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User experiences, public policy and OEM strategy towards electric vehicles (6730495)

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Abstract

This piece of research uses interviews with electric vehicle users to explore discrepancies between these users, vehicle manufacture strategies and government policies. Within the backdrop of a changing climate it is imperative that these mismatches are explored and documented so that strategy and policy can be focused in the most appropriate direction. This piece of work has found that policy and strategy have so far been useful in stimulating the uptake in electric vehicles but that changes need to be made to avert the risk of focusing in areas which will not achieve the best long term results. The key conclusions are in three areas. Firstly that the existing policies for public charging infrastructure focuses limited resources on slow charging solutions which have little use to EV users. Secondly the limited engagement with existing EV users and those at key decision points in the purchasing of new vehicles is a missed opportunity. Thirdly, that the rhetoric around EVs still focuses too much on the negative aspects of their use when attempting to encourage their take up.

Keywords: cost, incentive, infrastructure, leasing, policy,

1 Introduction

In the last 5 years electric vehicles (EVs) have become a reality: vehicle manufactures are gearing themselves up for growth in the EV sector in the coming decades. At present EV sales in the UK are relatively low, with about 500 Electric vehicles being sold per quarter at the moment, which is less than 0.1% of new vehicle sales. Most of these low emission vehicles will be electric. Some companies have invested huge amounts in the take-off of electric vehicles; the General Motors 'Volt' has been earmarked as the vehicle to 'save the company' [1]. This is a range of extended EV which includes an internal combustion engine (ICE) and demonstrates the direction the industry is taking. There are a number of inherent limitations with electric vehicles and each electric vehicle has different characteristics, but it is possible to generalise. The modern electric vehicle would expect to travel approximately 100 miles before needing to be recharged. This range decreases with activates that use up more battery life such as fast driving, using the heater and using air conditioning. Once the battery is depleted it can be charged up to 80% in less than 30 minutes, however this requires technology which is not widely available, generally called a 'rapid' charger. The vehicles are more likely to be charged

at home or work and take up to 8 hours for a full charge. It is generally accepted that electric vehicles are more expensive than a similar ICE alternative in capital expenditure, however the operation costs are normally less.

There are a number of mechanisms in place from the private sector and government to increase the uptake of electric vehicles. This paper will explore the view that an increase in electric vehicles is positive as it improves local air quality and has a greater potential to reduce greenhouse gas (GHG) emissions than ICE vehicles. This paper will explore the academic debates, government policy and Original Equipment Manufacturers (OEM) strategies, to gain an understanding of where electric vehicles sit within society and how they are being incentivised. The paper will then explore the experiences and thoughts of users of EVs to gain an understanding of mismatches between government policy, private sector involvement and users. The paper will then go on to provide a view on why such mismatches exist.

In the past Electric Vehicles have come to the fore, yet they have then disappeared for a variety of reasons which will not be explored in this paper. Peugeot, Citroen, Renault, GM, Nissan, Mitsubishi, Tesla and Ford have all either released EVs or will release them in 2013. Most other manufacturers are developing some kind of electric drive train with ambitions to release them in the next 1-5 years. This suggests that EVs are on the cusp of a major increase in sales, however at present there is little academic work on how this change would be realised - the mismatches between policy and practice need to be explored. Given the importance of a change to low Green House Gas (GHS) mobility there is a real need for research into this area. This piece will achieve this by interviewing EV users and exploring the publicly available information from OEMs and government institutions.

The central research question is 'What are the experiences of UK EV users and what are the mismatches between this, public policy and OEM strategy'.

7 Interviews with the users of electric vehicles form the cornerstone of this paper. This is alongside using publicly available information from government organisations and vehicle manufactures. The aim of this is to flesh out the debate around electric vehicles, to understand how electric vehicles are used for personal use in the UK and to place this understanding in the context of current policy and the directions of OEMs.

The objective of this study is to consider electric vehicles as the next stage of personal mobility and understand the mismatches between EV user's experiences, public policy and OEM strategy. The study will also seek to understand how government and OEM policy seeks to facilitate the take up of EVs and how effective they have been at doing this. The anticipation is that this piece will help develop the direction of the electric vehicle development.

Section 2 will explore the existing literature on the broader question of sustainability, the nature of mobility and CO2 emissions. The section will then explore the debates around electrification of the UK vehicle fleet drawing on academic literature, government policy and OEM strategy. The final part of this section brings together these points and argues that the experiences of EV drivers need to be explored further to inform the direction of this fledgling industry.

In section 3 the research method will be explored, with discussions around how and why these were implemented during the research. Section 4 will summarise the results of semi structured interviews with EV drivers.

Section 5 will use the context outlined in section 2 to inform a discussion on the information outlined in section 4 within the context of government policy and OEM strategy. In doing this it will allow for section 6 to provide three key conclusions and ideas of future academic work in the area.

2 Literature review

The literature discusses many aspects of automobility and the sustainability, or lack of it, in modern urban society. There are also a variety of discussions taking place as to the readiness of society to embrace changes to the current auto-dependant and fossil fuel -dependent model of society. In the policy arena there is an acceptance that changes need to be made to both the auto-dependant and fossil fuel dependant nature of society. Technology is now able to direct society away from fossil fuel, and to a lesser extent auto-dependence, and this is being reflected in policy. A technology which is high on the political agenda, with a number of policies around its use, proliferation and development is the Electric Vehicle (EV). There are a number of EVs on the market and most major manufacturers have EVs in development. This literature review will outline

the discussions which are taking place in the literature and policy summarised above.

2.1 Society's marriage with personal mobility

This section will explore the literature around the problems with the automobile in society and potential sustainable futures, as well as looking into the notion that the major uplifting of society required for a shift away from personal mobility is unrealistic.

Khristy and Ayvalik [2] discuss the multitude of problems with the automobile. They argue that the worst impact of the increase of automobility is on Land Use. They cite the creation of 'sprawling suburbs that are the most uneconomical, environmentally degrading and socially deplorable patterns of residential land-use development' as the key driver of the dystopia of suburban life. The environmental damage which is associated with roads, the making of roads and the petroleum infrastructure necessary for mass personal mobility is in contrast to sustainability [3].

Ewing et al [4] claim that the modern, unsustainable, form of urban development 'will require the reversing of trends that go back decades'. This argument is based on the argument that CO2 reduction targets of 60-80% by 2050, which form the base of a number of UK government targets, cannot be achieved through improvements to technology alone, and that some kind of redesign of society will be required. Newman and Kenworthy [3] discuss reducing automobile dependence and ways in which car dependant cities can be reconstructed. It is suggested that the concept of reducing the intensity of housing in city centres, with a minimum of 35 per hectare, has been found to have some basis in the literature, as this provides people with enough amenities to not have to rely on a car. However they provide no details of how this type of living arrangement can be retrofitted onto the existing housing stock.

Ewing et al [4] put forward the idea of the three pillars of lower CO2 emissions in personal urban mobility. They are: vehicle fuel efficiency, the CO2 content of the fuel being used, and the vehicle miles travelled (VMT). This is developed into the argument that policy makers have 'pinned their hopes' on dealing with the first two issues whilst neglecting the VMT. There is a call for changes in the mechanisms by which land use is planned. The concept of 'compact developments', areas of average density with mixed land uses, which design out travel, are put forward by Ewing et al [4] and are discussed by Khristy and Ayvalik [2] as a solution to the socially and economically unsustainable model of living. It is clear from the literature that this model could have a positive impact upon making housing more sustainable, however as Fray [6] makes clear there is greater scope for more rapid changes in vehicle design and fuel type and that VMT is not as dynamic.

Fraser et al [6] demonstrates that the majority of the housing stock at 2050 has already been built. They go on to state that any move towards a more sustainable model of society will need to be 'retrofitted' to what is built now. This suggests that the three pillars of sustainable mobility need to be dealt with on different time scales, with alternative fuelled vehicles and more efficient vehicles able to be brought in within a decade or two and the constructions that go alongside VMT reduction taking place over the next century.

Apart from major urban centres (London plan) new developments are being developed in the UK without a reduction in VMT designed into them [4]. This suggests that the issue is more complex than Fray's [6] assertion that VMT is less dynamic, that there is a deeper issue where the planning framework is not designing for a potential future reduction in VMT. With the grave consequences of a lack of action regarding CO2 emissions, it is therefore important to not allow a focus on the reduction in VMT to hinder progress in improving vehicle efficiency and reducing the CO2 content of the vehicles fuel. Vehicle development needs to fit with the reality of what is being designed and built rather than a theoretical ideal of what should be designed and built. In practise this means producing vehicles which work to the same constraints as ICE vehicles.

Nieuwenhuis et al [6] discussed the need to include the automobile in any construction of a sustainable future as 'we have literally built our world around the car in its current form, and this inevitably shapes the scope for constructing sustainable mobility'. The automobile is almost unconsciously unchallengeable. In 2008/09 42% of the budget DfT are assigned from the government for transport was spent by the highways agency [7] which itself is indicative of the way in which society accepts that the automobile is central to its workings.

The idea that much of the physical construction which society will be using in 2050 already exists is taken a step further by Davis et al [8]. They showed that the inertia from 'committed

emissions' of existing infrastructure and vehicles may be the primary contributor to total future global warming. This suggests that the response to climate change through future action to halt the proliferation of fossil fuel derived power will not be enough to stop the worst effects of climate change. Solomon et al [9] showed that if the atmospheric concentrations of CO2 rise above 450 parts per million there will be a variety of negative natural effects, such as desertification, and sea level rise. They go on to show that these effects will be felt over the next 100 years or more. That being said Stern (2007) explained that the intensity of these events is still within society's control. The idea that the committed emissions will have a major impact upon society's response to climate change strengthens the argument to decarbonise society as quickly as possible and suggests that this decarbonisation is still within society's control. The electric vehicle is able to affect the first two of Ewing et al [4] three pillars (vehicle technology and fuel technology) but is unable to, and may in fact inhibit, progress towards the final pillar, reduction in VMT.

It is generally accepted that between 20% and 30% of all global CO2 emissions are from transportation. Cruikshank and Kendall [10] have shown that EVs can reduce climate change gas emissions by over 50%. Other than battery electric vehicles, there are other technologies such as plug-in hybrids and the hydrogen fuel cell, which are in varying levels of market readiness. The battery electric vehicle has been available for the longest period of time and therefore presents the most information to study. As well as this, both hydrogen and plug-in electric vehicles use similar technologies and in some cases share the same constraints so exploring battery electric vehicles will also explore these elements of hydrogen and plug-in electric vehicles [11].

This section has shown that the literature makes it clear that the personal mobility in the form of the automobile is central to the unsustainable nature of society. It goes on to show that the automobile has the scope for changing more rapidly than the more static areas of society associated with vehicle miles travelled. The discussions in the literature around the costs of moving society towards a sustainable future and the emissions associated with the electric vehicle will be explored next.

2.2 Willing to pay

This dissertation will first explore the willingness of society to pay the additional costs associated with changing personal mobility towards electric vehicles. This will include the cost to convenience, and the increased monetary costs. Public attitudes globally are generally quite dismissive of climate change [12] and as Hulme, [13] outlines: society seeks the path of least resistance. This means that complex dialogues around future issues are unlikely to gain as much social traction as contemporary issues. This is especially true when they are perceived to be more important issues and when there is no strong group consensus. This first can be shown through the Chinese policy of building coal fired power stations - this is a highly polluting power generation method, but deals with what is perceived to be a more important issue, i.e., bringing the population out of poverty [14]. The second can be shown through the relatively small take up of 'Green Energy Tariffs' in the UK, which is 2 percent at present [15]. Bayley et al, 2001 found that in the UK there was a significant minority with a high willingness to pay for a move towards renewable energy. However this willingness to pay is not reflected in the low take up of green tariffs, which leads to the conclusion that there is willingness to pay but only if the burden is shared throughout society rather than taken on individually. This section highlights that there is a lack of action from a personal, psychological, level and this manifests itself within the individual and on a state level: this is a major barrier to the uptake of non fossil fuel energy technologies, especially when you introduce the costs associated with a move away from fossil fuels. Bayley et al, 2001, also showed that although there is an appetite to pay for non fossil fuel energy in the UK, this appetite reduces when the costs of renewable energy rises. This suggests that, at present, broader society will not tolerate a change in costs for environmental reasons.

The literature suggests that the primary barriers to electric vehicle take up are upfront costs, charge time and range [16] [17]. There are a number of secondary barriers which feed off the primary barriers. These include range anxiety, negative perception around EVs 'status', lack of understanding about modern EVs capabilities and a belief that EVs will not help climate change. There are a number of policies from the UK government and local authorities which hope to encourage the take up of electric vehicles. As well as this, vehicle manufactures are introducing novel mechanisms to encourage the take up of electric

vehicles. Charities and private companies are also involved, but this involvement is generally limited to the charging network.

Before exploring the policies and mechanisms to increasing electric vehicle uptake, the key barriers and changes which are required for electric vehicles to take off will be explored. Anderson and Patino-Echeverri [18] discuss the costs of Li-ion batteries and their place as a key determinant of the success of electric vehicles. Their findings indicate that the costs will decrease enough over the next two decades to make electric vehicles a viable alternative. But at present the costs are prohibitively high, with a lack of trust from the consumer on how long the battery will last [19].

A study by Hidrue et al [20] found that income, and owning multiple cars, was not important, but that people were driven by expected fuel savings more than by a desire to be green or help the environment. The study also found that youth, education, green lifestyle, fossil fuel prices and ability to charge, played an important positive role, and that range anxiety, charge times and high purchase prices were the main negatives factors. They found that the US federal tax incentive of $7500, which will start in 2014 was likely to significantly close the gap if forecasts for battery costs were accurate. This suggests that the current UK incentive of £5,000 may be premature as battery technology has not yet reached a low enough price.

Eberle and von Helmolt [21] discuss range and charge time with relation to fossil fuel, hydrogen and electric power trains. They developed a system in which, using current technology they show what each power train is most suited to. They show that due to the range and charge time constraints of an electric vehicle its application is limited to city driving. However they also argue that up to 80% of driving in Germany is less than 50 miles, which is well within the range of a modern electric vehicle. 92% of journeys are less than 100 miles, which is within the range of most modern electric vehicles. This shows that the majority of journeys do fall within the range of an electric vehicle, but as Eberle and von Helmolt [21] state, at some point a driver will want to drive over 100 miles on occasion, so drivers want to be able to know that they can drive long distances if required, and this is a major barrier to EV take up.

Accepting that the use of an EV is limited to shorter journeys with large stops in between long journeys, Franke et al [22] conducted a 6 month trial into stress associated with range and found that providing a usable and reliable range may be more important than increasing the range of the vehicle. This, coupled with research from Aston University which showed that drivers 'got used' to the limited range of a vehicle [23] suggests that drivers can become accustomed to this barrier but require an accurate idea of what this range is.

Alongside charge time is the ability to charge. There are three broad types of charging, standard charge, fast charge and rapid charge. These range from taking more than 8 hours to less than half an hour to fully charge a vehicle [24]. Broadly, a faster charge time places a heavier strain on the electricity grid. Jarvined et al [25] suggest that at neighbourhood level there may be issues associated with grid capacity, but there should not be issues at the regional level. In the UK this means that local grids will not be able to cope with multiple electric vehicles charging, especially if this charging is fast or rapid.

This section has described the key barriers to electric vehicles and will now discuss some of the mechanisms which are in place to overcome these barriers. First, the mechanisms in place from the private and third sector will be explored, followed by government policies.

2.3 OEM attempts to overcome

In overcoming the issues around cost of ownership, and overcoming the issues around battery life, a number of ownership models have emerged. These include leasing either the battery or the whole vehicle, which transfers some of the risk associated with battery degradation and the capital costs to a third party. This makes the payment method for the vehicle more similar to that of a fossil fuel vehicle in which you pay an initial capital cost, followed by operational costs in the form of paying for petrol [26]. Some manufactures have suggested that they will only lease the batteries for their electric vehicles to avoid any negative publicity associated with battery degradation whereas others are providing warranties on the batteries [27].

Options around car sharing with an electric vehicle are also developing. Users of electric vehicles are able to join a car sharing scheme, which mitigates the issues outlined by Eberle and von Helmolt [28], that users require the range of an ICE vehicle occasionally and that most trips are within the range of an electric vehicle. This concept has developed into the idea of OEMs selling mobility rather than vehicles [29].

There are also a number of concepts around the OEM also being involved in reducing the costs of the energy requirements for the vehicle. Ford are promoting the idea of selling a package of solar cells with the electric vehicle [17] and using batteries which are past their useful life in the vehicle for storing energy, to even out the peaks and troughs in domestic energy demand. This can be extended to selling energy back into the grid to offset the upfront costs. Parsons et al [30] examined a group of 3029 people and found that there would largely be a positive reaction to vehicle to grid contracts.

OEMs are also beginning to involve themselves in the charging network. For example, Nissan will be providing 400 charging points for free across Europe, with an expected 65 in the UK [31]. As well as this, a number of smaller businesses are emerging which provide charging infrastructure.

The variety of initiatives from the private sector which are being developed to assist with the uptake of electric vehicles is in its infancy: it is likely that a number of different methods of offsetting the costs and dealing with charge and range issues will emerge. This section has outlined how, according to the limited literature, this may look in the coming years. The next section will explore the policies in place which are also attempting to overcome the major barriers to EV proliferation.

2.4 Policies to overcome

In the UK there are a wide variety of policies designed to spark the take up of electric vehicles. The Office for Low Emission Vehicles (OLEV) has been set up as a body to orchestrate the move to low emission vehicles: it is a civil service partnership between the transport minister, BIS and the minister for the energy and Climate change. Their focus on electric vehicles has manifested itself in a grant for new personal vehicles of up to £5000 and commercial vehicles of up to £8000, and a number of vehicle and charging trials around the country. Nissan has stated that this commitment from the government has been an important point in Nissan's decision to locate an EV production, research and development centre in Sunderland (Singleton, 2010). However it could be argued that the other mechanisms could have brought that type of investment into the UK. Regional and city political bodies are bringing forward a variety of local level initiatives for promoting electric vehicles, often though funding from the EU and OLEV. As well as this, government departments are being encouraged to increase the take up of EVs in the fleet, for example TfL recently stipulated in a contract that EVs had to be used [33]. Whitman et al [34] states that these type of partnerships are essential for cities to become low CO2 centres.

These policies suggest that vehicles are expected to be too expensive to buy outright and that charging on street will be a key feature in the take up of electric vehicles. More recently however there has been a subtle change in the direction of policy. In the context of increasingly restricted budgets this can be hard to see, but it is clear that a move away from large scale on-street charging policies is taking place. For example in London, what is now called 'source London' initially stated that over 7500 charging points would be installed by 2013, this is now down to 1,300 [35]. There is a lack of literature on issues around what EV owners want and need in policy, and the best ways to target policies to increase the take up of EVs. Policy makers are still unclear as to how EV users use their EVs. Marad Quershi, an Assembly Member in the Greater London Authority and chair of the Environment Committee stated that '[The mayor] must demonstrate that the charging network is adequate and fits with the way people will actually charge their vehicles. It is unclear at the moment whether [the London charging network] is delivering value for money given the sums already spent on it.' [36]

The literature suggest that the model of charging will largely have no need for on-street charging, but having said that, street charging infrastructure is essential to removing the 'range anxiety' felt by drivers [22]. Moselle et al [37] stated that 'EV batteries would be charged mainly at night, when electricity systems normally have spare capacity, and could readily absorb any surplus of power from wind or other renewable. The batteries would be discharged during the day, which should not make substantial demands on the electricity system, though some daytime charging would be inevitable'. There is a lack of literature on electric vehicle charging.

In the UK there are a variety of policies which provide tax breaks or discounts for low emission vehicles and in some cases specifically electric vehicles. Gallagher and Muehlegger [38] conducted an assessment of the effectiveness of different schemes in the USA and found that tax incentives, rising fuel prices and social preferences were associated with 6%, 27% and 36% of hybrid vehicle sales between 2000 and 2006 respectively.

The research goes on to surmise that tax waivers are most effective if they are provided at the time of sale rather than (for example) a rebate at the end of the tax year. The strongest correlation was between fuel prices and sales of hybrid vehicles which suggests that tax waivers, as they are not a substantial amount of money, are not as powerful as fuel pricing policies. The UK has a relatively high tax on fuel which, based on the Gallagher and Muehlegger [28] research, is an effective way of incentivising EVs. However the VED, which is based on CO2 emissions, applies to all low CO2 vehicles, not just EVs, so is likely to be less effective.

This section has described the policies in place from the UK government to encourage the take up of electric vehicles and discussed the limited literature on the potential success and failures of these approaches. The next section will explore the role of technologies in reducing GHG emissions.

2.5 The role of technology

Grahn and Azar [39] used a Regionalised Global Energy Transition Model to understand the impact of different electricity generation methods and transportation fuel types, in a global scenario constrained at CO2 levels of 400-550ppm by 2100. They found that no single technology dominated and that a mix of Carbon Capture and Storage (CCS), Concentrated Solar Power (CSP) and the replacement of internal combustion engine vehicles (ICEV) with electric vehicles were interchangeable to some extent, in that no technology was able to dominate more than the others. However it was shown that, in light of dwindling fossil fuel supply, they all needed to be mainstreamed and that a symbiotic relationship between CSP and EVs where possible prolonged the use of traditional ICE vehicles. As Eberle and von Helmolt [40] suggests many journeys could be achieved using an EV as a substantial amount of city driving is achievable with EVs. Assuming that these can be charged using fossil fuel free electricity it would then be possible to continue to use conventional vehicles on journey's for which EVs are not suited. This suggest that policy should be aimed at understanding what trips are not achievable with an EV and discounting them from early policy and strategy work, targeting instead at those areas which are easiest to change. However, the capacity of the UK energy grid needs to be considered alongside the proliferation of EVs.

The UK electric grid has an important connection with the electric vehicle on two fronts: the ability of the national grid to cope with the additional demands of electric vehicle charging, and the inherent CO2 which is associated with electricity production in the UK. There is much technical and academic discussion taking place around these issues at present.

It is well documented that power generation is responsible for a major part of global CO2 emissions [41] [42]. Boaz et al [43] suggest that a radical change to the way society produces and thinks about energy and energy production is necessary to prevent a global temperature rise that would change the climate of much of the globe leading to a variety of natural and human disasters. A reduction in the amount of CO2 produced though the production of energy is central to the concept that an electric vehicle can be part of a sustainable future.

There are a number of 'costs' associated with the use of non fossil fuel forms of energy technology, both financial and social. For electric vehicles to be an environmentally sustainable means of personal mobility in the future, the public will need to accept these costs. The common renewable sources of power are highly visible and require large amounts of space to be able to produce energy effectively, and this often leads to local resistance alongside regional support [44]. An example of this can be seen in the local movement 'Action Against Matlock Moor Wind Farm Proposal (AMP)' which in April 2010 successfully stopped a wind farm in Derbyshire being built. This organisation is not against wind farms per se, just against the location of a wind farm close to them [45]. This kind of support is not mirrored with nuclear power, which in the developed world is generally opposed on a local and national level more severely than renewable sources of energy [46]. Emerging economies however are more supportive of nuclear energy due to a variety of political and social conditions [47]. The lack of support for nuclear energy stems from perceived issues with safety, security and post life radioactive material [48]. Bickerstaff et al, 2008, found a 'reluctant acceptance' when people were presented with the choice of climate change or nuclear power.

Fossil fuel derived energy in much of the world is often the most cost effective method of producing electricity. In the UK the cheapest form of power generation is gas, which costs approximately £23 per Mega Watt Hour (MWh). The cheapest form of renewable energy production in the UK is

onshore wind power, which cost approximately £55MWh and Nuclear energy which costs approximately £30MWh (Boaz, 2007). In these circumstances if the production of power is left to the markets, non fossil fuel derived energy is un-feasible. However Isoard and Soria [49] argue that in the long term the cost of renewable energy will reduce with technical improvements and economies of scale. Alongside the financial issues with alternatives to fossil fuel derived power there is also a major technical issue. Electricity grids are highly organised and managed networks, and when an intermittent power source such as the wind and sun are brought into this network they can sometimes add very little value. This is because power stations still need to be available when the wind drops or the sun does not shine. Boyal [50] states that, using gas fired power stations to mitigate this would cost the UK an extra £3 per MWh or 5 percent of the total cost of wind power.

Czisch [51] showed that regional grids which supply upwards of 500 million people would absorb the intermittent characteristic of renewable energy sources. An example of this kind of technology is the European Energy Grid. Arnulf Jaeger-Waldau of the European commission's institute for Energy, speaking at the 'Euroscience Open Forum' in Barcelona announced a grid which would include solar energy from north Africa and Spain, wind energy from the North Sea and hydroelectricity from the Alps though high Voltage Direct Current transition lines [52]. There is also the issue of the local grid, which also needs to be balanced and managed. As part of the national grid operating in 2020 trials, EVs are being explored as a means of balancing the renewable electricity element of the grid [53]. In this study the idea of having a wider scale smart grid, which turns on charging when there is low demand, is being explored.

This section has shown that there are technical issues to be overcome, but that none of these are insurmountable, it also demonstrates that EVs have a wider part to play in the decarbonisation of society.

2.6 The case for research

This review of the literature available on EVs has demonstrated that there are gaps in the knowledge around the use of EVs and the motivations for having EVs. Government policies and OEM strategies are being developed with regard for how EVs are being used at present and the motivations behind the purchase of EVs. Therefore mismatches between policy and reality need to be explored and documented, especially as it is likely that EVs will have to be part of a sustainable future.

3 Research methods

To understand the experiences and issues that EV users face and the motivations behind the purchase of an EV, semi structured interviews were conducted with EV users. Alongside this, publicly available documents on government policy and the directions of OEMs were used to inform the interviews and provide context for the discussions and conclusions. The EV interviewees where found through three routes. Firstly, a number of battery electric vehicle user groups were contacted through online forums and direct emails to the management of the society. Secondly social media was employed as a means of contacting EV users. Prominent EV advocates were asking to re-tweet my requirements and those who tweeted about EV experiences were contacted directly. Facebook was also used, with less success, by stating my requirements on EV associated pages. Thirdly I asked the initial contacts to provide details of other potential interviewees.

The research requirements were for drivers that lived in the UK and used an EV as their main form of transportation. This was to ensure that the comparison between UK policy and OEM directions in the UK could be explored and that those being interviewed were regular EV drivers.

Getting a larger research sample was considered, this would have been achieved by a combination of a wider questionnaire with the option to drill down into some of the questionnaires with follow up interviews. This was not undertaken partly due to the limited number of electric vehicle users willing to be interviewed, and partly due to the type of information that was sought. There is already information on the behaviour of electric vehicle users, for example Aston University have detailed telematic information of over 50 EV users for 18 months, so much of the type of information that would be expected to be gained from questionnaires on usage patterns and drive cycles had, to some extent, already been comprehensively catalogued. Baxter and Eyles [54] concept of 'saturation point' was considered, as a questionnaire on experiences would have very quickly resulted in similar answers. More detailed semi structured interviews allowed for a deviation from questions on performance and were able to understand the subtle undercurrents of the EV

movement. The more detailed information about thoughts, feelings and experiences would not have been adequately captured by a questionnaire.
The involvement of key government organisations and other key actors such as vehicle manufactures was considered. However those that were approached did not provide more information than that which could be found in press releases and on organisation websites. Discussions around the future of the technology and direction of the industry were one dimensional and did not provide new information. Because of this, speaking to these actors was not explored further.
The epistemological nature of the information gathered from the interviews was a mixture of truths and beliefs. On a number of occasions propositions were put forward on the basis of the truths explored. The interviewer ensured that throughout the interview the distinction between the two were clear. The semi structured interviews were conducted and recorded via Skype. The interviewee selection process produced a variety of EV users which will form the basis of the discussion. The experience of these different EV users was mixed; one was an electrical engineer and had converted an ICE into an Electric Vehicle whilst others were users of the new range of electric vehicles from Nissan and Mitsubishi. All of the users used the electric vehicle as their main vehicle, some had second ICE vehicles and other didn't, these ICE vehicles were considered to be the second car. The conclusions of these interviews and key information from policy and OEMs will be explored next in the results section before being discussed.
There was scope to conduct more interviews with EV drivers, the total figure of seven was on the verge of saturation point, however up to three more interviews would almost certainly added something to this piece of work. This dissertation underestimated the number of EV drivers that would be willing to be interviewed, there were two main reasons for this. Firstly it was found that many potential interviewees were experiencing interviewee fatigue, in that they did not wish to be interviewed as they had already been interviewed a number of times on similar subjects. Secondly the number of routes to interviewees was limited - the following methods were tried with no success: placing cards on the windows of EVs parked around London; contacting companies that ran charging networks and requesting they send an email on to drivers registered with them, [some were willing to do this with no success, others refused]; asking EV manufactures and sales people to contact their EV driver's databases, [all refused]. The seven interviews do provide enough information for a useful discussion as many of the experiences were shared. The final two interviews did not provide very much unique information. However, more interviews would have produced a more robust set of results.

4 Results

This section will outline the results of the semi structured interviews. There were some key points which were explored in each of the 7 interviews. The first area of the interview covered the motivations behind the decision to go electric. The second area surveyed the effect the various incentives have on the decision to buy an electric vehicle. The third section explored how the interviewees used the vehicle. The fourth and fifth sections study the issues and benefits with the interviewees. The sixth section examined the interviewee's preconceptions and the seventh section asks how those preconceptions changed with actual use.

4.1 Motivations

There were a variety of motivations for the purchase of the EV however there was a broad agreement that the electric vehicle was a compromise. However some of the interviewees stated that in actual use they felt the EVs were an improvement on an ICE. One of the interviewees stated that they were not using the EV for environmental reasons, however those that were, were doing so to differing extents. Interviewee 1 and 3 were doing so entirely on environmental grounds, whereas with the other interviewees, the environmental rational formed part of a wider set of motivations. That being said, there was a general acceptance that in general, they did not embrace a low CO2 lifestyle. For example one of the interviewees had just completed a helicopter pilot's licence and planned to be a commercial helicopter pilot, another interviewee has a heated swimming pool. Many of them had some form of personal electricity generation, generally solar panels. Some of the interviewees were involved in renewable energy creation and saw the EV as an extension of that, for example, one of the interviewees was in the process of building a wind farm on his land and felt that having an electric

vehicle fitted into that project. There was a variety of levels of understanding into sustainability, and what it means: only one of the interviewees mentioned peak oil or air quality. There was a largely 'CO2 centric' understanding of sustainability.

Many of them cited the 'cool factor' and the 'smugness factor' as reasons to buy the electric vehicle. The Tesla roadster, an electric sports car, was cited on a number of occasions as the moment when they realised that electric vehicles were not 'milk floats'. This was one of many elements which publicised EVs, one interviewee cited the 'who killed the EV' which documented the fall of a GM EV in the early 2000's as the starting point of their interest; another cited a car show discussing EVs.

There was an appreciation and a desire to be 'early adopters' at the cutting edge of a new technology, with one stating that he wanted to be 'part of the revolution'. There was a general acceptance that being part of this early phase was important and that because they were in a financial position to do that they felt they should.

There was a noticeable distinction between the people that had conversions from ICE, and those that had not. Those that had converted conventional ICEs had been involved in technology for much of their lives so had an idea of how EVs work, and could fix issues when they arose. Generally, those that had purpose built EVs such as the Nissan Leaf and the Mitsubishi i-MiEV knew less about the technological side of electric vehicles, but understood the basics.

Some of the EV drivers were on their second EV, often starting out with a more basic EV model and then upgrading to something newer and more comfortable.

4.2 Purchase modal and incentives

The people that convert their own EVs do so at fairly minimal cost compared with the cost of a modern purpose built EV, but they are generally not doing it for the cost saving - it was about being different and reducing CO2.

Some users expressed concern that the residual value will be low, or that the battery may not last, so they have offset this risk by leasing the vehicle rather than purchasing outright. Part of this decision was also down to financial reasons in that the outright cost of an EV was too great, but broken down over 3 years was manageable, if more expensive in the long run. Some users had confidence in the life of the battery and the residual value holding up and brought the vehicle outright. In all but one of these cases the users were not concerned with losing or gaining money on the vehicle as they were wealthy enough for it not to be an issue - the vehicle purchase was associated with an interest or hobby. Some stated that they understood that they were early adopters and were willing to pay a premium for that.

That being said, all of those that had brought their cars recently stated that the £5,000 grant from OLEV 'swung them'. They expressed the view that they had been on the verge of purchasing an EV and the grant made the final difference. When this was explored in more detail it was clear that this was partly because of the confidence the government had in electric vehicles as much as it was the financial stimulus - '…without the 5k grant, I would not have purchased the vehicle' (interviewee 3). The other extras [around not paying VED] were not seen as a huge incentive. However those that had purchased the vehicle through their business stated that the company car tax reduction was tangible benefit.

4.3 Vehicle use

All of the interviewees primarily used the EV for local journeys. Each of them expressed concern about travelling towards the limit of their range; however they seemed to have developed their own similar, but different, mechanisms for dealing with this. Interview 1 was with a retired person who was willing to take longer to get to places, thus conserving the distance he could travel, whereas interviewee 4 knew the journey he took was achievable so drove his vehicle very quickly, reducing the range, but as it was a set journey this was not an issue.

To charge the vehicles each of the interviewees stated that they did the vast majority of their charging at home, many on cheap and low CO2 night time tariffs or related to their personal micro energy generation. Most of the users considered work place charging or on street charging as pointless. This was due to a number of reason, including the lack of a guarantee that the charging post would be available when they arrived, slow charging only adding 15 miles for 1 hour of charging, and the numerous schemes with different memberships. Some did however consider opportunity charging when it was available, for example interviewee 2 stated that knowing there were locations nearby that he could go to in an emergency was reassuring. However others chose not to be explorative with the EV and erred on the side of caution with regard to range.

Each of the users had a variety of different approaches to dealing with longer journeys which were not achievable with the limited range of the EV: this generally involved a second car. However two interviewees stated that the second car was not used and they travelled by car to a train station and then were picked up at the other end. (This was only a reasonable option with people that were more flexible.) Another user used slow and fast charges to make their journey, even if it took many hours more. One interviewee stated that they would evaluate the ability of the EV to reach the destination on a route by route basis, - if there were fast chargers on the route, or if they were willing to stay at a friend house or hotel to charge overnight, they would consider using the EV. Interviewee 6 stated that as long as the trip did not require too many zig zags he would use the EV.

When pressed on the need for a vehicle at all, the interviewees generally shared the opinion of Interviewee 1, that our society has been built on the use of the vehicle, many of the community and friendship circles they were involved in required a car, (for example getting to church or visiting their daughter), and that it would take a wider change in society for vehicles to become less necessary. The concept of selling mobility rather than a vehicle was posed with some of the interviewees. They all suggested that they preferred to own their own vehicle, and the hassle involved in car clubs or such like would not be attractive to them.

4.4 Problems

The major issue faced by all drivers is the range of the vehicle: this manifests itself in a number of ways. Some found that they were unable to shake the 'niggle in the back of their mind' as interviewee 6 put it, that they may be left stranded. However this was not shared by all drivers, some of whom were supremely confident that they would make journeys which were within the range of the vehicle and had few worries on this front.

There was a general consensus amongst the drivers who travelled longer distances, and had used fast chargers, that a more complete fast charging network would provide them with the confidence and range required to use the EV for more of their journeys. Interviewee 3 stated that the '… charging infrastructure distorted the route' he wished to take. When pressed, some stated that the charging network would need to be as extensive as the petrol network for them to feel confidant.

Most of the interviewees, initially were ambivalent to positive about the slow charging network, however when this was explored in more detail it became evident that the current system with multiple RFID system, each requiring a different card or key was a major stumbling block to the usefulness of this type of charging infrastructure. Interviewee 5 stated that he felt the UK was quite a long way behind other parts of Europe with their charging network.

4.5 Benefits

Some interviewees stated that except for the climate change impact there was no benefit. However many of the interviewees expressed a view that the driver experience with an EV was a vast improvement on a conventional ICE. Interviewee 5 stated that of the 3 cars between the family of 5 the EV was by far the most popular. The reasons given for this were that the vehicle was quieter, faster at delivering acceleration and easier to drive.

Some stated that there was a small financial benefit associated with the electric vehicle, others stated that there was no financial benefit, this was directly related to the amount of driving the EV did.

4.6 Pre-conceptions

Many of the users stated that being part of, or speaking to EV clubs allowed them to have an insight into what owning an EV would be like. Many of them are active members in EV clubs and see this as a hugely positive forum for shared experiences. Some of them stated that the pre-conceptions they had were around the range of the vehicle and how to charge it. When pressed it was clear that the discussions with the EV club members meant they were prepared for the capabilities. This managing of expectations was seen as being very positive as there were many conflicting media reports on range and speaking to actual users meant that these could be firmed up.

4.7 Confidence

Depending on the level of preconditioning from other users, there was a different attitude to the range. Broadly speaking those that were less engaged beforehand were disappointed, whereas those that were more engaged with other users where surprised by the range.

Users generally started out as being more cautious with the range over the first few months, but when they had learned the dynamics of the car, started to take it closer to the limits of its range.
There was a general consensus that it takes 1 to 3 months to become confidant with the range. Many users have been able to use the vehicle far more than they expected to, for example Interviewee 4 stated that he never expected to save money using the EV, but with the amount which it is being used at the moment (13,500 miles in 10 months) means that he will recoup the capital expenditure with reduced operating over the life of the vehicle.
This section has highlighted the variety of experiences and motivations of electric vehicle owners and will now discuss the pertinent points this has unearthed.

5 Discussions

This section will discuss the results of the semi structured interviews within the context of the government policy and OEM strategy. It will start by discussing charging and the network before then looking at the government policy and OEM strategies which are in place to encourage the take up of EVs. Then I will explore the opportunity which is currently being missed to involve experienced EV users in discussions around the direction of EVs. This paper will then discuss the mismatch between what EV users are saying about using the vehicles and what is being portrayed by the government and OEMs about the vehicles. Finally the paper will discuss what this means for the future of personal mobility in the UK.

5.1 Charging

There was a consensus that the charging infrastructure in the UK was poor - this section will use the understanding which has been gained from the EV drivers to discuss the UK charging network. The plugged in Places (PiP) bids have trialled a number of different options which focus on slow charging; the interviewees were generally dismissive of this kind of infrastructure. The Source London network originally planned for a far reaching on-street charging network; however the scope of this has been reduced significantly (Vaughan, 2012). This is likely to be associated with two different factors, firstly the difficulty in finding suitable locations for charging infrastructure and the realisation that on street infrastructure is not useful, something which this research supports. There was much discussion of range anxiety being an important issue to overcome for the early phases of EV proliferation. However none of those interviewed in this study cited on-street slow chargers as key motivators for them to buy an EV. Charging at home and having a second car was seen as more important. This suggests that there was a mismatch between the original government policy direction and what is necessary now, however it also suggests that this has been recognised.
Although this mismatch has been recognised however, of the eight PiP trials the government have invested in, only The 'One North East' bid has fast chargers alongside slow chargers (chargeyourcar.com). It was clear from the interviews that some form of fast charging would be necessary for wider proliferation of EVs and this is not being reflected in modern policy. This is a mismatch between what owners of EVs need and what policies are being pursued by the government. It may be that the initial willingness of the government to facilitate the take up of EVs has achieved its goal of convincing Mitsubishi and Nissan to release their EVs in the UK and for Nissan to invest in a plant in Sunderland. The recent cut of 80% in subsidies [55] for the EVs and the lack of dynamism on the part of the PiP trials, which continue to invest in a technology with limited use, suggest the government is backing away from its involvement in EVs.
This reduction of the government's support for EVs does not seem to have had an effect on future EV releases being in the UK, with Renault the latest company to release EVs in the UK. In the longer term however it may hamper the UK's attempts to encourage vehicle manufactures to invest in EVs in the UK. How far and to what extent the government should be investing in assisting private entities is a valid argument for the reduction of subsidies for EVs. However as was made clear in section 2, reducing GHG emissions is a strong enough case for support in this sector. Where the government is not providing users with fast chargers, Nissan is planning to make 400 fast chargers available in Europe. It is expected that up to 60 of these will be in the UK however with the reduction in subsidies from the government, it may be that Nissan focus their efforts on other parts of the EU. This piece of research suggests that this lack of commitment from the government, and the lack of dynamism from PiP, who could divert

funds towards a nationwide fast charge network, will hamper the proliferation in EVs.

5.2 Network

It is understood that to facilitate the proliferation of EVs, changes need to be made to the electricity network. The UK national Grid trials suggest that EVs will need to be associated with a smart grid. The interviewees mostly charged using economy 7, which is a rudimentary version of a smart grid, and two of the interviewees stated that they charge their vehicles when they are producing power from micro generation. The concept from Ford of selling energy packages, including Solar cells and older batteries for energy storage suggest that OEMs are also aligning their strategies within this concept of smart grids. There is a 'hole' in government policy on this. There are limited trials into the future network, and for EVs to become a reality these need to be enlarged. This is an important mismatch between government policy and could undermine the proliferation of EVs. The interviews suggest that many EV drivers are already involved in energy stewardship; more should be done to engage with these users and involve them in the development of smart grids.

5.2 Incentives

Each of the recent EV owners stated that the monetary incentive they valued the most was the £5,000 grant: this suggests that this is an important part of the government package of policies. The pot from which this grant comes from has been reduced significantly (Vaughan, 2010), - this is a clear mismatch between policy and practice. However how far and to what extent this policy assisted in the greater uptake in EV sales is questionable. The subsidy for a Mitsubishi I- MiEV takes the vehicle from £29,000 to £24,000. Someone who is able to spend £24,000 on an EV which has similar characteristics to a £10,000 ICE vehicle may not really appreciate this discount. Those that purchased the car outright stated that they brought the car without the idea of saving money in mind. These were people that could afford to purchase the cars. For a wider scale proliferation of EVs the purchase price of £24,000 will be as out of reach as £29,000.

Those that were interviewed were likely to be the 2% of the population outlined by Charlswoth [56] that are willing to pay for the changes necessary to reduce GHG emissions. Most of these people were able to able to overcome the inconvenience associated with an EV because they were retired or could afford a second car, for wider proliferation, alternative measures will need to be put in place. The policy towards reducing the capital expenditure of EVs may be better if it was aimed at making leasing vehicles more attractive, as Dunn et al [26] found; leasing vehicles provides an easier pay back period. Those that did not lease vehicles stated that the reason they did not lease was because the overall cost of leasing was far higher than the cost of the vehicle. For EVs to be a realistic vehicle for those that cannot afford the capital expenditure, the leasing costs need to be reduced. This is something which government policy does not address: for EVs to be available to the sections of society which cannot currently afford EVs, appropriate policies need to be developed.

5.3 Missed opportunities

The development of EVs has required and will continue to require much research and many trials. An element of the proliferation of EVs which is in danger of being ignored is the knowledge, skills and experience of those that have been involved in EVs for many years. There are no policies which support the retrofitting of vehicles, which is a cheaper alternative to purchasing a new EV. The EV community need to be engaged to assist in the development of this. There is potential for existing vehicles to be retrofitted with batteries but the OLEV £5,000 grant is not available to retrofitted models. For a faster and cheaper take up of EVs the experiences of experienced EV owner's needs to be tapped into, and the knowledge they have around retrofitting vehicles needs to be supported.

5.4 EV virtues

There is a mismatch between what EV drivers are saying about owning an EV and what most OEMs and government policy suggest are the realities of owning an electric vehicles. Much of the rhetoric focused on the negatives of owning EVs: however there is much greater scope for talking about the positives of using an EV.

Tesla, have put the EVs into the 'cool' group. Many of the interviewees that had recently purchased their EVs mentioned the Tesla, either as an inspiration or as something which put the idea of a modern EV on their radar. This is something which other OEMs are not tapping into enough. The advertising around the Nissan Leaf tries to justify the existence of the leaf. For example the key elements of the website are around 'cost of ownership', which is aimed at explaining the high

capital cost and 'charging and range' which is designed to make people understand the capabilities of the EV. Nissan should ensure they accurately state the limitations of the vehicle, but they should not build the marketing campaign on this. The owners all suggested that the drive associated with an EV is better compared to an ICE, Interviewee 5 stated that the EV was far superior to his ICE. There is a mismatch between the confidences the OEMs have in their vehicle's ability and the users experience of the vehicle's ability.

This undervaluing of the ability of the vehicle is shared in the academic literature. For example Gross and Clarke, 2011 discuss a lack of trust from users in how long the battery will last. This opinion was shared by those drivers which had older EVs; however the drivers of modern EVs stated that they were confident about the batteries. This rhetoric from OEMs and the academic literature may undermine the proliferation of EVs.

5.5 Personal mobility

The concept of using EVs for manageable journeys and ICE for those which are not yet achievable was put forward by Eberle and von Helmolt, [21]. This research found that this concept is broadly true; many people had second vehicles which they used for longer journeys. For wider proliferation, for those who cannot afford or are unable to keep two cars, there would need to be a move towards car sharing and the idea of mobility being sold rather than vehicles. This concept was not something of which the interviewees were supportive, but there is very little work being conducted by OEMs or Car sharing companies to align themselves with the EV market. This is something which should be explored so that the lessons learnt on why these are not popular to EV drivers can be taken on board.

As Imrie (1994) states, the idea of personal mobility in the shape of the automobile is unsustainable. Section 2 argued VMT should be reduced on a different time scale to that of increasing efficacy and reducing CO2 from vehicles. The interviewees generally suggested that they would not be willing to change to a less car-orientated lifestyle. For example, interviewee 1 stated that his life is based around the automobile, and changing that would not be possible. EVs may have a detrimental effect on attempts to reduce VMT as it will provide a low GHG option for personal mobility to continue. Policy needs to be stronger in supporting developments which promote low VMT.

Issues around government policy and OEM strategy towards charging, incentives and the image of EVs have been discussed, as have the missed opportunities and potential for the future. This paper will now conclude with three key points around incentives, engagement and the EV experience before making suggestions for further academic work.

6 Conclusions

This section will outline three key conclusions that can be drawn from this piece of work. First, the disparity between the policies currently being pursued by the UK government and what was important to UK users. Second the lack of engagement with the EV community and finally the discrepancy between the users' experience and OEM and government rhetoric.

The government incentives have been positive in that they have encouraged OEMs to sell, and in some cases, make EVs in the UK. As well as this they are incentivising people to purchase EVs; however there has been a cutback in these incentives. The stepping back in government support for EVs is premature given the importance in a move away from ICE vehicles. In light of these limited funds it is important that the funds which are available are used to best effect. It is clear that there are mismatches between the incentives and therefore the policies and measures that would have the biggest impact on EV proliferation.

The policies in place to encourage charging infrastructure do not include a mechanism to develop a system that would be of most benefit to EV users. The PiP bids have so far focused on regions and largely encouraged slow chargers: this should be dropped and these funds should be diverted towards a nationwide system of fast chargers. The incentives which are aimed at encouraging the purchase of EVs do not include a mechanism to encourage those that cannot afford the high capital cost of an EV; this is also a failure in policy which will hamper the proliferation of EVs. There are a number of ways in which this can be pursued, one is to decrease the leasing costs and another is to encourage retrofitting of existing ICEs with batteries. The discrepancy between what is necessary for EV users and what policies are being pursued have the potential to slow the take up of EVs.

The engagement with EV drivers to date has been through controlled experiments via OEMs: there is a lack of policies and strategies to engage with the wider EV community. This is especially important as wider proliferations of EVs takes place. There is scope to involve EV drivers in conversations around the future of mobility, with car sharing and a reduction of VMT being key topics to be explored. As well as this, EV drivers need to be engaged with attempts to develop smart grids and encourage grid stewardship. Considering the government has an investment in many of the EVs in the shape of the £5,000 grant, engagement of this kind has potential which is currently not being realised.

At present much of the rhetoric from government and OEMs is on the issues and disbenefits of owning an EV. There is a mismatch between the experiences of EV users and the focus of marketing and government literature on EVs. For wide scale proliferation of EVs to take place, there is potential for a greater focus on the improved driving experience encountered in this research.

The three main conclusions from this would be more robust if more interviews were conducted: for future work this paper recommends that the same set of points should be covered in interviews with more EV users. As part of this study or as a separate study the impact of the governments reduction in subsidies should be explored. As well as this, research should be carried out on those who are considering purchasing EVs, to understand what the biggest barriers are, and where policy and strategy can be tailored to tackle these. Finally, it would be useful for further academic work to into the links between EV users' attitudes to the future of mobility, exploring VMT and changes to personal car use.

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