City of Westminster

Understanding existing electric vehicle recharging infrastructure, vehicles available on the market and user behaviour and profiles

April 2009

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Clear Zones For Liveable Cities

Transport for London

City of Westminster

Executive summary

Purpose of the study

This report was commissioned by Westminster City Council (WCC) and was funded by Transport for London through the Clear Zone Partnership. The report provides an overview of electric and hybrid electric private car and fleet vehicles currently available and being developed, as well as the future of these technologies and recharging infrastructure. The study also assesses the potential to offset or mitigate carbon emissions associated with electricity consumption through the use of renewable and low carbon technologies. Motivations and barriers to the purchase of low carbon vehicles are considered, along with strategies for accelerating uptake. The aim of this study is to inform the development of electric vehicle recharging infrastructure in the City of Westminster.

Electric vehicles

There is a wide range of electric vehicles (EVs) on the market including a number of small scale manufacturers and Original Equipment Manufacturers (OEMs) and the performance of these vehicles varies widely. The recent development of Lithium-Ion (Li-ion) battery technology which provides a greater range between charging times, means that the prospects for EVs are greater, however at present their high price prohibits mass market uptake.

The global vehicle industry is investing heavily in EVs, in addition national and regional policy sees that alternative electric and hybrid technologies will be important for the long term decarbonisation of the transport sector.1 It therefore appears likely that over the next decade EVs, which have been available for more than a century, will finally start to become a main stream consumer choice.

Hybrid vehicles and plug-In hybrid electric vehicles

There are a number of hybrid vehicles currently available on the market and more being developed, including plug in hybrid vehicles. Toyota launched the Prius, the world’s first mass produced internal combustion engine (ICE)/electric hybrid in Japan more than a decade ago and since then has sold more than a million Prius vehicles. As with EVs, the continued development – and lowering of production costs – of Li-ion batteries will be a key factor determining their viability for the mass market.

In recent years, the development of plug-in hybrid electric vehicles (PHEVs) has become a key subject of global research and development. PHEVs have the potential to combine the advantages of today’s hybrid vehicles, in particular being able to run on petrol or diesel without the range limitations of EVs with EVs’ potential for reduced CO_2 emissions.

Vehicle charging infrastructure

There are very few companies offering recharging points currently available on the market. In the future, the most common location for charging is likely to continue to be at home, however the availability of a public charging infrastructure will also be necessary to ensure widespread adoption of EVs and PHEVs. A number of cities have recently announced their intention to install extensive electric charging infrastructure, many in conjunction with the company Better Place who have ambitious plans for battery exchange systems and networks of charging points in Israel, Denmark and Australia.

Electric vehicle charging points are currently publically available in a number of local authorities and shopping centres throughout the UK. There are currently very few companies providing electric charging points. Major differences in products relate to the durability of the technology and data management capability. A review of models currently available in the UK focuses on Elektrobay and the Power Tower. Dutch company Epyon’s UFC charge is also considered for on street fleet charging.

A scenario for the density of the electric vehicle network needed found that approximately four charging points per square kilometre would be needed in Greater London by 2020. This was based on maintaining the current ratio of charging points to electric vehicles in London and an adoption of 2.5% of all cars being capable of

[1] Climate Change Committee Report, December 2008

connecting to an electricity supply. The key to successful vehicle charging infrastructure will be compatibility. To increase consumer confidence in the use of EVs and PHEVs, a London and UK wide charging network should be developed that allows consumers to charge their vehicles regardless of residence or make of charging point. This would require standardisation of charging leads or a common network across local and regional boundaries.

Reducing CO_2 emissions from electric and hybrid electric vehicles

Both electric and hybrid electric vehicles offer CO_2 emissions reductions; however an EV charged by electricity derived from carbon intensive sources would only achieve marginal savings over an Internal Combustion Engine (ICE). A vehicle charged from decarbonised electricity offers significant savings. As the UK government aims to increase use of decarbonised sources of electricity, future CO_2 savings from EVs and PHEVs will be greater. These vehicles should be promoted within a wider policy of promoting less energy intensive lifestyles and therefore avoiding unnecessary car journeys. Government guidance on company reporting for green electricity tariffs is that they do not offer a reduction in CO_2 emissions. It can be argued that only electricity companies who retire Renewable Obligation Certificates (ROCs) offer a genuine incentive to provide more renewable electricity for the national grid.

Local generation of low carbon or renewable electricity offers genuine carbon reduction potential for electric vehicles and if developed would aid Local Authorities in meeting their per capita CO_2 emissions reductions targets under the new National Indicators. The feasibility for the range of renewable and low carbon energy technologies to mitigate the CO_2 impact of electric vehicle charging was assessed as part of this study and found that solar technology would require a large panel area such as roof of a car park in order to make a substantial contribution to the energy demand of one charging point, based on average use in Westminster City Council. Wind power is unlikely to be viable due to the location of the wind turbines in the City of Westminster. The most viable technology available would be to develop a Combined Heat and Power (CHP) network within the area. The cost of implementing this could be contributed via vehicle owner tariffs charged by the council, thereby raising awareness of the need to avoid short and unnecessary car journeys which make up more than 25% of car journeys travel in London.

Vehicle demand

This study assesses market growth for electric vehicles together with consumer research into demand for alternative vehicles. It also examines the drivers for car purchasing and the pro-environmental behaviours in general. Demand for passenger car travel increased by 20% between 1990 and 2006. Current predictions are that car travel will increase by 1% each year. This increase has been offset by a reduction in CO_2 emitted per vehicle kilometre (gCO_2/vehicle-km), however current growth is likely to soon outstrip the benefit of CO_2 emission reductions. EU legislation to reduce average CO_2/vehicle-km for all new cars from 160g/km to 120g/km is expected in 2012.

There is little consumer research that specifically addresses the issue of changing from conventional to alternatively fuelled vehicles. It is generally agreed that the primary considerations for consumers purchasing a new car are the initial cost and performance, followed by fuel consumption, comfort and size. Research from the University of Gronigen in the Netherlands also argues that other factors such as sensation, power and feelings of superiority have a large bearing on a consumer's choice of car.

Overall research shows that car purchasers are not influenced by environmental concerns. However electric vehicle owners often list environmental concerns as a primary motivation for purchasing their vehicle. With increasing fuel costs, fuel economy has become a more important factor to consider when buying a new vehicle[2], thereby giving electric and hybrid electric vehicles a stronger selling point. However, some studies have found that users do not fully understand the link between fuel economy and CO_2 emissions.

Using market segmentation research, such as Defra's Pro-Environmental behaviour framework, the individuals most likely to take up low carbon vehicles will be among those who are already environmentally aware. They will want to reduce their environmental impact, but at the same time not want to give up the independence offered by the car. They are likely to have a higher than average income, hold a degree, be an urban dweller

[2] Frost & Sullivan. European Consumers' Attitudes Towards Sustainability, Environment and Alternate Power Trains (2008)

and have an interest in technology. Although younger consumers are more likely to be receptive to novel technology, older consumers will have the purchasing power to invest in low carbon vehicles.

High prices, difficulties in charging an electric vehicle and the limited availability of models are all reasons given for the low adoption of electric and hybrid vehicles[3]. However, consumers are becoming more confident in the performance abilities of such vehicles. It will be necessary for users to change their driving behaviour to achieve widespread adoption of electric vehicles, as journeys will be planned around charging points and charge level of batteries.

The future of electric vehicles

The future of electric vehicles is rated as excellent by the Centre of Excellence for Low Carbon and Fuel Cell Technologies (Cenex), the highest of any of its supported alternative fuel technologies. However, current studies indicate that mass market penetration of EVs is unlikely to happen before around 2014, and is more likely to occur around 2020, and that significant government and industry interventions will be needed to stimulate both supply and demand. Many studies do not predict electric vehicles having a larger market share than 10% without significant reductions in price or running costs[4].

A variety of incentives are possible for stimulating uptake of electric and hybrid vehicles. They include information campaigns, financial incentives for vehicle purchase and taxation and increased amenity of low carbon vehicles through schemes such as preferential parking.

Buses, taxis and fleet vehicles

Fleet vehicles offer great potential for accelerating the uptake of electric and hybrid vehicles as the most important considerations are those of reliability and cost rather than image. Fleet vehicles also offer the potential to introduce new technologies to a larger market. As company car tax is linked to vehicle excise duty (VED), based on the CO_2 output of the car, with further discounts for electric and hybrid vehicles, a strong incentive exists for the purchase of such technologies for fleet vehicles.

A hybrid drive train is the most applicable technology for buses, although some examples of smaller electric buses do exist. Transport for London (TfL) aims for all new buses entering their fleet to be hybrid by 2012, and Volvo claims to have produced the first commercially available hybrid bus. The conversion of taxis to lower carbon technologies is proving slower, partly as no financial incentives exist for this to happen. One London taxi company operates using Toyota Prius vehicles.

Current economic climate

Since this report has been written, the economic down turn has had a strong impact on the global automotive industry, with government financial intervention being required in both the UK and America. In the UK, the new car market declined sharply at the start of 2009, with new car registrations down by over 30%. Sales of alternatively fuelled vehicles have been particularly affected, dropping by 47%[5]. OEMs have announced substantial job cuts with some plants, for example Honda in Swindon, shutting down for months at a time in a response to falling sales[6]. Smaller EV distributers have also been affected; NICE Car Company went into administration in December 2008 after sales reportedly dropped to one vehicle per week and the Norwegian company Think is undergoing financial restructuring. Current industry predictions see the situation remaining similar during 2009 while the availability of credit and willingness to spend is low. OEM commitment to EVs and PHEVs appears to remain high, with new vehicles such as the Mitsubishi MiEV being announced[7]. However as all OEM activity is being curtailed by the financial situation, a delay in the roll out of new EVs and PHEVs is to be expected. An industry upturn is expected in 2010[8].

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[3] Frost & Sullivan. European Consumers' Attitudes Towards Sustainability, Environment and Alternate Power Trains (2008)
[4] Toner, J. (2005), *Investigating Household Demand for Alternative Fuel Vehicles.* ESRC research report
[5] SMMT New Car Registrations, press release 4625 05.02.2009. Available from www.smmt.co.uk
[6] www.autocar.co.uk/News/NewsArticle/AllCars/237464/
[7] www.mitsubishi-motors.com/special/ev/
[8] Industry predictions from PwC Automotive Institute (01.09.2008), *Analyst Note. Quarterly forecast update: Global Outlook*

Abbreviations/Terms of Reference

AC	Alternating Current
AEP	American Electric Power
AV	Aerovironment
BERR	(UK) Department for Business Enterprise and Regulatory Reform
CEV	City Electric Vehicle
CHP	Combined Heat and Power
CO	Carbon Monoxide
CO2	Carbon Dioxide
DC	Direct Current
DfT	Department for Transport
EDF	Electricité de France
EST	Energy Saving Trust
EV	Electric Vehicle
FDR	Fuel Duty Rebate
GHG	Green House Gas
GM	General Motors
HEV	Hybrid Electric Vehicle
HGV	Heavy Goods Vehicle
ICE	Internal Combustion Engine
ICV	Internal Combustion Engine Vehicle
Km	Kilometre
LGV	Light Goods Vehicle
Li-ion	Lithium Ion
MISRA	Motor Industry Software Reliability Association
MOU	Memorandum of Understanding
mpg	Miles per gallon
mph	Miles per hour
NEV	Neighbourhood Electric Vehicle
NiMH	Nickel Metal Hydride
NOx	Nitrous Oxides
OEM	Original Equipment Manufacturer
PHEV	Plug in hybrid electric vehicle
PIN	Personal Identification Number
PLC	Power Line Communication
PWC	PricewaterhouseCoopers
RCD	Residual Current Device
ReEV	Range Extended Electric Vehicle (US term, in UK PHEV)
RFID	Radio Frequency Identification
SEI	Sustainable Energy Ireland
TfL	Transport for London
TRO	Traffic Regulation Order
TSB	Technology Strategy Board
V2G	Vehicle to Grid
V2H	Vehicle to House
VED	Vehicle Excise Duty
Whr/kg	Watt hours per kilogramme (energy density)

Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1 Purpose of this report

The report was commissioned by the Westminster City Council (WCC) and was funded by Transport for London through the Clear Zone Partnership. Its aim is to make recommendations on the most suitable recharging infrastructure technology for the City of Westminster. The study also includes a brief overview of WCC issues and considerations for installing on street recharging points. It also includes the ongoing cost to the local authority of installing and operating the scheme and provides a scenario of how to cover the costs.

1.2 Overview of electric and hybrid electric vehicles in the UK

In the period 1990 - 2006 domestic transport emissions in the UK increased by 9%, and currently account for 24% of the UK's total carbon emissions. Private road transport is responsible for 86% of the total emissions associated with transport[9]. In 2007 (the latest year for which figures are available), the composition of the 33.9 million vehicles registered in the UK was 83.2% cars, 9.4% light good vehicles (LGVs) and 1.6% heavy goods vehicles (HGVs).

Of these registered vehicles, 2000 are electric cars. In 2007 there were approximately 1000 electric cars and 16,000 non plug hybrid electric vehicles (HEVs) registered for the first time. There were no registrations of electric or hybrid HGVs. The total distance travelled by UK vehicles in 2006 was 506.4 billion km. It is against this background of reliance on the car and slow uptake of low carbon vehicles that the introduction of electric and hybrid electric vehicles is set. However, the average car journey was 13.6km and 93% of car journeys were less than 40km[10]; both journey types would be suitable by electric or hybrid electric vehicles.

[9] Committee on Climate Change, Building a Low Carbon Economy – The UK's Contribution to tackling Climate Change. (2008).
[10] National Statistics (2007), Transport Statistics Bulletin: Vehicle Licensing Statistics 2007.

2 Electric vehicles

There is an increasingly wide range of electric vehicles (EVs) on the market including a number of small scale manufacturers and Original Equipment Manufacturers (OEMs), with a similarly wide range of performance. The recent development of Lithium-Ion (Li-ion) battery technology which provides a greater range between charging times, means that the prospects for EVs are greater, however at present their price prohibits mass market uptake.

The global vehicle industry is investing heavily in EVs, in addition national and regional policy sees that alternative electric and hybrid technologies will be key to the long decarbonisation of the transport sector.[11] It therefore appears likely that over the next decade EVs, which have been around for more than a century, will finally start to become main stream. However, it is important to remember that the greatest CO_2 reductions will only be achieved when partnered with decarbonised electricity generation.

2.1 Overview of the workings of an electric vehicle

Electric vehicles (EVs) have rechargeable batteries that drive either Direct Current (DC) or Alternating Current (AC) motors. DC motors were used in the first EVs over a century ago and are still used in some smaller EVs such as forklift trucks and in the majority of aftermarket EV conversions. However, most commercially produced cars and vans now use AC motors, which are more efficient and more reliable since (unlike DC motors) they do not have contact brushes that tend to wear out and need replacing.

Alternating Current motors also have the advantage that they can be used for regenerative braking. This is the process by which an EV's momentum is used to recharge its batteries. With an AC motor EV regenerative braking occurs whenever the driver takes their foot off the accelerator whilst the vehicle is still moving, either decelerating or driving downhill. This is possible because an AC motor is also a generator, so if the EVs wheels turn the motor/generator this produces a current which can be used to recharge the batteries. In urban driving conditions when there is more accelerating and braking, regenerative braking greatly increases a vehicle's overall efficiency.

A 'DC controller' is required to perform the role of the accelerator in an internal combustion engine. A supply from a battery is either fully on or fully off, so the DC controller sends pulses of power to deliver the required amount of power. For example, if the accelerator pedal is 30% depressed, the DC controller will send high frequency pulses that are (fully) on 30% of the time and (fully) off 70% of the time, which has the same effect as of a constant 30% power. A 'DC to DC convertor' is also required to reduce the high voltage supply out of the batteries to the lower voltage required for ancillary electrical equipment such as the lights, instrumentation, or stereo.

An 'AC controller' converts the direct current from the battery in to 3-phase alternating current to power the AC motor. In this context, '3-phase' means that the electricity in the AC supply takes the form of three sine waves, each offset by 120 degrees, which gives a near constant level of power because at any time one of the phases is nearing its peak.

Electric vehicles do not require a transmission since an electric motor delivers high torque even at low speeds. This goes some way towards offsetting the weight of EVs' batteries.

Batteries are the key to an EV's performance. A battery's energy density (Whr per kg) is the most important criteria for an EV because the amount of energy a battery can store dictates a vehicle's maximum range between charges. Power density is also important (W per kg), but for pure electric vehicles (as opposed to hybrid or plug-in hybrids) the size of the battery array required to give sufficient range means that almost by default there is usually sufficient power.

For most of the last century lead acid was the standard technology for EV batteries, but lead-acid batteries have relatively low energy density (20-30 Wh/kg), resulting in a low vehicle range. Nickel metal hydride (NiMH) batteries are approximately twice as energy dense as lead-acid batteries (50-70 wh/kg) and Li-ion batteries are nearly five times as energy dense (75-120 Wh/kg). Nickel metal hydride (NiMH) and Li-ion batteries also have longer lifetimes than lead-acid batteries, which is measured in terms of the number of times the batteries can

[11] Climate Change Committee Report, December 2008

be charged and discharged without significantly deteriorating. Li-ion batteries are therefore the favoured battery technology for EVs, but as discussed in section 2.3, they are relatively expensive.

2.2 Electric vehicles currently and soon to be available

Tables one and two provide a summary of electric passenger vehicles which are currently available and on limited release. Concept vehicles, which are showcase prototypes for new technology, are also included.

- ↓ indicates a feature that is below the average of all commercially available electric vehicles.
- ↑ indicates a feature that is above the average for all commercially available electric vehicles.

At the time of writing, NICE the car company was in administration and Th!nk has halted production citing financial difficulties. Apart from the Gem e2 and e4, the electric vehicles currently available are produced by small scale companies rather than Original Equipment Manufacturers (OEM's). The US government is providing $17 billion in loans to help carmakers General Motors and Chrysler survive; therefore it is uncertain whether smaller companies will survive the economic downturn. Further discussion of the possible impact of the economic downturn on the electric and hybrid electric vehicle market is provided in section 7.6.3.

PricewaterhouseCoopers Automotive Institute's January 2009 Analyst Note states that a European automotive market recovery is not likely until 2010. The demand outlook is expected to translate into an 11.8% decline in assembly of units in 2009. The briefing states that all parties, including OEMs, suppliers and car dealers will have to undertake aggressive restructuring to adapt to the new financial situation, while also preparing themselves for the expected industry upturn in 2010.[12]

Table 1: Electric vehicles available in the UK

Vehicle model	Availability	Price from (£)	Further information
Reva G-Wiz i 	Available now from Goin Green. Over 950 vehicles sold since 2004.	£7,995	48 miles per charge ↓ 8 hours for full charge ↓ Lead acid batteries Top speed of 50mph ↑ 2 seats ↓ Classified as a quadricycle
Aixam MEGA City 	Available now from The Electric Transport Shop.	£11,499	60 miles per charge ↑ 5 – 8 hours for full charge ↑ Lead acid batteries Top speed of 40mph ↓ 2 or 4 seats ↓↑
NICE mycar 	Availability uncertain due to NICE car company entering administration.	£8,995	60 miles per charge ↑ 5 hours for full charge ↑ Lead acid batteries Top speed of 40 mph ↓ 2 seats ↓ Classified as a quadricycle

[12] PwC Automotive Institute (January 2009), Quarterly Forecast Update (Global Outlook).

NICE Ze-0 	Availability uncertain due to NICE car company entering administration.	£14,000	65 miles per charge ↑ 8 – 10 hours for full charge ↓ Lead acid but optional longer range Lithium Ion batteries planned soon Top speed of 55mph ↑ 5 seats ↑
Sakura Maranello4 	No longer available in UK.	£9,950	45 miles per charge ↓ 6 – 8 hours for full charge ↓ Top speed of 35mph ↓ 2 seats ↓ Classified as a quadricycle
Quiet Car 1 	Available now (15 vehicles currently available in UK).	£9,950	60 miles per charge ↑ 5 hours for full charge ↑ Lithium Ion Batteries Top speed of 45mph ↑ 2 seats ↓
Quiet Car 2 	Available March 2009.	£12,995	60 miles per charge ↑ 6 hours for a full charge ↑ Lithium-Ion batteries Top speed 55mph ↑ 5 seats ↑
Future Vehicles Elettrica 	Available now	£12,750	70 miles per charge ↑ 5 hours for a full charge ↑ Lithium-Ion batteries Top speed of 45mph ↑ 2 seats ↓
Gem e2 	Available now	£10,015	30 miles per charge ↓ 6 – 8 hours for a full charge ↓ 25 mph top speed ↓ 2 seats ↓
Gem e4 	Available now	£12,669	30 miles per charge ↓ 6 – 8 hours for a full charge ↓ 25mph top speed ↓ 4 seats ↑

Table 2: Electric Vehicles soon to be released

Vehicle	Availability	Price (£)	Range (miles per charge)	Charge time (hours)	Battery type
G-Wiz L-ion	Pre-order Feb 2009, delivery May 2009	Unknown	75	6 hours (90% in one hour with fast charge station)	Lithium-Ion
Gem Peapod	2009	Unknown	30	6 – 8	Flooded electrolyte batteries
Fiat e500	End of 2009	Expected to be £25,000	75	6 – 8	Lithium-Ion
Th!nk City EV. As of December 2008, Th!nk have halted production due to financial difficulties.	Likely to be 2009.	£14,000	124	10	Sodium/Lithium Ion
Smart EV	Limited release in UK	£380 a month lease	71	8	natrium-nickel-chloride
Tesla Roadster	Limited release in UK	£92,000	220	4	Lithium-Ion
Mini E	Limited release in USA now, 2009 in Europe	Unknown	156	From 3	Lithium-Ion
Nissan Nuvu	2010	Unknown	78	3 – 4	Lithium-Ion
Subaru R1e	2009 Japan	Unknown	50	8, or 15 minutes for 80%	Lithium-Ion
Bollore/Pininfarina	2010 Europe	Unknown	153	5, or 5 mins for 25km	Lithium Metal Polymer
Microvett Ydea	Currently available in Italy	Unknown	105	8	Lithium-Ion
Renault Z.E.	Concept vehicle	Unknown	Unknown	Unknown	Lithium-Ion
Venturi Volage	Concept vehicle	Unknown	199	8	Polymer Lithium
Th!nk Ox	Concept vehicle	Unknown	155	12	Lithium-ion or Sodium
Porsche Ruf 911	Concept vehicle	Unknown	180	10	Lithium-Ion

2.3 Future of electric vehicles

Electric vehicles are very much on the ascendant with most industry commentators believing they will play a major part in a lower carbon vehicle future[13]. Worldwide, most volume vehicle manufacturers have their own EVs under development (see below) or are involved in joint ventures to produce EVs.

This renewed optimism about EVs is a relatively new phenomenon. For example, the last homologated EVs to sell in volume in the UK were Peugeots 106 and Peugeot Partners / Citroen Berlingo Electrique vans approximately 10 years ago. However, the high price and limited range (approx 50 miles) of these vehicles ensured that even with generous UK Government subsidies of up to £4000 per vehicle[14] , PSA sold only a few hundred units in the UK and within a few years the nickel-cadmium (Ni-Cd) batteries used by these PSA vehicles were effectively banned by EU Directive 2006/66/EC[15].

More recently, Reva has sold more than 950 of its G-Wiz EVs in the UK and more than 2000 units globally[16]. But this vehicle uses lead-acid battery technology that delivers low speed and small range (although a Li-ion version is promised) and it is classified as a quadricycle rather than a car, which means it does not have to comply with car safety standards. The G-Wiz and similar vehicles such as the Aixam Megacity are not necessarily indicative of a strong future for EVs since their success has been driven by one key factor: exemption from the London Congestion Charge.

The renewed global interest in EVs is being driven by improvements in battery technologies that hold out the prospect of EVs with much greater range. The key to this is development of lithium ion (Li-ion) batteries. The first commercial Li-ion batteries were released by Sony in 1990 and the technology has much improved over the last decade, now forming the power source for many of today's electronic devices such as laptops and phones. Li-ion batteries have extremely high energy density (W/kg), which is the factor that dictates vehicle range. Compared to lead-acid batteries, Li-ion are approximately five times as energy dense and even compared to NiMH batteries, such as used in the Prius, Li-ion batteries are approximately 50-80% more energy dense[17].

Li-ion battery prices have dropped in recent years but are currently still too expensive for genuine mass market uptake. The 2008 Department for Business Enterprise and Regulatory Reform (BERR) / Department for Transport (DfT) report 'Investigation into the Scope for the Transport Sector Switch to Electric Vehicles and Plug-in Hybrid Vehicles' (October 2008) estimates that Li-ion prices need to drop by approximately another 50% from today's prices before they will be viable for the mass market. The same report forecasts that costs will drop significantly in the medium to long term but not in the short-term.

One Li-ion EV already on sale in the USA is the Tesla, an EV sports car produced in the USA based on Lotus Elise body. The Tesla has received tremendous publicity over the last few years and has played an important role in reviving global interest in EVs. The Tesla's performance figures are impressive, with top speed of 130mph, 0-60mph acceleration of 3.9 seconds and a range 244 miles per charge[18] . However, its price tag of $109,000 reflects in part the high cost of its Li-ion batteries.

The development of Li-ion batteries and bringing down their production costs is critical for the future of EVs, and almost all volume vehicle manufacturers are involved with research and/or development of Li-ion EV projects. A clear distinction needs to be made between EVs with old battery technology and poor performance sold in small volume by niche manufacturers, and the expectation that major vehicle manufacturers will deliver high performance Li-ion EVs for the volume car market in the short to medium term.

[13] For example, Cenex rates the future of electric vehicles as 'excellent'.
[14] PowerShift database, Energy Saving Trust
[15] ec.europa.eu/environment/waste/batteries/index.htm
[16] www.goingreen.co.uk/store/content/gwiz_faq/#howmany
[17] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles
[18] www.teslamotors.com

2.4 OEMs' EV Plans

A number of OEMs (original equipment manufacturers) have plans to release an EV in the near future. These are outlined below.

2.4.1 Mitsubishi

Mitsubishi is in the final stages of testing EV called the I MiEV[19] which is due to be launched in Japan later in 2009. The I MiEV is based on the exiting 'I', a conventionally fuelled city car. It uses Li-ion batteries supplied by Lithium Energy Japan, a company established by Mitsubishi to ensure a reliable future supply of large capacity Li-ion batteries[20].

Mitsubishi report the I MiEV to have a range of 100 miles and 130km/h (81mph) top speed and that it can be fully recharged in 7 hours from a 200v 15A domestic supply or recharged to 80% capacity in 30 minutes using a 3-phase 200v 50kW fast charge system[21]. The price of the I MiEV has not yet been officially announced.

2.4.2 PSA Peugeot-Citroen

On 8 January 2009 Mitsubishi announced that from 2011 it may start supplying 10,000 I MiEV units per year to PSA Peugeot-Citroen for sale in Europe. The I MiEV would probably be badged as a Peugeot or Citroen for the European market[22].

2.4.3 Renault-Nissan

Renault Nissan has been developing Li-ion batteries since the early 1990s and intends to sell Li-ion EVs in Japan and the USA by 2010 with global roll-out the following year. The company also hopes to become a major supplier of EV battery packs to other vehicle manufactures. Carlos Ghosn (CEO) believes that electric vehicles must be offered in all market sectors to be economically viable, "not just city cars, but minivans, 4X4s - everything[23]".

The Renault-Nissan Alliance has announced electric vehicle initiatives in many countries including Israel, Denmark, Portugal, Japan, France (in partnership with EDF), and the United States.

2.4.4 Ford

In a business plan submission to the US Congress on 2 December 2008, Ford stated that the company will have a market-ready electric van for fleet use by 2010 and an electric car on sale by 2011[24]. It has now been confirmed that the car will be developed in partnership with Magna International using li-ion batteries and will have a range of 100 miles on a single charge. The company will also be developed 'next generation hybrids' including a plug in model[25].

2.4.5 Chrysler

Chrysler's submission to Congress on 4th December 2008 to request emergency financial assistance stated that the company intends to introduce their first full function electric drive model in 2010 and to extend this to additional models by 2013. The same submission also stated that "Chrysler's market penetration of electric-drive vehicles will further increase with over 500,000 units produced by 2013". It should be noted here the electric drive models could include series hybrids (EVs with range-extenders in US terminology) and perhaps other hybrid vehicles[26].

2.4.6 BMW

The car manufacturer BMW have developed a Li-ion all electric version of the Mini, 500 of which are currently available for lease at $850 a month in some areas of the USA. The Mini E uses 5000 Li-ion battery cells, has a

[19] www.mitsubishi-motors.com/special/ev/
[20] stg.mitsubishicars.com/MMNA/jsp/company/theenvironment.do?loc=en-us
[21] www.mitsubishi-motors.com/special/ev/whatis/index.html
[22] uk.reuters.com/article/governmentFilingsNews/idUKT8459920090108
[23] www.greencarcongress.com/vehicle_manufacturers/
[24] media.ford.com/images/10031/Ford_Motor_Company_Business_Plan.pdf
[25] www.ford.com./about-ford/news-announcements/press-releases/press-releases-detail/pr-ford-planning-new-electric-hybrid-29683
[26] www.media.chrysler.com/dcxms/assets/attachments/CommitteeHearing.pdf

top speed of 95mph a range of 150 miles per charge and can be recharged in 2.5 hours. The company state that they hope to produce more Mini E in the future depending on the results of this 'field test'[27]. BMW also claim impressive energy consumption figures for the Mini E of only 0.12kWh/km, based on the US Urban Driving Schedule.

2.4.7 Pininfarina

Pininfarina, the Italian car designer and coachbuilder famed for long running collaborations with manufacturers including Ferrari and Maserati announced a partnership with French industrial group Bolloré to bring a mass production EV to market by the end of 2009. Pininfarina state that the vehicle will use Lithium metal polymer batteries, which the company claims are inherently safer than Li-ion, and that it will have a 125 mile range[28].

2.5 Policy Context

The King Review of Low Carbon Cars (Part I) published in October 2007, reported that EV & PHEVs could make a significant contribution to reducing CO_2 from road transport, the conclusions of which were supported by the Government in November 2008[29].

In October 2008 the UK's Technology Strategy Board announced a five-year £100 million commitment to promote 'greener vehicles'. The announcement variously refers to 'greener vehicles' or 'other low carbon vehicles' but the only technologies mentioned are EV and PHEVs [30]. This was followed on 15th January 2009 by an announcement from transport secretary Geoff Hoon that £250 million, (supplementing an existing £100 million programme for research) was to be committed to "get more ultra low-carbon vehicles on Britain's roads, helping motorists to go green by stimulating consumer uptake and helping to reduce emissions from road transport and improve local air quality".

The Government report into the scope for electric vehicles, in 2008 proposes three scenarios to 2020, which envisage 70,000, 600,000 and 1.2 million EVs respectively. Interestingly the same report sees much less variation in its predictions for PHEVs, with both the low and medium scenario forecasting 200,000 and the high scenario 350,000[31].

In Europe, the German government has announced their aim to achieve 1,000,000 EVs & PHEVs on the road by 2020[32] and the Portuguese Government in partnership with Renault-Nissan has announced that it intends to install 1300 EV charging stations by 2011.[33]

Please see section 4.7 for further information on country specific policies on electric vehicles.

2.6 CO_2 emissions from electric vehicles

The Cenex report to BERR concluded that using the UK's current average grid generation mix EV's already give approximately a 40% reduction in CO_2 emissions compared to comparable conventional fuelled vehicles. However, the authors of the current report believe this figure may be optimistic since it is based on an assumption of 0.16kWh/km. The report cites that in practice the UK's current best selling large electric delivery van consumes approximately 0.5kWh/km. Assuming the vehicle is to be recharged from the UK grid with current average carbon intensity of 525kWh/kWh this gives CO_2 emissions of 263g/km, which is approximately the same or slightly higher than its best selling diesel equivalent the Ford Transit[34].

When comparing CO_2 emissions of EVs to their conventionally fuelled equivalents it is important to give due consideration to the vehicles being compared. For example, a G-Wiz might produce in the region of 75g CO_2/km when recharged from the UK grid (assuming 9kWh drawn from mains per charge, and a range of

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[27] www.miniusa.com/minie-usa/
[28] www.autobloggreen.com/tag/pininfarina+bollore/
[29] HMRC (2007), *The King Review of Low Carbon Cars Part I.*
[30] http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=382426&NewsAreaID=2&NavigatedFromDepartment=False (accessed 10th January 2009)
[31] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles
[32] www.elektromobilitaet2008.de/konferenz
[33] www.greencarcongress.com/2008/11/portugal-and-re.html
[34] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles

40 miles /64km), which is close to a 40% saving from a typical small petrol or diesel car producing 120g/km. However, the G-Wiz is a small two-seater vehicle with a range of 40 miles and top speed of 45mph and is not homologated and therefore does not have to comply with safety standards that would add to vehicle weight. In comparison, a small petrol or diesel car would typically be able to carry five adults, have a range of 300-400 miles, a top speed of around 100mph and would be legally required to meet stringent EU car (M1) safety standards. The Ford Fiesta ECOnetic or the VW Polo Bluemotion are already on sale and produce less than 100gCO_2/km.

Evidence suggests that some of the present CO_2 savings associated with EVs are the result of these vehicles being lighter and having a lower all-round performance than conventionally fuelled vehicles, rather than being due to their fuel per se. However, so long as EVs are used as direct replacements for conventionally fuelled vehicles the opportunity for CO_2 savings still exists and the potential for major carbon savings from future EVs in conjunction with decarbonised electricity generation is high if the UK meets it targets for renewable and low carbon energy generation.

Despite some uncertainty over current carbon savings from EVs, it seems unlikely that this will affect UK policies to promote the vehicles. Furthermore, as outlined above, the global vehicle industry is investing heavily in EVs and appears to believe they will play a major part in the industry's medium to long-term future. However, even fitted with Li-ion batteries, EV ranges will not compare with today's petrol or diesel vehicles which might mean that pure EVs remain predominantly as city cars or second cars for urban families or individuals, where there is likely to be better public transport infrastructure, and the opportunity to walk and cycle short journeys.

Please see section 3.6 for discussion of CO_2 savings and lifecycle emissions in comparison to hybrid electric vehicles.

2.7 Summary

Current electric vehicle owners are likely to have purchased their vehicle from a small scale EV distributor; however EVs from OEMs will soon enter the mainstream market. Coupled with a reduction in the cost of producing li-ion batteries leading to lower vehicle prices, the accessibility and credibility of EVs to the public will increase.

Due to support from UK and global policy makers, uptake of EVs is likely to increase. However, it is important to recognise that EVs are unlikely to act as a direct replacement for currently conventionally fuelled vehicles due to limited range on one charge.

Although significant CO_2 emissions savings can be achieved by EVs, this is partly the result of their lighter weight than conventional vehicles. Once more renewable and low carbon energy is bought on stream to supply the national grid, the potential for decarbonising the transport with electric or hybrid electric vehicles will be greatly increased. It is therefore important that the technology and infrastructure is supported now so that this is ready for the emergence of a low carbon grid. However, it should be noted that the most likely application for electric vehicles is in urban areas where shorter journeys and good public transport infrastructure mean that greater support is needed to promote modal shift towards walking, cycling and public transport.

3 Hybrid vehicles

Toyota launched the Prius, the world's first mass produced Internal combustion engine (ICE)/electric hybrid in Japan more than a decade ago and since then has sold more than a million Prius vehicles. In recent years, however, development of plug-in hybrid electric vehicles has become a key subject of global research and development. The increased all electric range coupled with the ICE as 'back up' is not only a more attractive proposition for drivers but also offers reduced CO_2 emissions through all-electric operation and a smaller ICE. As with EVs, the continued development and lowering of production costs of Li-ion batteries will be a key factor determining their viability for the mass market.

This section explains the workings of the different models of hybrid vehicle and provides a summary of vehicles currently and soon to be available. A consideration of the CO_2 emissions of hybrid electric vehicles (HEVs) and plug in hybrid electric vehicles (PHEVs) in relation to electric vehicles (EVs) and ICE vehicles is presented.

3.1 Overview of the workings of a hybrid vehicle

A hybrid electric vehicle (HEV) in this context refers to one that has both an internal combustion engine (ICE) and an electric motor.

A parallel hybrid is one in which both the ICE and the electric motor can power the wheels. With a series hybrid the ICE is not directly connected to the wheels or transmission but instead powers a generator producing electricity which can either be used to power the electric motor or to charge the vehicle's batteries.

Some hybrid vehicles, including the Toyota Prius, have power split devices which allow operation as either a parallel or series hybrid. The power split device is effectively a gearbox that can allow either one or both the ICE and the electric motor to power the vehicle directly. The power split device can also split the ICE's power so that simultaneously some of its power is being used to drive the wheels and some is used to drive the generator.

In a parallel hybrid vehicle the ICE can be smaller than in a non hybrid equivalent. In a conventional Internal Combustion Engine Vehicle (ICV), the engine is sized according to the maximum power the vehicle will require even though most vehicles only rarely use their maximum power, which decreases a vehicle's efficiency. When a parallel hybrid accelerates, the electric motor assists the ICE giving extra power to the wheels. This allows vehicle designers to specify smaller engines for hybrids, which increases their efficiency compared to non hybrid equivalents even when operating in simple ICE-only mode.

In a series hybrid, because the ICE does not drive the wheels or the transmission directly, engine speed is independent of vehicle speed. The engine can therefore operate at or near its most efficient speed regardless of vehicle speed. If the generator (which is powered by the ICE) produces more power than the electric motor requires, the generator output can be used to charge the batteries.

3.1.1 Plug-in hybrids

At present, none of the hybrid vehicles available in the UK can be recharged by being plugged in to a charging source; their batteries are only charged from the ICE or by regenerative braking, however this capability is expected to be developed by manufacturers in the near future. Plug in HEVs (PHEVs) have the potential to combine the advantages of today's hybrid vehicles, in particular being able to run on petrol or diesel without the range limitations of EVs with EVs' potential for reduced CO_2 emissions.

Plug-in HEVs have upgraded batteries compared with HEVs, giving them greatly extended electric-only ranges of 10 – 50 km compared to current electric only HEVs which ranges vary from zero to 3 - 4km. The benefits of a PHEV would be to offer a practical alternative for short city trips as well as the possibility to drive a greater distance at weekends or for holidays, switching to a similar mode of operation to today's (non plug-in) hybrids.

3.2 Parallel hybrid vehicles

The tables below summarise the range parallel hybrid vehicles by their market availability.

Table 3: Parallel hybrids currently available

Vehicle	Availability	Price (£)	Further information
Toyota Prius T3 Hybrid 	Available now	£18,250	Hybrid petrol/electric motor 104g CO_2/km 65.7mpg
Honda Civic IMA Hybrid 	Available now	£16,300	Hybrid petrol/electric motor 109g CO_2/km 61.4mpg Regenerative braking Switches off when idling
Lexus GS-450h Hybrid 	Available now	£38,508	Hybrid petrol/electric motor 186g CO_2/km 35.9mpg Switches off when idling Not positioned as a 'green' car
Lexus RX-400h Hybrid 4x4 	Available now	£36,393	Hybrid petrol/electric motor 192g CO_2/km 34.9mpg Billed as first hybrid performance SUV
Smart fortwocoupe 	Available now	£7,060	Hybrid petrol/electric motor 103g CO_2/km 60.1mpg

Table 4: Parallel hybrid electric vehicles expected soon

Vehicle	Availability	Price (£)	Drive train	Further information
Lexus LS 600h with V8 hybrid	2009	Unknown	Hybrid petrol/ electric motor	220g CO_2/km 29.7mpg
Lexus Rx 450h	2009	£36,273	Hybrid petrol/ electric motor	192g CO_2/km 34.9mpg
Mercedes S-class hybrid	2009	Approx $US100k	Hybrid petrol/ electric motor	29.8mpg
Kia Motors Rio hybrid	2010	Unknown	Hybrid petrol/ electric motor	126g CO_2/km 53.4mpg
Mercedes E320 Bluetec hybrid	Available in USA	Unknown	Hybrid diesel/ electric motor	
Peugeot Prologue hybrid	Concept – 2011	Unknown	Hybrid diesel/ electric motor	109g CO_2/km
Nissan Altima hybrid	Limited release USA	$25,480	Hybrid petrol/ electric motor	35mpg
BMW X5 hybrid	Concept vehicle	Unknown	Hybrid diesel/ electric motor	172g CO_2/km 43.5mpg Roof mounted solar panels X6 model to follow with 20% reduction in emissions
Vauxhall Corsa hybrid	Concept vehicle	Unknown	Hybrid diesel/ electric motor	99g CO_2/km 75mpg
Audi Q5 hybrid	Concept vehicle	Unknown	Hybrid petrol/ electric motor	
Peugeot 307 hybrid Hdi	Concept vehicle	Unknown	Hybrid petrol/ electric motor	
Toyota Camry hybrid	Concept vehicle	Unknown	Hybrid petrol/ electric motor	

3.3 Series hybrid

Table 5: Series hybrid electric vehicles expected soon

Vehicle	Availability	Price	Drive train	Information
Toyota Plug in hybrid	Concept vehicle: 2010	Unknown	Plug in hybrid electric vehicle	Lithium Ion batteries Approx 4 hours charge time
Chevrolet Volt	2010	Expected: $40,000	Plug in hybrid electric vehicle	40 miles on one charge 3 – 8 hours charge time Lithium Ion batteries
Audi A1 Quattro	2010	Unknown	Plug in hybrid electric vehicle	62 miles at 62mph on one charge 112g CO_2/km 57.6mpg
Hyundai Santa Fe Blue	Concept vehicle	Unknown	Plug in hybrid electric vehicle	148g CO_2/km 38mpg Lithium Polymer batteries
Fisker Karma	2010	$US80k	Plug in hybrid electric vehicle	Lithium Ion batteries Solar panels on roof

3.4 Future of plug in hybrid electric vehicles

Toyota launched the Prius, the world's first mass produced ICE/electric hybrid in Japan more than a decade ago. Since then the company has sold more than a million Prius, bringing the technology to the mainstream[35].

There are now many petrol/electric hybrid models available from volume manufacturers, but with one exception (see below) the hybrid vehicles available today cannot be plugged in and charged from the mains; they are charged by electric motors working as generators. This occurs either during regenerative braking or by a vehicle's internal combustion engine being used to power its electric motor/generator.

As with EVs, the continued development and reduction of production costs of Li-ion batteries will be a key factor determining their viability for the mass market. Most manufacturers' PHEV development projects use Li-ion batteries; however there are differences in EV and PHEV battery requirements. For a PHEV the all-electric range is not as critical since the consequence of exhausting the batteries is reverting to 'normal' hybrid operation. This means that the development of Li-ion batteries for PHEVs focuses on a balance between power density (for acceleration) and energy density (for range), whereas for pure EVs the focus is on maximising energy density.

3.5 OEM plans for PHEVs

3.5.1 BYD Automotive

BYD Automotive is a Chinese vehicle manufacturer and a subsidiary of BYD Company Ltd, the world's second largest manufacturer of mobile phone batteries. The company's aim is to be the world's largest vehicle manufacturer by 2020. In December 2008 BYD Automotive launched the world's first mass produced PHEV to the Chinese market. The vehicle is not currently licensed for sale in either Europe or the USA although it has been widely reported that BYD intends to sell PHEVs in Europe by 2010[36].

[35] www.toyota.co.jp/en/news/08/0515.html
[36] www.autobloggreen.com/2009/01/09/detroit-preview-byds-f3dm-plug-in-hybrid-will-be-unveiled-mond, www.reuters.com/article/innovationNews/idUSTRE48S19B20080929

3.5.2 Toyota

Toyota has already developing PHEV versions of the Prius, although this is not yet in commercial scale production. The vehicle, which has NiMH batteries and an approximate eight mile all-electric range, has been trialled in Japan, France and the UK. The French and UK trials were both run in conjunction with energy supplier EDF[37].

3.5.3 General Motors

General Motors expects to start production of the Chevrolet Volt PHEV car, in late 2010 for sale in 2011[38]. The vehicle will be a series hybrid, meaning its transmission will be driven only by the vehicle's electric motor. Its petrol engine will be used to power a generator which can either power the electric motor or recharge the vehicle's Li-ion batteries. In US nomenclature the Volt is called an EV with a range-extender, sometimes referred to as a ReEV, since the US Society of Automotive Engineers currently defines a hybrid as a vehicle in which two or more sources of power can drive the wheels, but with the Volt only the electric motor powers the wheels.

General Motors is also developing a PHEV called the Saturn Vue, which is expected to be launched in 2009 or 2010. In contrast to the Volt, the Saturn will be a 'blended' hybrid (similar to a Prius) meaning it can operate in a range of different modes to incorporate features of both a parallel and a series hybrid[39].

3.5.4 Ford

Ford is developing a PHEV version of its Escape SUV using Li-ion batteries. In December 2008 Ford's submission to the US Senate Banking Committee (to request $9bn of 'stand-by' credit) stated that the company's line-up would include "PHEV capability for 2012 & beyond"[40].

3.5.5 Chrysler

Chrysler announced in 2006 that it was developing a PHEV car called the Sprinter. The company's submission to the Senate Banking Committee in December 2008 stated that Chrysler's viability plan includes 24 major product launches through 2012, including hybrid electric-drive vehicles within several categories: Neighborhood Electric Vehicles (NEV), City Electric Vehicles (CEV), Range-extended Electric Vehicles (ReEV), and full-function battery electric vehicles. A ReEV in European terminology is a series hybrid PHEV[41].

3.5.6 Volkswagen

Volkswagen are developing a PHEV concept version of the Golf, called the Golf Twin Drive. The vehicle is a parallel hybrid with the ICE connected to the driven wheels by a single high ratio gear. At low speeds therefore it relies entirely on the electric motor, with the ICE engaging to power the wheels above approximately 30mph. Volkswagen have removed the gearbox in order to compensate for some of the additional weight of hybrid systems. The Golf Twin Drive is reported as having an electric-only range of 30 miles[42].

3.5.7 Audi

At the Paris Motor show in October 2008, VW's sister company Audi unveiled a PHEV operating with a different system (including, more conventionally, a transmission to couple ICE to wheels) and a claimed electric only range of 62 miles, however as yet there is no planned launch date for this vehicle[43].

3.5.8 Fisker Karma

The Fisker Karma PHEV sports car, which the company claims to have a 50 mile all-electric range, will be on sale in the USA by the end of 2009[44].

[37] www.thegreencarwebsite.co.uk/blog/index.php/2008/09/10/uk-plug-in-hybrid-trial-between-toyota-and-edf-energy/
[38] media.gm.com/volt/eflex/docs/paper.pdf
[39] www.autobloggreen.com/2008/03/09/calcars-jumps-into-the-gm-toyota-phev-battle-the-winner-is/
[40] media.ford.com/images/10031/Ford_Motor_Company_Business_Plan.pdf
[41] www.media.chrysler.com/dcxms/assets/attachments/CommitteeHearing.pdf
[42] www.motortrend.com/features/auto_news/2008/112_0809_2011_vw_golf_twin_drive_preview/index.html
[43] www.greencarcongress.com/2008/10/audi-introduces.html#more
[44] www.fiskerautomotive.com/

3.6 CO_2 savings from hybrid vehicles

The opportunity for CO_2 savings from hybrid vehicles exists in two areas: all electric operation and reduced fuel consumption, as the ICE in a hybrid vehicle is smaller than that of a conventional vehicle and is capable of running at a higher level of efficiency. As with EVs, achieving the greatest potential for carbon savings from hybrid vehicles relies on decarbonising electricity supplied by the national grid.

A recent report from Carnegie Mellon University in America investigated the impact of battery weight and charging patterns on the economic and environmental benefits of PHEVs. A PHEV with a smaller battery, therefore requiring frequent charging (approximately every 20 miles) using electricity generated through the standard US mix released fewer green house gas (GHG) emissions than hybrid electric vehicles (HEVs) and ICE vehicles are more cost effective. PHEVs with moderate charging requirements (every 20 - 100 miles) also released fewer GHG emissions, but HEVs were cheaper to run. GHG savings were also achieved by a PHEV with a large battery (40+ miles of all electric operation), however these vehicles were not cost effective in any scenario[45].

The report does not take into account CO_2 emissions from manufacture of vehicles, but concludes that policy should focus on promoting small capacity PHEVs for use by urban drivers who will be able to charge frequently.

A 2001 study from Japan compared CO_2 emissions for the full life cycle (manufacture, charging and operation) of an electric vehicle, a hybrid (non-plug in) electric vehicle and an ICE vehicle. This showed that EVs have higher embodied CO_2 emissions through manufacture than either the ICE or HEV. In terms of emissions from use, the HEV achieved significant reductions from the ICE vehicle. The report also highlighted the importance of the source of electricity on the CO_2 emissions of an electric vehicle: the EV charged from coal derived electricity emitted only marginally less CO_2 than the ICE vehicle and more than the HEV. However, an EV charged from fully decarbonised electricity (in this case, from hydro power) achieved CO_2 savings in the region of two thirds in comparison to the ICE vehicle and just under 50% in comparison to the HEV[46].

3.7 Future of PHEVs: Conclusion

It seems clear that PHEVs are likely to play a major part in the future of low carbon vehicles. The authors of this report believe that PHEVs will be far more acceptable than EVs as both fleet and private vehicles, and that sales will outstrip EVs in the medium term since PHEVs are not limited by range. Furthermore, the broad acceptance that already exists of (non plug-in) hybrid vehicles such as the Toyota Prius will make promoting PHEVs a relatively easy proposition for manufacturers.

Although the CO_2 savings that could be achieved from EVs charged using decarbonised electricity are greater, significant savings are also associated with PHEVs, particularly in urban settings. PHEVs should be included in any charging schemes alongside EVs as the vehicles will not only act as a means of introducing EVs to a wider audience, but will also provide support for the expansion of recharging infrastructure.

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[45] Shiau et al (2009), *Impact of battery weight and charging patterns on the economic and environmental benefits of plug-in hybrid vehicles.* Accepted for publication by *Energy Policy* February 2009.

[46] Tahara, Kiyotaka et al (2001), *Comparison of CO2 Emissions from Alternative and Conventional Vehicles*. World Resources Review v.13 n.1, pp. 52-60

4 Electric vehicle charging infrastructure

A review of models of recharging points currently available in the UK focuses on Elektrobay and the Power Tower. Dutch company Epyon's UFC charge is also considered for on street fleet charging. This section considers the financing of electric charging infrastructure and provides a scenario for the density of recharging points needed in London.

In the future, the most common location for charging is likely to continue to be at home, however the availability of a public charging infrastructure will be necessary to ensure widespread adoption of electric vehicles and plug in hybrid electric vehicles. A number of cities have recently announced their intention to install extensive electric charging infrastructure, many in conjunction with the company Better Place who have ambitious plans for battery exchange systems and networks of charging points in Israel, Denmark and Australia.

Electric vehicle charging points are currently publically available in a number of local authorities and shopping centres throughout the UK. There are currently very few companies providing electric charging points. Major differences in products relate to the durability of the technology and data management capability.

4.1 Charging points

Cenex has put great emphasis on the development of recharging infrastructure for the widespread roll out of electric vehicle technology in its recent report to BERR[47]. Recharging networks are gaining increasing publicity in the media, with many countries and cities announcing their intention to install battery charging infrastructure (see section 4.7). The Mayor of London recently established London Electric Vehicle Partnership which aims to increase the use of electric vehicles in the capital[48] and has challenged the electric car industry to develop a battery powered family car[49], therefore electric vehicle are high on the political agenda.

The growth of the market for electric vehicles may be currently being restricted by the availability of charging points. Consumers need confidence in their ability to recharge their vehicles and Cenex states that a degree of underutilisation of recharging points is to be expected as the market develops, however this will be necessary to support the widespread application of battery powered vehicles[50].

4.2 Methods of EV and PHEV recharging

The most common location for charging is currently at home, using a 240v/13 or 16A connection[51]. However, as Cenex state, "for practical and peace of mind reasons the abundance of public charging points will be important"[52]. Electric vehicles and PHEVs can be recharged from standard domestic or work-place electricity circuits, using outdoor weatherproof connectors. A residual current device (RCD) circuit breaker should also be used if one is not already built into the electrical system.

Charge times are dependent on the power that a circuit supplies. A standard circuit in the UK can deliver a maximum of approximately 3600 W (240v x 15A), and depending on the vehicle in question a full charge from such a supply is likely to take in the region of seven hours. Much shorter charge times are possible with dedicated high power charging systems. For example, Mitsubishi state that for their forthcoming I MiEV Li-ion EV (see section 2.4.1) charge times will be 14 hours at 100v; 7 hours at 200v; or 30 minutes for an 80% charge with a fast charge system[53].

Fast chargers produce more heat which reduces the efficiency of fast charge systems and means a cooling system is required. The heat produced by fast charging can also damage batteries. The heat in a battery increases with charge, therefore sophisticated fast charge systems monitor battery temperature and reduce the current once batteries are more than approximately 80% charged. A 'trickle charge' is also used as charging

[47] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles.
[48] www.london.gov.uk/view_press_release.jsp?releaseid=19879
[49] news.bbc.co.uk/1/hi/uk_politics/7760372.stm
[50] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles.
[51] ibid
[52] ibid
[53] mmnastage.cachefly.net/MMNA/green/iMiEV.pdf

nears completion, to allow for 'equalisation', the process that ensures the even the weaker battery cells are fully charged, which increases battery life.

Fast chargers use either inductive or conductive charger-to-vehicle coupling systems. A conductive coupling has a straight forward metal to metal contact that makes a connection through physical contact. Intelligent design of the interface ensures that these metallic contacts are completely covered and inaccessible to the operator whether or not the coupling is attached to a vehicle[54]. An inductive coupling makes use of the electromotive force produced by an electric current and the changing magnetic flux produced by an alternating current. An inductive charging system is effectively a transformer, with the primary winding on the supply side and the secondary winding built in to the vehicle side. The primary winding is built into a device sometimes known as a paddle, which docks into a receptacle on the vehicle side. Both systems are considered safe and convenient[55].

In the late 1990s General Motors (GM) produced an inductive charging system called Magne Charge. GM and Toyota Motor Company agreed on a standard 'small paddle' interface for the Magne Charge that they hoped would become widespread. The two companies installed 323 of these units in California, Georgia and Florida during 2001-3, but in 2002 GM withdrew support for Magne Charge after the California Air Resources Board agreed on a standard conductive charging interface[56].

An alternative for EV recharging is to have battery exchange stations where drivers can exchange their nearly empty batteries for fully charged batteries. Better Place, an organisation founded in 2007, is working in Denmark, Israel and Canada to implement battery exchange stations[57]. Better Place has developed fully automated battery exchange stations, which it compares to an automatic car wash. The Better Place model also envisages a large number of 3kW and 6kW 'trickle charge' points, with standardised conductive couplings, conveniently located next to public parking spaces and in car parks. Drivers would recharge from these when convenient therefore reducing the frequency with which they would need to exchange their batteries (see section 4.6.1 for more information).

There are currently no fast charging stations available for public use in the UK. Reva has just announced the launch of a fast charge unit for the G-Wiz in 2009 (see table 2) and Dutch company Epyon have installed their NRG spot fast charger in Rotterdam (see section 4.5.3).

4.3 The grid & varying demand for charge

The electricity demand on the grid varies at different times of the day during the course of a year, although fluctuations in demand can be predicted to some extent. Widespread uptake of electric vehicle charging would need to be carefully managed to ensure that distribution networks were not put under pressure.

The evening peak generation period is caused by consumers returning home, and it is likely that this would also coincide with the preferred time for recharging electric vehicles and could lead to significant increase in load on the grid. However, this problem could be mitigated by offering preferential electricity tariffs to those who charge their vehicles overnight or at other times of low demand[58].

There are significant price differentials for electricity supplied during the day and night: for example, EDF energy rates for London area in September 2008 were 13p/kWh (excluding VAT) but only 4.9p/kWh (excluding VAT) overnight. This might offer an incentive to vehicles users to charge overnight, however the costs of charging a vehicle are extremely low compared to petrol or diesel vehicles. The off peak mix of electricity is generated by lower carbon sources, for example nuclear and hydropower. Overnight temperatures also improve generating efficiency[59].

[54] Electric Vehicle Battery Systems; Sandeep Dhameja, Published by Newnes, 2002
[55] Ibid.
[56] Letter from General Motors Advanced Technology Vehicles, 15 March 2002; accessed from www.ev1-club.power.net archives on 21 January 2009.
[57] www.betterplace.com
[58] BERR (2008).*Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles.*
[59] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles.

A recent report by Cenex modelled a number of different scenarios for electric vehicle uptake to investigate the potential impact on the national grid. It concluded that there is sufficient generating capacity to cope with uptake, assuming that demand is well managed and that off peak periods with surplus capacity take the majority of the strain. Although local networks that are already close to capacity may be disrupted, the report states that this problem can be overcome by reinforcing the supply to these networks.

4.3.1 Smart metering and vehicle to grid connectivity

Vehicle to grid (V2G) connectivity is the connection between individual homes or charging points, and the national grid. As the grid has little storage capacity, generation and transmission must be continuously managed to meet fluctuating consumer demand for power. Electric vehicles are capable of storing electricity in the vehicle battery, and as they are not in constant use are capable of providing power to the grid while parked. As an EV is already equipped with a grid connection for charging and a sizeable battery, it is suitable for this application. A PHEV is suitable for the same reason, although with a smaller battery.

Another application for V2G connectivity could be regulation, also known as automatic generation control or frequency control. This is used to fine-tune the frequency and voltage of the grid by matching generation to load demand. Regulation is under direct real time control of the network operator and responds within a minute or less by increasing or decreasing the output of the generator[60].

Vehicle to grid technology is not likely to be available in the near future, however could become necessary if the number of electric vehicles registered in the UK increases. There are a number of issues to be resolved before V2G technology becomes a viable option:

- The rate of energy transfer is determined by the connection between the vehicle and the grid, which will usually be 230v, the standard domestic rate;
- The amount of energy available at any one time will depend on the number of vehicles connected to the grid and state of charge in their batteries. Vehicle owners may not be prepared to accept constraints on their vehicle use to guarantee availability of energy;
- Energy providers will need to be fully confident of the availability and consistent reliability of the V2G connection, and vehicle users will need to be confident of having a fully charged battery when they require the vehicle; and
- Increased cycling of batteries in this application could adversely affect battery life.

An alternative to V2G could be vehicle to house (V2H). This would link the car to the house it is parked outside rather than the grid, which would ease some of the issues surrounding transporting electricity back to the grid and the associated demands[61].

4.4 Installing recharging units

4.4.1 Considerations

A number of considerations for installing electric vehicle charging points are listed below. For a more in depth discussion, see the Westminster City Council Report *Installation of two on street recharging points for electric vehicles* (2006).

- Compliance with Westminster City Council's street design guidelines;
- Not adding to 'street clutter';
- Durability of the point, particularly as usage intensifies with the expansion of electric vehicles;
- Continuity and appearance: taking into account the setting of the infrastructure and the need to maintain the council's livery;
- Suitability of the point for use by people with a disability; point must comply with the regulation on the design of buildings and their approaches to meeting the needs of people with a disability: the height of

[60] W.Kempton & J.Tomic (2005). Vehicle to grid power fundamentals: Calculating capacity and net revenue. J. Power Sources, vol. 144, issue 1, pp 280 – 294.

[61] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles.

controls must be of a suitable height and the accessibility of the plinth and parking space must be assured;
- Compatibility with all electric vehicles in use in London;
- Number of vehicles that can be charged simultaneously;
- Charge that unit can deliver;
- Ability to download data from charging point/ other applications of smart metering;
- Durability of post;
- Additional infrastructure required; and
- Design of charging lead.

4.4.2 Location of charging points

A survey carried out on behalf of the South and West London Transport Conference (Sweltrac) asked 108 electric vehicle owners where they charged their car. 68% of respondents charged their car at home, with 45% of those questioned carrying this out overnight. Only 8% used public recharging points, however at the time the survey was carried there were fewer public recharging points in London.

The survey also asked respondents about desirable locations for charging points. The most popular location named was the town centre, followed by home, work and supermarkets. Only 4% listed recharging facilities within station car parks (an option that is sometimes suggested due to proximity to a high voltage electricity supply).

Sweltrac identified the key considerations for choosing the location of a charging point, which are summarised below[62]:

- Will the site impact on congestion and other road users?;
- Is the site easily visible and therefore offers maximum exposure to current and potential EV users?;
- Is the site in an area of potential demand?;
- Is there an existing management structure or central point of contact for the site to assist with management of the recharging point?;
- Is there a link with existing transport infrastructure?;
- What existing street clutter is already in the area?;
- Is an electricity supply available and is the local delivery network capable of supporting recharging?;
- How accessible is the site to main roads and the local area?;
- Is vehicle parking simple?;
- What existing parking control mechanisms are in place?;
- How secure is the location?; and
- Impact on the public: are there any safety implications, in particular relating to the charging cable?

Westminster City Council also identified a number of additional considerations when making final decisions on where to put electric charging points:

- The proximity of bays to bicycle ranks, to link sustainable methods of transport;
- Maximising the visibility of signs with information that electric vehicles are recharging; and
- Busy locations to provide electric vehicles with maximum exposure.

Of the existing charging points installed in the City of Westminster, certain locations receive heavier usage than others, such as Berkeley Square which is a popular charging point. An analysis of the surrounding area to the charging points (for example traffic flow, proximity to other amenities) would be useful to identify features that make a site a popular charging location. This knowledge can then be applied when installing further charging points.

[62] SWELTRAC (2007). Provision of Electric Vehicle Recharging Points Across the SWELTRAC Region.

If the charging point is to be installed on street, then the following process will be followed:

- Identify a suitable kerb space and carry out a safety audit. If this is an existing space rather than a newly created space then the loss of parking revenue must be considered;
- The availability and peak load demands of the electricity supply must be established;
- A Traffic Regulation Order (TRO) must be applied for and advertised;
- Installation of the point will include line painting to mark out the spot, and display of signs; and
- Traffic wardens must be briefed on the procedure for electric vehicle parking.

For off street parking, the issue of location is especially important to consider, as the charging point will not be as visible as on street.

4.4.3 Density of the network

For the purposes of this report it was not possible to find any existing research or best practice guidance on the density of a recharging network needed to support a widespread uptake of electric vehicles. The BERR/Cenex mid range scenario assumes 2.5% of vehicles will be capable of being connected to the grid by 2020. Using the assumptions set out in Table 6: Density of Electric Recharging Points in 2020 below we have estimated the number of charging points that will be needed per square kilometre in Greater London by 2020. Assuming that the existing ratio of recharging points per electric vehicle is maintained, and the existing utilisation rate is the same, the number of recharging points needed per square kilometre by 2020 in London would be 4.3.[63]

There are a number of limitations to this scenario. Firstly, the BERR/Cenex scenario was produced to understand the potential increase in demand for electricity rather than forecast the expected growth in electric vehicles. The BERR/Cenex mid range scenario assumes the continuation of the London congestion charge, and therefore high local demand for HEVs and L class EVs (quadracycles). In addition, this scenario assumes based on current usage that people will continue to charge their cars mainly at home. Charging points are likely to be concentrated in the UK's major cities where they most suit travel needs and where interventions will be centred, therefore the average number of charging points per square kilometre will be greater in urban areas and is also likely to be concentrated in areas most suited to providing re-charging. In addition, this scenario does not take account of the improvements to the range vehicles can travel between charges.

Assumptions used in mid range scenario for take up of electric vehicles	
Number of people with cars which can connect to the grid (2.5% of cars owned by 2020 Cenex/BERR scenario) [64] [65]	119,021.2
Current number of charging points in London 73[66]	73

[63] Area of Greater London square kilometres 1579
[64] Number of people who regularly use cars (63 % of people in London regularly use a car) National Statistics 2000, Regional Trends 37, using National Statistics population of Greater London 2007, 7,556,900
[65] National Statistics 2000, Regional Trends 37

[66] Newride website

Current number of electric vehicles in London[67]	1,278
Current utilization rate of electric charging points (based on usage data provided by Westminster City Council)	29%
Current number of charging points per electric vehicle	0.057121
Number of charging points needed for Cenex/BERR scenario 2020	6,798.5
Number of charging points per square km in London by 2020	4.3

Table 6: Density of Electric Recharging Points in 2020

4.5 Available Recharging Units

In the UK the most popular recharging infrastructure is Elektrobay, manufactured by Elektromotive. In America, Better Place and Coloumb have recently announced ambitious plans to develop recharging infrastructure in California. The infrastructure companies are also starting to manage the wider application of the technology, including the smart metering software, administration and data analysis.

The table below summarises the electric vehicle charging points available for outdoor, municipal use. Other charging points are available, however these are more suited to indoor use by fleet or industrial vehicles (for example, Spie Trindel) and therefore have not been included in this report.

Product	Locations in use	Cost
Elektromotive: Elektrobay	Throughout the UK, local authorities and shopping centres	£6600 installed
Park and Power: Power Tower	Commercial applications in London	Unknown
Charge Point Network (Coloumb)	San Jose	\$1,000 - \$2,000
DBT Borne LRH Libre Service	La Rochelle, France	Unknown
DBT Borne VE de Paris	Paris	Unknown
Epyon	Netherlands	€5,000 plus cost of external UFC unit
REVA Fast Charger	Due to be launched in 2009	Unknown, purchase or lease
Brusa	Unknown	£7,700 fully installed
SGTE Power	Due to be launched in 2009	£1000
Posicharge	Available 2010	Unknown

Table 7: Recharging infrastructure

4.5.1 Elektrobay

Elektrobays are in use by Westminster City Council, as well as throughout the UK in shopping malls managed by Capital Shopping Centres.

4.5.1.1 Features

- Electricity is supplied at 240v through a three pin plug;
- Users are identified by an electronic tag that communicates wirelessly with the charging unit. One recharging is started, the same tag that opened the unit must be used to retrieve the charger;
- An active display panel shows the user's name and vehicle registration number, as well as informing the user of the vehicle's current status;

[67] Department for Transport, March 2005 cited in City of Westminster, December 2006 Installation Two On Street Recharging Points for electric vehicles.

- Recharging points can be custom built for colour or charging requirements;
- A coiled charging lead is provided, reducing trip hazards as the lead uncoils on contact; and
- Bays can be programmed to have a recharging time limit with a 'no-return' function, to promote access and good use of bays[68].

The posts have Power Line Communication (PLC) technology developed by EDF, which allows the bay to 'talk' to the vehicle without the need for additional wires, providing data on billing and power requirements and usage, as well as transaction security and safety. This will not only render Elektrobays suitable for future requirements of vehicle manufacturers and energy suppliers, but also provides valuable information for operating authorities concerning unit usage[69].

Elektromotive will take responsibility for the entire installation, on or off street. For a typical on street installation, the unit is bolted to a galvanised steel foundation post or 'ground anchor', which is then cast in concrete. This results in a mass of about 150kg, reducing the chance of the foundation post being displaced. A wall mounted installation is also possible where the ground surface cannot be disturbed. A feeder pillar may also be required, which allows power to come from a metered supply. This pillar is designed to allow a sign to be displayed, reducing the need for additional street furniture. Six Elektrobays can be powered from one feeder pillar[70].

Figure 1: Elektrobay (picture from www.elektromotive.co.uk)

4.5.2 Power Tower

Park and Power provide the 'Dual Socket Power Tower' and are based in the UK and are installed at a number of private business locations. The company are preparing to launch the 'Version 2 Power Tower' in early 2009.

4.5.2.1 Features

- The charging system is designed to ensure that people with limited mobility can easily insert and remove the plug from the Tower;
- Each post can charge two vehicles simultaneously and does not require a separate feeder pillar. It is also possible to install a post where only shallow foundations are possible.
- The charging point is hidden behind a door. Access to the tower is through a RFID key fob and/or a PIN.
- Each Tower has a Smart Meter. Power use is metered and fed back to Park and Power for billing; data is also accessible remotely. Offering cost-free charging can be configured remotely;
- All the software personnel involved in the preparation of the Park and Power solution are familiar with the 'MISRA' (Motor Industry Software Reliability Association) standards;
- The tower includes an LED screen to display user information and can be customised to fit with a particular branding scheme;
- New members are sent a high visibility coiled power cable with the appropriate plug for their vehicle;

[68] www.elektromotive.com/html/elektrobay_instructions.php
[69] www.sinc.co.uk/news/Elektromotive_talkstocars_15_09_08.pdf
[70] www.elektromotive.co.uk

- Park and Power can organise administration, installation and servicing of the Power Towers.

Figure 2: Power Tower

4.5.3 Epyon

Epyon, a Dutch company originating from the University of Delft, have developed an ultra-fast charging system for use in a public infrastructure, with a particular focus on fleet vehicles.

The system can charge a Lithium-ion battery pack within 6 - 60 minutes. The fast charge unit can be placed on street, up to 50m away from the external ultra fast charge (UFC) unit. The UFC system includes automatic vehicle and battery detection, safety protection and battery life cycle enhancement.

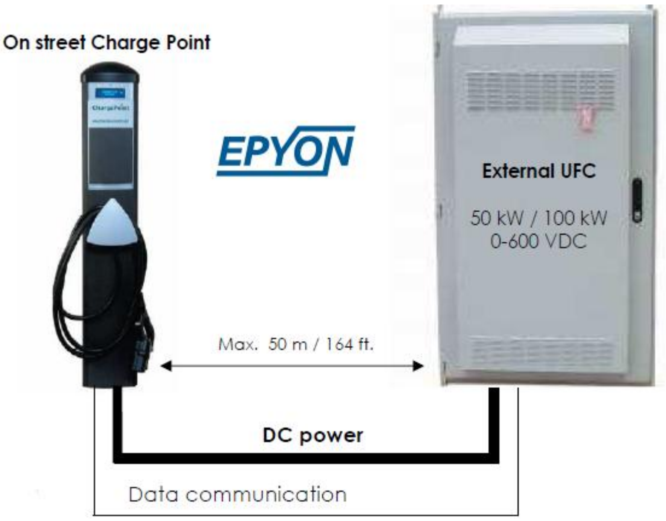

Figure 2: Epyon UFC on street charge point

4.5.3.1 Features

- The post is accessed through automatic vehicle and battery detection, as well as the option of a RFID tag or individual access code;
- Vehicle and battery data from the post are logged. Smart metering and more advanced data logging are being developed. Epyon are able to develop this feature based on customer requests.

Epyon have also installed the NRG Spot electric charging point in Rotterdam, as part of a demonstration project. The UFC system is of interest for fleet vehicles that would benefit from on street charging capabilities, particularly as the main charging unit can be placed up to 50m away from the on street charging post, thereby reducing on street clutter.

4.5.4 Coloumb

An American company, Coloumb technologies, offers the ChargePoint Network; a family of products and services providing a smart charging infrastructure for plug in vehicles. The core technology is the Smartlet

Charging Station, which is available as a pole mounted, wall mounted or bollard unit. The technology is designed for municipalities and parking lot owners, with an operating system providing authentication, usage monitoring and real time control. Users gain access through a subscription and RFID key, which gives access to any Smartlet.

Smartlet charging stations communicate to the server via a Smartlet Communications Network. Up to 100 Smartlet charging stations can be part of a single wireless local area network mesh. This communication mesh dynamically adapts to changing conditions in a real-world environment to ensure that all Smartlet charging stations remain in contact with the ChargePoint Network Server. The company's technology comprises public charging stations, a consumer subscription plan and grid management software for utility companies[71]. Each station will cost between $1,000 and $2,000 to set up[72].

San Jose will see the installation of Smartlets throughout the city by the end of 2008[73] and the company has stated its intentions to build 'dozens' of charging stations across the first quarter of 2009. The stations will be solar powered and will sell electricity for EV charging, as well as ethanol, biodiesel and petrol[74].

Figure 3: Coloumb charge point

4.5.5 DBT

A second company based in France, DBT offer a range of wall mounted and bollard chargers. Most relevant to urban street charging is the 'Borne LRH Libre Service', a metal bollard suitable for outdoor use. Its design integrates well into urban settings, and the bollard is operated by a key or electronic badge. An electronic card allows the vehicle to be recognised, allowing integration into a subscription system. A separate fixture is available to fix the bollard into the ground.

Also suitable for public use is the Borne V.E. bollard, which allows simultaneous charging of up to four vehicles. This unit has an 'electronic banking' function to allow users to pay for their charging time. Given the larger size of the unit, this would be more suitable for a public car park.

71 www.coulombtech.com/products.php
72 news.cnet.com/8301-11128_3-9996353-54.html
73 earth2tech.com/2008/07/22/plug-in-2008-san-jose-partners-with-coulombs-smart-charging
74 earth2tech.com/2008/11/20/holy-electric-vehicle-charging-network-news

Figure 4: Borne VE and Borne LRH

4.5.6 REVA Fast Charger

In January 2009 REVA, the manufacturer of the G-Wiz announced that they will be introducing a fast charge station capable of charging its new lithium-ion battery car to 90% in one hour. The off board station uses three phase power and will be aimed at organisations that require constant vehicle availability during the day. The charger will be available for lease or purchase. Prices and further information will be available later in the year.

4.5.7 Brusa

Maunfactured in Switzerland, the charging point is available with housing that allows coin or access card operation. The charging station offers maximum power of 32A[75]. The post is distributed in the UK by Amberjac Projects and in use by Smith Electric Vehicles.

4.5.8 SGTE Power

SGTE are a French company supply battery chargers cleaning and industrial vehicles but are also developing their knowledge of rapid charging bollards that would be suitable for local community applications[76].

4.5.9 Aerovironment Posicharge

Aerovironment (AV) is a supplier of fast charge systems for industrial electric systems and states that its Posicharge fast charge system will help create the infrastructure necessary for the widespread uptake of electric passenger vehicles. The Posicharge fast charge EV (electric vehicle) system is scheduled for commercial roll out in 2010. The company envisages a network of fast charging systems to allow drivers access to a ten minute charging station.

4.5.10 Other available models

Eaton’s Smart Start Pedestal has been developed for the marine sector and provides charging for electric batteries on boats. The pedestal is activated by the swipe of a credit card. A centrally located kiosk at the marina can control up to 32 units. The user must enter the amount of time they wish to charge the battery for. After this time the pedestal will shut down and not provide any more power. The manufacturers claim that the pedestal prevents ‘transient boaters’ from stealing power and eliminates the need for 24 hour monitoring of slip ways[77].

4.5.11 Custom designed

It may be possible for a council or group of councils to work in partnership to provide custom designed electric charging points, in order to provide a cheaper alternative to what is currently available on the market. We were unable to find any working example of a custom designed product, however as the technology behind electric charging points is relatively simple, in theory this may be possible.

[75] www.brusa.biz
[76] www.sgte-power.com/images/Manuel%20Qualit%C3%A9.pdf
[77] www.eaton.com/EatonCom/Markets/Electrical/Products/ResidentialProducts/MarinaPowerProducts/SmartStartPedestal/index.htm

4.5.12 Software

As stated earlier in this report, smart metering will be involved in future electric vehicle charging networks, to allow monitoring of usage and open up the possibility for V2G connectivity. A number of companies are developing software to enable this, outlined below.

4.5.12.1 V2Green

V2Green is developing 'smart-grid technology' that enables smart charging and V2G services. This would allow utility companies to monitor the flow of electricity to 'grid-aware' vehicles. The software is currently being deployed in pilot projects in America and is not yet commercially available.[78]

4.5.12.2 gridSMART

gridSMART is the 'cornerstone' of American Electric Power's (AEP) future energy delivery systems. The technology will employ smart meters that communicate with data centres to indicate energy usage levels. The company state that they are working with electric vehicle manufacturers to determine rates of adoption and include electric vehicle storage potential in their modelling[79].

4.5.12.3 GridPoint

GridPoint's electric vehicle management system will establish two way power flow between plug-in vehicles and the electricity grid. This will allow utility companies to detect the connection of the vehicle to the grid, but still control the timing and the pace of the charging. The software will also allow V2G connectivity as well as detailed billing and usage management options[80].

GridPoint has recently teamed up with GM to demonstrate their ability to manage plug in vehicle load using a fleet of cars at GM's battery lab, as well as simulated electric vehicle resources. It should also be noted that GridPoint acquired V2Green in September 2008[81].

4.6 New developments

There are a currently a number of projects in development that would see the widespread deployment of electric charging infrastructure, developed through partnerships between vehicle manufacturers, utility companies and infrastructure specialists which would see a managed network of recharging points. Examples are listed below.

4.6.1 Better Place

Better Place is an ambitious venture which aims to install electric vehicle infrastructure networks in a number of countries. Their system consists of charging spots to keep batteries 'topped off with power', and automated roadside 'battery switching stations' to extend driving range. Battery exchange stations will stock all models of batteries available for Better Place compliant cars, ensuring compatibility with all available electric vehicles.

The model also envisages the vehicle batteries being used as distributed storage for clean electricity while charging at home in the evening. Better Place are working on projects with Israel, Denmark, Australia, California and most recently, Hawaii. Israel's situation as a geographically small country, with all major urban centres less than 150km apart means that it is suited to the shorter range of an electric vehicle battery. In December 2008, Better Place Israel demonstrated its first electric car park and charge points[82]. The infrastructure is due to be implemented in 2010.

[78] www.v2green.com
[79] www.aep.com/citizenship/crreport/energy/gridsmart.aspx
[80] www.gridpoint.com/solutions/electricvehiclemanagement/
[81] www.greencarcongress.com/2008/12/gridpoint-and-g.html
[82] www.betterplace.com

Figure 5: Better Place charging point in Israel

Critics of the Better Place model cite the emphasis that the infrastructure model puts on battery exchange which would be expensive to maintain, and could cause damage to the connecting components of the car through repeated severing of the connection between the car and the battery. This has the potential to cause a massive discharge of electricity during exchange. In addition, as fast charging technologies are improving, there may be less need for battery exchange systems. Cenex state that battery exchange could have a role in the early introduction of electric vehicles, as it would give consumers confidence in travelling longer distances by electric vehicle; however it is likely to require some level of battery standardisation and therefore co-operation between battery manufacturers.[83]

4.6.2 Fast charging

Fast charging will enable vehicle batteries to be charged to 80% within 10 minutes and is obviously an attractive proposition for car drivers. The Dutch NRGspot is the only fast charging unit available for public use. If each vehicle requires a 10 minute charge, combined with parking and coupling time, it is likely to take at least 15 minutes per vehicle, which would potentially create long queues of vehicles and still not match the convenience of a conventional filling station. A number of charging points could be installed at one location; however this could put considerable strain on local infrastructure.[84]

Lithium-Ion battery manufacturers Ener1 are developing rapid charging systems with Japanese Energy Company Kyushu Electric Power (KEPCO). A recently signed Memorandum of Understanding (MOU) between the two companies marks states that a rapid charging system will be developed, allowing 80% vehicle battery charge in approximately 20 minutes[85].

4.7 Case studies: electric charging networks and infrastructure

4.7.1 EV Network

Electric vehicle owners with a charging point available at their home register as a member of the website, listing their charging point for use by other members of the website. There are also publicly available charging points available through local authorities and businesses. The network covers most of England with some points in Scotland and Wales. A file to display these data on a car’s satellite navigation system is also available to download from the website[86].

4.7.2 London Boroughs

There are currently electric charging points available in the London Boroughs of Camden, Westminster, Islington, Richmond, Wandsworth and Sutton.

4.7.2.1 City of London

A trial of free of charge parking for electric vehicles has been in place since 2001. As of November 2007 the City had issued 496 free on-street parking permits for electric vehicles and 539 free season tickets for its off-street public car parks. This offer is now being withdrawn and electric vehicle users will have to pay for an

[83] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles
[84] www.greentechmedia.com/articles/electric-car-firms-push-alternative-to-project-better-places-idea-892.html
[85] www.ener1.com
[86] www.ev-network.org.uk

annual car park permit if they wish to drive into the City. The council are concerned that free parking has encouraged car use instead of public transport, walking and cycling, contributing to congested roads[87].

4.7.3 Paris, France

Over the last ten years a network of charging points has been installed by EDF throughout the Île de France. There are 84 charging points throughout the 20 Arrondissements of Paris, located on the street, in underground parking and residential parking areas (only available to residents of that area). A free of charge access card is provided to electric vehicle users. Electric vehicles are also eligible for free parking in their residential area, and qualify for two hours free parking outside of this zone[88].

4.7.4 Capital Shopping Centres

Capital Shopping Centres installed Elektrobay charging points at nine of its shopping centres across the UK in 2009. Vehicle users are not charged for the electricity used, and access keys are freely available from the shopping centre management.

4.7.5 Housing Developments

4.7.5.1 Bright Green Homes, Sheffield

A sustainable housing development in Sheffield has included charging points on site, with all future residents automatically members of car club with access to battery electric vehicles[89]. Photovoltaic installations on two of the residential blocks will supply electricity for communal areas as well as three Elektrobay charging points[90].

4.7.5.2 Clydebank Housing Association

In response to resident concerns about limited parking space and the cost of running a car, Clydebank Housing Association has installed three electric cars and charging points at one development, powered by electricity generated by an onsite CHP plant. The charging points are standard weather proof sockets, rather than a specially designed charging point[91].

4.8 Future infrastructure

4.8.1 Better Place

Better Place are working to install electric vehicle charging infrastructure in Israel, Denmark, Australia, California and Hawaii (see section 4.6.1).

4.8.2 China

In September 2008 the Chinese government announced that the State Grid Corporation, the world's largest electric power transmission and distribution company plans to build electric car charging stations. Located in Shanghai, Beijing, Tianjin and other large cities, the charging stations will initially be built as a pilot project to charge electric buses and sedans[92]. During the Beijing Olympics in 2008, China showcased its charging station network, during which it supplied power to 600 electric vehicles[93].

4.8.3 Berlin

There are two infrastructure projects planned in Berlin. The first; 'e-mobility' is a partnership between Daimler and German Utility Company RWE and will provide over 100 electric vehicles, with RWE handling the installation and operation of a network of 500 charging points. The project is supported by the German government. The first vehicles will be delivered at the end of 2009[94].

In a separate project, BMW will introduce 50 Minis to Berlin in spring 2009 with public access to charging points. The project will be supported by academic research investigating how drivers use the charging points,

[87] www.cityoflondon.gov.uk/Corporation/media_centre/files2008/City+of+London+ends+parking+trail+for+electric+cars.htm
[88] www.espacemobelec.fr
[89] www.yorkshirepost.co.uk/localnews/Green-estate-to-have-electric.3184545.jp
[90] norfolkparkgreenhomes.blogspot.com/search/label/Green%20Features
[91] www.clydebank-ha.org.uk/ecars-clydebank-ha.html and personal communication, 08/12/2008.
[92] www.aib.subdivisions.co.uk/?p=3004
[93] green.yahoo.com/blog/ecogeek/764/china-planning-electric-vehicle-charging-stations.html
[94] www.daimler.com/dccom/0-5-7153-1-1125767-1-0-0-0-0-0-9293-7145-0-0-0-0-0-0-0.html

as well as investigating the possibility of electric vehicles compensating for fluctuations in wind energy supply through intelligent grid management[95].

4.8.4 Ireland

The Irish Government recently set out its plans for the mass deployment of electric vehicles in Ireland. Along with a variety of incentives for the purchase of electric vehicles, a 1 million Euro project will be carried out by Sustainable Energy Ireland (SEI) researching, developing and demonstrating electric vehicles. A National Task Force will also be established to examine infrastructure options for a national roll out of electric vehicles including on street charging[96].

4.8.5 Portugal

In November 2008 the Portuguese government announced they will be installing 320 electric charging stations by the end of 2010, with a further 980 available by the end of 2011. Tax incentives will be provided for the purchase of electric vehicles. A partnership has been announced with the Renault-Nissan alliance to provide the country with electric vehicles by 2011. Although the provider of the charging stations has not yet been announced, there is media speculation that this role will be filled by Better Place[97].

4.8.6 France

Renault and EDF announced in October 2008 that the two companies were forming a partnership to build a network of charging stations across the country. A study will be produced by 2010 which will detail the engineering, regulatory and financial requirements to set up a France wide electric vehicle infrastructure. French President Nicolas Sarkozy also announced a pledge of 400 million Euro to support the development of electric and hybrid cars[98].

4.9 Recommendations for charging points

Elektrobay and Park and Power are the only available charging points in this country, and are the only two systems which it has been possible to find out extensive information about, therefore a detailed comparison has been made of these two products. However, with more time it would be worth pursuing other options, particularly the UFC unit from Epyon due to its fast charging capability for fleets, and the points offered by DBT as these have been extensively used throughout Paris.

Table 8: Comparison of Elektrobay and Power Tower

Feature	Elektrobay	Score	Power Tower	Score
Cost	Two Elektrobays with a feeder pillar costs approximately £13,000 to install	0	The cost of the Tower is expected to be less than the Elektrobay per charging point which will provide charging for two vehicles. A separate feeder pillar is not required.	1
Integration with existing system	Elektrobays are most common public charging point in country and also already in use throughout London.	1	Power Towers have different plug system therefore users would require separate leads for charging point	0
Track record	Successful application throughout the UK, including local authorities	1	No charging points installed with local authorities; successful application with businesses.	0
Plug	Three pin	0	More robust and easier for disabled users	1
Lead	Coiled lead	1	Coiled lead	1

95 www.vattenfall.com/www/vf_com/vf_com/370103press/558539press/index.jsp?pmid=95774
96 www.greenparty.ie/news/latest_news/govt_announces_plans_to_electrify_irish_motoring
97 www.greentechmedia.com/articles/portugal-renault-nissan-set-electric-car-plan-5272.html
98 www.greentechmedia.com/articles/renault-edf-go-electric-in-france-1558.html

Access	With a RFID key	0	With a RFID key and PIN for back up if users lose key	1
Compatibility with electric cars	Charging lead compatible with all electric cars currently available	1	Charging lead compatible with all electric cars currently available	1
Aesthetics/ customisation	Has successfully been customised to fit in with street design guidelines	1	The shape of the Tower is easily modified and specific colours and branding can be applied.	0
Ongoing costs and maintenance	Each post requires a twice yearly service at a cost of £96 a time, performed by Elektrobay. Elektromotive will also manage administrative tasks, for £6,000 per year.	1	Park and Power will carry out service checks and manage relationship with users. Costs unknown.	0
Smart metering	Data can be downloaded from the charging points.	0	Data can be accessed remotely, both by Park and Power and users.	1
Total		6		6

As can be seen from table 7, the main advantage of the Elektrobay is that the technology is proven and has been successfully deployed throughout the UK and is currently subsided by EDF. Introducing a new charging point would require users to carry two separate charging leads. However, the Power Tower offers increased functionality, costs half as much per charging point and does not require a separate feed pillar. As yet the Power Tower has only been proven in private car parks not for on-street use.

It is recommended that the possibility of installing Power Towers be explored by London boroughs that do not currently have Elektrobays installed, as there is little incentive for Westminster City Council to install charging points that are not compatible with existing charging leads.

For simplicity, it is recommended that the same brand of charging point is used throughout a borough, so that users only need to carry one charging lead.

4.10 Covering the cost

4.10.1 Costs

- Maintenance: Westminster City Council report that the charging points have required little maintenance. Elektromotive service the Elektrobays twice a year and issue a safety certificate, for a charge of £96 per service. The Sweltrac report of 2007 estimates an additional £200 for annual maintenance[99]. This is a total maintenance cost of around £400 per year.
- Administration of membership and access: tasks include sending out welcome packs, distributing leads and access cards and renewing membership. Elektromotive run the administration programme for most of their charging points at a cost to the Local Authority of £6,000 per year. This is a capped fee and would not increase in line with the number of charging points, unless the network of points or membership was to rapidly increase. This cost has been used as indicative for other charging points.
- Publicity: It is necessary to promote the location of the charging points and any membership schemes.

[99] SWELTRAC (2007). Provision of Electric Vehicle Recharging Points Across the SWELTRAC Region

The following table was developed by SWELTRAC and has been updated with the costs identified in this report.

	Elektrobay	Power Tower	On going costs
Charging point supply and installation (for two charging points)	£13,000	£5,000	
Signage/line painting	£500	£500	
Traffic order	£500	£500	
Feeder and pillar installation	£600	£0	
Connection to grid	£200	£200	
Annual safety check			£200
Maintenance			£200
Power usage based on 7p per KW			
5% use			£132
10% use			£264
15% use			£396
20% use			£528
Total	**£14,800**	**£6,200**	**Between £432 - £828**

Table 9: Cost comparison of Elektrobay and Power Tower

4.10.2 Available funding

There are a number of options for financing the development of charging infrastructure, such as grant or partnership funding, membership fees and using the local planning system.

4.10.2.1 Cenex Infrastructure Grant Programme

The original Cenex Infrastructure Grant Programme ran from 2005 – 2008 and funded the installation of 74 electric vehicle recharging points. The programme is currently suspended for negotiations over state aid and plans to be open for applications in early 2009. The programme will consist of application windows lasting 4 – 6 weeks of which there are likely to be three a year for next three years. £1,500,000 is available over three years, and 40% will be available towards the cost of installing charging points.

4.10.2.2 EDF

EDF and Elektromotive are working in partnership to provide Elektrobay charging points to local authorities. EDF will provide 60% of the funding towards a charging point. There is funding available for 250 charging points, of which 70 have already been agreed. The funding is available on a rolling basis.

4.10.2.3 Low Carbon Vehicle Integrated Delivery Programme

The Low Carbon Vehicles Innovation Platform was launched in 2007 and in October 2008, the Technology Strategy Board (TSB) announced a £200 million investment programme to speed up the introduction of low carbon vehicles in the UK. Funding will be available from 2009 and aims to integrate university and industry research to encourage the exploitation of more radical approaches. Initially only ‘vehicle-centric technologies and applications’ will be covered.

The TSB will also work with the Energy Technologies Institute to develop a second wave of low carbon vehicle demonstration activity, which will focus on understanding the requirements of the recharging infrastructure[100].

[100] www.innovateuk.org

4.10.2.4 Charging for electricity

There are currently no public charging points that charge for the electricity used during vehicle recharging, on a per charge basis. It would be possible to charge for individual electricity use, providing the recharging point had an in built metering system. Individual users would be identified by their access key and could be billed at regular intervals. To ease grid load, variable tariffs could be offered with preferential rates for those charging over night, much as mobile telephone tariffs are arranged.

For the last quarter that usage data is available for Westminster City Council's recharging points (August to October 2008), the electricity used was 3.6MW for the 11 points in operation. This is an increase on the previous quarter, however for the purposes of this calculation will be taken as representative. At this level, a year's electricity usage would be 14.4MW. Depending on the cost of electricity, the annual cost of this would be as follows:

- Electricity at daytime price of 15p/kWh: £7,200/year
- Electricity at overnight price of 6p/kWh: £2,880/year

Westminster City Council currently has 160 members paying £75 a year each for use of the electric charging points, which raises £12,000. This covers more than the cost of current electricity usage. However, it is not known whether this covers the cost to the council of managing the system.

4.10.2.5 Membership fees

Most local authorities providing an electric car recharging system charge a membership fee which allows unlimited access to the recharging points. Sample costs are listed in the table below:

Local Authority	Annual membership fee
Camden	£50
Hammersmith and Fulham	£100 for first year, £25 thereafter
Islington	£67 for first year, £17 thereafter
Richmond	£100 for first year, £25 thereafter
Sutton	£100 for first year, £25 thereafter
Wandsworth	£100 for first year, £25 thereafter
Westminster	£75

Table 10: Electric vehicle charging membership fees

The advantage of charging for electricity use through membership fees is that an upfront fee is received and can be included in budgets. As more electric vehicle users sign up to the scheme, it would be possible to offer variable tariffs depending on usage levels and the time of day that charging is carried out. This would be possible to achieve through smart metering as individual users are indentified by a PIN or RFID chip, the charging point would be able to 'lock out' a user on an off-peak tariff at certain times, or charge a premium for charging outside of the terms of the tariff. This model is used for mobile telephone contracts.

4.10.2.6 Planning gain

Cenex has recently produced draft guidance concerning the use of the planning system to reduce transport emissions. The primary aim of 'Low Emission Strategies' is to provide a package of measures to help mitigate the transport impacts of a development. The primary aim is to accelerate the uptake of low emission fuels and technologies in and around new developments, which could of course include electric vehicle infrastructure. The report suggests that an approach for mitigating the impacts of transport emissions from development is to require contributions to a central low emission fund.

Planning Policy Statement 23 (PPS23) outlines the statutory basis for applying a combination of planning conditions and legal obligations to address the environmental impacts of proposed developments. 'Section 106 agreements can be used to improve air quality, make other environmental improvements or offset the subsequent environmental impact of a proposed development[101]'. The developer is expected to make all reasonable efforts to reduce the emissions impact of proposed development. For all developments over a set threshold it is practical to request a standardised contribution, to contribute to a general fund for low emission projects and related activities. Greenwich council has developed the 'Greenwich formula' for low emission funding, which is detailed below:

> "Contributions will be sought for all residential schemes of 10 dwellings and above, and mixed use and commercial schemes of 500 m2 and above. A standard contribution will be sought of £100 per dwelling for residential development and £10 per m2 for town centre and commercial developments[102]".

Greenwich Council has raised approximately £1.5 million from planning gain towards infrastructure to support its air quality strategy[103].

4.10.2.7 Regulated assets

Cenex suggest that electric charging infrastructure could be designed as a regulated asset, as with water and power networks. This would typically enable the service provider to cover installation and operating costs, and achieve adequate return on investment[104].

4.10.2.8 Local Implementation Plan (LIP) funding

The Mayor of London has committed to funding 100 electric vehicle charging points by 2012 through Local Implementation Plan settlements, and a further 75 will be funded by TfL through the 2009/10 LIPs settlement[105].

4.11 Net present value analysis

Net present value analysis has been carried out for Eletrobay charging points, using a discount factor of 3.5% (taken as standard for the public sector). This analysis takes into account the capital investment costs, operational and maintenance costs, income from grants and membership charges. The present value is calculated at the end of each year and over the defined period of ten years the net present value can be calculated.

At present Elektrobay charging points are eligible for 100% grant fund from EDF and Cenex. Park and Power are eligible for the 40% grant from Cenex, however the cost of a Park and Power charging point is £5,000 for a unit with two charging points; less than half the price of an Elektrobay charging point.

The analysis has been carried out based on the installation of ten additional points and two different scenarios: one consisting of the same number of members and the other based on an increase in members which is proportionate to the current number of users per charging point.

Assumptions	10 charging points (BAU)	10 charging points (141 additional users)
Cost of two installed points	£13,000	£13,000
Connection cost	£200	£200
Feeder pillar and installation	£600	£600
Safety check (annual)	£96	£96
Maintenance costs (Sweltrac) and safety check	£400	£400

[101] PPS 23 Annex 1: Pollution Control, Air and Water Quality (2001, paragraph 1.50).
[102] Beacons Low Emission Strategy Group (2008: draft consultation document), *Low Emissions Strategies: Using the planning system to reduce transport emissions.*
[103] Personal Communication, Cenex London Information day, 05/12/2008.
[104] BERR (2008).*Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles*.
[105] www.london.gov.uk/electricvehicles/benefits/pressreleases/10032009.jsp

Cost of electricity from BERR (£/kWh) * 3.6MW used over 82 days divided by 11 points	£0.112310	£0.112310
Average electricity consumption per person per year (based on data from Westminster City Council)	90	90
Registration with juice point, one year	£75	£75
Number of people registered	170	311
60% EDF capital cost grant	£7800	£7800
40% Cenex capital cost grant	£5200	£5200

Table 11: Assumptions used for Elektrobay NPV analysis

		10 charging points BAU users (£)			10 charging points, additional users (£)		
Year	**Disc. Factor**	**Disc. Outgoing**	**Disc. Incoming**	**NPV**	**Disc. Outgoing**	**Disc. Incoming**	**NPV**
0	1.00	67,000.00	67,000.00	0.00	67,000.00	67,000.00	0.00
1	1.04	2,781.01	12,318.84	9,537.83	4,158.03	22,536.23	18,378.21
2	1.07	2,686.96	11,902.26	18,753.13	4,017.42	21,774.14	36,134.93
3	1.11	2,596.10	11,499.77	27,656.80	3,881.56	21,037.81	53,291.18
4	1.15	2,508.31	11,110.89	36,259.38	3,750.30	20,326.39	69,867.27
5	1.19	2,423.49	10,735.16	44,571.05	3,623.48	19,639.02	85,882.81
6	1.23	2,341.53	10,372.13	52,601.65	3,500.95	18,974.90	101,356.77
7	1.27	2,262.35	10,021.38	60,360.68	3,382.56	18,333.24	116,307.45
8	1.32	2,185.85	9,682.50	67,857.33	3,268.17	17,713.27	130,752.55
9	1.36	2,111.93	9,355.07	75,100.47	3,157.65	17,114.27	144,709.18
10	1.41	2,040.51	9,038.71	82,098.68	3,050.87	16,535.53	158,193.83

Table 12: NPV analysis Elektrobay

4.12 Summary of electric vehicle charging infrastructure

As stated earlier in this chapter, there is little to differentiate the two main charging points available in the UK. For those local authorities already operating an electric vehicle charging network, it is easiest to expand the network using same brand of point as is already installed to ensure compatibility. Alternatively, pressure could be put on manufacturers to produce a standardised charging lead that could be used by different charging points.

The plans for charging networks emerging both in America and the wider world (through Better Place) offer more than just a charging point: software, standardisation of technology and the creation of a network to support widespread electric vehicle use on offer. This 'joined up' approach will facilitate widespread uptake of electric vehicles through ease of use for electric vehicle owners.

It is therefore of critical importance to the increased uptake of electric vehicles that local authorities, both within London, the UK and possibly Europe maintain communication and knowledge sharing in relation to their plans to install electric vehicle charging infrastructure. Standardised leads, access and the ability for users to find charging points should be co-ordinated, particularly in the early stages of the development of an electric vehicle charging network, to make the process of running an electric vehicle as simple as possible.

A scenario for the density of the electric vehicle network needed found that approximately 4 charging points per square kilometre would be needed in Greater London by 2020 based on maintaining the current ratio of charging points to electric vehicles in London and an adoption of 2.5% of all cars being capable of connecting to an electricity supply.

5 Renewable and low carbon energy

This section sets out the options for reducing CO_2 emissions associated with electricity use, which have important implications for the local authority targets to reduce borough wide carbon emissions under the new set of National Indicators for climate change. Green tariffs and offset schemes offer limited prospects, however local low carbon and renewable energy technologies could help to mitigate this impact whilst also raising awareness among residents of the boroughs.

5.1 Green tariffs

Since the introduction of the renewables obligation (RO), the UK's electricity suppliers have been obliged to meet an increasing proportion of the electricity they supply from renewable sources. For each unit of renewable electricity generated, suppliers are eligible to claim renewable obligation certificates (ROCs) which can be retained as evidence of the supplier's own compliance with the RO or traded to another supplier who can use it as evidence that they have sourced a sufficient proportion of their electricity from renewable sources.

One consequence of this is that green tariffs in the UK are now almost entirely based on the sale of renewable electricity which suppliers have been mandated to sell. It is for this reason green tariffs are often marketed as being cost-neutral as the electricity suppliers don't have to do anything more to supply new green tariff customers so there are no additional costs. There is a very small voluntary market with more expensive tariffs, in these cases a proportion of the ROCs are claimed but never redeemed which limits supply of ROCs, raising their value. At present, there are no green tariffs which retire all their ROCs which is the only way for a green tariff to have a genuine claim to being zero carbon. Green electricity companies such as Good Energy and Ecotricity sell ROCs to major suppliers that have a shortfall in their share of renewable generation; this means that they are contributing to the obligatory share of the overall electricity market which is to be met from renewable sources (as described above).

Current Defra guidance on company reporting of greenhouse gas emissions[106] recommends using the UK grid average electricity figure for green tariff sourced electricity since the situation described above "means that existing evidence suggests that green tariffs deliver insignificant additional carbon savings from renewable energy". Their guidance also suggests that company reporting could add a footnote stating electricity is purchased on green tariffs in order to demonstrate environmental commitment. In the context of electric vehicle charging points, a similar statement could be put on the charging point below the instructions. There is a weak case for saying that choosing a green tariff will demonstrate consumer demand for renewable energy although this will not contribute significantly to the more rapid take-up of renewable energy.

5.1.1 Offsetting

A joint statement on offsetting carbon emissions published in 2006 by Friends of the Earth, Greenpeace and WWF (UK) stated that "there are strong concerns over the environmental credibility of the credits and the contribution of the projects to sustainable development."[107] They recommend that if greenhouse gas emissions are truly unavoidable, offsetting projects which comply with the industry Gold Standard[108], although since this has statement was issued, others have questioned the scale and certainty of emissions reductions claimed by even these activities.

An alternative offsetting route is to purchase ROCs or EU emissions trading scheme (ETS) permits and retire them. This has its risks, particularly with EU ETS which issued an excessive number of permits for the first phase which led to a complete collapse of the price of credits. Since the failure of the first phase, changes have been made to the allocation of permits for the second phase which appear to have resolved the problems associated with the first phase. Purchasing ROCs to cut emissions is a very expensive means of offsetting emissions (although it could be argued it has the advantages of transparency and a close link to UK electricity which is the commodity being discussed here).

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[106] Guidelines to Defra's Greenhouse Gas Conversion Factors for Company Reporting, June 2008 www.defra.gov.uk/environment/business/envrp/pdf/ghg-cf-guidelines2008.pdf

[107] A joint statement on offsetting carbon emissions, FoE, Greenpeace, WWF, 2006. www.foe.co.uk/resource/briefings/carbon_offsetting.pdf

[108] www.cdmgoldstandard.org, a best practice methodology and a high quality carbon credit label for both Kyoto and voluntary markets.

5.1.2 CO_2 impact

As discussed in section 5.1, green tariffs offer no assured CO_2 reductions relative to conventional electricity supplies. Offsetting emissions is a very uncertain area; there are two primary routes that could be taken.

The first is investing in projects which aim to improve energy efficiency or install renewable electricity. These offer very uncertain emissions benefits, even if there are clear emissions savings resulting from the project, it may never be clear that the scheme was only possible due to the investment from carbon offsetting.

The second is purchasing and retiring tradable certificates, either for a scheme such as the EU ETS or ROCs. This should offer greater certainty of reductions, the ETS appears to have resolved the problems which led to the failure of the first phase and is now an established mechanism for reducing emissions. ROC retirement offers emissions reductions by leading to greater supply of renewable electricity in the UK and hence, in spite of the higher costs, may be considered preferable for offsetting the emissions from supplying electricity in the UK.

5.1.3 Effect on costs

5.1.3.1 Per charging point

Option	Cost impact (per year)	CO_2 impact
Purchasing Electricity on Green Tariffs	None	None
Purchasing offsets (emissions reductions made by an external body on your behalf)	Max/High/Typical: £130/£89/£38	Uncertain (see section 5.1.1).
Retiring ETS Credits or ROCs	Max/High/Typical: ETS[109]: £207/£143/£61 ROCs[110]: £1438/£988/£425	Relatively certain levels of reduction, for ETS credits, one tonne should be saved per credit retired. For ROCs, the CO_2 savings are dependent on the CO_2 intensity of grid electricity (latest Defra figure is 0.537 kg/kWh)

Table 13: The cost of offset scheme per year, using three scenarios

As this table shows, the costs of offsets and other alternatives vary tremendously.

In these cases, the level of emissions has been assessed against three scenarios, Max, High and Typical.

- Maximum usage equates to a constant power supply at the maximum rated output of an Elektrobay charging point, 3.2 kW
- High assumes constant charging of G Wiz electric vehicles at a rate of 2.2 kW (the requirements of the G Wiz)
- Typical assumes that all vehicles charged are G Wiz cars and that the time spent charging is the average observed by Elektrobay across 11 charging points in London (10 hours per day).

5.1.3.2 Per subscriber

The overall energy consumption of the existing charging points, allocated equally among all the subscribers comes to 101 kWh per year. In order to account for the CO_2 emitted by the charging network on a per subscriber basis, any of the three options outlined above could be offered to registering customers at a maximum cost of just over £5. Provided the data is available to the charging point operator, subscribers could pay for their individual usage of the charging points. In this way, subscribers would be taking direct responsibility for the emissions for which they are responsible, rather than a scheme wide average. Alternatively, given the modest ‘per subscriber’ cost, it could be absorbed into the subscription fee with the amount of energy used by each subscriber and the corresponding emissions being communicated to subscribers electronically.

[109] Costs based on spot price for EU ETA allowances, source: www.pointcarbon.com accessed 16/12/2008
[110] Costs are the average price paid for ROCs at auction administered by the NFPA on the 9th October 2008, www.e-roc.co.uk/trackrecord.htm

Assuming all subscribers drive a G Wiz and drive 8,870 miles per year (the average distance travelled by cars in the UK), the costs would be higher – between £8 for purchasing offsets and £91 for retiring ROCs to account for the annual emissions of the vehicle.

5.2 Generating electricity locally to supply charging points

Generating a low carbon electricity supply within the borough would help to reduce per capita CO_2 emissions recorded for performance on NI186. Three technology options have been studied for the generation of electricity at or near the charging points to meet the energy needs. These are solar photovoltaic panels, small scale wind turbines and combined heat and power (CHP). With the exception of biomass CHP, (which has not been considered due to concerns regarding air quality issues in Central London) wind and solar are the only electricity generating renewable identified in the London Renewables Toolkit. CHP is an important technology which offers significant fuel efficiency advantages over conventional, remotely sited large thermal power stations through the use of the heat generated.

The amount of energy needed for a charging point has been calculated based on the number of charges per point per day assuming that each charge is for a G Wiz lasting the average charging duration of 2.75 hours. This gives an annual electricity demand for each charging point of 8,281 kWh. The amount of each kind of technology required to run a charging point has been investigated and the results can be seen below.

Technology	Capacity required to supply one charging point	Cost to install this capacity	Notes
Solar PV	10.35 kWp	£50,000	A capacity of 10 kWp would require a panel area of approximately 80 m^2.
Wind	4.14 kW	£17,500	These calculations are based on a Proven 6 kW turbine at an average wind speed of 5 m/s. One turbine could supply 1.45 charging stations under these conditions.
CHP	1.23 kW	£2,200	CHP will be done at substantially greater scale. The council may be able to purchase excess electricity from a CHP scheme in the area and use this to supply charging points. This may prove more valuable than selling the electricity to a third party.

Table 14: Renewable energy options and costs

5.2.1 CHP viability

Carbon Descent carried out a large scale CHP pilot site identification study in 2007 for the borough of Camden to identify clusters where CHP could be most effectively introduced. Should this lead to the introduction of a CHP network, local charging points could be supplied by this network. Clusters 3, 5 and 9 from the map in figure 8 were found to be the most promising as part of this work.

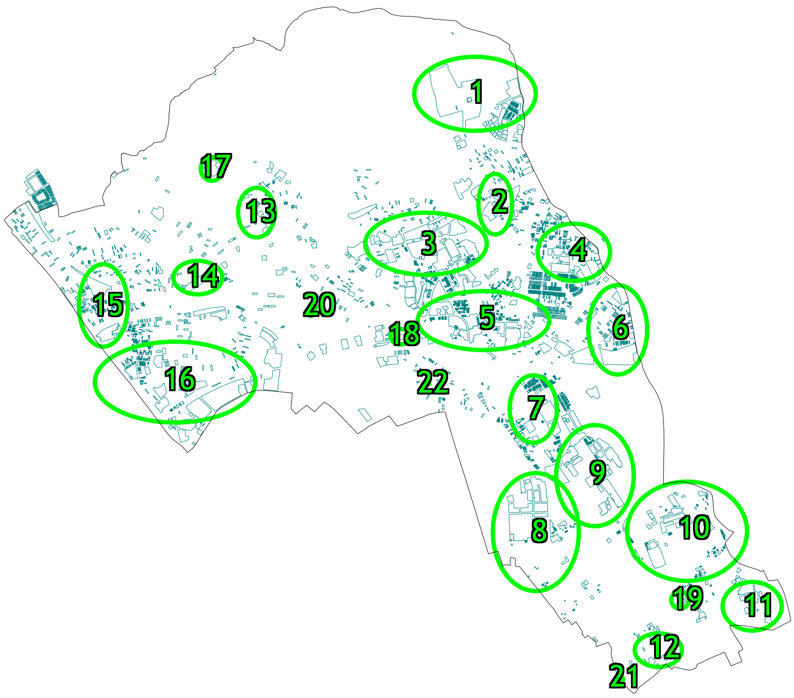

Figure 6: CHP pilot site identification in Camden

5.2.2 Showcase renewable charging point

It is clear from the results of the table that it would not be practical to power a charging point entirely using an integrated solar panel because the panel area required is very large. Because charging points will be in turbulent airflows at ground level, typically in street canyons, integrating wind power is also unlikely to be a viable option. Seemingly, the most likely option for integrating renewable energy generation into a flagship charging point would be for a small solar panel making a modest contribution of only a few percent to the overall requirements of the charging point (one square metre of panel would contribute 1.2% of a charging point's electricity demand). If this kind of showcase option is considered, it should have a large visible display showing the amount of energy generated and informing users of the saving compared to conventional fossil fuels (in terms of grid electricity, transport fuels or both).

One option may be to identify a multi storey car-park which could have solar panels fitted to the roof which would provide electricity to a charging point within. The panel area required for a single charging point equates to the area of around seven parking spaces. It may be possible to fit a shed roof to the entire upper storey with solar panels mounted on top of this structure. An additional benefit of this kind of approach would be reduced potential for vandalism compared to panels installed at street level. A multi-storey car park was built along these lines (new-build not retrofitted) in Freiburg, Germany in 2000[111].

Since integrated renewable energy is not a feasible option and the cost of supplying energy via a green tariff or otherwise offsetting emissions is negligible, one alternative for using electric vehicle charging points for the promotion of sustainable energy would be to contribute a proportion of subscribers' fees to local renewable energy installations, either in the form of grants or interest free loans, or through installation of renewable energy on council owned sites. It may be appropriate to install off-site renewable/CHP generation at a rate which covers the demand of any new charging points which are installed. This would provide a genuine carbon offset scheme for residents whilst also raising awareness of the need to avoid unnecessary private car travel.

[111] Solargarage Vauban Project Summary. www.pvdatabase.org/projects_view_details.php?ID=313

6 Fleet vehicles

Fleet vehicles offer great potential for accelerating the uptake of electric and hybrid vehicles as the most important considerations are those of reliability and cost rather than image. Fleet vehicles also offer the potential to introduce new technologies to a larger market. As company car tax is linked to vehicle excise duty (VED), based on the CO_2 output of the car, with further discounts for electric and hybrid vehicles, a strong incentive exists for the purchase of such technologies for fleet vehicles.

A summary of hybrid and electric buses and taxis already in operation is presented, along with a consideration of the impact of currently policy on the uptake of these technologies.

6.1 Fleet managers

Fleet managers are often considered 'early adopter' consumers because reliability, cost and maintenance are higher priorities than image and there is a great sensitivity to financial incentives. Fleet managers therefore have a significant role to play in the early stages of market development. Company cars are also suitable as a 'testing ground' for new vehicles, as it gives consumers the opportunity to test vehicles without having to purchase technology they may view as unproven.

The main obstacle for fleet managers in adopting new technology is the issue of reliability. It is often necessary to be tied into a three to four year contract, meaning that future market developments have to be predicted (for example future resale value). A fleet manager cannot risk having unproven vehicles, or technologies that do not have the sufficient expertise to be easily managed[112].

6.1.1 Suitability of electric or hybrid electric vehicles for fleet vehicles

- There are a number of reasons supporting the use of electric or hybrid electric vehicles as part of a fleet:
  - Low carbon vehicles can be tested and monitored;
  - Demonstrating leadership by the company involved and helps increase the visibility of low carbon vehicles;
  - Specialist refuelling infrastructure can be implemented at the fleets depot or company car park; and
  - Fleet fuel costs will be reduced.
- However, there are a number of potential barriers to use of these vehicles:
  - If vehicles are also for personal use by employees, then a solution for how these vehicles will be charged when not on company premises is necessary; and
  - If fleet vehicles are required to travel long distances, then fully electric vehicles may not be suitable.

6.1.2 Company car tax

If an individual earns more than £8500 a year and uses a company car for private purposes, then it is necessary to pay company car tax which is currently graduated to favour low CO_2 emitting vehicles[113]. In 1999 when company car tax was reformed to incentivise lower CO_2 emitting vehicles there was a sharp increase in diesel vehicles being purchased for company car use[114]. The maximum tax rate payable on any car is 35% and an electric car has the lowest taxable rate of 9%. A hybrid vehicle has a discount of 2% on its tax rate (determined by its CO_2 emissions). The lowest emitting hybrids fall into the lowest tax band of 10%, therefore would be charged at a rate of 8%[115].

Research by the Low Carbon Vehicle Partnership (2005) states that fleet managers are responsive to pressure from employees, and therefore are able to influence fleet managers' purchasing. Recent research shows that company car drivers understand the benefits of driving a low CO_2 emitting car and 87% of such drivers

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112 B. Lane. Car *Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars.* Low Carbon Vehicle Partnership, (2005).

113 B. Lane. *Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars*. Low Carbon Vehicle Partnership, (2005).

114 B. Lane. Car *Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars.* Low Carbon Vehicle Partnership, (2005).

115 www.vcacarfueldata.org.uk/search/companyCarTaxSearch.asp

surveyed for Leasedrive Velo stated that CO_2 emissions would influence their next choice of company car. 10% said they would opt for a hybrid car, and 1% electric[116].

6.1.3 Congestion charge

A fleet of ten or more vehicles can be registered with the London Congestion Charge as part of an account which can be made up of chargeable and non chargeable vehicles. For a charge of £10 a year per vehicle, electric vehicles can be registered for a 100% discount. Vehicles on the Power Shift register[117] are also eligible for this discount. Based on 200 visits per vehicle per annum, an eligible vehicle could save £1400 a year in congestion charge costs.

6.1.4 Employee incentives

- A number of incentives can be provided to encourage employees to choose a low emitting vehicle for their company car:
  - Provide employees who opt for a more fuel efficient car with additional extras in their car, for example alloy wheels;
  - Provide preferential car parking spaces for those who drive lower emitting cars; and
  - Restrict the choice of company cars to those with lower emissions.

6.1.5 Case studies

Honda's Civic hybrid is currently in use with a number of UK companies, including British Airways and Ikea. British Airways purchased 100 such vehicles in 2008 and claim to have reduced their car fleet's carbon dioxide emissions by one third[118].

6.2 Electric buses

Electric buses are typically used in inner city routes where there is a need to improve local air quality and reduce traffic noise. Electric buses have been operated since 1996 in Uppsala and are used in a number of Italian towns, including Rome, where a fleet of 42 electric buses are in operation.

Buses are available in two forms. Trolley buses are powered by overhead electrical wires, which rotate motors to propel the vehicle. There may also be batteries or a small diesel engine for use when the electric 'booms' are not in contact[119]. The vehicles are similar to trams but do not need rails to run. However, overhead wires are often seen as aesthetically undesirable. The second form is a battery powered bus, where motive power is provided by a battery pack.

6.2.1 Case study: Liverpool

With funding achieved through the Jupiter-2 European Project, six electric Tecnobuses were purchased in 1998 by Mersey Travel, at a capital cost of £539,032 and were loaned to operating companies. The vehicles were capable of operating for 17 hours a day, with a battery recharge taking 7 - 8 hours. Batteries could be charged off the bus, overnight. The batteries were used for six hours at a time, covering 70 - 80km. During the operating period of the buses, only 0.33% of scheduled mileage was undelivered due to vehicle fault[120].

6.3 Hybrid buses

Depending on the drive train employed, hybrid buses have a varying potential to reduce CO_2 emissions. A 2005 study from the University of Connecticut measured the particulate emissions from the two hybrid transit buses and two conventional diesel buses during 'over the road' tests. The researchers found no decrease in particulate emissions from the hybrid buses compared to the conventional buses.[121] However, plug in hybrid electric (series hybrid) buses do offer the possibility for a reduction in emissions. Transport for London state

[116] www.leasedrivevelo.com/news/99
[117] The Powershift register is the authoritative source for information regarding vehicles which are eligible for discount from the Transport for London congestion charge scheme, available from www.energysavingtrust.org.uk.
[118] www.britishairways.com/travel/csr-procurement/public/en_es
[119] www.tbus.org.uk/faq.htm
[120] www.eltis.org/studies/53e.htm
[121] www.hybridcenter.org/hybrid-transit-buses.html

that the hybrid buses introduced to their fleet have the potential for a 38% reduction in CO_2 emissions and a 40% reduction in fuel use[122].

Total lifecycle costs, taking into account operating costs, capital expenditure and maintenance grants are greater than those for equivalent buses operating on ultra-low sulphur diesel; therefore there has not always been a clear economic case for bus operators to use hybrid vehicles[123].

6.3.1 Available vehicles

6.3.1.1 Volvo

Volvo launched the 7700 parallel hybrid bus in 2008, which claims to be the first commercially viable hybrid bus. Lower fuel consumption reduces the emission of CO_2 by up to 30% and particulates and NOx by up to 40 – 50% compared to an equivalent diesel vehicle. The hybrid concept, called I-SAM comprises combined start motor, electric motor, generator and an electronic control unit. I-SAM works together with a diesel engine and Volvo’s I-shift gearbox. In addition, a lithium-ion battery is used that is charged during braking via the electric motor/generator. This battery then provides energy to the electric motor for drive power.

The 7700 can be powered by the electric motor or diesel engine independently, or together, which would enable a smaller five litre engine to be deployed compared to the standard 9 litre. The diesel engine is turned off while the bus is idling and moving from stationary up to speeds of 20kph is performed by the electric motor. Hybrid components have been specifically developed by Volvo for their vehicle. The bus weighs only 100kg more than its diesel counterpart, and due to improved weight distribution can carry seven further passengers. The vehicle will be deployed during 2009 with commencement of mass production in 2010[124].

6.3.1.2 Wright Group

The Wright group hybrid bus is available as a single or double decker vehicle. It has a capacity of 87 passengers and is used by TfL’s London bus fleet. It can achieve reductions of up to 89% NOx, 83% CO and 38% CO_2 compared to a conventionally fuelled diesel bus. The bus has an electric drive line which ensures quiet acceleration, and also makes use of regenerative braking.

6.3.1.3 Scania City Bus

The bus is based on a ‘full hybrid’ concept, which involves an internal combustion engine working together with an on-board electrical power system. There is no direct mechanical coupling between the engine and the wheels as the electric motor provides the driving force. The vehicle is currently undergoing testing in Scandinavia and is due to enter service in Stockholm in 2009.

6.3.2 Barriers to uptake

Fuel Duty Rebate is a subsidy paid to bus operators according to the amount of fuel used, and refunds about 80% of the duty operators pay on diesel. The Bus Service Operators Grant (BSOG), also known as Fuel Duty Rebate, FDR) was identified by an EST survey as one of the main perceived barriers to uptake of alternative fuelled buses. In December 2008 the Government announced that from April 2010, BSOG rates will be uprated to for those operators who have achieved an improvement in fuel efficiency equivalent to 3% per annum for each of the two previous years. Other measures that are being taken forward in discussions with stakeholders include incentives in the form of differential BSOG rates for low carbon buses, a fuel efficiency cap, the funding of a project to encourage fuel efficient driving in the bus and coach sector and the formation of a working group with stakeholders to discuss details of the implementation of these measures[125].

[122] www.tfl.gov.uk/corporate/projectsandschemes/2019.aspx
[123] EST (2003). *The Route to Cleaner Buses.*
[124] www.volvo.com.py/bus/uk/en-gb/newsmedia/pressreleases/NewsItem.htm?ItemId=48931&sl=en-gb
[125] www.dft.gov.uk/press/speechesstatements/statements/busserviceoperatorsgroup

6.3.3 Case studies

6.3.3.1 Transport for London

Transport for London (TfL) has run a series of trials with hybrid buses and will have 56 hybrid buses in operation by early 2009. A further 300 hybrid buses will be in operation by 2011. By 2012 TfL expects that all new buses entering the fleet will be hybrid. Wrightbus has provided the earlier hybrid buses, with the newer models including the first hybrid buses from Alexander Dennis, Volvo and Optare[126].

6.3.3.2 Strathclyde

Two diesel buses have been converted to hybrid drive trains and have entered a trial run in Strathclyde. The conversion cost an estimated £107,000[127].

6.3.3.3 Dublin

A hybrid bus started operation in Dublin in 2008, powered by a 2.4 litre diesel engine, less than a third the size of normal bus engines, and is supplemented by a Siemens hybrid-electric drive system supported by Lithium ion batteries. It has been built by the Wright Group.

6.4 Taxis in London

Taxis in London are required to meet the relevant Euro Standard for exhaust emissions (currently Euro 3) in order that they are granted a licence. There is currently no regulation providing an incentive for alternative fuel vehicles. Taxis have high carbon emissions per passenger kilometre, mainly due to their low occupancy and time spent driving without passengers in between fares.

Green Tomato cars is a West London based private hire service that uses the Toyota Prius to transport passengers. The company has an environmental policy which states that they will meet and, where appropriate, exceed industry standards.

6.4.1 New York

In early 2008 it was announced that private hire limos that service corporate clients will be required to meet stringent fuel efficiency standards that are currently only available by using hybrid technology[128]. However, in late 2008 a federal judge ruled that regulation of fuel emission standards fall under federal, not city authority, meaning that an earlier call for every new taxi to have a minimum standard of at least 30mpg will not be enforced[129].

6.4.2 Boston

In 2008, Boston announced that the city's entire taxi fleet would be converted to hybrid drive trains by 2015. The new standards for hybrid vehicles will be phased in as current vehicles reach their mandatory retirement age of six years. As a result of this new plan, owners will be required to replace their taxis with hybrid vehicles[130].

[126] www.tfl.gov.uk/corporate/media/newscentre/10631.aspx
[127] www.spt.co.uk/News/date_title.aspx
[128] www.autoindustry.co.uk/news/29-02-08_11
[129] www.reuters.com/article/environmentNews/idUSTRE49U6EK20081031
[130] www.treehugger.com/files/2008/09/boston-taxis-to-be-hybrids-by-2015.php

7 The market for electric vehicles

7.1 Introduction

Maximising uptake of electric and hybrid electric vehicles could mitigate the impact of increased passenger kilometres. This chapter will explore the decisions that new vehicle purchasers make, and how this could be used to increase the market for electric and hybrid electric vehicles, using market segmentation to profile those consumers most likely to invest in an electric or hybrid electric vehicle. A summary of industry predictions for sales of electric and hybrid electric vehicles is also provided.

7.1.1 Current electric vehicle sales

The number of private licensed cars in Great Britain at the end of 2006 was 26.5 million, compared to 1.9m in 1950. Demand for passenger car travel increased by 20% between 1990 and 2006. Current predictions are that car travel will increase by 1% each year. This increase has been offset by a reduction in CO_2 emitted per vehicle kilometre (gCO_2/vehicle-km). However, the current growth in passenger kilometres is likely to soon outstrip the benefit of CO_2 emission reductions[131].

There are currently 2,000 electric vehicles registered in the UK and the Department for Transport estimates that over 4,000 electric vehicles (excluding cycles and scooters) will be registered in London by 2012[132]. In late 2008, it was reported that electric vehicle sales had slumped; 156 G-Wiz vehicles (the best selling UK fully electric vehicle) were sold in the UK from January to October 2008 compared to 374 of the same period last year[133]. During November 2008, the electric car company NICE also went into administration after sales fell to less than one vehicle per week[134]. However, similar reductions have been felt in the wider automotive industry; new car registrations fell 36.8% in November, and year to date volume is down 10.7% to 2,023,104 units[135].

7.2 New vehicle purchasing behaviour

Interventions and incentives that are used in travel demand management initiatives focus on reducing single occupancy car use in favour of walking, cycling and public transport. Although alternatively fuelled vehicles achieve a reduction in carbon emissions relative their conventional alternatives, they do not support healthy lifestyle and local economy objectives. The City of London recently revoked its decision to provide cost free parking for electric vehicle owners due to concern that free parking had encouraged car use rather than the use of public transport, walking and cycling[136].

Attitudes to car use reflect attitudes to life styles and aspirations in general, and are therefore complex and multi layered. Many people see the car as a necessary part of their lifestyle, particularly in relation to transporting heavy items or picking up family members; others say that poor public transport provision leaves no alternative. Other motives include independence, freedom and being in direct control of personal mobility[137].

Academic research carried out in the Netherlands suggests that, if people are asked to directly evaluate the attractiveness of different aspects of car use, instrumental aspects such as fuel economy or price rate highly. However, if the research purpose is ambiguous, then more symbolic aspects such as feelings of power and seniority are indicated. The research shows that people may not always be willing to admit that the car fulfils many symbolic and affective functions that lead car drivers to justify their choices[138]. The findings of this research suggest that electric vehicles need to be more attractive to consumers, as many reviewers are negative about these vehicles[139].

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[131] Committee on Climate Change, Building a Low Carbon Economy – The UK's Contribution to tackling Climate Change. (2008).
[132] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles
[133] www.guardian.co.uk/environment/2008/dec/04/gwiz-green-car-sales-slump
[134] www.cleangreencars.co.uk/jsp/cgcmain.jsp?lnk=101&id=3050
[135] www.smmt.co.uk/articles/article.cfm?articleid=18615
[136] www.cityoflondon.gov.uk/Corporation/media_centre/files2008/City+of+London+ends+parking+trail+for+electric+cars.htm
[137] ibid
[138] L. Steg. Car use: lust and must. Instrumental, symbolic and affective motives for car use. Transportation Research Part A 39 (2005) pp. 147 – 162.
[139] For an example, please see: www.fqmagazine.co.uk/G_Wiz.aspx

7.2.1 Factors influencing car purchasing decisions

A large number of studies define the factors that are of greatest importance to car purchasing choices, summarised in the Table 15. It is generally agreed that the primary drivers are cost and performance[140].

Most important (10 – 30%)	5% - 10%	Least important (<5%)
• Price • MPG/Fuel consumption • Size/Practicality • Reliability • Comfort • Safety • Running costs • Style/appearance	• Performance/power • Image/style • Brand name • Insurance costs • Engine size • Equipment levels	• Depreciation • Personal experience • Sales Package • Dealership • Environment • Vehicle Emissions • Road tax • Recommendation • Alternative fuel

Table 15: Factors that influence car purchasing decisions[141]

7.2.1.1 Environmental concerns

One key motivator for purchasing an electric or hybrid electric vehicle could be a desire to reduce the impact of driving a vehicle on the environment.

Research carried out by the British Market Research Board (BMRB) rates environmental issues as a low concern for new car purchasers, with only 11% of respondents in a 2007 survey stating that they would take environmental factors into account when choosing a new car[142].

A survey carried out for the insurance company Swiftcover found that 97% of consumers would consider buying a ‘green car’ (the details of term are not specified), although 73% said that the car would need to be cheaper to purchase than their current model, and 70% would only consider a ‘green car’ if its running costs were cheaper than a conventional vehicle. In the same survey group 67% stated that they would switch to alternative fuelled cars if the necessary refuelling or recharging infrastructure was more widely available[143]. Further research for Swiftcover in 2008 found that 42% of people considering buying a new car this year have looked into purchasing a ‘green’ or fuel efficient model[144].

A survey of electric vehicle owners carried out for Sweltrac found that 59% of respondents were motivated by environmental concerns to buy an electric vehicle. Only 14% listed exemption from the congestion charge as a key motivation[145].

The research is conflicting. Although the BMRB research states that environmental issues have low priority, the most recent research from Swiftcover in 2008 indicates a willingness to investigate ‘green’ options. For those who already own electric vehicles, environmental concerns are clearly a high priority. This indicates that although the environment may not be the top priority for the wider public while purchasing a new vehicle, it is likely to be a key motivation for those purchasing electric vehicles.

7.2.1.2 Fuel economy

There is some debate over whether new car purchasers consider fuel economy when deciding which car to buy. Recent Europe wide consumer research from Frost and Sullivan found that 7 in 10 purchasers rated fuel economy as the most important consideration in their choice of next vehicle[146]. However, other studies say that consumers pay little attention to a vehicle’s fuel efficiency, because buyers assume that there is a minor

[140] B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005).
[141] B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005).
[142] BRMB Report: Climate Change Benchmark Survey (2007)
[143] www.swiftcover.com/about/press/car_use/
[144] www.swiftcover.com/about/press/green-car-bullied-brits/
[145] SWELTRAC (2007). Provision of Electric Vehicle Recharging Points Across the SWELTRAC Region
[146] Frost & Sullivan. European Consumers’ Attitudes Towards Sustainability, Environment and Alternate Power Trains (2008)

difference between cars in the same class, and fuel efficiency is an aspect that can only be changed through compromising vehicle performance and safety[147].

Consumer interest in fuel economy has increased markedly in the last year, most likely due to the high fuel prices that were seen during 2008. This is supported by Frost & Sullivan's research, as well as EST research which saw consumers rank fuel economy as the third most important consideration when buying a new car, behind safety and price. However, CO_2 emissions were ranked last, showing that there is lack of understanding of the causal link between the two[148]. This indicates that a stronger link between CO_2 emissions and fuel usage should be made, and that increased fuel prices may be an opportunity to promote the cost savings of electric vehicles.

7.3 Barriers to uptake of electric and hybrid electric vehicles

Frost & Sullivan's European consumer research identified a number of reasons why people do not adopt hybrid of alternative fuel vehicles.

- 67% of respondents across Europe stated that high prices would stop them from purchasing such vehicles;
- 61% stated that the inconvenience of fuelling stations was a deterrent;
- 51% are held back by the limited availability of models, a problem associated with an early stage market;
- 35% cite the inconvenience of monitoring battery charge; and
- Overall performance of alternative fuelled vehicles as a concern reduced from 37% to 25% between 2006 and 2008[149].

In his report 'Consumer Attitudes to low carbon and fuel efficient passenger cars', Ben Lane highlights the factors that concern potential purchasers of electric and hybrid vehicles as being the higher maintenance costs of a vehicle, reliability, the life of the battery pack, acceleration power and the availability of the vehicle that they want. A further barrier to acceptance is consumer familiarity with the technology[150]. The replacement cost of a vehicle battery may also be prohibitive given that the most popular cars lose 50 - 60% of their purchase price after three years; the cost of a replacement battery is likely to exceed the value of the car and could lead to the vehicle being scrapped[151].

7.3.1 Perceptions of cost

Research has shown that car owners underestimate the costs of running a vehicle. Although they are aware of fuel costs, road tax and insurance, they do not always account for servicing, repair and cost of depreciation. The RAC estimates that drivers are prepared to endure an extra £1,100 in vehicle running costs each year before switching to a more fuel efficient car[152]. This is supported by research from Swiftcover which found that 27% of respondents said they would not cut their car use even if the overall cost of motoring doubled and would not be encouraged to drive less[153].

The BERR report into the potential for electric and hybrid vehicles in 2008 recommends that the public is provided with information about whole life operating costs which would allow low carbon vehicles to compete with internal combustion engines, as the high forecourt price of electric and hybrid vehicles will act to deter consumers[154].

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[147] TRI/ECI (2000) Choosing Cleaner Cars: The Role of Labels and Guides. Final report on Vehicle Environmental Rating Schemes. Transport Research Institute, Napier University and Environmental Change Institute, University of Oxford

[148] EST (2008), Driven: a review of the passenger car market in the UK through history to the present

[149] Frost & Sullivan. European Consumers' Attitudes Towards Sustainability, Environment and Alternate Power Trains (2008)

[150] B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005)

[151] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles

[152] B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005)

[153] www.swiftcover.com/about/press/car_use/

[154] BERR (2008).*Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles*

Other studies investigate consumer understanding of the link between fuel economy and miles per gallon (mpg). One report asked respondents to pick the most effective way to reduce CO_2 emissions from a number of options, however, less than a third chose the correct option of burning less fuel in a car[155]. The study suggests that there is a 'blind spot' with regard to fuel efficiency reducing the environmental impact of car use[156].

7.3.2 Summary of barriers to adoption

Due to the early stage of electric vehicle technology and the firm place that the car holds in British society, there are a number of barriers to the uptake of electric vehicle technology. Most problematic will be the higher cost of the technology while it is still a relatively niche product, and the perceived limitations in performance. However, hybrid vehicles such as the Toyota Prius have gone some way to convincing car drivers that an alternatively fuelled vehicle is a viable option.

7.4 Incentives & strategies

7.4.1 Information

Information campaigns, such as the UK government's 'Act on CO_2' campaign serve to increase environmental knowledge and consumer concern for environmental issues. However existing attitudes and misconceptions can affect how information is interpreted and reduce the efficacy of such schemes.

The point of sale is a key location for further information on low carbon vehicles. The EU currently requires dealers to display information concerning a vehicle's fuel consumption and CO_2 emissions at point of sale. The King Review proposed a colour coded tax disc indicating fuel efficiency and/or CO_2 emissions, enabling consumers to assess how emissions vary between and within vehicle classes[157].

7.4.2 Financial incentives

There are a number of ways in which financial incentives for purchasing a low carbon vehicle can be provided:

- A cash reward for purchasing a low carbon vehicle;
- A tax incentive for purchasing a low carbon vehicle; and
- A tax penalty for purchasing a high emitting vehicle.

An EST report from 2004 found that 80% of car buyers would buy a 'greener' car if financial assistance were available[158]. In 2002, the Dutch government introduced a scheme whereby purchasers of cars in 'A' and 'B' bands (where A was the lowest emitting vehicles and B the next band up) received a financial reward of 1000 or 500 euro respectively. In the year that the scheme was running the percentage of A band cars being purchased rose from 0.3 to 3.2%, and B band cars from 9.5 to 16.1%[159]. These results indicate that a financial reward for purchasing a low carbon vehicle serves to increase uptake of such technology.

Consumers are often hesitant to support actions that, while reducing the environmental impact of driving, would have a direct financial implication for drivers themselves. A survey undertaken for the Low Carbon Vehicle Partnership showed that 82% supported rewarding drivers of low carbon vehicles[160], and one in three of the UK respondents surveyed by Frost & Sullivan stated that they would agree with some level of green car taxation[161]. Swiftcover's research found that 74% of people believe that the government's current tax regime penalises drivers rather than providing positive incentives to buy 'greener' vehicles; 68% of respondents in the same survey stated that the purchase of a new car would be influenced by current tax regimes[162]. Feedback from the

[155] TRI/ECI (2000) Choosing Cleaner Cars: The Role of Labels and Guides. Final report on Vehicle Environmental Rating Schemes. Transport Research Institute, Napier University and Environmental Change Institute, University of Oxford
[156] B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005)
[157] Committee on Climate Change, *Building a Low Carbon Economy – The UK's Contribution to tackling Climate Change.* (2008).
[158] EST (2004) *New Vehicle Survey.* Energy Saving Trust.
[159] Committee on Climate Change, *Building a Low Carbon Economy – The UK's Contribution to tackling Climate Change.* (2008).
[160] B. Lane. Car *Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars.* Low Carbon Vehicle Partnership, (2005).
[161] Frost & Sullivan. *European Consumers' Attitudes Towards Sustainability, Environment and Alternate Power Trains* (2008).
[162] www.swiftcover.com/about/press/green-car-bullied-brits/

vehicle community which was obtained by Cenex for their report produced for BERR suggested that government intervention should be based on emission levels and should not prescribe a particular technology.

7.4.3 Increasing the amenity of low carbon vehicles

Lane states that the status symbol of the car has been a key factor in reinforcing anti-environmental travel behaviour. One way to improve the status of a low carbon vehicle is to increase its amenity value. This could be achieved through offering free of charge or preferential parking to such vehicles, or to offer preferential access to cities or certain roads at different times, as already in operation in many London Boroughs. This then offers the electric or hybrid vehicle a capability that a conventional ICV does not have and therefore increases its attractiveness[163]. This is currently coupled with a financial incentive in the form of reduced charges: electric and hybrid electric vehicles are generally exempt from the London Congestion Charge, the Low Emissions Zone charge and vehicle tax.

7.5 Market segmentation

Market segmentation takes a targeted approach to achieving an aim (in this case increasing uptake of electric and hybrid electric vehicles). This section presents a summary of the segmentation exercises that have been carried out in relation to low carbon transport and environmental purchasing, to create a profile of those consumers most likely to purchase an electric or hybrid electric vehicle. From this, they key messages to promote can be ascertained.

Research by Anable with visitors to National Trust Properties segmented the population into six sectors, four car owning and two not. The four car owning sectors are as follows[164]:

1. Malcontented Motorists
    - See a high number of constraints to public transport use;
    - Unhappy with car use, frustrated;
    - Feel they have a moral responsibility to change their behaviour.
2. Complacent Car Addicts
    - Admit use of alternatives is possible;
    - Don’t feel any moral imperative or incentive to change car use.
3. Aspiring Environmentalists
    - Have already substantially reduced car use for environmental/health use;
    - See practical benefits so are unwilling to give up entirely.
4. Die Hard Drivers
    - Fond of cars and car travel;
    - Believe in the right to drive cheaply and freely;
    - Negative feelings towards all other travel modes.

Two segments, the Die Hard Drivers and the Complacent Car Addicts exhibit very high car dependence and low intention to use alternative modes. The most relevant in relation to promotion of electric and hybrid vehicles are the Malcontented Motorists. This group exhibits high car use but also demonstrate a relatively high intention to change, and therefore may be receptive to alternative vehicles. Aspiring environmentalists are also a key group as they are willing to curtail their car use for environmental reasons and therefore may be more likely to accept the limitations of an electric vehicle[165].

An MBA research project carried out for Shell focuses on consumer acceptance of new car fuel technologies during the early growth phase of market development. The report identifies seven early adopter segments, summarised in appendix 1. It should be noted that this research did not consider uptake of fully electric vehicles[166]. There are a number of shared characteristics across these segments. The individuals have higher

[163] B. Lane. Car *Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars.* Low Carbon Vehicle Partnership, (2005)
[164] J. Anable. ‘Complacent Car Addicts’ or ‘Aspiring Environmentalists’? Identifying travel behaviour segments using attitude theory. Transport Policy 12 (2005) pp 65 – 78
[165] J. Anable. ‘Complacent Car Addicts’ or ‘Aspiring Environmentalists’? Identifying travel behaviour segments using attitude theory. Transport Policy 12 (2005) pp 65 – 78
[166] B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005)

than average education levels and wealth, and are urban dwellers. There is also an interest in technology and innovation.

Canadian Research shows that younger respondents are more likely to choose an 'innovative' vehicle. It is to be expected that younger consumers will be more receptive to new technologies than older purchasers, as they will have been exposed to the technology from an earlier point in their life. The same research also stated that consumers who are concerned about the environment are more likely to buy an innovative car[167].

The Department for the Environment, Food and Rural Affairs (Defra) has carried out extensive research to segment the population into seven clusters, relating to their attitudes and beliefs towards the environment and environmental behaviours. Segments 1 and 2 offer the greatest potential to take up pro environmental behaviours as they are both willing and able to act. Sections 6 and 7 are the least likely to adopt pro environmental behaviours. The research by Defra also identifies a number of 'headline goals' for its environmental behaviour change programme. One goal is to use more fuel efficient vehicles. The acceptability of this goal to each segment is summarised in the table below:

Segment	Acceptability of goal
1: Positive Greens	High
2: Waste Watchers	High
3: Concerned consumers	High
4: Sideline supporters	Medium
5: Cautious Participants	Medium
6: Stalled starters	Medium
7: Honestly disengaged	Low

Table 16: Acceptability of headline goals (Defra)

The table above shows that segments 1 – 3 are the most likely to accept fuel efficient vehicles.

Overall the research highlights the importance of personal recommendations and face to face contact in encouraging uptake of sustainable products and suggests that segments with high acceptability of a headline goal could be used as community champions, to 'myth-bust' about pro-environmental behaviours and products. A strategy could be to pilot electric or hybrid vehicles with a group identified as belonging to one of receptive segments, allowing this group to share their experience with other, less convinced consumers. Another option could be to promote electric vehicles through street car and car share schemes. Key traits of these segments are summarised below:

[167] Quoted in B. Lane. Car Buyer Research Report: Consumer Attitudes to low carbon and fuel efficient passenger cars. Low Carbon Vehicle Partnership, (2005)

Segment 1: Positive greens (18% of population)	Segment 2: Waste Watchers (12% of population)	Segment 3: Concerned Consumers (14% of population)
• Hold the most pro-environmental behaviours of any group • Doing the most to reduce impact, but still scope for more, particularly in relation to travel behaviour. • Least motivated of all groups to save money • Seek to influence friends and family • Most likely to be in AB socioeconomic groups, highest levels of household income. • Most likely to have a degree, age profile 41 – 64, owner occupancy	• Pro-environmental behaviours motivated by avoiding waste rather than reducing impact • Do not share group 1's pro environmental attitude to travel • Current behaviour includes focusing on using fuel efficient cars • Middle age and older bias • Many on low incomes	• Broadly pro-environmental beliefs, but with less conviction than groups 1 and 2 • Greener attitudes to travel than most, but average levels of dependence on car • More likely to have higher income and be owner occupier • Second most likely to have a degree

Table 17: Defra pro environmental behaviour segments

7.5.1 Innovation Adoption Curve

Another model that is useful for understanding the uptake of new technology is Rogers' Innovation Adoption Curve. Adopters of an innovation (in this case a low carbon vehicle) can be classified into different categories based on the assumption that some people will be more open to new technology than others. The categories are summarised in the table below:

Segment	Description
Innovators	Brave people, pulling the change. Innovators are important in communicating an idea.
Early Adopters	Respectable people, opinion leaders, try out new ideas but in a careful way
Early Majority	Thoughtful people, careful but accepting change more quickly than the average
Late Majority	Sceptical people who will use new ideas or products only when the majority is using it
Laggards	Traditional people who are critical towards new ideas and will only accept ideas once they have become mainstream or even tradition.

Table 18: Innovation adoption curve segments

The curve is represented graphically below[168]:

[168] Rogers, Everett M. (2003).*Diffusion of Innovations*, 5th ed.. New York, NY: Free Press , image from www.dcenr.gov.ie/Communications/Communications+Development/Broadband+Demand+Report.htm

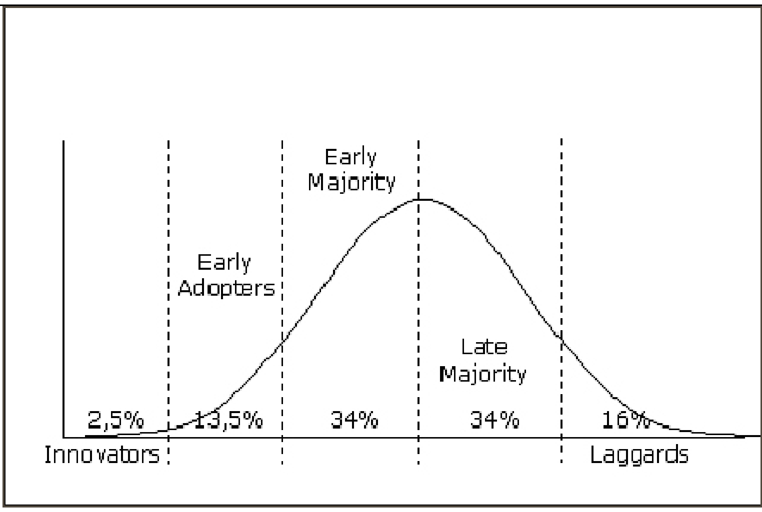

Figure 7: Innovation Adoption Curve

The theory states that trying to quickly convince the mass market to adopt a new technology, particularly one that has an element of controversy, will not work. Innovators and early adopters should be the primary target of any intervention, and the percentages listed on the graph can be used to estimate market shares and target numbers for advertising campaigns[169].

7.5.2 Summary of segmentation

The purpose of segmentation is to divide the population up into groups with shared characteristics (in this case in relation to willingness to purchase electric or hybrid electric vehicles), so that marketing efforts can be directed at those groups most likely to respond positively.

The segments of the car buying population who should be targeted for low carbon vehicle uptake will sit mainly in the 'early adopters' segment of the Innovation Adoption Curve. Summarising the available research, this group is likely to:

- Be environmentally aware
- Want to reduce their impact on the environment, but see public transport as a constraint and value independence of the car
- Feel a moral responsibility to change their behaviour
- Hold a degree
- Be an urban dweller
- Have an interest in technology and innovation
- Have a higher than average income
- Age groups: although younger age groups are more likely to be receptive to new technology middle age groups will have greater purchasing power.

7.6 The future market for electric and hybrid electric vehicles

Cenex rates the future of electric vehicles as excellent, the highest of any of its supported alternative fuel technologies. Current studies indicate that mass market penetration of EVs is unlikely to happen before around 2014 and is more likely to occur around 2020, but that significant government and industry interventions will be needed to stimulate both supply and demand[170].

[169] www.valuebasedmanagement.net/methods_rogers_innovation_adoption_curve.html
[170] BERR (2008).Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles

There are two sets of figures which indicate the likely growth in the market; the first set is from consumer intention surveys that consider new car purchases, the second are projections based on a Cenex study for BERR.

7.6.1.1 Growth projections using consumer research

Frost & Sullivan's European consumer research asked people who currently drive diesel and petrol cars whether they planned to purchase an alternatively fuelled car for their next vehicle, including biofuels, CNG and LPG as well as hybrid and electric vehicles. This question was asked across the EU in 2006 and 2008, and the results are summarised in the table below. It can be seen that a there has been a small increase in the intention to buy an alternatively fuelled vehicle, and that petrol users are slightly more likely than diesel drivers to consider an alternatively fuelled car. Reasons for this could be that diesel users already enjoy increased fuel efficiency and reduced CO_2 emissions from their vehicles in comparison with petrol drivers.

	2006	2008
Currently using petrol	9%	11%
Currently using diesel	7%	9%

Table 19: Intention of vehicle owners to purchase alternative fuelled vehicle for next car

The same research also asked all consumers about their next car purchase. The results for the UK are shown below. The percentage of people stating that it is likely their next car will be alternatively fuelled has more than doubled between 2006 and 2008[171].

	2006	2008
Petrol	55.3%	39%
Diesel	41.0%	51.2%
Other (alternative fuel)	3.8%	9.8%

Table 20: Consumer preference for next vehicle fuel type

These consumer surveys show that there is an interest in fuel efficient and alternative fuel cars amongst new car purchasers, however they are unlikely to dominate the market. The American automotive forecasting company JD Power predict that hybrid market share is expected to top out at 3% of the U.S. automotive market by 2010 and claim that their uptake is limited by the price premium of $3 - 4,000 that consumers must pay for a hybrid vehicle[172]. In 2006 17 hybrid electric vehicle models were available on the U.S. market. This is predicted to rise to 38 models (17 cars and 21 light trucks) by 2011, with vehicle sales reaching 535,000 units or 3% of U.S sales.

A recently published study by PricewaterhouseCoopers (PWC) predicts that production of all-electric vehicles will take another eight to ten years before reaching the level of today's hybrid cars, and can only reach even this level with significant government subsidies and investment. While Nissan-Renault predict sales of 7 million electric vehicles by 2020, the PWC report predicts that manufacture could reach 500,000 units by 2015, and 1.5 million by 2020. The report again highlights the issue of high purchase price as holding back vehicle sales[173].

Modelling carried out by the University of Leeds estimated a maximum market share of 9% for alternative fuel vehicles. Even including financial incentives and technical improvements in vehicles did not push the market

171 Frost & Sullivan. European Consumers' Attitudes Towards Sustainability, Environment and Alternate Power Trains (2008)
172 www.canadiandriver.com/news/050204-1.htm
173 www.hybridcars.com/news/consulting-firm-slow-growth-electric-cars-25299.html

share substantially above 10%. The report states that this will be the case unless some sort of stimulus is given to the market[174].

7.6.2 Scenarios for adoption

Although the figures for the market penetration of electric and hybrid electric vehicles are minor, government intervention could significantly impact on the uptake of low carbon vehicles. In their report to BERR, Cenex state that the following developments are necessary to achieve widespread uptake of electric vehicles:

- Increased consumer confidence in electric/hybrid vehicles, and increase consumer knowledge through information provision;
- Improvements in vehicle battery performance and cost;
- Charging infrastructure that keeps pace with demand; and
- Stimulation of the market through appropriate incentives which encourage uptake of low carbon vehicles.

Cenex predict that HEV products will become more widespread after 2010, with plug in HEVs (PHEVs) being introduced in 2014/15. Introduction of PHEVs will dramatically reduce demand for HEVs. By 2014, pure EVs will start to come to market in volume, initially as small commuter vehicles[175]. The report for BERR developed four scenarios for the introduction of electric vehicles in the UK.

Number of vehicles in UK						
	2010		2020		2030	
Scenario	EV	PHEV	EV	PHEV	EV	PHEV
Business as usual	3,000	1,000	70,000	200,000	500,000	2,500,000
Mid range	4,000	1,000	600,000	200,000	1,600,000	2,500,000
High range	4,000	1,000	1,200,000	350,000	3,300,000	7,900,000
Extreme range	4,000	1,000	2,600,000	500,000	5,800,000	14,800,000

Table 21: Scenarios for the introduction of EVs in the UK

These scenarios are not forecasts or estimates of the future, but have been created to understand the potential magnitude of electrical energy required, and the emissions savings possible. However, they are useful to understand the different factors affecting the uptake of electric and hybrid electric vehicles.

There are a number of variable costs that will influence the market penetration of EVs:

- Fuel price;
- Battery cost which has the most significant influence on vehicle price;
- Cost of electricity; and
- Market interventions.

Business as usual scenario

- No further action taken to encourage electric cars;
- Only existing incentives continue;
- This will limit growth of electric cars to congestion zones and green consumers; and
- Uptake is constrained by cost and lack of capability of vehicles.

Mid range scenario

[174] Toner, J. (2005), *Investigating Household Demand for Alternative Fuel Vehicles.* ESRC research report.
[175] BERR (2008).*Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles*.

- 2.5% of cars can connect to the grid in 2020, 11.7% by 2030. The scenario includes the continuation of the London congestion charge, which is evidence by high local demand for HEVs and L class EVs (quadracycles);
- Assumes whole life costs of EV are comparable to conventional vehicle by 2015. Leasing of batteries is allowed for;
- EVs are unlikely to appear in large volume before 2014; and
- EVs are projected to be concentrated in the UK's major cities where they most suit travel needs and where interventions will be centred.

High range

- Relies on UK government wanting to position the country as a world leader in low carbon car use, manufacture and development;
- Assumed that whole life costs of EVs will be similar to conventional vehicles by 2015;
- Results in 4.9% percent of cars connecting to grid by 2020 and 32% by 2030; and
- Lack of vehicle availability is still a constraint.

Extreme range

- Total dominance of grid connected cars to achieve a low carbon future;
- 10% of cars connecting to grid by 2020 and 60% by 2030;
- This is possible, assuming a renewal of a maximum of 8% of the UK car park by new cars each year; and
- Would require nearly all new cars purchased to be grid connected after 2025.

7.6.3 Current economic climate in early 2009

Since this report has been written, the economic down turn has had a strong impact on the global automotive industry, with government financial intervention being required in both the UK and America. In the UK, the new car market declined sharply at the start of 2009, with new car registrations down by over 30%. Sales of alternatively fuelled vehicles have been particularly affected, dropping by 47%[176]. OEMs have announced substantial job cuts with some plants, for example Honda in Swindon, shutting down for months at a time in a response to falling sales[177]. Smaller EV distributers have been have also being affected; NICE Car Company went into administration in December 2008 after sales reportedly dropped to one vehicle per week and the Norwegian company Think is undergoing financial restructuring. Current industry predictions see the situation remaining similar during 2009 while the availability of credit and willingness to spend is low. OEM commitment to EVs and PHEVs appears to remain high, with new vehicles such as the Mitsubishi MiEV being announced[178], however as all OEM activity is being curtailed by the financial situation, a delay in the roll out of new EVs and PHEVs is to be expected. An industry upturn is expected in 2010[179].

The economic down turn has increased the importance of financial savings. While perhaps the consumer spending power to purchase electric and hybrid electric vehicles does not currently exist, promoting the cost savings offered by the technologies is particularly relevant, and could serve to develop the post recession market. The opportunity also exists for local authorities to develop their electric charging infrastructure and strategies for encouraging uptake of electric and hybrid electric vehicles, in anticipation of the increased demand for the technology in the future.

7.7 Summary of vehicle demand

Market segmentation provides guidance for the key messages to promote to increase uptake of electric and hybrid electric vehicles. Those consumers who already engaged with environmental issues and new technologies are most likely to purchase an EV or HEV. These people are the 'quick wins' to be targeted to achieve initial uptake of vehicles. Other successful strategies to increase uptake of EVs and HEVs are

[176] SMMT New Car Registrations, press release 4625 05.02.2009. Available from www.smmt.co.uk
[177] www.autocar.co.uk/News/NewsArticle/AllCars/237464/
[178] www.mitsubishi-motors.com/special/ev/
[179] Industry predictions from PwC Automotive Institute (01.09.2008), *Analyst Note. Quarterly forecast update: Global Outlook.*

incentives to make vehicles financially attractive and increasing the amenity of vehicles through exemption from costs such as the London Congestion Charge, or giving preferential access to services such as parking.

It is difficult to assess how the demand for EVs and HEVs will increase in the current economic climate, as all vehicle manufacturers have experienced a downturn in sales. Industry predictions do not expect widespread uptake of EVs before 2014, which presents the opportunity to increase knowledge of the benefits of EVs and HEVs, and install suitable infrastructure to support their use.

8 Conclusion

Local and national policy supports the uptake of electric vehicles and hybrid electric vehicles, and sees this as a key to reducing carbon emissions from domestic transport. Electric vehicles (EVs) are currently mainly available from small scale distributors, however vehicle OEMs (original equipment manufacturers) are preparing more mainstream electric vehicles for market. Coupled with a reduction in the price of li-ion batteries, which will reduce the overall price of electric vehicles, this will greatly increase the attractiveness of EVs and work to diminish their current status of niche vehicle.

The plug in hybrid vehicles (PHEV) are not yet commercially available, however they could offer reduced carbon emissions of electric only operation for short trips as well as the possibility for longer journeys, enabling a wider acceptance among consumers. This development will also give consumers greater confidence, as the 'range extender' will be seen as offering back up should the battery run down. It is likely that PHEVs will achieve higher mass market sales than EVs in the short term, and should be allowed to participate in membership schemes.

Both electric and hybrid electric vehicles offer CO_2 emissions reductions; however the potential for reduction depends on a number of factors. Internal combustion engine cars (ICEs) have lower embodied CO_2 than electric or PHEVs, mainly due to the energy required manufacturing a battery. An EV charged by electricity derived from carbon intensive sources would only achieve marginal savings over an ICE; however a vehicle charged from decarbonised electricity offers significant savings. As the UK government aims to increase use of decarbonised sources of electricity, future CO_2 savings from EVs and PHEVs will be greater. These vehicles should be promoted within a wider policy of promoting less energy intensive lifestyles and therefore avoiding unnecessary car journeys.

In the current economic downturn which has had a significant impact on the automotive sector, both in the UK and America, several smaller electric vehicle distributors have recently gone into administration; however the major OEMs are continuing to develop EV and PHEVs in preparation for the market upturn that industry commentators currently expect to happen in 2010.

For electric vehicles to become a mainstream consumer choice a wide vehicle charging infrastructure is needed. At present there are very few companies who provide electric charging points therefore choice is limited and Elektrobay currently dominates the UK market. Power Tower offers a cheaper product per charging point, but do not benefit from the EDF subsidy. Product offerings from recharging companies are becoming more sophisticated, particularly in relation to the data manipulation services they offer. Companies installing widespread charging infrastructure or battery exchange stations, such as Better Place and Coloumb, are also accelerating the pace of development internationally.

The key to successful vehicle charging infrastructure will be compatibility. To increase consumer confidence in the use of EVs and PHEVs, a London and UK wide charging network should be developed that allows consumers to charge their vehicles regardless of residence or make of charging point. This would require standardisation of charging leads or a common network across local and regional boundaries. The density of the network that could be needed in future if current number of charging points per electric vehicle in Greater London is maintained would be 4 per square kilometre by 2020 assuming 2.5% of all private vehicles on the road are capable of being connected to an electricity supply.

In order to reduce carbon emissions associated with electricity consumption (in addition to tailpipe emissions) and support boroughs with achieving their CO_2 reduction targets, the network of local low carbon and renewable energy should be developed. Solar PV installation has the benefit of providing a visible symbol for low carbon living, however a large roof area would be needed in order to significantly contribute to one charging point. A more economic option would be develop CHP networks in the City of Westminster. Carbon offset schemes and green energy tariffs are unlikely to provide genuine carbon reductions and will not help local authorities meet their National Indicator targets on Climate Change.

Fleet managers could help to introduce electric and hybrid electric vehicles to the mainstream, both through providing for employee use of the vehicles and public exposure of them. Further promotion of the company car tax discounts available could provide a tool for encouraging the uptake of electric and hybrid electric vehicles; the reform of Company Car tax has already lead to an increase in uptake of diesel vehicles.

Consumer research shows that drivers are becoming more aware of running costs as fuel prices increase, which is having a greater impact on purchasing decisions, however environmental performance is generally a low priority in new car purchases. The major barrier to wide uptake of electric vehicles is cited as their high cost. A summary of market segmentation research in this report indicates the key consumer segments who should be targeted now to encourage early uptake of EVs and HEVs, so that a firm basis can be established for the growth of the market for these vehicles in the UK.

Since this report has been written, the economic down turn has had a strong impact on the global automotive industry, with government financial intervention being required in both the UK and America. A number of smaller EV distributors have been affected however OEM commitment to EVs and PHEVs appears to remain high, with new vehicles such as the Mitsubishi MiEV being announced[180]. However, as all OEM activity is being curtailed by the financial situation, a delay in the roll out of new EVs and PHEVs is to be expected. An industry upturn is expected in 2010[181].

Further research is needed to assess the potential to coordinate a London wide network of recharging points which could reduce costs and ensure ease of compatibility for drivers. In addition, further research is needed into how the sector can encourage responsible use of electric and hybrid vehicles (and conventional fuelled vehicles) and minimise the risks associated with promoting an ‘environmentally responsible choice’ in favour of more sustainable transport choices of walking, cycling and public transport.

[180] www.mitsubishi-motors.com/special/ev/
[181] Industry predictions from PwC Automotive Institute (01.09.2008), *Analyst Note. Quarterly forecast update: Global Outlook.*

9 Appendices

Appendix 1: New fuel and vehicle technology early adopter segments

Table 4.5 New fuel and vehicle technology early adopter segment definitions (Shell 2004)

Stars	Green papas	Ms Fast-tracker	Mr Fast-tracker	Individualists	Long hauler	Fleet buyers
Extremely fashionable High social status Low mileage / high frequency use Private use Emotional view of vehicles Urban dweller Not motivated by environmental concerns Interested in technology Cost insensitive Performance driven	Extremely sensitive to cost Middle class - "nest builder" Medium mileage and frequent use Private/professional use Functional view of vehicles Urban dweller Environmentally conscious Less interested in technology Insensitive to performance	Concerned with safety Medium mileage and frequent city user Private use Functional view of vehicles Urban dweller Less sensitive to environment No interest in technology Insensitive to performance	Fashionable middle class Medium mileage and frequent user Private use / commuting Emotional view of vehicles Urban dweller Not environment driven Interested in technology Insensitive to cost Performance driven	Medium mileage / usage frequency Private use Emotional view of vehicles Urban dweller Highly environmental sensitivity Interested in technology Demand similar refuelling experience Style driven	Extremely sensitive to cost and technology reliability High mileage and frequent use Commuting Functional view of vehicles Urban/rural dweller Less sensitive to environment Interested in technology Sensitive to availability and performance	Motivated by total cost of ownership Highly sensitive to financial incentives High mileage and frequent use Technology reliability paramount Centrally/ depot based Business/professional use Less interested in fashion Environmental issues not a priority

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http://www.westminster.gov.uk/transportandstreets/evcharging/

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