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Lessons and Insights from Experience of Electric Vehicles in the Community

Ian Bruce[1], Neil Butcher[2], Christina Fell[3]
[1]Arup, 560 Mission Street, 7th Floor, San Francisco, CA 94105 ian.bruce@arup.com
[2,3]Arup, Blythe Valley Park, Solihull, UK

Abstract

In this paper Arup present their perspective on the present state of the UK electric vehicle domain based on actual user data and vehicle charging patterns from two years of studies into consumer behaviour. It reviews new and historic projections of electric vehicle uptake and compares and contrasts these projections in the context of the early years of mainstream electric vehicle availability. It provides information related to the effect of the anticipated adoption of electric vehicles at an energy generation system level and at the power distribution system level, further divided into the domestic, business and public sub-systems.

Keywords: charging, demonstration, sales

1 Introduction

The sustainable transport domain is fast moving with frequent technological developments delivering disruptive innovation that in turn provides exciting opportunities and new risks that have to be managed.

The low carbon transport industry has brought together disciplines from vehicle design, transport and urban planning, energy, and sustainability who have not traditionally worked so closely.

The breadth and dynamics of the domain fit well with Arup's wide experience and strong foundation in systems engineering, planning, environmental management, automotive design and other technical engineering disciplines. Arup are unique in having experts across almost all of the disciplines required to make a successful transition to low carbon transport.

Arup is involved in a number of leading research and demonstration projects where new and emerging technologies can be evaluated and new business models tested. This paper concentrates on the CABLED project as a source of real world user behaviour.

1.1 Coventry and Birmingham Low Emission Demonstrators (CABLED)

CABLED - short for Coventry and Birmingham Low Emission Demonstrators – is a consortium comprising 12 organisations, led by Arup.

CABLED have been trialling 110 of the 340+ vehicles taking part in the Technology Strategy Board's Ultra Low Carbon demonstrator programme. Each of the five vehicle manufacturers in the consortium – Jaguar/Land Rover, Mitsubishi/Colt, Mercedes Benz/smart, Tata Motors and Microcab Industries – plus Arup have contributed vehicles which are a mix of fully Electric Vehicles (EV), plug-in hybrids and hydrogen fuel cell cars.

Electricity providers E.ON have installed standard charging points for the trial with assistance from the city councils of Birmingham and Coventry.

Three of the Midland's leading universities play a major role in the project: - Coventry University undertaking the selection process of drivers and supporting Microcab; Aston University analysing vehicle usage data; and the University of Birmingham contributing access to and expertise gained from its hydrogen fuelling station, which is currently one of the very few of its kind in UK. A new hydrogen station has also been installed in Coventry University.

The Technology Strategy Board's Ultra Low Carbon Vehicles Demonstrator programme, launched in 2009, is the largest demonstrator trial of its kind in Europe. 340 vehicles ranging from high performance vehicles to small city cars and vans have been driven by private and fleet drivers in seven different demonstrator hubs across the UK. The programme is supported by the government's Office for Low Emission Vehicles. The aim of the trial is to show that ultra low carbon vehicle technology in the UK is at a promising stage of development, that the vehicles are suitable for everyday use, and to ensure that the country is well placed to play a competitive role in an emerging global low carbon vehicles market.

1.2 ETI World Class Plug-in vehicle programme

In a separate project, in 2010, the Energy Technologies Institute launched three major research projects to develop pathways to a self-sustaining mass-market for electric (EV) and plug-in hybrid electric (PHEV) vehicles. Arup led the consortium that considered the economics and carbon benefits of the mass roll-out of plug-in vehicles.

The project considered the interaction between technological, economic, fiscal and consumer response factors and evaluated EV and PHEV deployment scenarios through to 2050.

Considerable new research was undertaken to understand future vehicle manufacturing and running costs, electricity infrastructure costs, and consumer response to new vehicle offerings. The research was integrated into a computer model of the plug-in vehicle industry to predict future vehicle sales and carbon emissions in a range of scenarios for macroeconomic conditions and government policies.

Results from this work are being presented in other papers at EVS26.

2 User experience

Actual user data and vehicle charging patterns in this paper have been taken from the CABLED project taking place in the West Midlands region of the United Kingdom. Real life monitoring of vehicle usage is taking place over a number of years with each vehicle being with a driver for at least 12 months.

Each vehicle has been fitted with a data-logger to capture journey and charging behaviour. The combination of GPS and charging data allows the project to understand which charge points are being used and when.

Although the data shows some interesting trends, extrapolation from these few cars should be undertaken with great care.

The daily mileage of the vehicles in the trial is compared to the daily mileages driven in the UK's National Travel Survey [1]. Since there are so few electric vehicles the daily mileages from the Survey are assumed to be of internal combustion engine (ICE) vehicles. This allowed a comparison to be made between the two sets of drivers Fig.1.

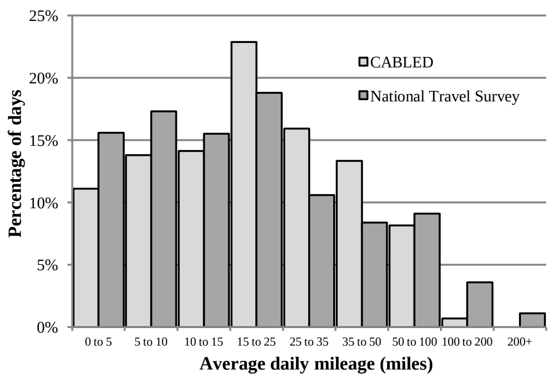

Figure1: Daily mileage of EVs vs. ICE vehicles

The daily distances driven by EV drivers are similar to those of ICE drivers up to 100 miles per day. For more than 100 miles, the ICE drivers use their vehicles more often than the EV drivers. Greater than 200 miles per day is beyond the capability of the EVs, even with a full recharge. Drivers travel greater than 100 miles on 5% of days. It is these days on which EVs cannot meet the drivers' needs and they need to consider alternatives.

Fig.2 shows a comparison of individual journey lengths. On journey lengths of up to 50 miles there is little difference in the distribution between EV users and ICE users.

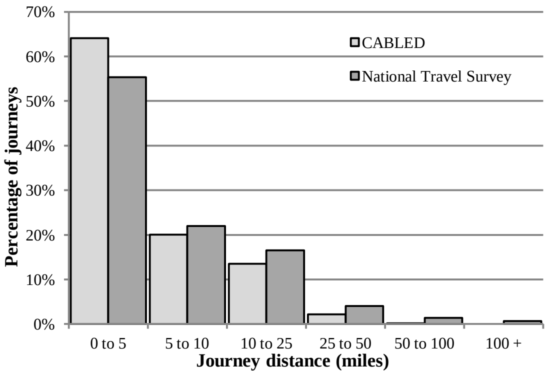

Figure2: Journey lengths of EVs vs. ICE vehicles

The National Travel Survey shows that 95% of journeys are less than 100 miles and within the range of the EVs. This represents 75% of the total mileage. EVs that are currently available have not been designed for long journeys, but the data shows that the bulk of journeys fall well within their capability.

Most of the volunteer drivers in the trial had two vehicles in their household. Two car households are a likely initial market for EVs with an alternative ICE vehicle available to meet the longer journeys. For households with only one vehicle, plug-in hybrids (PHEVs) are likely to be a popular option until electric vehicle range or recharging options allow for these occasional long journeys. Drivers who frequently make journeys of greater than 50 miles are unlikely to move to plug-in vehicles in the short term.

Data from the state of charge (SOC) of the battery can give information about the behaviour of the users. Fig.3 shows the state of charge of the battery at the end of charging.

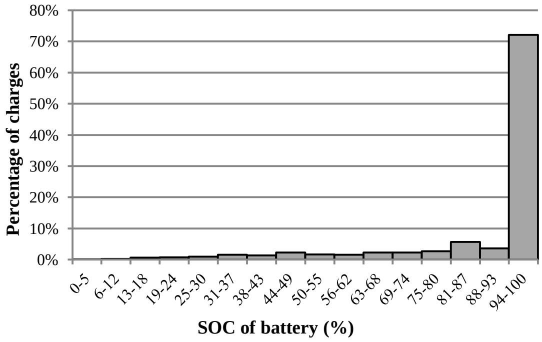

Figure3: Battery SOC at end of charge

The vehicle is left on charge long enough for the battery to charge fully in more than 70% of charging events. This indicates that the users have enough time to fully charge their vehicles, even when only 3kW charging is available as in this trial. It also suggests that users leave their vehicles plugged in until they need to use the car again. With the vehicles plugged in for long periods of time, there appears to be the opportunity for staggering the charging of vehicles, using smart technology, to avoid peaks of electricity demand.

Fig.4 show the state of charge of the batteries when vehicles are put on to charge. It provides an insight into how comfortable drivers are in using their vehicles at low levels of battery charge.

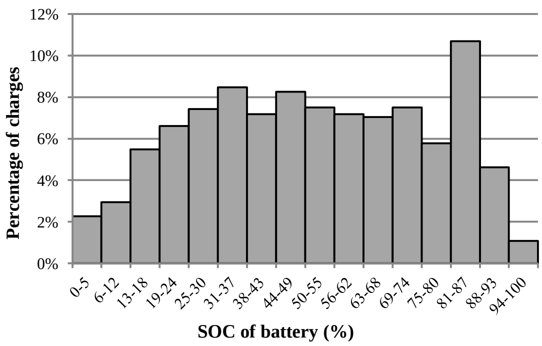

Figure4: Battery SOC at start of charge

There is little trend in the level of charge between when the battery is 25% full and 90% full. There is a peak at 83%, equivalent to usage of about 10 miles after a full charge. The data shows that this is most commonly due to two journeys of 5 miles, but also that 10 miles is a common commuting distance for those users who are charging at work as well as at home.

The graph indicates few charge events starting from 95-100% indicating people do not often plug in when the vehicle is almost full. The number of events also starts to tail off below 25% indicating that people feel uncomfortable using the car when their batteries run down to this level – an indication of range anxiety perhaps.

Fig.5 shows the energy transferred per charge. Given that a large percentage of charges are to 100% we would expect the energy transferred to the battery per charge to be largely the inverse of the SOC at start of charge. Looking at Fig.5 there are two differences to that expected - a larger number of 0-5% charges, and a peak at 25-30% charge.

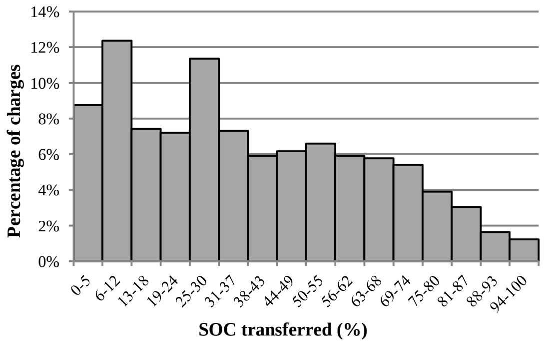

Figure5: Energy transferred to battery per charge

Since Fig.4 shows that drivers are rarely charging when the vehicles are nearly full, it must be concluded that a large number of the 0-5% charges are top up charges that do not charge the vehicle to 100%. These are fairly small top-ups, up to 20 minutes in length, for example, because it is possible to charge whilst parked but not needed.

The spike between a quarter and a third of the battery in Fig.5 also isn't seen in Fig.4 so would indicate these charges are not charging to full. Therefore topping up with this amount is often needed to feel comfortable completing a round trip, or that 1.5-2 hours is a common dwell time for which drivers wish to recharge whilst doing other things.

3 Energy perspective

The average electricity demand profile through the day from the vehicles on trial was measured and Fig.6 shows the demand profile scaled to represent one vehicle over a 24 hour period. There are peaks at 9am, 7pm and 12 midnight corresponding to arrival at work, arrival home from work and late night off peak charging.

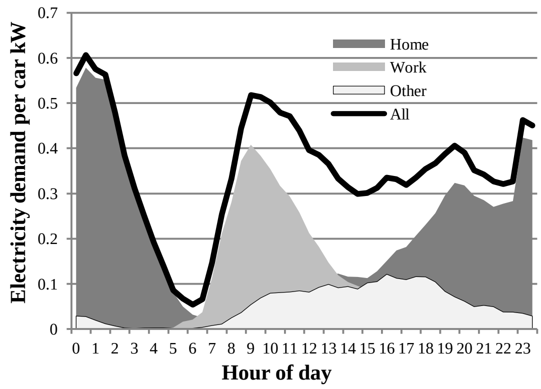

Figure6: Electricity demand profile from trial vehicles

Approximately half the vehicles were compatible with timers and users were able to set the timers to charge the vehicles using off-peak electricity. Users could choose a domestic electricity tariff with a peak rate only slightly more expensive than the standard peak rate, but with significantly cheaper night-time electricity. Approximately one third of users chose this tariff. All users regardless of their tariff were offered incentives of up to £50 per annum to use off-peak electricity for charging their vehicles.

The demand profile from the trial can be scaled up and compared to the predicted UK grid demand to estimate the effect that widespread adoption of electric vehicles would have.

Based on the data collected so far and the future EV sales forecasts, increase in UK electricity demand due to EVs will be very small until 2030.

Fig.7 shows the position in 2050, assuming that 100% of the UK car fleet is fully electric, and that EV efficiency has improved by 40% from 2010 figures.

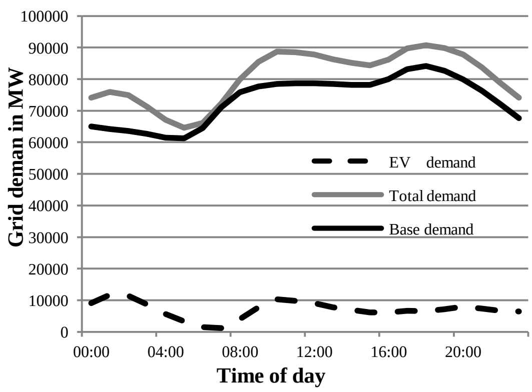

Figure7: Predicted UK grid demand in 2050

EVs overall would apply a small but significant additional load. However if this load coincides with the peaks in the base demand, then it will cause a concern for the electricity suppliers. The data suggests that the morning peak on plugging in at work and the peak on returning home are likely to cause issues. The desired behaviour is for off-peak late night charging. Whilst the trial indicates that it is possible to influence the timing of domestic charging, workplace charging will take place during working hours with limited options to shift it away from the period 9am-5pm. It is possible that some fleet charging could be shifted outside of these hours. The UK government strategy currently assumes workplace charging will be a major enabler for those without offstreet parking at home; this behaviour may increase the daytime peak electricity demand.

4 Distribution perspective

The collected GPS and charging data has allowed type of charging location to be studied. The percentage of charging at each type is shown in Fig.8. The majority of charges, greater than 60%, took place at home, with approximately 30% taking place at work. However, not all users had workplace charging. Of those who had workplace charging the split was closer to 50:50.

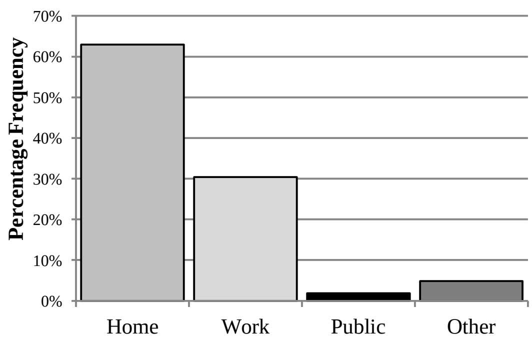

Figure8: Location of charging during trial

Public charge points represent a small percentage of charges, although this has increased recently with more cars on the road and more public charge points being introduced in areas frequented by EV users.

Hotspots of EV ownership are likely to require local grid reinforcement in residential areas in only a few years unless smart charging and differential tariffs can encourage staggered overnight charging. New business models will need to be developed and tested in order that the electricity suppliers and distributors can influence consumer behaviour.

5 Forecasts of the future

A great unknown is how well electric vehicles will sell in the next 40 years. Rather than make a new prediction, we have looked at the predictions for 2020 that have been published over the last 4 years, and how they have changed. The forecasts have been made by a wide variety of organisations - governments, environmental organisations, vehicle manufacturers, power companies and consultancies. They provide a wide range of estimates.

Fig.9 shows the predictions. The vertical lines show the range of values predicted by one source, with the highest and lowest prediction at either end of the line. A cross on a red line shows other scenarios from the same source. An individual cross indicates a source that only gave one predicted value.

The earliest prediction in our sample from 2008 has the largest range from 2% to 24% of sales. Later predictions have narrower ranges, suggesting that individual sources may feel more confident in their prediction. However, looking across all sources in 2011 the overall range is from 1% to 21% and therefore the overall uncertainty has not reduced. The lower bounds have tended to get lower over time, indicating people are more pessimistic about the worst case scenario. The average prediction is for 8% of vehicle sales to be plug-in vehicles in 2020, with half the sources predicting 5-10% of vehicles.

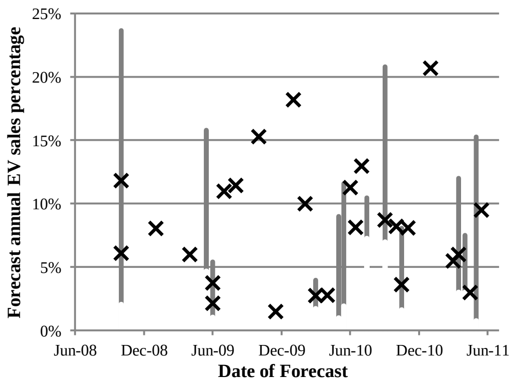

Figure9: Forecasts of Plug-in vehicle sales in 2020

In terms of percentage of sales, the consensus is that EVs will be almost twice as popular in the EU making up 11% of sales compared to less than 6% in the US and China.

In terms of numbers of vehicles predicted to be sold, European sales will be twice those of the USA. In the much larger Chinese market, EV sales will be comparable to European numbers.

The forecasts of total cost of ownership suggest that an EV will reach price parity with an ICE vehicle around 2022. This date is however very dependent upon government decisions on grants and fuel taxes, as well as battery price reductions. Regulations on CO_2 emissions may also force vehicle manufacturers to subsidise low carbon vehicles at the expense of high emission vehicles.

The car-buying public is used to comparing purchase prices in the forecourts, and maybe including a small allowance for the relative fuel economy of competitor vehicles. For EVs to flourish, the public requires education and information on the total cost of ownership at the point of sale.

6 Conclusions

Initial trials are yielding useful data and insights into the use of electric vehicles in real world situations.

EVs are already well matched to users' travel needs in households where there is more than one vehicle.

Electricity demand from EVs needs to be managed. Incentives for off peak charging have been successful in encouraging behavioural change and this is a promising method for managing domestic demand.

However demand management for charging of vehicles at work places still needs to be considered to minimise the increase in peak grid demand.

Future forecasts indicate uptake through to 2020 will be steady but there is still a great deal of uncertainty on the level of sales.

References

[1] Department for Transport, *National Travel Survey 2010,* http://www.dft.gov.uk/statistics/series/national-travel-survey/

Authors

Ian Bruce
Ian has over 10 years experience in the automotive industry specializing in analysis and systems engineering.

Neil Butcher
Neil has been working on the issues associated with the deployment of electric vehicles since 2006. He has been Arup's lead on the CABLED project since its inception, and is currently developing computer models to understand the potential future implications of electric vehicles on the UK infrastructure.

Christina Fell
Christina is Arup's project manager for the CABLED electric vehicle demonstrator project. Her experience also includes finite element analysis, measurement and data collection, statistical data analysis and reporting.