current battery costs, V2G becomes viable at around £500/MWh. If EV battery costs come down, V2G would become viable at £320/MWh. But comparisons with published forecast price duration curves for 2020 suggest that the electricity price may only exceed this level for less than 1% of the time. Clearly, EV battery costs will have to fall lower still for V2G to have significant potential.[41] Consideration will also need to be given as to how best to structure consumers' electricity billing arrangements if their EVs are able to feed electricity back to the grid.

40 National Travel Survey figures suggest that at any particular time during the day or night there's a high chance that at least 90% of cars are parked.

41 If EV battery costs get lower still, as is the target of the US Advanced Battery Consortium, V2G would be viable at an electricity price of £170/MWh.

EVs and renewables

Decarbonisation of the grid is a prerequisite if EVs are to achieve their maximum carbon savings potential. At high levels of EV uptake, decarbonisation of the grid reduces car emissions by approximately 70% more than if the grid is powered by fossil fuels as it is currently.[42]

DECARBONISATION OF THE GRID IS A PREREQUISITE IF EVS ARE TO ACHIEVE THEIR MAXIMUM CARBON SAVINGS POTENTIAL.

EVs are therefore highly compatible with greater use of renewables. EVs can help to 'fill in the troughs' of electricity demand, by using renewable power when it might otherwise not be used, They can also 'shave off peaks' by storing excess generation capacity of renewables. In future, EVs may be able to supply power back to the grid through V2G at peak times of demand.

A significant increase in electricity from renewables is required if the UK is to meet the government's 15% renewable energy target by 2020. This will include a large increase in wind capacity on the grid. There's a need for much greater investment in wind and other types of renewable energy, in the UK and the rest of Europe, if we are to achieve a 100% renewables future by 2050. This point was further supported in a recent report from the European Climate Foundation (ECF)[43].

The variability of wind power is often cited as a criticism. But according to the ECF report, which shows that a future European energy system based on 100% renewable energy is technically feasible and at costs that are not substantially higher than other ways of decarbonising the power sector[44], the best way to manage the variability of some forms of renewable energy power is by investing in new interconnection infrastructure and management systems between the different European grids.

42 See Appendix B to this report for a sensitivity analysis of car CO_2 emissions by level of carbon intensity of the grid.
43 ECF, *Roadmap 2050: a practical guide to a prosperous, low-carbon Europe*, 2010.
44 The same report found that nuclear energy and fossil fuel power stations with carbon capture and storage technology were not essential to decarbonise the power sector while protecting system reliability.

EVs are highly compatible with greater use of renewables. EVs can help to ‘fill in the troughs’ of electricity demand, by using using renewable energy when it might not otherwise be used. They can also ‘shave off the peaks’ by storing excess generation capacity. In future, EVs may be able to supply power back to the grid through vehicle to grid (V2G) applications at peak times of demand.

5. CHALLENGES AND OPPORTUNITIES

Price, range and infrastructure are the biggest barriers to EVs being accepted by consumers. Changes to driver attitudes will also be required for EVs to gain acceptance and to encourage less driving. Government policy intervention will be needed to overcome these issues and help UK companies make the most of EV market opportunities.

5.1 Challenges

The introduction of EVs, at the rate required by the targets under the Climate Change Act, will be a significant challenge in itself, given the very low levels of EVs that exist at present, as discussed in Section 1.4. To move from thousands to millions of EVs in future will clearly be an enormous task, requiring substantial investment and government support.

The main barriers to the effective roll-out of EVs are discussed below.

£

THE MOST OBVIOUS AND IMMEDIATE BARRIER TO THE RAPID TAKE-UP OF EVS IS THEIR SIGNIFICANT PRICE PREMIUM COMPARED TO CONVENTIONAL VEHICLES

Price

The most obvious and immediate barrier to the rapid take-up of EVs is their significant price premium compared to conventional vehicles.[45] According to Financial Times research, 76% of UK consumers say that they would not pay more for an EV.[46]

Much of this price difference is associated with the high cost of lithium batteries. As demand increases and battery technology improves, EV prices will decline. But in order to kick-start the market, a significant level of subsidy will be required. The CCC has indicated that this could be in the region of £10,000 per vehicle and may need to be as high as £20,000.[47]

Although capital grants of up to £5,000 per vehicle are being offered by the government from 2011 to 2012, worth up to £43 million, this falls well short of the £230 million promised by the previous government. We believe that additional funding will be needed, well beyond 2012, if EVs are to gain market share. As most consumers are unlikely to purchase EVs until the charging infrastructure is well established and the economy improves, it's very important that these subsidies continue for some time.

It's worth noting here than in its recent report on the UK's innovation challenge[48], the CCC stated that based on its assessment of portfolios required to develop climate objectives, current stages of technology development and the UK's research and industrial capabilities, EV technology was one of the key technologies that the UK should seek to develop and deploy. The CCC highlighted in the same report, confirmed in its Fourth Carbon Budget, that given the key role that a widespread roll-out of EVs could have in the 2020s to support the cutting of transport

45 EVs are initially expected to cost over £20,000. For example, a Nissan Leaf will cost £23,990 when it goes on sale early in 2011, even after the £5,000 government subsidy has been included.
46 www.ft.com/cms/s/0/acc0a646-c405-11df-b827-00144feab49a.html#axzz16lbhFfe2
47 Committee on Climate Change, *Meeting Carbon Budgets – the need for a step change* (2009), p207 www.theccc.org.uk/reports/progress-reports
48 Committee on Climate Change, *Building a low-carbon economy – the UK's innovation challenge* (July 2010).

emissions and power sector decarbonisation, funding up to £800 million should be seriously considered to support the purchase of EVs before the technology becomes competitive with conventional alternatives around 2020[49].

Range

Although the current range of EVs is around 100 miles before the battery needs charging, which is sufficient to capture the vast majority of car journeys, customers would prefer EVs to have sufficient range for longer journeys. For instance, a recent survey by Deloitte Consulting found that 70% of potential US buyers would require a minimum range of 300 miles before buying an EV.[50] Drivers are also concerned about the length of time that it takes to completely recharge an EV – currently around six to eight hours – and having to do this while travelling. Extended EV range and faster battery charging are therefore preconditions for rapid EV uptake.

The fear of being stranded because of insufficient EV battery power, or 'range anxiety', is not an issue for PHEVs which, unlike BEVs, are not limited by the energy storage capacity of the batteries. In use, PHEVs have a similar range to conventional cars with the internal combustion engine available to power the car once the full range of the batteries has been used. PHEV drivers do not therefore need to recharge or swap batteries during a long journey.

Resolving this issue will require improvements in battery technology to provide a higher energy density to increase EV range, and more power density which will enable faster battery charging and discharging. A widespread network of fast charging points and/or battery swap stations will also help to reassure drivers about EV range.

Infrastructure

THE LACK OF CHARGING POINTS AND A STRATEGIC INFRASTRUCTURE PLAN TO SUPPORT EVS ARE MAJOR BARRIERS TO THEIR ACCEPTANCE, ALTHOUGH IMPROVEMENTS TO THIS PROCESS HAVE RECENTLY BEEN ANNOUNCED BY GOVERNMENT

The lack of charging points and a strategic infrastructure plan to support EVs are major barriers to their acceptance. Current EV deployment in the UK is very region specific and there are no planning structures associated with EV charging. Previously, this has made planning applications for EV charging points difficult for the developer, although improvements to this process have recently been announced by government. It can also be confusing for the consumer, who currently has little idea of where to find EV charging points. A clear planning policy for EV charging infrastructure, to increase the number of charging points in the UK, needs to acknowledge that the greatest number of these will need to be at home or in the workplace.

Charging policy needs to be informed by a strategic infrastructure plan to deliver maximum utility from this investment. The use of fast-track planning applications for new EV infrastructure could remove red tape and increase the speed at which it could be built. The mandatory installation of EV charging points for new workplace developments could also be used to send clear signals to the market. The roll-out of these new charging points has to be accommodated by the local grid. In some cases this may require upgrades to the local network.

Until the UK develops a strategic infrastructure plan to support EVs, there's a risk that it will not be ready for the additional load or peak demand placed on the grid by EVs – or be able to best harness their potential for grid balancing and, potentially, storing and providing power back to the grid at times of peak demand. This will

49 Committee on Climate Change, *Building a low-carbon economy – the UK's innovation challenge* (July 2010), p22.
50 Deloitte Consulting, *Gaining Traction: a customer view of electric vehicle mass adoption in the US automotive market*, 2010.

THE PROMOTION OF EVS WITHOUT IMPLEMENTING POLICIES TO REDUCE CAR KILOMETRES AND CAR OWNERSHIP RISKS INCREASING CONGESTION AND REINFORCING THE ESTABLISHED RELIANCE ON PRIVATE TRANSPORT

require government intervention to ensure that infrastructure planning for EVs is coherent and consistent in its approach.

A Europe-wide approach to grid infrastructure will also be needed if EVs are to be powered by a decarbonised European grid in order to deliver maximum carbon savings both in the UK and on the continent. An integrated European grid is also needed to ensure the rapid deployment of renewables and smart grids. European strategic planning of infrastructure would avoid costly, localised solutions which could be environmentally damaging and inefficient and incompatible with an integrated European grid.

Driver attitudes

A significant shift in public behaviour will be called for if drivers are to embrace a new and novel technology that has had a bumpy history. They may need to adapt their driving practices and even relinquish their relationship to the private car.

The EV must be presented as the replacement for necessary car travel rather than a hi-tech alternative to public transport or walking and cycling

The promotion of EVs without implementing policies to reduce car kilometres and car ownership risks increasing congestion and reinforcing the established reliance on private transport. The ultimate aim for EV uptake is therefore car sharing rather than ownership.

Tax incentives to encourage EV uptake, such as exemption from road tax, free parking, free charging and an exemption from congestion charges and VED, will also be important. However, such incentives should not encourage excessive EV driving. The EV must therefore be presented as the replacement for necessary car travel rather than a hi-tech alternative to public transport or walking and cycling.

For consumers to accept EVs and for them to become widespread in use, they first need to be 'normalised'. More could be done to expand the market through early public sector procurement of EVs. Consumers could get greater exposure to EVs through private sector car fleets, as well as car sharing clubs. To get over possible 'techno fear' of charging EVs, consumers may need government and industry support as well as financial incentives, such as lower electricity tariffs to charge their EVs at optimum times.

5.2 Opportunities

FOR CONSUMERS TO ACCEPT EVS AND FOR THEM TO BECOME WIDESPREAD IN USE, THEY FIRST NEED TO BE 'NORMALISED'

Many of the challenges outlined above could be turned into market opportunities for UK manufacturers and businesses. Key opportunities are in the areas of EV manufacture, battery technology and new business models.

UK EV industry

The UK already has a head start in EV manufacturing – with Modec, Smith Electric Vehicles and Allied Vehicles having a well-established presence in the commercial vehicle market.

Renault-Nissan's decision to produce the Leaf EV and build a new battery plant in Sunderland, and Toyota's production of the Auris hybrid at Burnaston, Derbyshire, have helped to establish the UK as an important centre for EV manufacture and innovation. Vauxhall is also considering manufacture of its Ampera in the UK.

Support for UK EV manufacturers is therefore important to help establish the industry at home and abroad. Additional capital grant funding to encourage people to buy EVs would provide the best market stimulus to benefit UK manufacturers.

Government and private sector funding for EV R&D, for example through the European Investment Bank, would also help to establish the UK as a leader in EV technology.

There are also considerable opportunities for new supply chain or supporting industries, such as servicing companies – not only for EVs but for charging points. These companies must be created as the EV industry develops in the UK.

Battery technology

The UK has the potential to be a world leader in new battery technology. With a strong research background in solid state and ionic chemistry, the UK is ideally placed to develop domestic manufacturing plants (such as the Renault-Nissan plant scheduled for 2013 in Sunderland) and research centres that specialise in EV battery technologies.

Developing batteries suitable for light goods vehicles (LGVs) would extend UK manufacturing potential beyond EVs for the passenger car market. Further trials are needed in the LGV sector but this could represent an early opportunity for electrification of road transport.

There are also sustainability and environmental issues associated with lithium-ion batteries which need to be addressed

Significant improvements to battery technology are needed to improve range, reduce charging times and cut costs, making EVs more attractive to the consumer. There are also sustainability and environmental issues associated with lithium-ion batteries which need to be addressed. New types of battery charging such as pad transmitters, wireless and road charging technologies also represent potential market opportunities for UK companies.

Alternative business models

According to Frost and Sullivan, three out of four EVs sold in 2015 will be through new business models.[51] These new approaches, which would help to reduce the cost of EVs to consumers as well as range anxiety, include vehicle and battery leasing as well as battery swap business models. They are likely to be similar to those of a mobile phone contract where the high upfront capital cost is only partially paid for by the consumer, with the remaining cost being paid by a monthly charge. Utility companies may play a large role in this type of business model but it will also present an opportunity for new service businesses.

An example of a new business model for EVs is the US company Better Place, which is developing a subscription service that provides customers with access to a network of charging points and gives them the ability to exchange their flat battery at a network of special service stations.

The creation of battery swap stations requires significant capital investment, which could only be recouped by high levels of use. The battery swap model may also require some sort of battery leasing scheme, so that the consumer and vehicle manufacturers would not lose value or warranty by swapping batteries. Greater standardisation of batteries would enable swap stations to cater for more types of EVs.

EV car sharing is another alternative business model. Through car sharing clubs or public use rental facilities similar to those for bicycles[52], people would be able to use EVs within cities without the need to buy them.

51 www.frost.com/prod/servlet/market-insight-top.pag?Src=RSS&docid=165187779
52 An EV rental scheme, similar to that for bicycles, is being introduced in Paris, France, with 3,000 EVs available for hire on a subscription basis, as from autumn 2011.

6. POLICY RECOMMENDATIONS

Early action by the government will be necessary if numbers of EVs are to rise to the levels necessary, and with the right conditions and infrastructure to deliver significant carbon savings and reduce our oil dependency.

6.1 Reducing car emissions and supporting EV growth

WE BELIEVE IT'S ESSENTIAL THAT THE UK GOVERNMENT PROVIDES GREATER SUPPORT FOR EVS AT THE SAME TIME AS IMPLEMENTING OTHER ESSENTIAL MEASURES TO REDUCE CAR EMISSIONS, SUCH AS ICEV EFFICIENCY IMPROVEMENTS AND REDUCED CAR KILOMETRES

Currently, the UK is not doing as much as many other countries to plan for the roll-out of EVs or to stimulate the market[53]. International examples show that there are various approaches to supporting EVs, although reducing the cost of EVs through subsidies or tax incentives are most common. Countries that are most serious about EVs are also investing heavily in infrastructure, R&D, and manufacturing facilities.

We believe it's essential that the UK government provides greater support for EVs at the same time as implementing other essential measures to reduce car emissions, such as ICEV efficiency improvements and reduced car kilometres.

According to our analysis, at least 1.7 million EVs will be needed by 2020 and 6.4 million by 2030 if they're to achieve significant carbon savings and reduce fuel demand. This level of EV uptake will require serious levels of government policy intervention so that the UK is fully ready for EVs within the coming decade.

We're calling on the UK government to take the following early actions so EVs can realise their full carbon savings potential:

Support ambitious EU and domestic climate change targets

We welcome the government's calls for increasing the EU level of ambition to a 30% reduction in emissions by 2020 from 1990 levels. The current EU target of a 20% cut now looks to be little more than business as usual. In line with this move, the government should also swiftly adopt the CCC's 'intended' target to cut UK emissions by 42% target by 2020. Both the UK and the EU targets should be met through domestic action rather than offsetting.

Early government action to encourage the growth of EVs will help the UK to achieve both EU and UK climate change targets. It will also prove critical in reducing our dependency on increasingly risky and unconventional sources of oil.

53 For more information on how the UK compares to other countries on policies to support EVs, see Element Energy's research report, Section 6.1.

-42%

THE GOVERNMENT SHOULD SWIFTLY ADOPT THE CCC'S 'INTENDED' TARGET TO CUT UK EMISSIONS BY 42% BY 2020

Decarbonise the power sector

We advocate the decarbonisation of the power sector by 2030, as recommended by the CCC, if the UK is to achieve its climate change targets. Rapid growth in renewables is essential to achieving this goal and should be a priority for receiving government support and investment. A high renewables future is also compatible with the growth of EVs. It ensures both the utility of renewables and the carbon savings potential of EVs by reducing the CO_2 intensity of the grid when charging EVs.

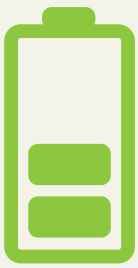
Support tougher EU legislation for ICEV emissions, higher VED and other charges for the most polluting cars

We're calling on the UK government to support the implementation of EU emissions legislation for 2015, which requires average emissions for new cars to be 130gCO_2/km. Given the early achievement of this requirement by the automotive industry, we believe that the EU 2020 target should be even more ambitious than the 95gCO_2/km target currently being proposed. We support a further tightening of this target. Longer term, we support the CCC's 4th carbon budget recommendation for an 80gCO_2/km emissions target for conventional cars in 2030.

It's not a given that these standards will be achieved at EU level or in the UK. Specific policies, such as higher rates of VED for the most polluting cars and increases in fuel duty will be needed to ensure that the UK's ICEV efficiency improvements are at least in line with the EU average.

The government also needs to support the implementation of the recently agreed EU emissions legislation for van and light commercial vehicles of 147gCO_2/km by 2020. The CCC's recommended target for conventional vans of 120gCO_2/km by 2030 should also be pursued.

The 'polluter pays' principle, at the point of purchase, the fuel pump and on the roads, should increasingly be used to encourage a switch away from conventional cars. This will help to make up for the gradual decline in tax revenue due to EVs.



If EVs are to be successful and environmentally beneficial, far greater government and business investment in battery charging infrastructure, particularly at home and in the workplace, will be required

Invest in charging infrastructure

The UK currently lacks a comprehensive national framework for EVs. If EVs are to be successful and environmentally beneficial, far greater government and business investment in battery charging infrastructure, particularly at home and in the workplace, will be required.

A strategic, national-level infrastructure plan to support the roll-out of EVs is urgently needed. Initiatives to date tend to be at the regional and local level, such as 'Plugged-in Places' and 'Source London'. These should continue to be expanded and supported, but as part of a comprehensive national framework for EVs. Introducing a clear planning policy for EV charging and fast-tracking applications for new charging infrastructure will also help to increase the number of charging points available. We welcome the government's intention to allow charging points to be built on streets and in outdoor car parks without the need for planning permission. We'd also like to see subsidies for business and homeowners to install off-street charging points.

Lower off-peak charging tariffs for EVs should also be introduced to encourage EV charging at times of low electricity demand and low carbon intensity of the grid

The use of charge delay devices should be encouraged so that drivers don't charge their EVs at times of peak demand. Lower off-peak charging tariffs for EVs should also be introduced to encourage EV charging at times of low electricity demand and low carbon intensity of the grid.

Provide stimulus measures for rapid EV uptake

We recognise the fiscal constraints that the government currently faces. But a key priority needs to be the continuation of the £5,000 capital grant beyond the end of this Parliament – and therefore an increase in the £43 million funding set aside for this purpose.

The £400 million announced in the Comprehensive Spending Review for funding low-carbon vehicles may also need to be substantially increased. We support the CCC's suggestion, in its recent report on the UK's innovation challenge, that funding of up to £800 million for low-carbon vehicles should be seriously considered, including a possible increase in the capital grant per vehicle, given the need for a rapid and widespread roll-out of EVs to reduce transport emissions. These costs should be viewed against the greater benefits of less oil dependency and a smaller trade deficit, with EVs able to reduce the bill for oil imports by over £5 billion by 2030.

Incentives to drive down the price of EVs and encourage broad public support and market commercialisation should be complemented by a targeted approach to ensure their comprehensive uptake in those sectors where they offer the greatest immediate return – for example, LGV fleets, public sector fleets and car sharing clubs. This will help to 'normalise' the EV and create economies of scale and market learning that will help to drive the broader market.

We'd also like to see the widespread installation of charging infrastructure on the government estate and a government fleet of EVs to demonstrate commitment to carbon reduction from cars and support for UK EV manufacturers.

Support demand management measures to reduce car kilometres

Support for EVs should not reduce the government's commitment to its 'smarter choices' agenda to encourage walking and cycling, or the improvement of public transport to reduce the need for car travel. Other demand management measures such as an increase in fuel duty, more toll roads and congestion charging, should be considered to reduce car kilometres and reduce emissions from both ICEVs and EVs. A focus on road maintenance rather than major road building is also needed to discourage traffic growth.

Encourage UK EV industry competitiveness

Government support for UK manufacturers and investment in EV technology R&D should be early priorities to ensure the future competitiveness of the UK EV industry. Bank loans for low-carbon vehicle projects from sources such as the European Investment Bank should continue to be supported. Once the Green Investment Bank is well established, and is funding priority projects such as the Green Deal and renewables, EVs should be considered as another priority for investment. This will help to increase EV performance, reduce costs and risks, and build market share.

6.2 Planning for grid impacts

To better coordinate the electrification of heating and transport, to achieve the optimal use of the grid and to minimise the need for new power supply, we believe that capacity planning is needed now at both the national and local levels. This will require the following actions:

Commit to an integrated European grid

We'd like to see greater UK commitment to an integrated European grid and support for a standardised charging infrastructure, using compatible charging technology for EVs across Europe. As the recent report from the ECF[54] made clear, cooperation at the European level is key in order to achieve the decarbonisation of the power sector, as well as that of other sectors – in particular transport and heat. The report also showed that enhanced interconnection between the different European grids would make it technically feasible to develop a future European electricity system based on 100% renewable energy sources at a cost that was not substantially higher than other options available to decarbonise the power sector

Support the development of smart grids

Greater government support of smart grids needs to start now so that they are ready once EVs are more widespread. Smart grids that include intelligent monitoring, control and communications technologies will help to manage the impact of EVs on the grid and help to ensure charging happens at times when the carbon intensity of the grid is low. They will also help to unlock the potential of EVs to deliver power back to the grid at times of high demand – although development of supporting technologies, such as grid-tie inverters[55], will also be needed. Once again, an integrated European approach is called for, as this would increase their overall utility and benefits.

6.3 Business recommendations

Reduce ICEV emissions beyond EU legislation targets

AS EV BATTERIES ARE BY FAR THE LARGEST COST ELEMENT, PROVIDING BATTERIES THROUGH LEASING OR OTHER SCHEMES TO SPREAD THE COST WILL HELP TO REDUCE THE PRICE OF EVS

WWF challenges UK vehicle manufacturers to achieve emissions standards for ICEVs that are tougher than those currently agreed or under discussion, for passenger cars and vans. Vehicle manufacturers should work together with government to support tougher targets at EU level.

Focus on reducing EV price, improving battery technology, and delivering a national network of standardised charging points

As these are the biggest issues that could potentially limit the uptake of EVs, they are the areas where EV and battery manufacturers, as well as infrastructure providers, need to focus their efforts.

As EV batteries are by far the largest cost element, reducing the cost of lithium batteries or developing a suitable, low-cost alternative – or providing batteries through leasing or other schemes to spread the cost – will help to reduce the price of EVs.

54 European Climate Foundation, *Roadmap 2050: A practical guide to a prosperous, low-carbon Europe* (2010), see in particular pages 19 to 21.

55 Grid-tie inverters convert the direct current produced by EVs into the alternating current supplied by the grid for homes and businesses.

Extending EV range to well beyond 100 miles will help to reduce range anxiety. This will require improvements to battery energy density. In addition, greater power density of batteries to facilitate faster charging will increase public willingness to drive EVs.

Power companies need to work together with central and local governments to ensure that charging points are rolled out in a planned and strategic way, mindful of the need for standardised EV charging technology across both the UK and EU.

Have a clear plan for recycling batteries

EV and battery manufacturers need to have a clear plan for how they intend to recycle and ultimately dispose of EV batteries to limit their environmental impact. Non-car uses for battery materials should also be considered as part of this full lifecycle planning.

Work together with large fleet owners to encourage widespread, early uptake of EVs

EV MANUFACTURERS SHOULD BE WORKING WITH LARGE PUBLIC AND PRIVATE FLEET OWNERS TO DELIVER AN ATTRACTIVE PACKAGE TO REDUCE UPFRONT EV COSTS

EV manufacturers should be working with large public and private fleet owners to deliver an attractive package to reduce upfront EV costs. These could include leasing or subscription schemes with providers of battery swapping stations. Such ventures would not only help to increase the number of EVs on the road and improve economies of scale for manufacturers, they would also be very useful in developing new, lower cost business models for EV roll-out.

Work collaboratively to encourage uptake, avoiding proprietary solutions

Proprietary solutions should not be a barrier to EV uptake. The EV industry needs to work together with the power sector to ensure that there is a common charging technology, to support a national charging infrastructure for EVs. Interoperability of batteries is also desirable as it would enable battery swap stations to cater for more types of EVs.

Provide incentives for delayed charging

Power companies will need to give consumers strong incentives to recharge their EVs at times of low electricity demand and when the grid's carbon intensity is low. A tiered pricing structure is needed to shift battery charging away from times of peak demand. This should be incorporated into billing systems.

Climate change is one of the greatest threats to the natural world and the people that depend on it. As the primary cause of climate change is the burning of fossil fuels (coal, oil and gas), reducing humanity's carbon footprint must be a priority.

7. APPENDICES
APPENDIX A

Detailed scenario assumptions and parameters

BAU scenario

Key assumptions and parameters for the BAU scenario are as follows:

Assumption	Vehicle type	2020	2030
Number of cars by type in car park	EVs ICEVs	160,100 31,865,200	1,768,800 33,607,100
Percentage of car stock	EVs ICEVs	0.5% 99.5%	5% 95%
EVs as percentage of new car sales	EVs	1%	8%
Useful electric range[56] (km)	BEVs PHEVs	90 60	112.5 60
Demand for car travel (bn car km/yr)	All cars	461.4	520.3
Percentage increase in car travel	All cars	8%	13%
Carbon intensity of grid (gCO2/kWh)	NA	313	80
Average fleet emissions in electric mode (gCO2/km)	BEVs and PHEVs	45.2	9.8

WWF's BAU scenario is not at all ambitious compared to other commentators. EV numbers for 2020 and 2030 are lower than those in an Arup/Cenex study commissioned by BERR (now known as BIS) and the DfT.[57]

56 As calculated from technical range and utilisation factor; see Element Energy research report p83.
57 *Investigation into the scope for the transport sector to switch to EV and PHEVs research*, Arup/Cenex for DfT and BERR, October 2008. The BAU scenario contained in the Arup/Cenex report shows a somewhat higher figure for 2020 (270,000 EVs) but a significantly higher figure for 2030 (3,000,000 EVs).

Extended scenario

Key assumptions and parameters for the Extended scenario are as follows:

Assumption	Vehicle type	2020	2030
Number of cars by type in car park	EVs ICEVs	1,750,800 30,274,500	6,367,700 29,008,200
Percentage of car stock	EVs ICEVs	5.5% 94.5%	18% 82%
EVs as percentage of new car sales	EVs	15%	20%
Useful electric range (km)	BEVs PHEVs	90 60	112.5 60
Demand for car travel (bn car km/yr)	All cars	420	420
Percentage increase in car travel	All cars	0%	0%
Carbon intensity of grid (gCO2/kWh)	NA	313	80
Average fleet emissions in electric mode (gCO2/km)	BEVs and PHEVs	45.2	9.8

Overall, WWF's Extended scenario is in line with other commentators who have provided optimistic estimates for the future number of EVs. WWF's number of EVs in the UK car park for 2020 is roughly comparable to the Arup/Cenex study (high scenario), but is more cautious for 2030.[58]

As mentioned previously, our EV figure for 2020 is based on the CCC's indicative figures for EVs, in line with the UK achieving a 34% emissions reduction target. Our 2030 figure is also based on the CCC indicative figures, using linear extrapolation beyond 2020. Our figures also assume a UK emissions reduction target of 80% by 2050 and that emissions savings from cars needs to be 90% in order to meet this target.

58 The Arup/Cenex high scenario estimates that 11,200,000 EVs will be in the UK car park by 2030.

Stretch scenario

Key assumptions and parameters for the Stretch scenario are as follows:

Assumption	Vehicle type	2020	2030
Number of cars by type in car park	EVs ICEVs	4,227,300 27,798,000	26,261,200 9,114,700
Percentage of car stock	EVs ICEVs	13.2% 86.8%	74.2% 25.8%
EVs as percentage of new car sales	EVs	44%	80%
Useful electric range (km)	BEVs PHEVs	140 75	212.5 80
Demand for car travel (bn car km/yr)	All cars	420	420
Percentage increase in car travel	All cars	0%	0%
Carbon intensity of grid (gCO2/kWh)	NA	258	66[59]
Average fleet emissions in electric mode (gCO2/km)	BEVs and PHEVs	37.3	8.1

WWF's Stretch scenario is, admittedly, a highly ambitious scenario which is well above that of other commentators[60] and may not be possible to achieve. However, for illustrative purposes it is useful as it shows what is possible in terms of EVs' maximum potential to reduce UK oil imports and car emissions. It also usefully tests the upper limit of EVs' impact on the national grid.

59 Based on research commissioned by WWF and other NGOs, which demonstrates the pathway to near complete decarbonisation of the grid by 2030.
60 For example, the Arup/Cenex study for BERR and DfT only estimates 20,600,000 EVs by 2030 in their 'Extreme' scenario.

APPENDIX B

Sensitivity analysis

In addition to the three 'baseline' scenarios, we asked Element Energy to perform some additional sensitivity analysis, to see if changes to key assumptions had a particularly significant impact on the scenario results.

Given the correlation between total kilometres travelled and CO_2 emissions from cars, the testing focused on the impact of further reductions in demand for car travel. Both medium and extreme demand reduction were tested, using the following parameters:

Table 5: Demand reduction parameters for sensitivity testing

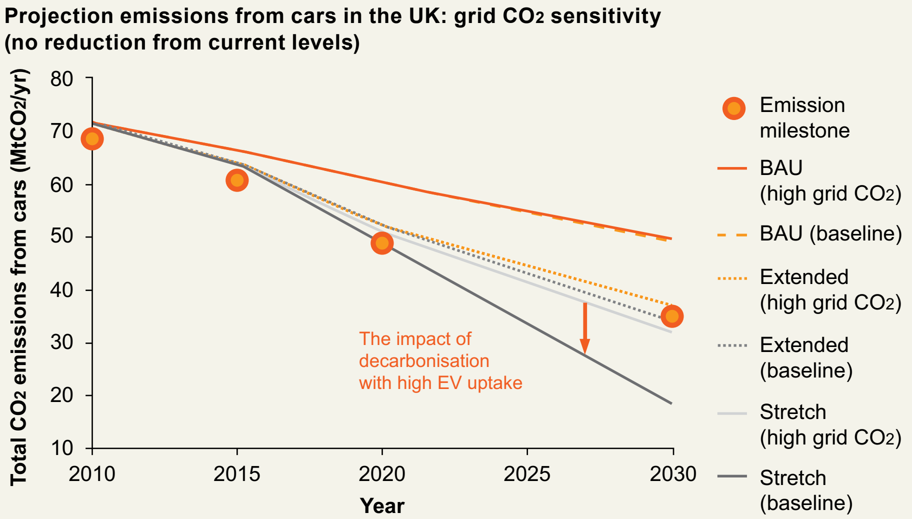
		2020	2030
Demand for car travel in the UK (bn car km/yr)	Traffic growth	420	420
	Traffic stabilisation (as per Extended and Stretch scenarios)		
	Percentage decrease in demand	0%	0%
	Medium demand reduction	351.4	351.4
	Percentage decrease in demand	16.3%	16.3%
	Extreme demand reduction	323.7	262.8
	Percentage decrease in demand	22.9%	37.4%

The impact of reducing car kilometres can be seen in Section 3.2.

The impact of grid decarbonisation

A further sensitivity test was done to show the impact on CO_2 emissions from cars if the carbon intensity of the grid is not reduced. We compared these with our three baseline scenarios, where decarbonisation is assumed. This shows, quite conclusively, that grid decarbonisation is a prerequisite if significant carbon savings are to be achieved from high levels of EV uptake.

Figure 8: Emissions projections under each scenario for cars in the UK – high grid CO_2 sensitivity



According to this analysis, decarbonisation of the grid provides around an additional 70% reduction in car emissions by 2030 in the Stretch scenario, from today's levels, compared to reduction levels with existing high grid CO_2.

APPENDIX C

Oil import calculations, by scenario

The following table uses Element Energy research plus DECC central (£81/91/bbl) and high-high prices (£152/152/bbl) for oil in 2020 and 2030[61] respectively to calculate the possible savings in oil imports (in £ and barrels) represented by EVs, according to our three scenarios.

	litres/yr less than 2010 by 2020 (millions)	barrels	central price 2020 (£ millions)	high-high price 2020 (£ millions)
BAU	72	452,830	36.7	68.8
Extended	704	4,427,673	358.6	673.0
Stretch	1,933	12,157,233	984.7	1,847.9

	litres/yr less than 2010 by 2030 (millions)	barrels	central price 2030 (£ millions)	high-high price 2030 (£ millions)
BAU	571	3,591,195	326.8	545.9
Extended	1,702	10,704,403	974.1	1,627.1
Stretch	8,992	56,553,459	5,146.4	8,596.1

61 See Section 8.7.2 in Element Energy research plus http://www.decc.gov.uk/assets/decc/What%20we%20do/A%20low%20carbon%20UK/2050/216-2050-pathways-analysis-report.pdf for further information.

Electric Vehicles in numbers

1.7M

At least 1.7 million EVs will be needed by 2020 and 6.4 million by 2030

£5 BILLION

EVs could account for nearly a third of the reduction in fuel demand, representing over £5 billion a year in avoided oil imports by 2030

30%

Burning liquid hydrocarbon fuels made from oil is responsible for around 30% of global CO_2 emissions contributing to climate change

28%

High numbers of EVs could reduce car emissions by 28% by 2030

WWF

Why we are here

To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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