HIGHWAYS AGENCY

Safe roads, reliable journeys, informed travellers

Preparing the strategic road network for electric vehicles

A research programme

An executive agency of the Department for Transport

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1. Introduction

Vehicle technologies are advancing at an ever increasing rate, driven by international regulations and consumer demand for more efficient vehicles. As technology develops, ultra-low emission vehicles (ULEVs), including pure electric vehicles, plug-in hybrids and fuel cell electric vehicles, will play an increasing role in the way we travel. These vehicles are already coming to the market in significant numbers, and in the coming years will become a common sight in our towns and cities and on the strategic road network.

The government is committed to supporting the growth in the market for ULEVs. The Office for Low Emission Vehicles are providing over £900 million between 2010 and 2020 to position the UK at the global forefront of ULEV development, manufacture and use. This investment will build the right conditions to establish a stable and growing market for ULEVs in the UK, and allow for mass-adoption in the decades ahead.

The increasing use of these vehicles provides a number of significant opportunities for the UK. An efficient and effective transport system is vital to the UK's economic wellbeing and road transport remains the dominant transport mode in the UK. However, traffic and new road capacity can bring concerns over air quality and noise. The growing numbers of ULEVs on our roads therefore have a very important role to play in supporting mobility while reducing the impacts of road transport. A rapid uptake in these vehicles can also help to attract a new generation of investment into the UK's car industry and supply chains, helping economic growth, which the Highways Agency is committed to support.

The Action for Roads command paper, published in July 2013, identified the importance of managing the road network over the coming years to prepare for ULEVs. To support this, the Highways Agency is going to investigate how it can respond to this shift in the types of vehicles that use the strategic road network, and what direction it should take.

The Agency has a commitment to minimise the impact the strategic road network has on communities that live by it. By supporting the growth of electric vehicles using our network we aim to reduce noise, carbon emissions, and improve air quality.

Andrew Jones
Director
Operational & Technical Solutions Division
Network Services Directorate

2. Context

During the past five years there has been a gradual shift in the types of vehicles that are using UK roads, which is set to continue in the years and decades ahead. The government's Driving the Future Today strategy, has set out a vision that almost every car and van in the UK will be an ultra low emission vehicle by 2050[1].

There is general consensus that the internal combustion engine will continue to play a role in road transport for many years, with improvements in fuel efficiency and increased hybridisation. However, as emissions targets become tighter and technologies continue to develop it is expected that ULEVs, including battery electric, plug-in hybrids and fuel cell electric vehicles will take an increasing share of the market for cars and vans.

This shift is already occurring in both the private car market and the LGV/HGV market. In recent years, we have seen an increase in the electrification of the UK vehicle fleet with significant growth in mass-market hybrid vehicles and the introduction of battery electric and plug-in hybrid vehicles. Between 2010 and 2013 statistics from DVLA show a 25 per cent[2] rise in the number of such vehicles. The Vehicle Licensing Statistics 2011 report states:

> *'The proportion of the licensed car fleet that is made up of alternative fuel vehicles has continued to grow. By the end of 2011 the number of hybrid electric cars climbed above the 100 thousand mark for the first time and the year also saw the appearance of the first plug-in hybrid cars. There were also 154 thousand gas, electric or hybrid electric cars in December 2011, 20 thousand (or 15 per cent) more than at the end of 2010.'*

This rate of increase is expected to continue, as ever increasing fuel costs for both private car and LGV/HGV owners, and concerns about the environment (air quality, noise, carbon emissions) will drive up demand for hybrid and battery electric vehicles in coming years.

Alongside this expansion has been continuous development in SMART vehicles. In vehicle technology is now so sophisticated that fully autonomous vehicles are now a reality, and at some point in the not to distant future, they will appear on the strategic road network.

'We need to use this opportunity to prepare for forthcoming advances in technology. We need to maximise the benefits from ultra low emission vehicles and we need to make sure that other technologies can be applied quickly and smoothly across the network[3]'

3. Government policy

The government is committed to supporting this growing market, as outlined in the DfT command paper Action for Roads, where it states:

> *'An important part of managing the road network over the next thirty years will be preparing the infrastructure for a shift to these new types of vehicle'.*

It also gives strong support for an environmentally friendly network:

> *'Our vision for roads must be matched with an aggressive policy of decarbonisation, to address the carbon consequences of motoring and move us to a lower-impact future…… Reducing carbon and other greenhouse gas emissions is at the heart of our vision for transport, and is a key component of sustainable economic growth'.*

The Government has been increasing the amount of funding it has been giving to support the growth of the EV market:

> *"We will continue to foster the market for Ultra Low Emission Vehicles (ULEVs) in the UK. We have already committed £400 million to support the early adopters of new ULEVs. We will now go further, and commit over £500 million of additional capital investment by 2020 to continue supporting industry and consumers in the switch to the latest low-carbon technology. This investment will build the right conditions to establish a stable market for ULEVs in the UK, and allow for mass-adoption in the decades ahead"*[4]

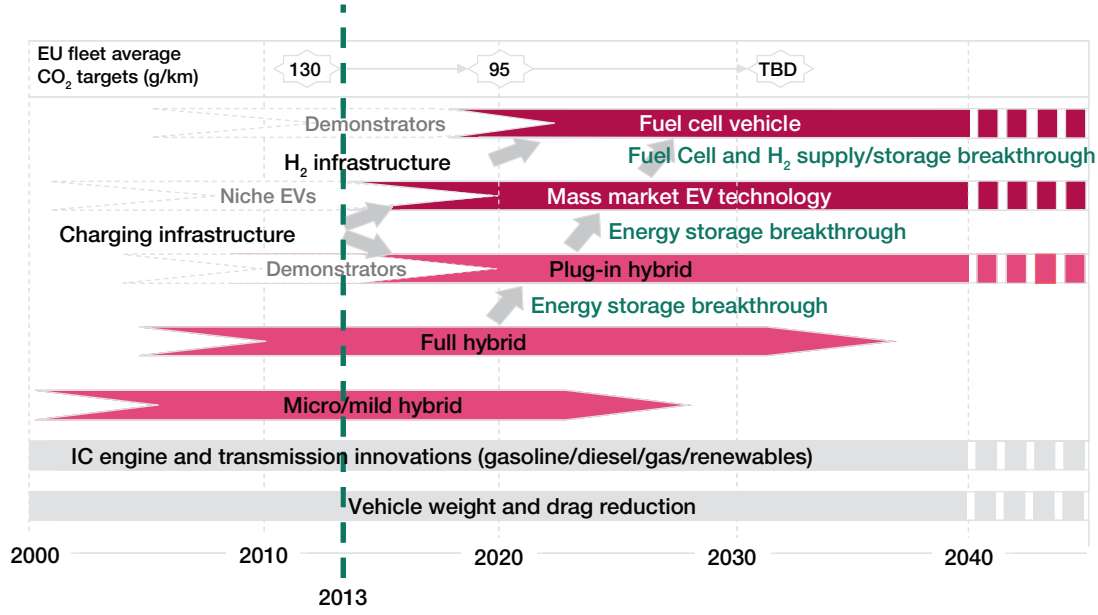
4. External drivers

4.1 Technology roadmap

The Automotive Councils, roadmap (fig.1) sets out how low carbon technologies are likely to evolve for cars over the next thirty years and reflects the views across the UK's leading automotive developers and manufacturers. The roadmap acknowledges that the internal combustion engine will continue to have an important role to play for years to come, but also makes clear that a wide portfolio of technologies and systems, including hybrid, electric and fuel cell vehicles, will play an ever greater role in the coming years and decades .There are also efficiency savings that can be realised across each of these technologies from making vehicles lighter and more aerodynamic.

Fig.1

The technology roadmap for cars and vans



Source: NAIGT

4.2 Uptake of electric vehicles

Around the world, governments are looking to simultaneously reduce their reliance on foreign energy imports, to clean the air in their towns and cities, and to reduce carbon emissions from their societies. There are now vehicle emission targets in place in the major trading blocks around the world. These are driving a revolution in the development of ULEV technologies. Manufacturers are investing billions of pounds into the research, development and production of alternative powertrains, which are now being introduced to the market.

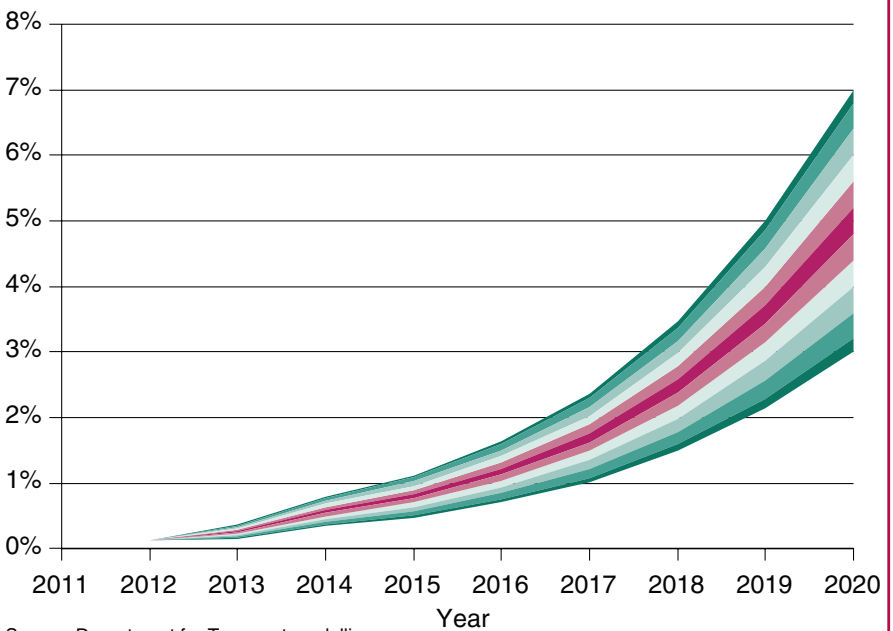
While the number of ultra low emission vehicles on our roads is still relatively small, they are growing significantly year on year. The government is committed to supporting this growing market, as outlined in the Driving the Future Today strategy, which sets out a vision that almost every car and van in the UK will be an ultra low emission vehicle by 2050.

The speed of the transition to ULEVs remains difficult to predict, particularly beyond 2020. It will be determined by a number of factors – most critically the speed with which manufacturers bring ULEVs to market and the price they charge for them. Figure 2 outlines the government's latest projections of ULEV uptake to 2020 as a proportion of all new car sales. It estimates that by 2020 between 3 per cent and 7 per cent of all new car sales will be ULEVs.

In addition to the factors quoted above, the range in Figure 2 also reflects the uncertainty over some of the key drivers of future uptake of ULEVs. These include: battery prices, fuel costs, residual values, purchasing models (e.g. battery leasing), and accessible rapid charging.

Fig. 2

Projected ULEV car sales as proportion of all car sales (2011-20)



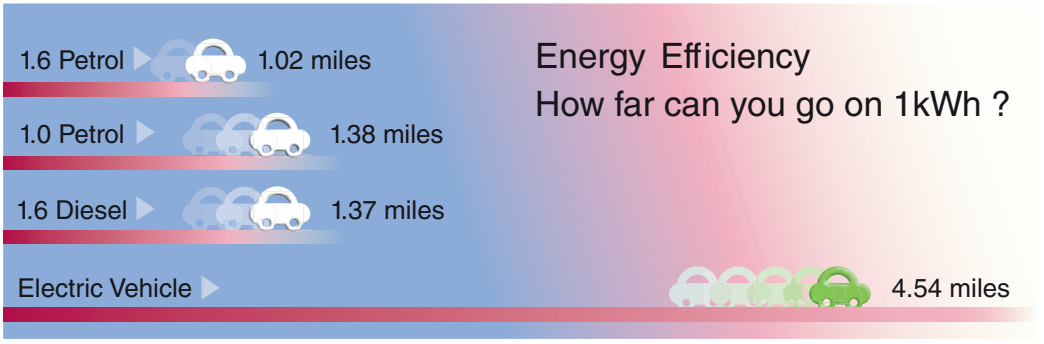
Source: Department for Transport modelling

Major car manufacturers BMW, Nissan, Renault, Toyota and Vauxhall are all backing the Go Ultra Low campaign[5] in a ground breaking partnership with government to debunk common myths and misconceptions that put drivers off switching to electric or hybrid cars, such as cost and how far the vehicles can travel before being recharged.

Electric car owners do not have to pay car tax or congestion charges and many charge points are free to use. The cars cost from just 2p a mile, which means a family that drives an electric vehicle 10,000 miles in a year would save around £1,000 on fuel costs each year. Electric power is also more energy efficient.

Fig 3

The efficiency advantages of electric power



(Distances approximate, theoretical calculations using best in class vehicles)

Source: Driving the Future Today OLEV, September 2013

There is also evidence that fuel cost savings are also available to HGV's as shown by the trial below.

Leyland DAF hybrid lorry

DAF Trucks started manufacturing the 12 tonne LF Hybrid model at its Leyland facility in Lancashire inDecember 2010 and was the first European manufacturer to enter serial production with a hybrid lorry. This followed a successful three-year field trial (in the UK and Netherlands) to demonstrate the benefits of the technology. This identified that a 24 per centfuel and carbon saving can be achieved when operating on a suitable stop/start duty cycle compared to an equivalent diesel truck. The trial also proved that the hybrid technology could meet the customers' demanding operational requirements. DAF LF hybrid trucks are now operating in eight different countries around Europe.

The DAF LF hybrid is a 'parallel Hybrid configuration' vehicle, with an electric motor installed between the engine and gearbox. The vehicle is fitted with a lithium Ion battery, which allows up to 2 km of electric driving. This is recharged automatically when the vehicle is coasting or braking. The vehicle automatically decides which mode to drive in – either electric, blended electric and diesel power or diesel only modes – depending on the driving conditions.

Source: Driving the Future Today OLEV, September 2013

4.3 Supply chain

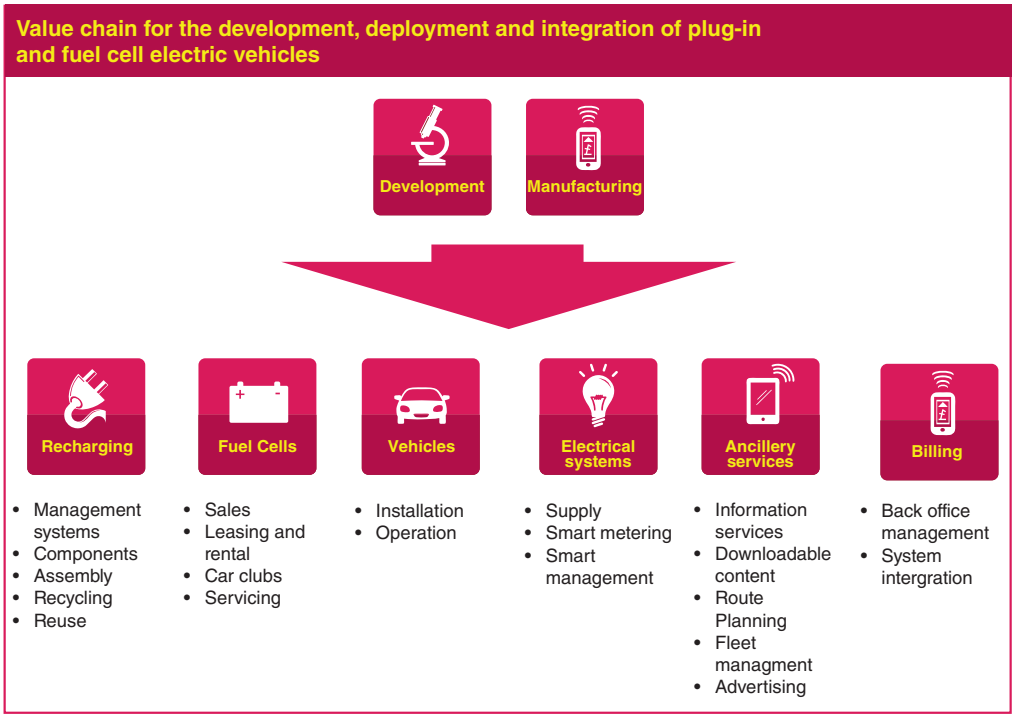
The UK manufacturing sector has key skills in the technologies required for the transition to EVs. Our comparative advantage extends from our world-leading foundations in electrochemical research, through technology specialisms in batteries, fuel cells, lightweighting, motors and power electronics to niche and mass volume manufacturing.

A growing EV market in the UK therefore presents a major opportunity to boost economic growth in the UK supply chain for these technologies, which will supply the next generation of vehicles and beyond. If every UK-made vehicle had a 50 per cent UK supply content rather than the current estimate of around 36 per cent, this would be worth at least 30,000 more direct manufacturing jobs at first tier suppliers[6], quite apart from the spin-off to their suppliers.

A growing market for EVs will also provide opportunities further along the value chain (fig. 4) where the UK already has a number of active companies, for example in the provision of charge point infrastructure or in the hydrogen for transport supply chain. Inductive charging is likely to offer similar opportunities.

The Highways Agency is in a position to support this economic growth.

Fig4



Source: Driving the Future Today OLEV, September 2013

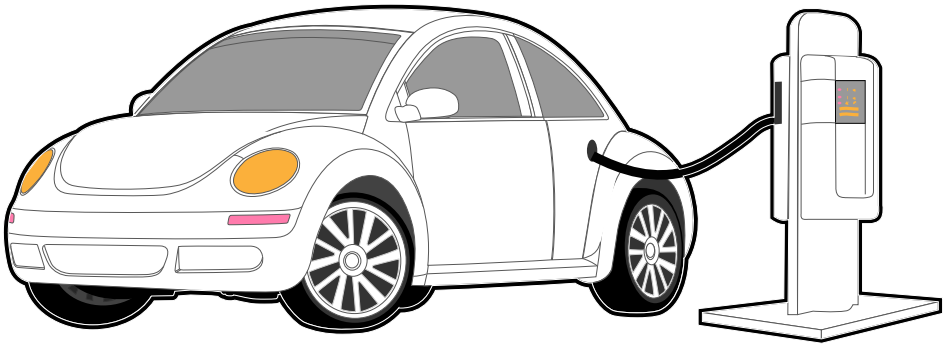
5. Current situation

A key benefit of plug-in vehicles is that they are able to be conveniently charged at home or at the workplace. Nevertheless, some targeted publicly accessible infrastructure is required to facilitate longer journeys, particularly for battery electric vehicles.

At this moment in time there are two technologies available for the purpose of charging the battery of an electric vehicle.

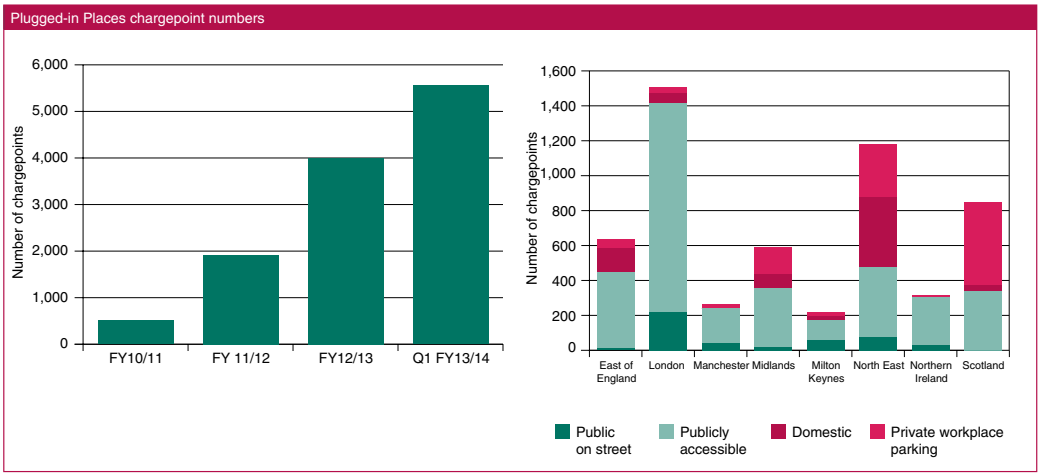
5.1 Plug in charging

Plug in charging operates in a similar way to any electric driven item. There is an electricity supply point, a cable with a plug on it, and a socket in the vehicle which accepts the plug that is on the cable.



The Office for Low Emission Vehicles (OLEV) has been supporting the introduction of plug in charging points for electric vehicles since 2009, which has resulted in the introduction of nearly 6000 charge points (Fig.6) in the UK.

Fig. 6



Source: Driving the Future Today OLEV, September 2013

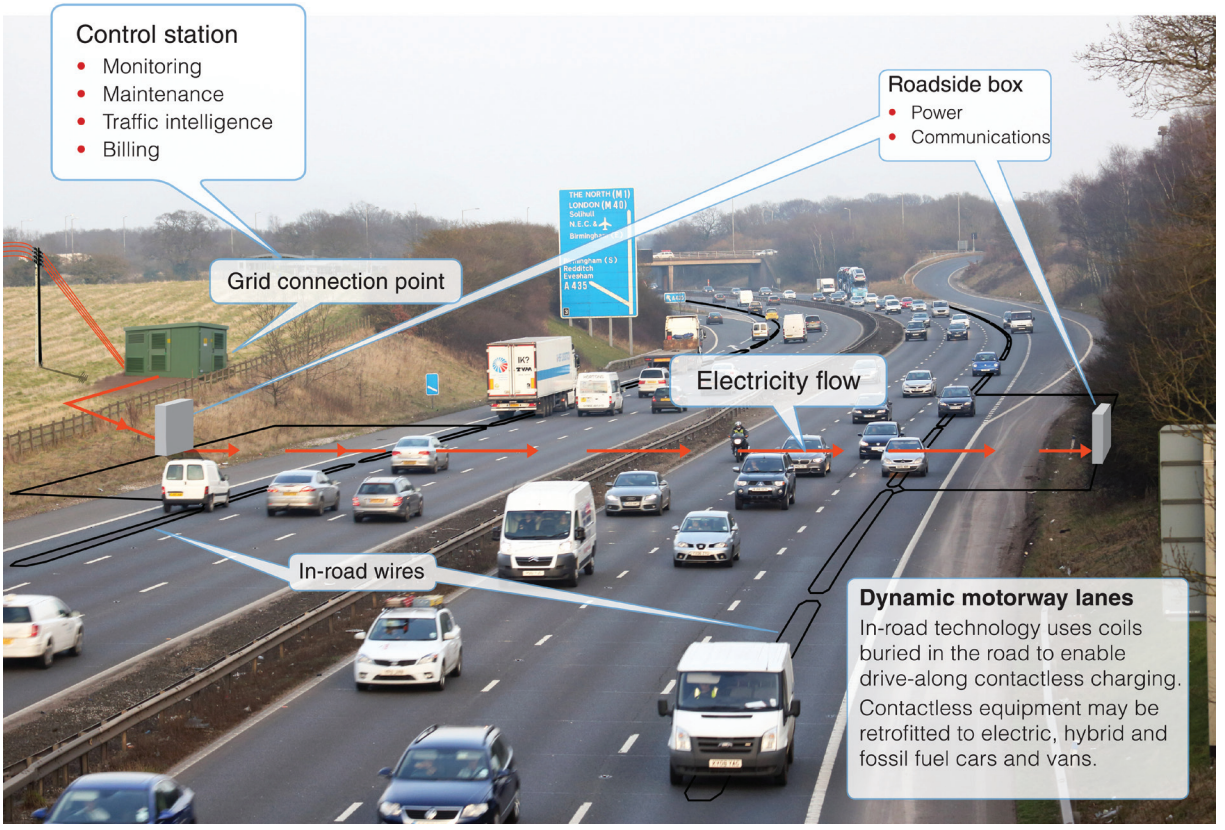
These are being supplemented by a network of rapid chargers across the country, which are capable of charging a vehicle to around 80 per cent charge in 20 minutes. There could be around 500 in the UK by 2015, helping pure electric vehicles to undertake longer journeys. They are being introduced at most motorway service areas, (MSA) but MSA operators have reported relatively low levels of uptake by road users so far. This is probably due to the current low number of electric vehicles in comparison to petrol/diesel ones, lack of knowledge or awareness about the network and anxiety from owners about whether their vehicles have sufficient battery capacity to complete a journey on the motorway network (range anxiety).

5.2 Inductive charging

The development of plug in charging networks have primarily been in city or town environments, but there is a requirement for a charging system that will enable EV's to travel safely, and greater distances, on the strategic road network using only electric power.

Inductive charging offers a solution to this.

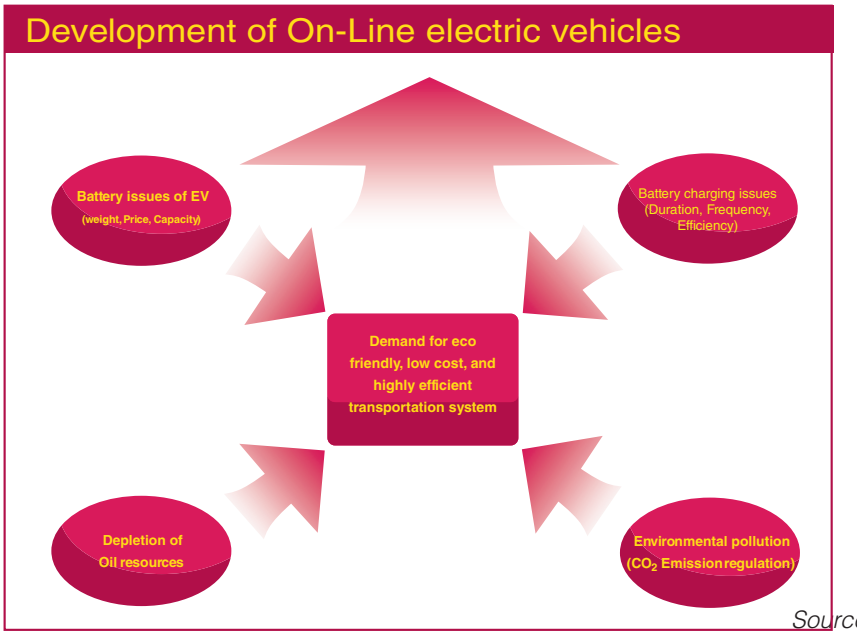
This is a process that provides a charge to electric vehicle batteries without the need for plugging the vehicle into a charging point. This process is carried out wirelessly and can be done whilst the vehicle is stationary or on the move. Where inductive charging occurs whilst a vehicle is on the move, this is known as dynamic charging.



On the strategic road network, the picture below shows how it could operate. There are suppliers with systems that are at, or near market readiness. Trials have been conducted in several countries, and started recently in the UK in Milton Keynes and London to prove the suitability of such systems in a city centre environment.

Recent research conducted worldwide identifies that the development of dynamic charging systems has been driven by several factors (fig.7) which are also applicable to the strategic road network.

Fig 7



Source: KAIST[7]

These factors have driven trials of inductive charging, particularly on bus routes, where they are proving to be a more economical proposition to petrol/diesel driven buses.

In Gumi city South Korea, (fig. 8) dynamic charging has been installed under the road surface of an entire bus route, and more are to follow. A similar trial is underway in Park City Utah, in America.

Fig 8

Gumi city South Korea, first commercial operation.

Source: KAIST[8]

6. Agency response

As suggested by the evidence given above, there is a continued move towards the introduction of inductive charging as an addition to the EV charging infrastructure in the UK.

To support this growing market and infrastructure for it, and government policy behind it, the Agency is investigating how the strategic road network could respond. The challenge for the Agency is to test out the feasibility of an EV battery charging system that can operate on the strategic road network.

7. Aims and objectives of research programme

The aim of the programme is to inform the HA of a potential environmentally friendly solution that will provide a safe road environment for the projected growth in electric/ hybrid vehicles using the strategic road network.

There are four objectives as follows:

a) To investigate dynamic battery charging systems for electric vehicles on the strategic road network that will:
- Mitigate against EV's running out of power.
- Help reduce fuel costs, thus supporting economic growth.
- Have a minimum impact on the road surface in terms of installation and maintenance.

b) Help reduce environmental impact from road users in terms of:
- Better air quality, thus reducing risk of EU fines.
- Reduced noise levels, improving quality of life of those living next to network.
- Reduced pollution from lower tailpipe emissions (carbon).

c) To consider the financial charging mechanisms for energy received by EV owners.

d) Identify what additional services that could be introduced at the same time, supporting value added services to road users and operationally for the Agency.

8. Stakeholders

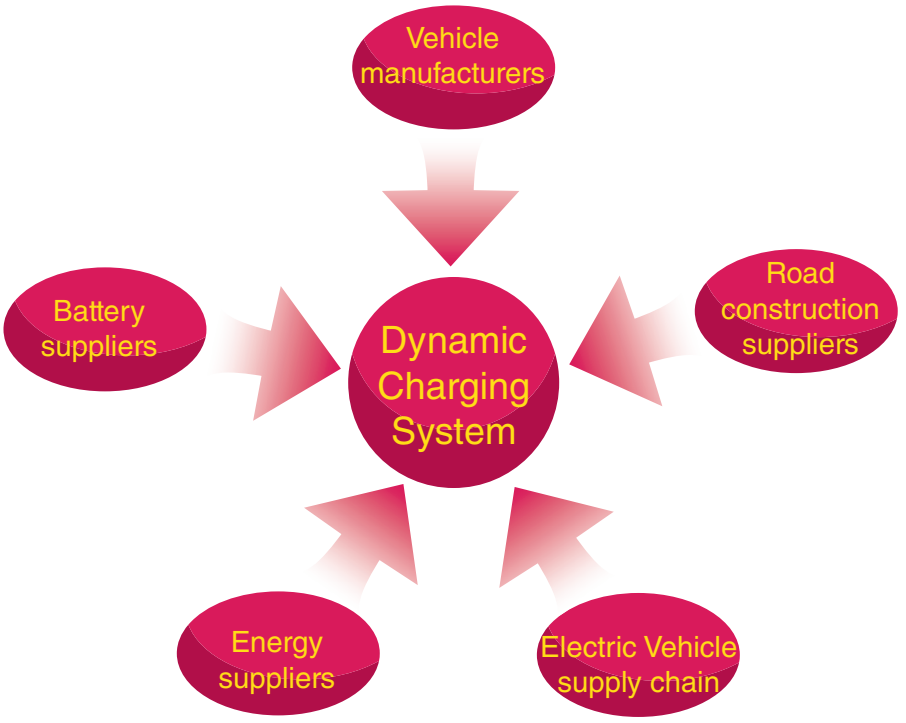
The road user is our primary stakeholder, but there are other stakeholders that we will be engaging with to ensure that the outcome of the research has had their views taken into consideration and influenced the end result. The Agency wants to ensure transparency and an all ways dialogue between our stakeholders: Government; Road User associations; Vehicle Manufacturers associations; Local Authorities; EV supply chain; Energy suppliers; other Highways Agency Directorates.

We will also have dialogue with stakeholders in the European Union who are conducting similar research, such as the Flanders Drive programme[9], or where inductive charging systems have been successfully operated, such as in Turin[10] in Italy and in the Netherlands[11].

9. Approach

The project will be investigating a number of emerging technologies that are feeding into the development of battery charging systems for EV's and as such the agency will be adopting a collaborative approach to the research programme, (fig 10). This will ensure that we get best value for money, minimise potential blockages, share expertise, and deliver the programme on time.

Fig. 10



10. Research programme

The research will be conducted in three stages

- a feasibility study
- an off road trial
- an on road trial

10.1 Timelines

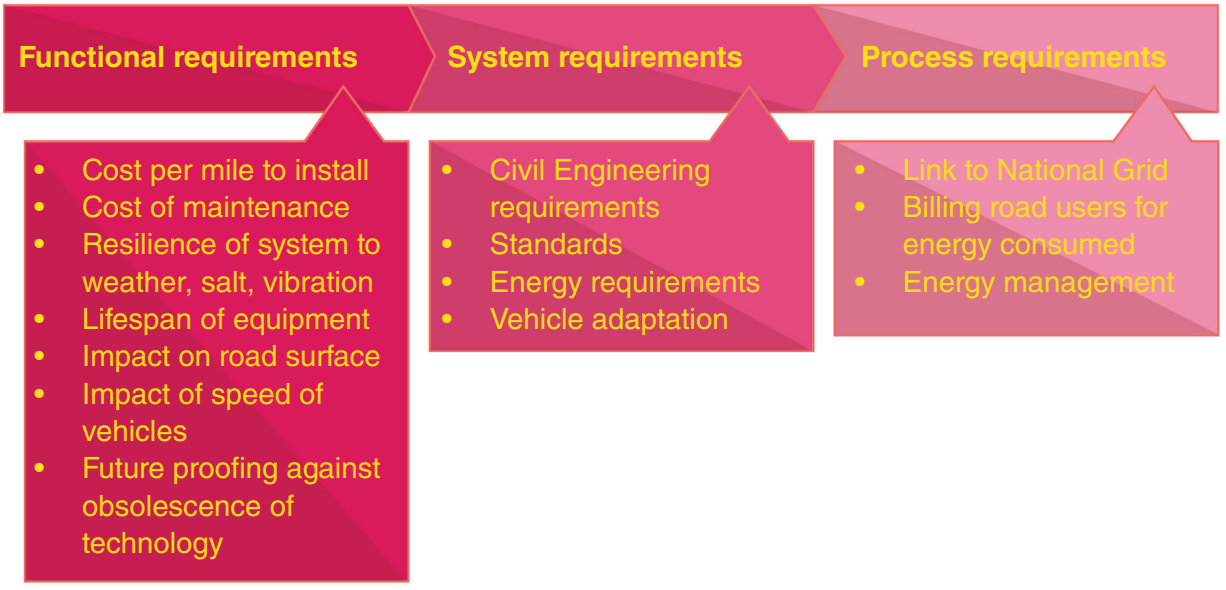
The timelines for the road trials may be subject to amendment, as they are reliant on a number of factors that will not become clear until the feasibility study is completed.

10.2 Feasibility study

The Feasibility study will be an in depth analysis of the potential for the installation of an dynamic charging system under the surface of the road where there will be fast moving traffic of cars, coaches, LGVs and HGVs with varying volumes and road conditions. It will provide the Agency with recommendations for the way forward.

10.2.1 Milestones

The feasibility study has three key milestones. They are not necessarily sequential, as this will be influenced by the stage of development that the technologies required have reached. This is when the collaborative approach will ensure smooth transition from one milestone to the next.

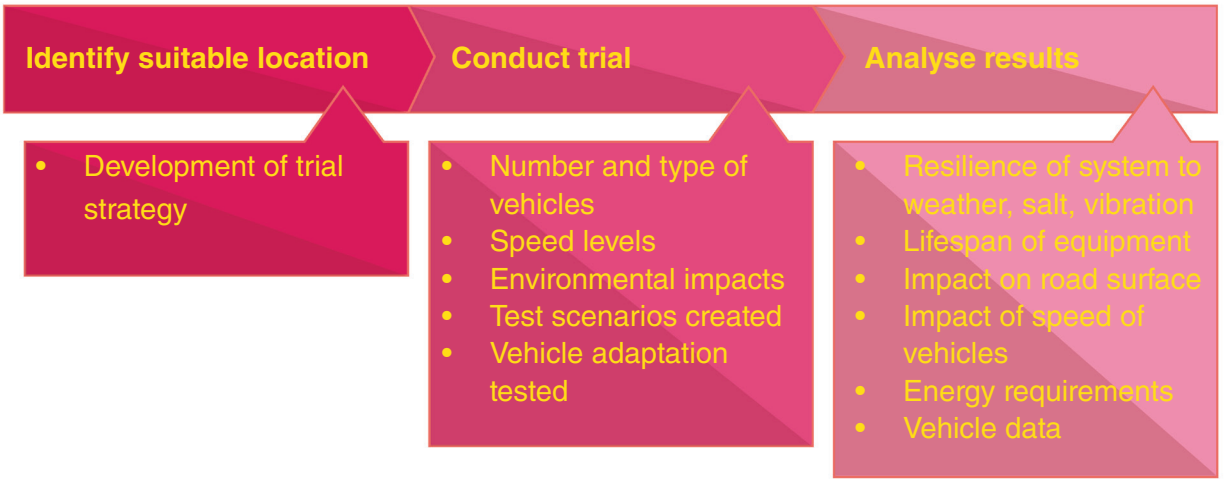


10.3 Off Road trial

The model for the off road trial will be determined by the results of the feasibility study, but it will be looking to replicate as near as possible a range of situations that will be encountered should a dynamic battery charging system be installed beneath a road surface. In order to do this an outdoor venue with a reasonable length of road that can accommodate various speed scenarios from a range of vehicles will be utilised.

10.3.1 Milestones

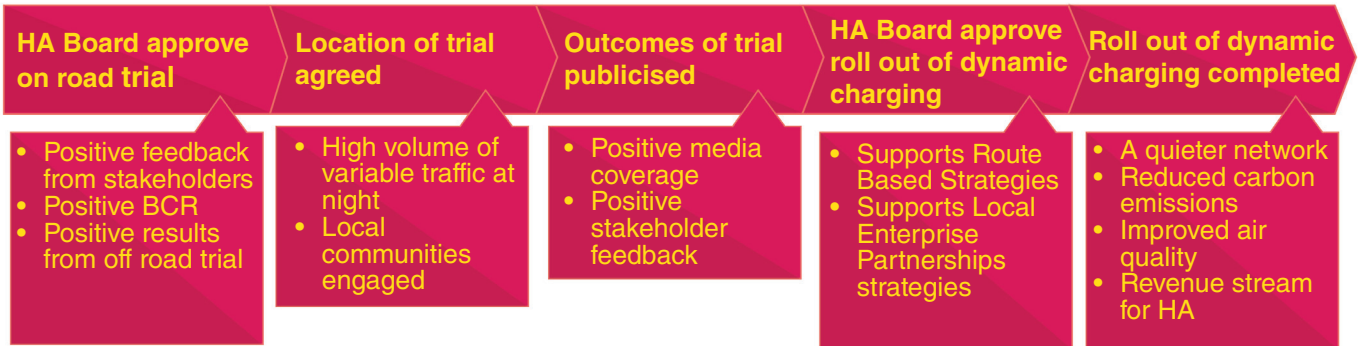
There will be three planned milestones for the off road trial.



10.4 On road trial

The model for the on road trial will be determined by the results of the feasibility study and the off road trial, but is likely to involve a length of motorway with a high volume of night time commercial traffic.

10.4.1 Milestones



10.5 The european picture

Our research programme has synergies with other studies taking place in Europe, for example, the EU Feasibility analysis and development of on road charging solutions for future vehicles (FABRIC) programme, and the Forum of European Highways Research Laboratories (FEHRL) Forever Open Road programme, and we will ensure the outcomes of such research inform our own.

11. What success would look like

The planned roll out of dynamic charging on the strategic road network has now been running 10 years, with the installation of the system beneath the road surface being undertaken at the same time as scheduled road resurfacing or replacement programmes, thus making it a cost efficient process. In order to minimise disruption to road users, and save on time, a special machine tool has been used that means when the system is being installed, the entire road does not need to be dug up. This tool also has allowed us to install other services under the road surface, including wireless and fibre optics to give us instant real time data on vehicle movements on the strategic road network.

Since the roll out started, there has been a steady increase in the number of electric vehicles coming on to the strategic road network and using the system. It has been reported to us at our liaison meetings with HGV and bus operators that they have seen a considerable drop in their fuel costs since they adapted their fleets to be able to use the dynamic charging system, despite having to pay the Agency for the electricity used.

In those parts of the network where dynamic charging has been implemented, where there is a speed limitation of 60mph required for vehicles to be able access the system, there has been a noticeable reduction in accidents.

Our motorway service area operators have reported a steady increase in the number of private cars accessing their plug in and inductive charging points across the strategic road network, which means that owners of electric vehicles are now confident that they can take their cars on to the strategic road network without the prospect of the vehicle running out of power in the middle of the carriageway.

The Environment Agency has informed us that they have had no adverse comments from their stakeholders about the system, as it is not seen, and the increasing number of electric vehicles is now starting to have an impact, by reducing carbon emissions and noise levels where communities live close to the network.

Road users who are accessing the system have reported to us that they like the billing process we have adopted for charging them for the electricity used, where they receive a bill similar to their mobile phone, which shows them the time, date, and location when the system was accessed, along with the energy consumed in KW and the charge per unit. Payment options include direct debit and via the Agency website.

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