

PLUGGING THE GAP – CAN PLANNED INFRASTRUCTURE ADDRESS RESISTANCE TO ADOPTION OF ELECTRIC VEHICLES?

Keith Bevis
Austin Smyth
Sue Walsh

University of Hertfordshire, England

ETC 2013 Conference Theme: Low emission vehicles - providing infrastructure and achieving higher levels of usage

1. Introduction

In May 2008 Carlos Ghosn, CEO of Nissan set out his company view of Electric Vehicles (EV's).

“Although clean diesels, hybrids, downsized engines and other technologies are important steps in the technological evolution. Near-zero emissions is also only part of the answer. For an automaker, the best way to address both trends over the long term is through zero-emission vehicles, which are totally neutral to the environment.”

At the launch of the Leaf electric car, in 2010, he claimed Nissan would be selling 500,000 cars a year by 2013 and that mass production will drive down prices. In 2012 however, approximately 120,000 EV's from all manufacturers were sold worldwide, arguably reflecting extreme over-confidence on the part of the motor vehicle industry in the short term prospects for the market for electric vehicles.

The Boston Consulting Group, (2011), predicted that EV's will likely account for approximately 8% of new car sales in Europe by 2020 and combined EV and HEV sales could reach aggregate sales of 15% in the four major markets of North America, Europe, China and Japan. Critically, they also consider that EV's will face stiff competition from ICE's when competing solely on the basis of total cost of ownership (TCO) economics and, hence, will not become the preferred option for most consumers.

At a more restricted geographical level, while overall the UK car market saw its biggest growth in more than 10 years in 2012, achieving their highest volume since the credit crunch with more than 2 million vehicles sold, and while overall sales of alternative fuel vehicles (including electric cars) increased by 9.4% to almost 28,000 (itself a record market share of 1.4%), take up off electric vehicles represented less than 0.02% of the total market.

This paper explores some of the key constraints to growth of EV's and how far planned infrastructure and related measures might encourage market uptake. It encompasses a review of literature/ evidence concerning:

- The current EV market, EV adoption scenarios and Independent projections of the future EV market
- Characteristics of EV early adopters and considerers
- Evidence on consumers' purchase motivations and concerns and Willingness to Pay (WTP)

as a precursor to consideration of various EV adoption barriers, including:

- Technical barriers
- Business and institutional barriers
- Financial barriers
- Public acceptability
- Regulatory and legal barriers
- Commercial strategy barriers

This paper also draws on evidence from the practical experience gained by EValu8, a not for profit company set up by the University of Hertfordshire to run Source East, the East of England Plugged in Places (PiP) project. Plugged-in-Places was a UK Government initiative running from April 2010 to March 2013. The Government's Office of Low Emission Vehicles, OLEV, has been working with eight regions of the UK, London, Milton Keynes, the North East, Scotland, Northern Ireland, Manchester and the East of England. The expressed intention was for these separate projects to make their own differing approaches to test ideas and at the same time address the market failure where the lack of infrastructure was seen as an inhibitor of electric vehicle market growth (OLEV 2011).

It is from this arguably unique perspective that the authors offer an insight into various EV adoption barriers. There are a mix of technical, business, institutional, financial, regulatory, legal, strategic commercial barriers and issues of public acceptability with which to contend. To cover all these barriers in detail requires more than a single conference paper. However, the examples that are covered are significant and can be illustrated directly from the experience of two years of active implementation.

2. The current EV market, EV adoption scenarios and Independent projections of the future EV market

Less than 500,000 hybrid vehicles were sold worldwide in 2008, with the market for plug-in hybrids (PHEVs) and battery electric vehicles (BEVs) limited to conversions of current technologies or high-end vehicles manufactured by specialty producers. However, as oil prices surged rapidly, EV's were widely expected to experience rapid growth over the coming decades.

Lache et al. (2008) forecasted all types of EV's would represent 20% of US new sales and 50% of Western Europe in 2015, the vast majority being hybrids. This could increase to 49% in US and 65% in Europe by 2020.

Brown et al (2010) referred to a 2009 study by JP Morgan that projected that by 2020 11m EV's could be sold worldwide, including 6m to North America (Automotive News 2009). According to JP Morgan, this would mean that the EV would equal nearly 20% of the North American market and 13% of the global passenger market at that time.

In 2010 Nemry & Brons published a paper for the European Commission. They considered governmental policies planning investment in favour of electromobility and financial and fiscal incentives for EV purchase. The following Table sets out the

announced national sales targets for 2020 (Netherlands 2015, Spain 2014) as set out 2009 in the International Energy Agency's *Technology Roadmap – Electric and plug-in hybrid electric vehicles*.

Table 1 National EV Sales Targets Towards 2020

Country	Target
France	2,000,000
UK	1,550,000
Germany	1,000,000
Spain (2014)	1,000,000
Sweden	600,000
Ireland	350,000
Denmark	200,000
Netherlands (2015)	10,000
Total	6,710,000

Source: Nemry & Brons (2010)

One particular national example from the last decade serves to illustrate the unrealistic implications of this unbridled enthusiasm and optimism of EV advocates. In 2007, the Irish Private Car Fleet numbered just under 1.9 million vehicles, of which none are classified as EV or PHEV. In November 2008, the Irish Minister with responsibility for Transport and for Energy announced a “target of 10% of all vehicles in the transport fleet to be powered by electricity by 2020” (Dempsey, 2008).

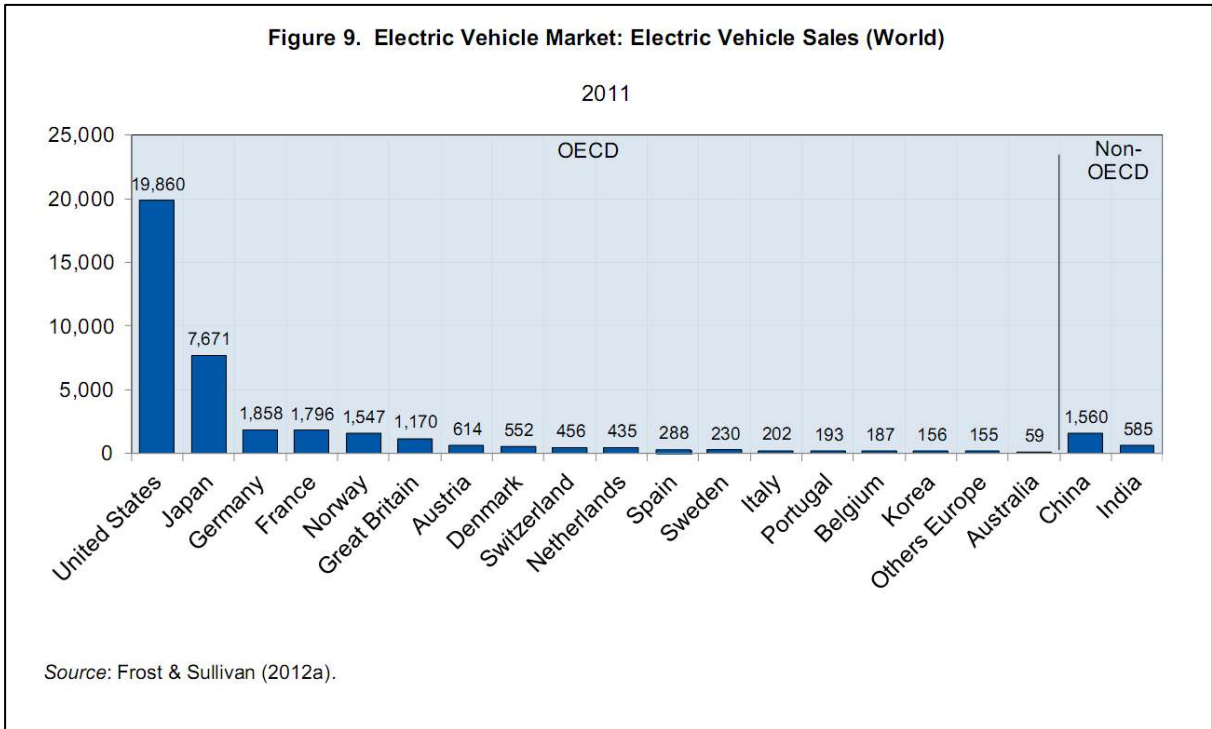
By 2010 however, there were signs of a dampening of expectations. The JD Power Survey 2010 predicted that approximately 5.2 million HEVs and BEVs would be sold worldwide in 2020, with some 3.9 million units expected to be HEVs (JD Power, 2010).

Nevertheless, even as recently as last year Gartner, the technology market research firm, forecast 100,000 electric car sales in 2012 in the United States. Thilo Koslowski, Vice President of their Automotive and Vehicle Practice acknowledged 100,000 to be quite a jump from the 18,000 sold in 2011 which included 9,674 Nissan LEAFs, 7,671 Chevrolet Volts, and 655 other plug-in cars (January 24, 2012, CleanTech *Blog*, by John Addison).

Notwithstanding the increasing acceptance that many industry and advocacy projections had been vastly over optimistic the data and more recent reserach does suggest a modest upward trend in sales of Ultra Low Emission Vehicles in the United States and Western Europe. A HEV study conducted by Polk & Company (2009) indicated an upward trend of market share of HEV sales in US and Western Europe

In 2012, the OECD published the following figures for EV worldwide sales in 2011 as part of the series of Green Growth Papers. Total sales were 39,574 with the US leading the way with 19,860 EV's sold, followed by Japan 7,671 and China, Japan, Germany, France, Norway and Great Britain all with between 1,000 and 2,000 EV's sold.

Figure 1 OECD Estimates of Worldwide EV Sales for 2011

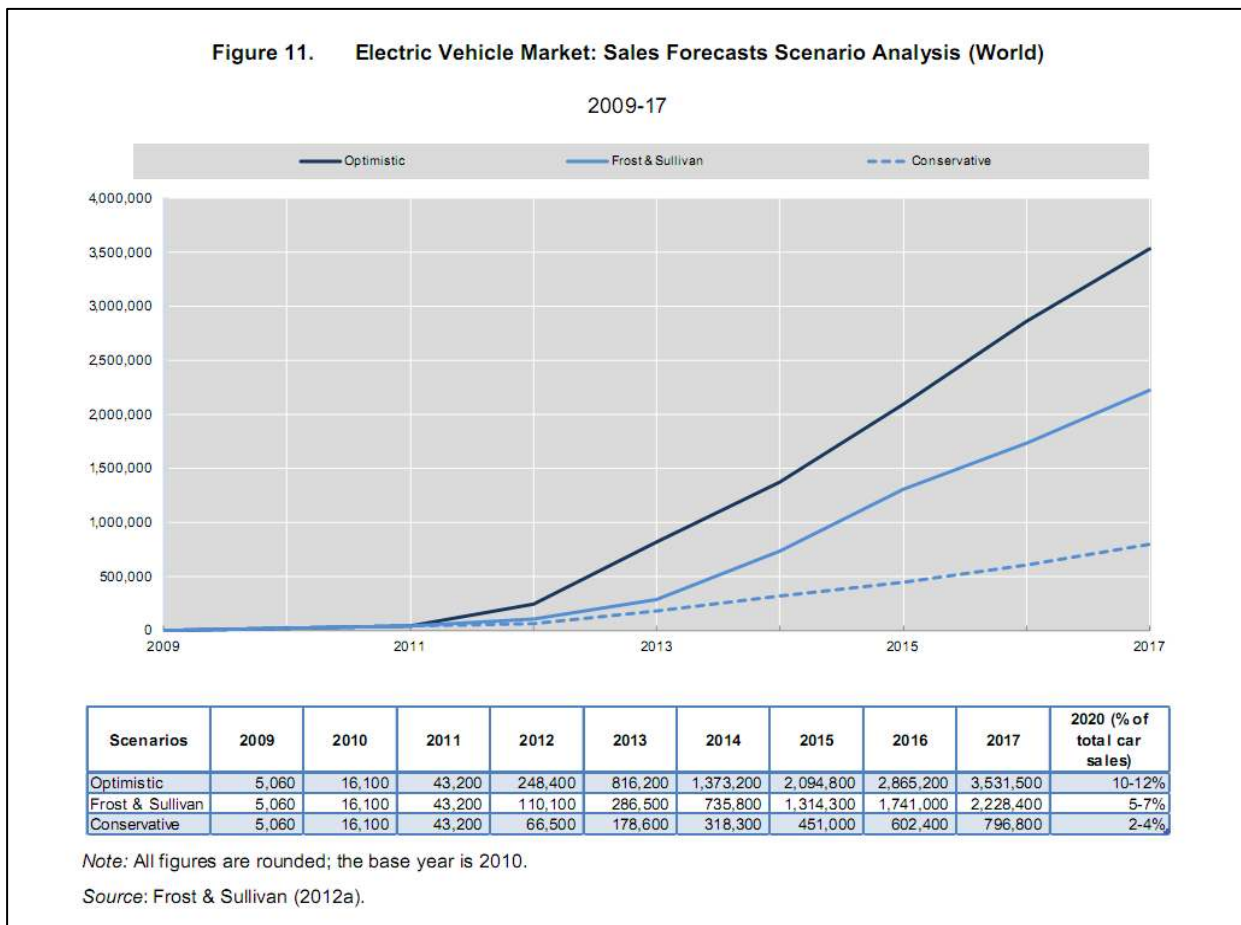


Source: Frost & Sullivan (2012)

In 2010 the total number of registered vehicles in the UK was over 34.2m, of which cars were 28.4m (83.5%) of these around 154,000 were gas, electric or hybrids. The number of hybrids reached over 100,000 for the first time. In that year the Plug-in car grant was introduced into the UK, offering discounts of up to £5,000 on the purchase of new vehicles. Registrations of electric cars went from 250 in 2010 to 1,200 in 2011 and the first plug-in hybrids were registered in 2011. (DfT 2011a, 2012).

In 2011, the OECD published updated world EV sales forecasts using 2010 as the baseline. It will be apparent that the 2020 forecast sales of 6.7m across eight countries in Europe reported by Nemry & Brons (2010) let alone JP Morgan’s projected 11m EV’s worldwide by 2020 look remarkably optimistic compared to the OECD’s forecasts of between 0.5m and 3.5m worldwide by 2017.

Figure 2 OECD Forecast EV Sales Worldwide to 2017



Source: Frost & Sullivan (2012)

3. Characteristics of EV early adopters and considerers

Future prospects for the EV are, and have been, heavily couched in terms of a wide range of uncertainty. The following summarises research undertaken to explore who are the likely purchasers and if there can be any predictions in terms of market segmentation for the uptake of EV's,

In 2008 Arup and Genex published a report on the market for EV's based on four scenarios for adoption of Battery Electric Vehicles (BEV's) and Plug in Electric Vehicles (PHEV's) (Table 2). The scenarios of BEV and PHEV adoption reflect assumptions about future vehicle costs, level of support, incentivisation and market demand. The scenarios encompassed:

- Business as Usual – with no incentives leading to zero growth;
- Mid-Range – assumes that whole life costs of EV's are comparable to Internal Combustion Engines (ICE's) by 2015;
- High-Range – wide availability of charging infrastructure and comparable whole life costs; and
- Extreme-Range – assumes a very high demand with sales restricted only by supply. 10% of all cars are plug-in by 2020 and 60% by 2030.

Table 2 EV Adoption Scenarios

'business-as-usual'	Current incentives are left in place and no additional action is taken to encourage the introduction of EVs. Battery costs are such that whole life cost parity with conventional cars would not be achieved until around 2020. This would be expected to limit the growth of EVs to congestion zones such as London and amongst green consumers.
The Mid-Range scenario	Assumes that environmental incentives continue to grow at their current rate. This scenario assumes that whole life costs of an EV are comparable to an ICV by 2015. Sales of EVs are largely restricted to urban areas and by their cost and limited capability whilst PHEVs are limited due to their price premium compared to ICVs.
The High-Range scenario	Assumes significant intervention to encourage electric car sales. Charging infrastructure is widely available in urban, suburban and in some rural areas. The whole life costs of EVs are comparable with ICVs by 2015 with battery leasing easily obtainable.
The Extreme Range scenario	Assumes that there is a very high demand for electric cars, with sales only restricted in the short term by availability of vehicles. In the longer term, almost all new vehicle sales are EVs or PHEVs.

Source: Arup & Genex (2008)

While the 'business-as-usual' scenario suggests zero growth in the market for Ultra Low Carbon Vehicles (ULCVs), the 'mid-range' scenario (which assumes whole-life cost parity for all drive-trains by 2015), projects 2.5% of all cars to be plug-in by 2020 and 12% by 2030. Under the 'high-range' scenario (in which the UK is a world leader in Ultra Low Carbon Vehicle manufacture) 4.9% of all cars are plug-in by 2020 and 32% by 2030. In the 'extreme-range' scenario, 10% of all cars are plug-in by 2020 and 60% by 2030. These scenarios are reflected in the projected market uptakes in EV's and PHEV's for the UK. Table 3 sets out how these scenarios would translate into numbers of vehicles in the UK. Even under the Business-as-usual scenario the increase between the actual UK sales of 1,200 in 2011 and a prediction of 70,000 EV's and 200,000 shows a considerable degree of optimism.

Table 3 Number of Vehicles in the UK as a result of Different Scenarios

Number of Vehicles in UK Car Park						
Scenario	2010		2020		2030	
	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

Source: Arup & Cenex (2008)

The wide range of market projections begs questions about the composition of the market for EV's. Markets are rarely if ever homogeneous in the composition of their customer base. Understanding of the priorities of the consumers making up the overall market is a first step to informing an enhanced understanding of the likely development of the market and increased reliability and robustness of the forecasts of future trends. A Shell sponsored project in 2004, undertaken by Lane, identified seven early adopter segments: Star, Green papas, Ms Fast-tracker, Mr Fast-tracker, Individualists, Long hauler, Fleet Buyers.

Table 4 New Fuel and Vehicle Technology Early Adopter Segment Definitions

Star	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 vehicle 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

Source: Shell (2004)

All seven early adopters share common characteristics. They are: predominantly purchasers of new cars, have higher than average education level and higher than average wealth, live in cities and are interested in technology and innovation

According to that study Fleet buyers represent the largest of the early adopter segments and account for around 53% of the total car market. The other six early adopter market segments account for 10%-20% of the *private* UK car market (47% of the total car market). Fleets therefore are likely to play the key role in the early stages of market development and are seen as the key drivers of infrastructure and vehicle development. They therefore play an important role in raising awareness of new fuel/vehicle technologies.

Table 5 Absolute and Relative Sizes of UK Early Adopter Segment

Market (per year)	Total (1000s/%)	Stars	Green papas	Ms Fast-tracker	Mr Fast-tracker	Individualists	Long hauler	Fleet buyers
Private UK car sales	120-124	5-11	26-52	13-25	21-41	27-55	28-56	
	10-20%	0.4-0.9%	2.2-4.3%	1.1-2.1%	1.7-3.4%	2.3-4.6%	2.3-4.7%	
Total UK car sales	1487-1608	5-11	26-52	13-25	21-41	27-55	28-56	1367
	28-62%	0.2-0.4%	1.0-2.0%	0.5-1.0%	0.8-1.6%	1.1-2.1%	1.1-2.2%	53.0%

Source: Shell (2004)

Lane undertook a further market adoption study in 2011 to assess the existing level of knowledge of ULEV's with emissions of less than 75gCO₂/km. He points out that BEV and BEV owners are broadly defined by the Innovator and Early Adopter market segments. Early adopters represent 13.5% of the potential market share. They follow the innovators but tend to have pragmatic reasons for adopting new technologies.

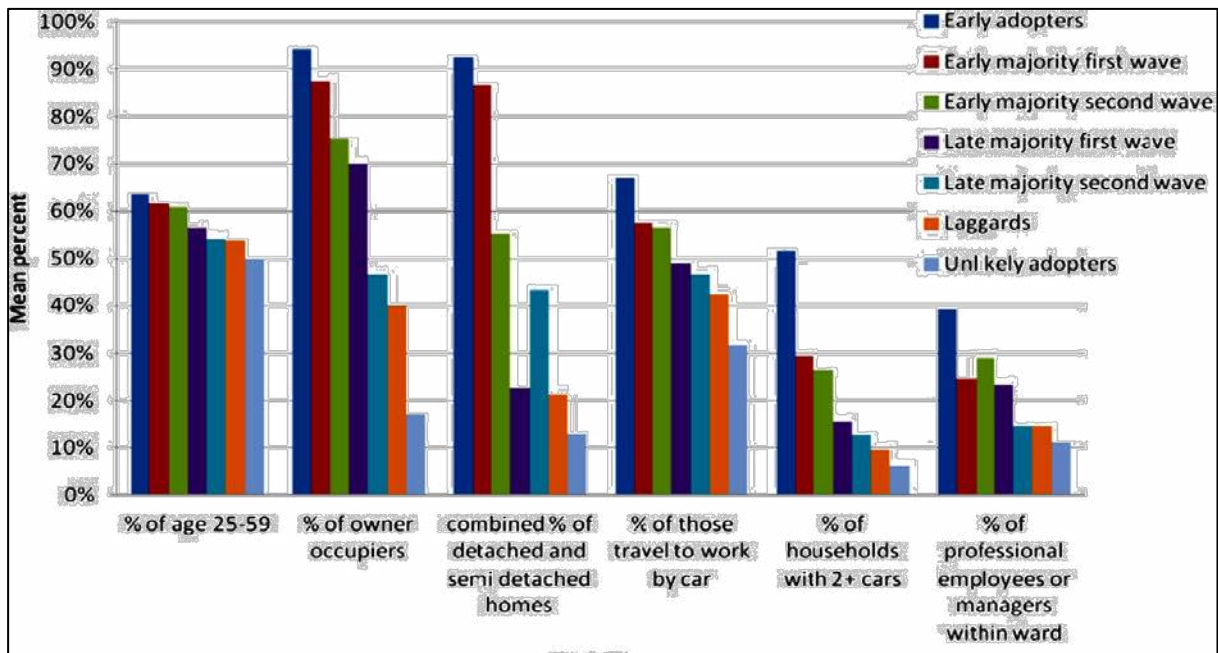
The urban concentration of such groups is reflected in three key early market groups in London identified by TfL (Girard 2010):

- Global Connectors – wealthy, single, living in central London
- Cultural Leaders – live in suburbs and work in central London
- Corporate Chieftains – senior managers owning large suburban properties

Their conclusion is these market segments will continue to play disproportionately large roles in future adoptions of Ultra Low Emission Vehicles (ULEV's).

Elsewhere in the UK Campbell et al (2012) carried out research in Birmingham to identify early adopters and unlikely adopters. It can be seen that the profile of Early Adopters, Early Majority First Wave (and, generally, to a lesser extent Second Wave) are likely to belong to the highest proportions of owner occupiers, travel to work by car, are part of households with more than 2 cars and are professional employees or managers.

Figure 3 Characteristics of Early Adopters



Source: Campbell et al., (2012)

Research carried out in the US by Deloitte (2010) and Hidrue et al (2011) produced similar findings.

O'Garra et al 2005, suggested being highly educated is a strong indication of having prior knowledge of new vehicle technologies. Williams and Kurani (2006) show consumers who support mobile energy technologies, and are most likely to own their own homes, have parking facilities close by and drive an average of 100 miles per week, as promising potential purchasers of such vehicles.

Gärling and Thorgerson (2001) suggest that multi-car households offer significant opportunities for EV sales while Graham-Rowe et al, (2012) who state that current BEV's are too restrictive to have as the only household vehicle but rather as a second vehicle to make short, local journeys. Those less likely to be among adopters of EV's include unemployed households, those who are price sensitive or do not have access for secure home charging (Williams & Kurani 2006).

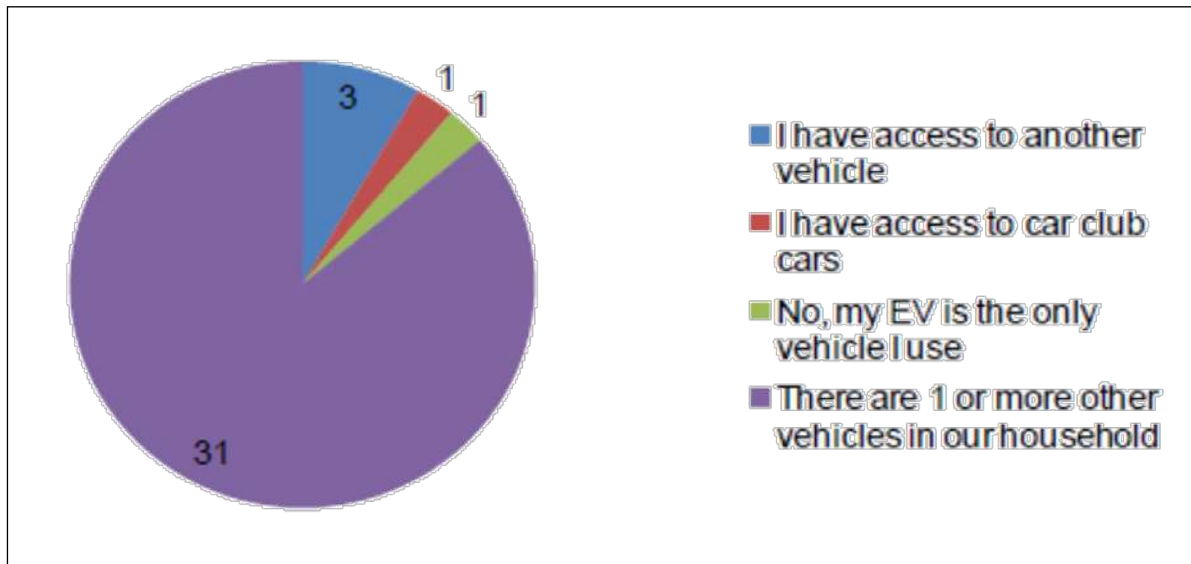
While these studies offer insight into context of and the potential market for EV's inspection of existing purchasers of ULEV's may offer an enhanced understanding of the characteristics and motivations of potential future EV purchasers. For instance, Scarborough Research (2007) found hybrid owners were wealthy, highly educated and active. 50% of US households that own or lease at least one hybrid have an income of \$100k +, most are older than average with a degree. In collaboration with Toyota GB, Ozaki, & Sevastyanova (2011) surveyed Prius hybrid car owners and found them to be mostly men aged 50+; retired couple or single; net monthly household income of over £4,000 who own more than one vehicle.

A 2009 on-line survey by Element Energy was carried out by Slater et al, to identify consumer purchase behaviour (Figure 4). Of 278 EV owners and considerers 215 were householders. Nearly all were male and the majority have access to a non-EV

car. This is an important consideration if, from a two car household, the lower mileage driver is female.

It can be seen that the majority either have more than one vehicle in the household or have access to an alternative, only one has an EV as the only vehicle used.

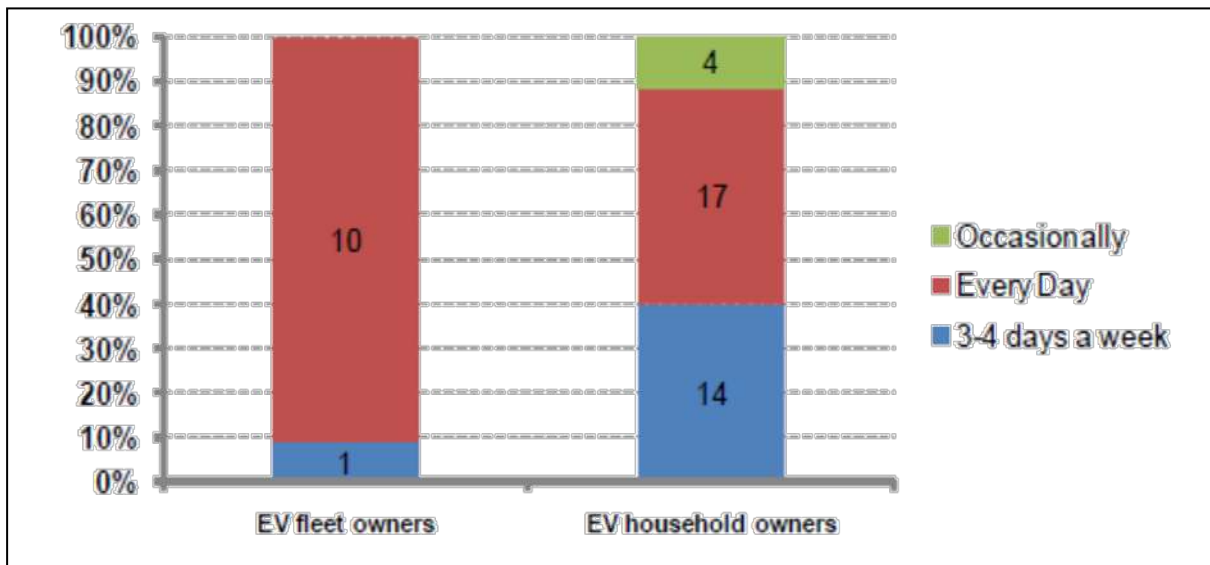
Figure 4 Access To / Use of Another Car



(household EV owners. Base=36)
Source: Slater et al. (2009)

Figure 5 below shows EV use and frequency, highlighting the differences between Household and Fleet usage. Household EVs are used most days for short distances, while Fleet EVs are used almost every day, typically for somewhat larger mileages

Figure 5 EV Usage (Frequency)

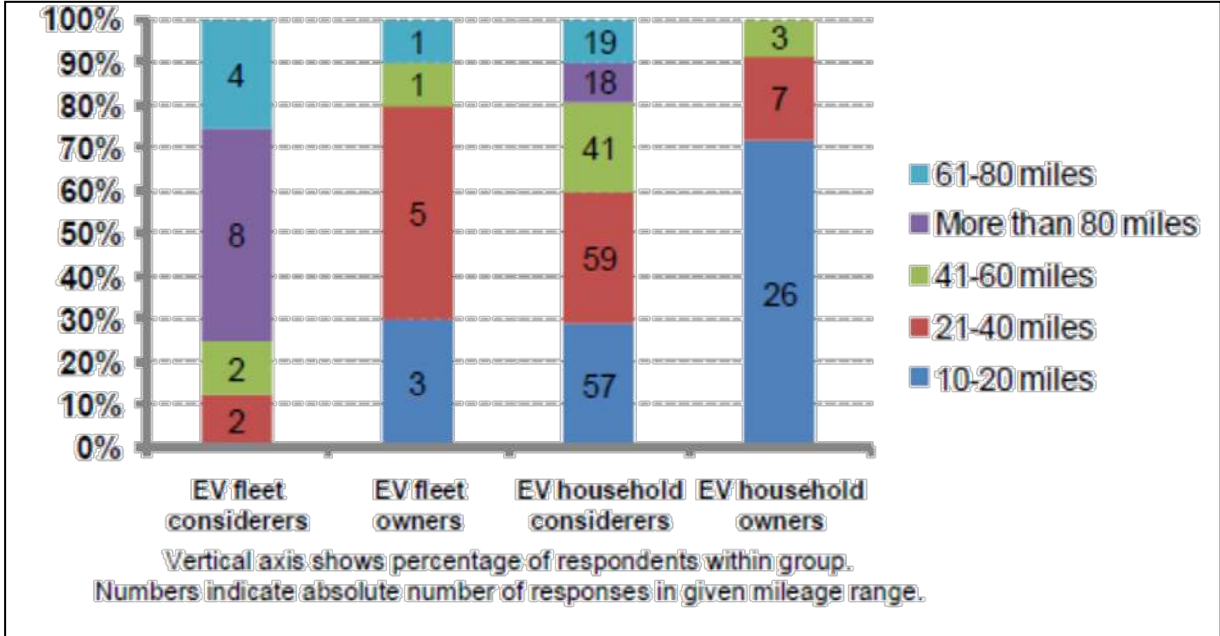


(household base=35, commercial base=11)

Source: Slater et al., (2009)

On the other hand, according to Element Energy many EV considerers have daily mileages greater than 40 miles, and some have a requirement for daily mileage in excess of 80 miles. These potential users are likely to require access to distributed recharging infrastructure.

Figure 6 Estimation of Overall Daily Mileage



(household EV owners base=36, household EV considerers base =194, fleet EV owners=10, fleet EV considerers=16)
 Source: Slater et al., (2009)

Household EV’s are most commonly used for driving 10-20 miles per day, fleet for 21-40 (Figure 6). However, many EV considerers have a daily mileage greater than 40 miles and some up to 80 miles requiring a re-charging infrastructure.

4. Research on consumers’ purchase motivations and concerns and Willingness to Pay (WTP)

A major question mark for the adoption of alternative power trains is the consumers’ willingness to pay more for new technology.

JD Power & Associates, (2004, 2008) have undertaken studies over several years and found (in 2004) petrol hybrid owners were more likely to be female, older, highly educated and from very high income households, drive lower than annual mileage and keep their vehicle for longer than 5 years before re-sale. These consumers are more likely to want to reduce pollution, are more willing to pay for ‘greener’ products, more likely to recycle and believe that fuel prices will be higher in the future. In 2008 they found, while most want to purchase an environmentally friendly vehicle, only 11% were willing to pay a premium, those who were willing were likely to be female and highly educated. Kahn, (2006) found social peer pressure would reinforce individual’s desire to purchase a green vehicle, especially for those living in a green community.

Given the higher capital costs of ULCVs, together with the importance of vehicle price at the point of purchase, several studies attempt to quantify the extent to which consumers are willing to pay for more expensive, but lower emission cars. A study undertaken by Potoglou and Kanaroglou (2007) in the US found that Households would pay between \$500 and \$1200 to save \$100 in annual maintenance cost, and \$2200 to \$5300 in order to save \$1000 in annual fuel costs. Individuals are willing to pay between \$2000 and \$5000 if their next vehicle would emit only 10% of a present day average car.

Kurani et al. (2008), cite several research findings regarding willingness to pay for ULEVs. In one study, 26% of a sample of US car buyers said that they would pay an extra \$4,000 (about £2,600) for a PHEV (capable of a 20-mile EV range). A market research study by the Electric Power Research Institute found that, among a sample of 'mid-sized car buyers', 53% were prepared to pay a \$3,000 (£2,000) premium for a similar type of PHEV. However, only 16% of these same respondents were prepared to buy a PHEV if the additional cost rose to \$9,000 (£6,000). The findings of a Canadian study are broadly in line with this US research; Pollution Probe and Environics (2009) conclude that few car buyers are prepared to pay more than a 15% premium for a PHEV.

The Boston Consulting Group (2011) found there is a segment of "green" consumers, of around 6% of car buyers in the US and 9% in Europe, willing to pay more for an environmentally friendly car even if the TCO economics are unfavourable. These buyers were willing to pay a premium of \$4,500 - \$6,000 which they did not expect to be amortised over time through lower operating costs. This represents a WTP of 10-20% in terms of TCO over the life of the vehicle. However, 56% of US car buyers, 48% in Europe and 34% in China were not willing to pay more up front.

Hidrué et al. (2011) found that people with the highest values for electric vehicles were willing to pay a premium above their WTP for a gasoline vehicle that ranged from \$6000 to \$16000 for electric vehicles with the most desirable attributes. These findings of a WTP premium are above most of the other studies and probably reflects that this group were those with the highest values for EV's, in general WTP levels range between a \$3,000 - \$6,000 premium or £2,000 - £4,000.

This body of research suggests a cost premium to own an EV does represent a barrier to widespread adoption of such vehicles. However, this evidence typically refers to the principle of owning an EV and does not offer real insight into the extent to which vehicle performance affects resistance to take up of EV's.

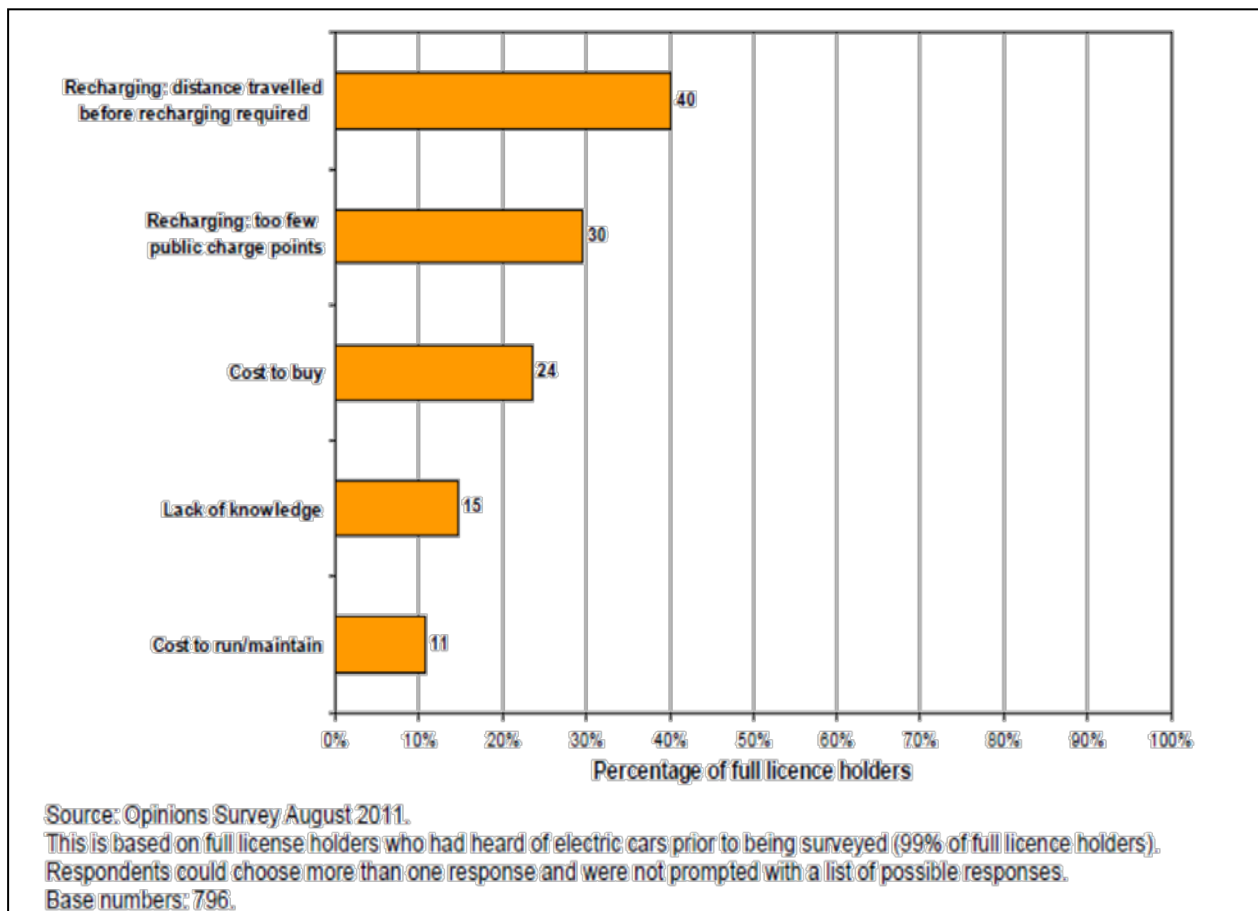
5. Consideration of EV Adoption Barriers

This body of evidence together with the review of consumer characteristics and market segments provided above points to a wide range of barriers to substantial growth of the market for EV's, including technical and financial barriers as well as business and institutional barriers and wider issues of public acceptability. These barriers however, tend to be interlinked; technology and politics, space and policy; charging and lifestyle.

Although the annual UK Office for National Statistics (ONS) survey (Department for Transport, 2011b) has found purchase cost to be a significant barrier to EV adoption

among one in four licence holders the main things drivers said would discourage them from buying an electric car/van centre on ranges achievable by EV's and facilities for recharging (Figure 7).

Figure 7 The Main Perceived Barriers to Purchasing Electric Car/Vans



Source: Department for Transport, (2011b)

Battery costs are also a key area of concern. For instance, Yang (2010) recognised that the cost of batteries is the primary barrier to making plug-in hybrid electric vehicles (PHEVs) and pure electric vehicles (EVs) commercially price competitive. He claimed that without pioneering companies offering loss-leader products, early entrants to the PHEV markets are likely to continue to face high-cost batteries and such markets suffer from inadequate demand.

Hidrué et al. (2011) argued that despite the high premium some consumers are willing to pay a modest premium for electric vehicles. However, battery costs need to fall considerably, at least as perceived by the car purchaser if EV's are to be competitive without high levels of subsidy at current US gasoline prices.

Pollet et al. (2012) state that major organisations share a common view on the pace of cost reductions of fuel cells and batteries. Battery prices are expected to fall by 50% within 10 years compared to 75% for fuel cells. By 2020, a 25 kWh battery pack is expected to cost \$6000–10,000, giving a similar premium over conventional vehicles as FCEVs. These costs are still a long way off \$1000 for the IC Engine they replace; however, they represent only a modest increase in the cost of a complete

vehicle, and are widely thought to be low enough to encourage the development of a substantial vehicle market.

We now turn to consideration of the influence of charging infrastructure on EV adoption. In 2010 Pike Research forecast 4.7 million charge points for electric cars will be installed worldwide from 2010 to 2015. Pike forecasts that by 2015, more than 3.1 million EVs, including plug-in hybrids and all-electric vehicles, will be sold worldwide. and that competition from infrastructure providers will intensify by the end of 2011. Leading the first 20,000 U.S. charge point installations are AeroVironment, Better Place, Coulomb Technologies, and ECOtality. GE, Panasonic, Samsung, and Siemens are moving into the space with hardware and network services in support of EV operations (June 10, 2010 Posted in Charging, Clean Fleet Articles, Electric Cars www.cleanfleetreport.com).

It is evident that the range a vehicle can achieve on a full charge is a key constraint on EV take up, ready access to charging infrastructure can help to mitigate this constraint. We now turn considering the contribution charging infrastructure can make in addressing a variety of barriers to EV adoption, with particular reference to a case study focusing on the practical experiences of creating a charging infrastructure in the East of England region of the UK.

6. The Plugged-In Places (PiP) Programme: A Case Study of Experience in the East of England Region

In 2010 the UK Government embarked on a major programme to support the introduction of low emission and particular electric vehicles. It also recognised that the automotive sector already accounts for 12% of the UK's manufacturing employment; LEV's and ULEV's (low and ultra-low emission vehicles) were seen to offer the potential to secure these jobs and build upon them, supporting the rebalancing of the economy (OLEV 2011).

This programme consisted of:

- the Plugged in Car Grant of over £300M to fund a grants (subsidies) worth up to £5000 off the purchase price of every new plugged in vehicle including both pure battery and battery hybrids; and
- The Plugged-In Places (PiP) programme of £30m available to match-fund eight pilot projects installing and trialling recharging infrastructure in support of the Carbon Plan commitment to install up to 8,500 chargepoints.

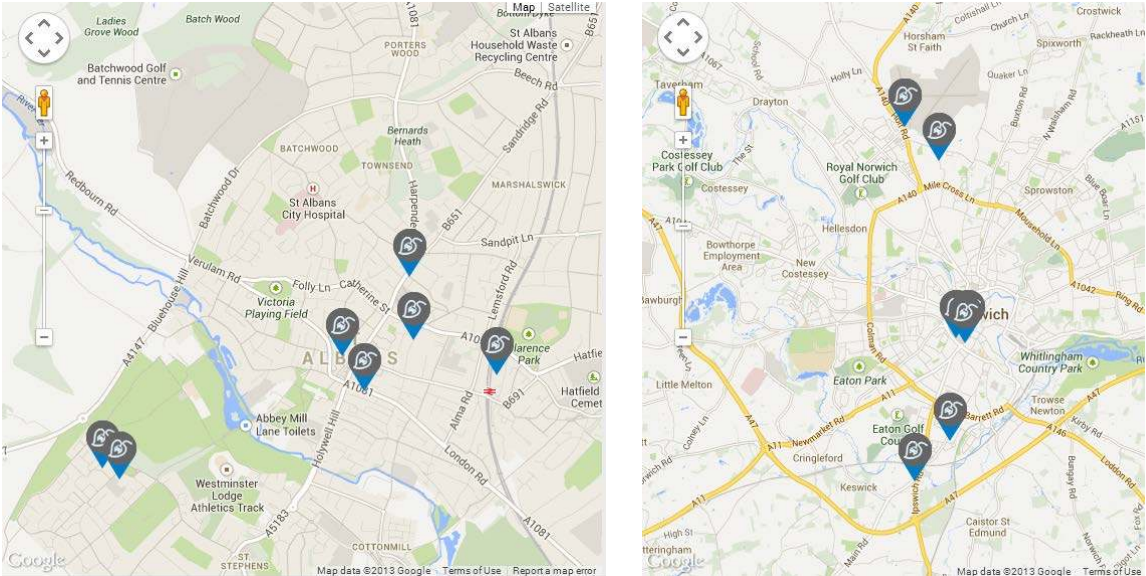
The East of England region has significant features, covering 20,000 square kilometres bordering London with a number of medium sized cities and towns spaced just under 100km apart – it is a relatively rural region with no dominant city, high levels of car ownership and use and within easy commuting distance of a major metropolis. As noted above, Source East was the region's response by bringing together a partnership of the municipal and sub-regional authorities, academia, industry (including key automotive R&D centres) and elements of the voluntary sector.

The location of public infrastructure is driven by a number of factors, including existing traffic regulations and management policies, electricity capacity at the points of distribution and a need to carry political acceptance. Two locations within the East

of England region, St Albans and Norwich, serve to illustrate local implementation of the Plugged-In Places programme. Both are historic cities, the first close to London and with a known high level of pollution from traffic congestion, the second the major city in a predominately rural area.

St Albans has its infrastructure in the city centre, at the railway station and supermarket. By contrast Norwich has its infrastructure at its two out of town “Park and Ride” locations and two vehicle dealerships. Its two central locations are in commercial shopping malls. On the one hand a city is saying it is open to electric vehicles as part of its transport mix. The other is treating electric vehicles as any other to be used positively but encouraged to keep out of the city centre.

Figure 8 Source East Charging Points in St Albans and Norwich



Source: Source East “Live Availability Map” at www.sourceeast.net which overlays points on Google maps data.

During its two years of funded operation Source Club East installed over 500 electric vehicle charging points. Of these eight are 50kW DC rapid chargers and another 140 are domestic EV charging installations. To make as many of these charging points available to EV drivers, EVU8, the University of Hertfordshire’s not for profit company launched its Source East network (www.sourceeast.net). EV drivers can become members for a small annual membership fee. Source East is bordered by three other PiP projects (Source London, Plugged-in Midlands, and Milton Keynes) bringing challenges around cross-boundary working. “Roaming Agreements” were drawn up with Source London and Plugged-in Midlands to support drivers travelling across the boundaries.

Range anxiety was identified amongst 40% of considerers, followed by “too few public charging points”, 30%, (Department for Transport, 2011b). The number of installed charging points, their spacing and the roaming agreements between adjacent projects represent an attempt to mitigate those barriers.

The question arises; how and when will these new electric car drivers charge their cars? British Gas has had the advantage of working closely with EV users in its role as a domestic charge point installer. Research by British Gas, and backed up by the

preliminary analysis of detailed home, workplace and public data from the Source East back office system, shows that 59% of electric car charging takes place at home, 32% is at the workplace and at present only 9% of charging uses public infrastructure (Atkins 2013; Rowney 2013). This lends to a view that public infrastructure will be used for topping up on cars that normally leave the home fully charged. Moreover, there is no longer a concern that charging times at public charging posts are excessive; in fact public charging posts are more suited to 'grazing'.

Given the early state of the market, it is anticipated more robust insights will ultimately emerge from projects such as Source East and areas with a high concentration of EV's. Preliminary analysis of the Source East data suggests that charge points in regular use are used between 3 and 15 times a month, the majority of these for less than five kilowatt hours (to fully charge the battery in a Nissan Leaf requires 24 kilowatt hours). Evidence drawn from 39,525 charging events across all the PiP projects shows the average charge taken during one charging event to be 6.2kWh with a median value of 4.5kWh (OLEV, 2013). While the number of EV's is low, usage patterns remain sporadic. The level of actual grazing suggests that range anxiety may be a phenomenon experienced more amongst considerers than actual EV users.

Two examples show how technical developments can contribute to addressing barriers. A seemingly simple technological challenge had been that of connectors. In 2008, ARUP and CENEX identified the need for standardised connectors (ARUP 2008). However, it was not until April 2012 that the UK standardised on the EN62196-2 Type 2 socket, using Mode 3 control. At the time of writing production vehicles and hire vehicles in the UK are provided with the conventional 13Amp BS1363 type connector, leaving a disconnect between infrastructure installers and vehicle manufacturers. The additional cable that is required remains a tangible barrier to adoption.

Experience with vehicle batteries has grown. The manufacturers of PEV's have become more relaxed about the use of rapid charging and it is now positively encouraged. The East of England has eight rapid chargers all deploying the so called CHAdeMO protocol. Since their installation other vehicles have been designed to accept either a 3Phase supply or a DC supply using the SAE CCS Combo connector with a higher energy rating. However, the summer of 2013 has witnessed international political wrangling over standards for rapid charging. The CHAdeMO protocol provides for 50kW DC charging. This is suitable for current models on the market. The later SAE CCS Combo protocol is designed to allow higher rates of charging when newer vehicles arrive that can tolerate much faster charging.

With vehicles arriving in the market from a much wider range of manufacturers with designed preferences for one standard or the other, the infrastructure operator has to manage the expectations of its customers if it is not to raise a further barrier. It is considered that the only option for the East of England region is to focus either on devices that can operate on all three protocols or ones that can be easily upgraded. A rapid charging environment is developing, with the majority of the "existing chargers" CHAdeMO and 3Phase AC. The TEN-T (a major European infrastructure project, the Trans Europe Network – Transport) and Scottish installations will include the three protocols of CHAdeMO, 3Phase AC and SAE CCS Combo. The challenge for the market is how many of the remaining new installations due to be installed by

2013 will carry all three protocols. Furthermore whilst rapid charging lowers a technical barrier to EV sales and improves public perception, it raises the issue of electrical grid capacity, especially with multi standard equipment.

In 2012 around 2 million (2,044,609) cars were sold in the UK according to the Society of Motor Manufacturers and Traders (SMMT) of these, 2198 were EV's representing 0.1% of UK vehicles sales. However, fifteen of the East of England region's car dealerships are now geared up to sell electric models within their brand ranges and 10% of the UK's grant claims under the UK's plugged-in-places incentive have been registered in the East of England. We are now at a critical juncture in the development of the market for EV's in the UK.

7. Conclusions

In 2009, JP Morgan projected worldwide EV sales would reach 11 million units by 2020. In 2011 the OECD produced revised forecast worldwide sales by 2017 of between as little as 0.5 million or at its most positive 3.5 million units. This dramatic reigning in of the extreme optimism exhibited as little as three years ago for the market prospects for EV's, at least in the short to medium term, suggests that understanding of the contribution of various factors influencing the response of the consumer has been poor.

Certainly at a generic level and in terms of broad attitudinal indicators it is possible to identify many of the key perceived barriers reported by the potential purchaser or user of EV's. Overall costs of purchase and range anxiety appear central to inhibiting take up. However, our understanding of how far these influence individual consumer decisions, let alone for the main potential market segments in relation to EV acquisition is extremely limited.

What is apparent is that the cost premium that the battery adds to the cost of purchase of an EV undoubtedly deters many potential customers. The available evidence suggests that at least in the case of the US niche markets, those espousing green credentials appear willing to bear a premium of between \$3,000-\$6,000 to adhere to their principles. However, these niches represent only a small segment of the overall market for car purchase. There is much less evidence on the willingness to pay for EV' among the main car purchasing market segments.

The other key consideration is that of range anxiety. The current limited range of most EV's would suggest an important role for a comprehensive network of charging infrastructure as a way of reducing - or at least addressing - that technical limitation of the vehicles themselves, thus removing a key barrier to substantial market growth of straight EV's. However, the extent to which public charging is required for actual recharging as distinct from raising public awareness of the technology is a moot point.

The electric car is perceived as a relatively new phenomenon. It is evident that average journeys are for the most part within the range of the typical electric vehicle. From experience with the EValu8 project, it would seem 'considerers' agonise about range, but users seem to be able to manage any constraints imposed by battery range. This would tend to suggest that to lower these barriers, experience of EV's is

key and various vehicle manufacturers have responded to this directly by making vehicle trials available.

If most charging is done at home how much of a charging infrastructure is required to satisfy the need to 'graze'? In parts of the UK we have very underused infrastructure, while in parts of London there are reports of "Charger rage" arising from demand exceeding available charging space. Moreover, although public infrastructure provides only a small proportion of the fast charging, it nonetheless raises the profile of electro-mobility in a region, both practically and politically.

Should the provision of infrastructure be solely the responsibility of the market to provide? The provision of broadband infrastructure can be considered as an example of recent experience in promoting access to modern information technology. It was apparent that there had to be government intervention to push providers to supply services outside major conurbations not considered to offer profitable markets for broadband.

In the light of this example, who should provide EV charging infrastructure; the state or commercial enterprise? Should it be an incentive for cleaner technologies or should it be taxed more heavily than domestic uses of electricity? What has happened in the UK is that the infrastructure has been part Government, part local authorities and part commercial. There are arguably good reasons for all three, the balance is about local priorities, the need or desire for "sustainable credentials" and transport strategy. This is why we have seen in the latest funding round some local authorities bidding and others ignoring.

The experience of Evalu8 also poses a series of further questions related to how far planned infrastructure and associated arrangements can address market resistance to adoption of electric vehicles. There are spatial issues around the siting of infrastructure. Can the infrastructure itself change driver behaviour or encourage particular habits? How does it affect the shape of our cities? The most important spatial issue is about how we deal with domestic charging for city dwellers who rarely have access to off-street parking. The UK Government's latest round of funding announced in February 2013 includes funds for local authorities to install on-street charging for apartment dwellers. Evalu8's own soundings in this area show that local councils are unwilling to engage with this initiative. It is over complicated for cash strapped councils to justify.

The industry is still developing, so although the provision of infrastructure does send out a positive message and encourage the market, at the same time the shifts in technology are unsettling and could potentially destabilise the market. Production vehicles are impressive and smart, but the EV driver and the fleet manager are faced with more choices than ICEV drivers to understand the charging landscape and to optimize vehicle performance.

Different connectors and different charging protocols offer the prospective buyer just more uncertainty, even if their effect is improved performance of the vehicle. Depending on how the political and spatial issues are tackled, technology can either facilitate or inhibit the growth of the new paradigms needed for the infrastructure businesses of the future. Manufacturers have provided a dazzling array of methods for charging EVs, of energy formats and connectors. Industry now has a great deal of expertise and experience available to develop workable charging solutions.

The ULEV market is diverse in the range of options currently being offered and developed. While the CEO of Nissan is on record as seeing the future of vehicle manufacture as belonging to EV's, there is no doubt that ICE efficiencies can continue to increase and other powertrain combinations will be developed which, while they include an electric capability, will also offer an additional power source. Moreover, in parallel with development of the EV the automotive industry's own ICE developments have provided enthusiasts for sustainable technology with fossil fuelled vehicle with equally low pump to tailpipe emissions. This continues to make the electric vehicle a hard choice.

Battery Costs and efficiencies are a key area for consideration. Some manufacturers (Renault, Smart) are offering a business model for purchasing an EV with the battery paid on a monthly rental basis which allows for full warranty cover for the battery and a rescue service if the car becomes stranded. This has had the impact of putting the at point of sale purchase price of a Renault Zoe, the recently launched EV equivalent to a small conventional ICE car broadly within the bounds of the premium sustainable for such vehicle suggested by the research reported above. The extent to which this will influence purchaser intentions and ultimate behaviour will take a little time to emerge. However, what is apparent is the potential value of much greater behavioural sophistication in the market assessment tools that could be employed to yield substantially more robust forecasts of the future market for EV's than deployed hitherto.

References

Arup & Centre of excellence for low carbon and fuel cell technologies (Cenex) (2008). Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles. Report for Department for Business, Enterprise & Regulatory Reform (BERR) and Department for Transport (DfT). <http://www.berr.gov.uk/files/file48653.pdf>.

Atkins, A. (2013). Electric vehicles: a utility perspective. The Electric Vehicles Conference: Overcoming barriers, driving adoption. London.

Boston Consulting Group (2011). Powering Autos to 2020: The Era of the Electric Car? www.bcg.com/publications

Brown, S., Pyke, D. & Steenhof, P. (2010). Electric vehicles: The role and importance of standards in an emerging market. *Energy Policy*, 38: 3797-3806.

Clean Fleet Report: Charging Clean Fleet Electric Cars. Articles June 2010, www.cleanfleetreport.com).

Campbell, A. R., Ryley, T. & Thring, R. (2012). Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom. *Transportation Research Part A*. 46: 1318-1327.

EST (2013). Plugged-in fleets initiative:charging forward, Energy Savings Trust.

- Gärling, A. & Thøgersen, J. (2001). Marketing of electric vehicles. *Business Strategy and the Environment*. 10: 53–65.
- Girard, M-B. (2010). Turning London Electric. Presentation given at LowCVP Annual Conference, June 2010.
- Hidrue, M. K., Parsons, G. R., Kempton, W. & Gardner, M. P. (2011). Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics*. 33, 686–705.
- J. D. Power and Associates. (2010). Driving green 2020: More hope than reality? A special report by J. D. Power and Associates.
http://www.ifsttar.fr/fileadmin/uploads/recherches/geri/PFI_VE/pdf/drive_green_2010.pdf.
- Kahn, M. E. (2006). Do greens drive hummers or hybrids? Environmental ideology as a determinant of consumer choice. *Journal of Environmental Economics and Management* 54: 129–145.
- Kurani, K.S., Reid, R. H. & Turrentine, T. S. (2007). Driving plug-in hybrid electric vehicles: Reports from US Drivers of HEVs Converted to PHEVs. University of California, Davis: November 11.
- Lache, R., Galves, D. & Nolan P. (2008). Electric car: Plugged in - Batteries must be included. Global Autos Research Team, Deutsche Bank.
- Lane, B. (2011). Market delivery of ultra-low carbon vehicles in the UK: An evidence review for the RAC Foundation. Ecolane Report for the RAC Foundation.
- Marra, F. (2011). Central Station Design Options. Danish National Research Database.
- Morrall, D. (2010). Driving EcoInnovation in the East of England.
- Nemry, F., Brons, M. (2010). Market Penetration Scenarios of Electric Drive Vehicles. European Commission Joint Research Centre, Institute for Prospective Technological Studies.
- Nissan GT 2012 and Fiscal Year 2007 Results. Press conference Carlos Ghosn, President & CEO, Nissan Motor Co., Ltd. May 13, 2008.
- OECD (2012). Green Growth Papers 2012-03. Market Development for Green Cars. www.oecd.org/greengrowth.
- O'Garra, T., Mourato, S. & Pearson, P. (2005). Analysing awareness and acceptability of hydrogen vehicles: a London case study. *International Journal of Hydrogen Energy* 30 (6), 649–659.
- O'Garra, T., Mourato, S., Garrity, L., Schmidt, P., Beerenwinkel, A., Altmann, M., Hart, D., Graesel, C. & Whitehouse, S. (2007). Is the public willing to pay for hydrogen buses? A comparative study of preferences in four cities. *Energy Policy*, 3630–3642.

OLEV (2011). Making the connection: the plug-in vehicle infrastructure strategy. London, Department for Transport.

OLEV, (2013), Driving the Future Today: a strategy for ultra low emission vehicles in the UK, London, Department for Transport

Ona E. & Suzanna L (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*.48, 717-729.

Ozaki, R. & Sevastyanova, K. (2011). Going hybrid: an analysis of consumer purchase motivations. *Energy Policy* 39 (5), 2217–2227.

Pollet B.G., Staffell I. & Shang J. L. (2012). Current status of hybrid, battery and fuel cell electric vehicles: From electrochemistry to market prospects. *Electrochimica Acta*, In Press.

Pollet B.G., Staffell I. & Shang J. L. (2012). Current status of hybrid, battery and fuel cell electric vehicles: From electrochemistry to market prospects. *Electrochimica Acta*, In Press.

Potoglou, D. & Kanaroglou, P. S. (2007). Household demand and willingness to pay for clean vehicles. *Transportation Research D* 12, 264–274.

Rowney, M., Straw, W., (2013). Leading the Charge: Can Britain develop a global advantage in Ultra-low-emission vehicles? London, IPPR: 58.

Scarborough Research. (2007). Hybrid-vehicle owners are wealthy, active, educated. http://scarborough.com/press_releases/Scarborough-Hybrid-Vehicle-Owner-Consumer-Profile.pdf.

Shell. (2004). Consumer acceptance of new fuels and vehicle technologies. Cambridge MBA students' study conducted on behalf of Shell). Presentation to the LowCVP.

Situ, L. (2009). Electric vehicle development: The past, present & future. 3rd International Conference on Power Electronics Systems and Applications.

Slater, S., Dolman, M., Taylor, P., Trichakis, P. & Shine, J. (2009). Strategies for the uptake of electric vehicles and associated infrastructure implications. Element Energy report for the Committee on Climate Change.

Williams, B. D. & Kurani, K. S. (2006). Estimating the early household market for light-duty hydrogen-fuel-cell vehicles and other 'Mobile Energy' innovations in California: a constraints analysis. *Journal of Power Sources*. 160, 446–453.

Yang C-J. (2010). Launching strategy for electric vehicles: Lessons from China and Taiwan. *Technological Forecasting & Social Change*.77: 831-834.