Customer-Led Network Revolution

High Level Summary of Learning

Electrical Vehicle Users

DOCUMENT NUMBER
CLNR-L254

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ISSUE DATE
23rd January 2015

Reviewed by	Robin Wardle, Durham University
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Date	**Issue**	**Status**
23/01/15	1.0	Published

1. Executive Summary

This report by Durham University examines the nature and practice of energy use by domestic customers in the Customer-Led Network Revolution (CLNR) project who own an Electric Vehicle (EV) and have access to a home charging point.

This CLNR project output is the largest socio-technical study of domestic EV charging in the UK and brings together monitoring data to examine electric vehicle usage patterns and expected network loading in the event of large-scale take-up of electric vehicles.

Customers on the trial exhibit "working household" house demand profiles with EV demand profiles that track these. EV charging strongly follows domestic occupancy, especially as it relates to working patterns; the standard working day rhythms define and constrain EV charging patterns with weekend charging load different from weekdays.

The EV charging practices show diurnal as well as seasonal patterns of activities. The EV load increases in winter months, likely due to battery charging demand (increased vehicle heating) and decreases in summer months (possibly) due to other factors such as summer holidays. This supports the predominant use the EV as a week-day car used to commute to work.

Concerns about range affect the charging patterns and timing. Customers express concerns about the range and seem to always need to be confident the vehicle is charged, which qualitative evidence describes as a tendency for "topping up", "maxing up the miles" and opportunistic charging.

Annual demand for this group falls within the bounds for domestic customers in general (as per the sample group TC1a), and is in line with the TC1a average consumption. This is perhaps surprising as we might expect these EV owners to fall into Mosaic[1] groups exhibiting a higher annual consumption (e.g. groups B, F, G, representing working families in suburban areas). However this might be explained by the lower-than average daytime consumption for these customers. This group reports strong interest in general energy saving and are assumed to be predominantly at work during the week.

[1] http://www.experian.co.uk/assets/business-strategies/brochures/Mosaic_UK_2009_brochure.pdf

2. Introduction

This report describes the CLNR trial which examined electric vehicles usage patterns and expected network loading in the event of large-scale take-up of electric vehicles. The trial involved domestic customers who owned an electric vehicle and had access to a home charger, analysis being carried out by Durham University's CLNR project engineering and social science teams. Observations are based on a semi-qualitative analysis of EV dataset collated from online survey, face to face interviews with householders enrolled in the CLNR project, and power monitoring data collected from households and electric vehicle (EV) chargers.

This CLNR **project output is the largest socio-technical study of domestic EV charging in the UK**. This work sits alongside other studies such as: Plugged-in-Places, an Office for Low Emissions Vehicles (OLEV)-funded scheme designed to inform future development of the UK's recharging network[2]; The Ultra-Low Carbon Vehicle Demonstrator Programme, a series of eight Technology Strategy Board (TSB)-funded pilot schemes investigating EV driving habits; My Electric Avenue, an Ofgem-funded programme to investigate EV clustering and load control; and Low Carbon London, a LCNF-funded project, part of which is studying demand at public charging stations.

The CLNR study complements and extends learning from these previous and ongoing projects, which concentrate either on public infrastructure; driving behaviour and vehicle charging; vehicle clustering and charging control; or technology demonstration. This study examines customer practices and behaviour at the household level in relationship to technology ownership and life rhythms, illuminating how the patterns of EV use and domestic charging constrain the network, and suggesting how these constraints might, or might not, be lifted.

2.1 Methodology

The research adopts socio-technical and practice-based approaches as the lenses through which to undertake this work, and a range of methodologies across social and engineering sciences is used. The work in this report draws on the findings of 13 qualitative research visits and 83 survey responses from EV owners, as well as electricity use data generated by 143 monitored domestic charge points and households.

[2] Note that PIP has delivered not only public infrastructure – only 65% of the 4000 UK charge points funded through PIP are publically accessible.

Social science research methods consist of two main approaches: a survey, and qualitative interviews/tours. The survey instrument was designed to capture EV household composition and socio-demographic make-up, and to inquire into respondent's attitudes towards energy usage. The qualitative semi-structured interviews centred on participants' energy use in general terms as well as their thoughts, experiences, and feelings about EV use, charging, and driving.

The quantitative analysis of electrical demand data collected from the trial participants included basic data validation check, following which group electrical consumption properties, such as mean, variability, and totals, over varying time periods, could be calculated. The direct measurements from the field trials could then be matched with survey and interview findings to elaborate and explain observed or reported behaviours.

3. Charging practices in a domestic context

This research highlights the importance of home charging in the set of charging strategies available to EV owners, while also setting the CLNR research in context; **without workplace and public charging, domestic charging demand would be increased with a corresponding increase in evening peak demand**. The loading scenarios presented in this work may thus be at the lower end of the scale for domestic loading.

The studies carried out on CLNR are centred very much on the domestic charging environment and the effect of EV charging on the local distribution network. The North East of England has been host to EV ownership and driving studies (Future Transport Systems, SwitchEV trials 2013), has a well-developed public and workplace charging infrastructure (North East Plugged-in-Places project, 2013), and it is reasonable to expect that not all EV charging will take place at the domestic level. Robinson et al.[3] studied the relative frequencies of work, home, public and residential charging for SwitchEV project participants, the results of which are shown in Figure 1 below.

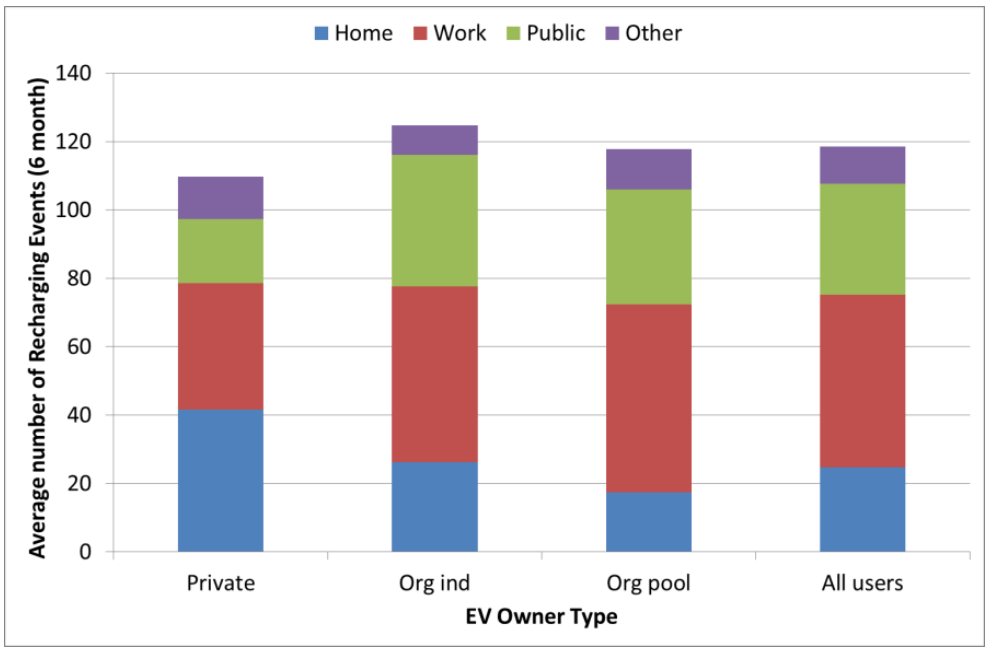

Figure 1: EV Owner Charging Locations (source: Robinson et al. (2013)

[3] Robinson, A. P., et al. (2013). "Analysis of electric vehicle driver recharging demand profiles and subsequent impacts on the carbon content of electric vehicle trips". Energy Policy 61 (2013) 337-348.

3.1 Evening Charging

At home, evening charging is very much the predominant mode of refuelling the electric vehicles in the trials. The chart below (Figure 2) shows the comparison of EV households with TC1a households, averages for January[4]. We observe the evening peak of EV charging demand at around 8pm; this is slightly later than the evening peak exhibited by homes in the CLNR control group trial. During the day charging demand is low.

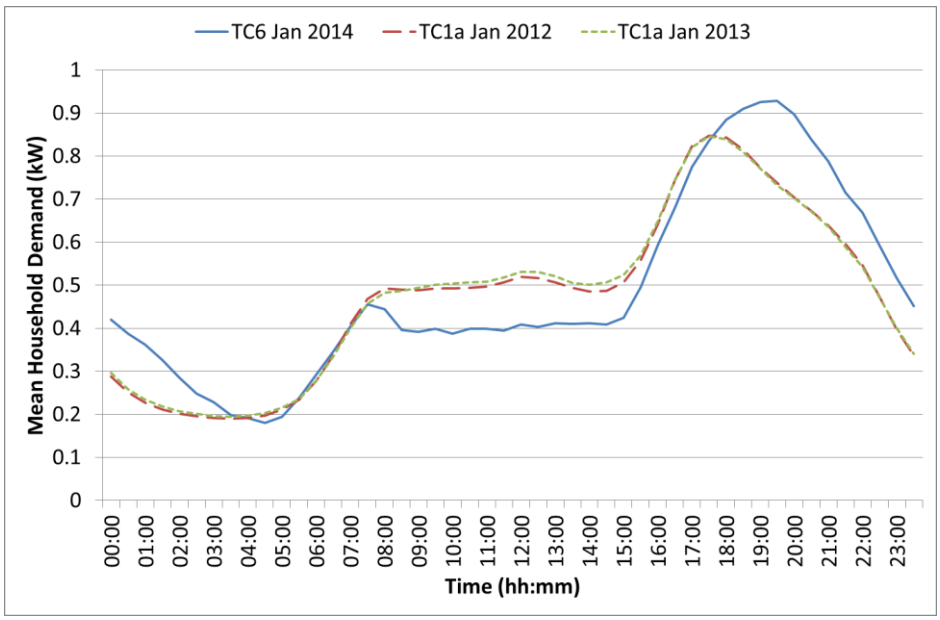

Figure 2: Comparison of EV households with TC1a households, January

The analysis of the EV survey shed light on timing of charging times (Figure 3). According to the survey 61% of respondents (54 people) reported they charge the car in the evenings. As the second answer (14%) was reported charging anytime/when needed.

[4] The different years are due to availability of data. Despite this, examination of the trials data in general confirms this trend.

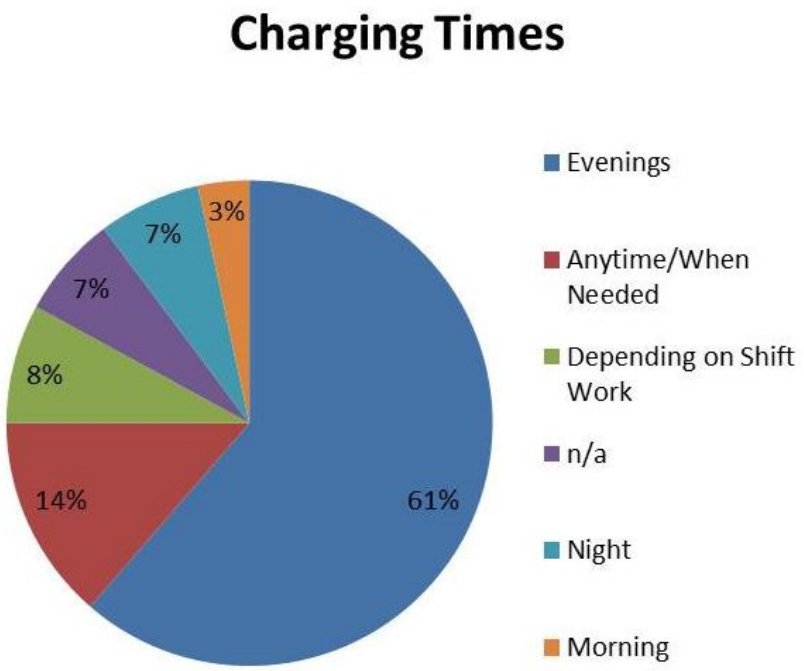

Figure 3: Survey responses - EV owners' attitudes to charging times

Interview data show that charging behaviour is dependent on daily routines; customers are coming in from work and putting the car on charge at a particular time:

"My wife would come back around half-six and would put it on charge just if it needed to". (Peter)

3.2 Weekday vs Weekend Charging

Figure 4 shows the average diurnal (daily) pattern of electricity supplied to the EVs for weekdays and weekends. It can be seen that in general weekday charging is significantly more concentrated at around 20.00 with limited daytime charging, which is consistent with the EVs being used as work transport. At the weekend, the diurnal peak is lower and more spread out with considerably more charging happening during the afternoon and less morning charging.

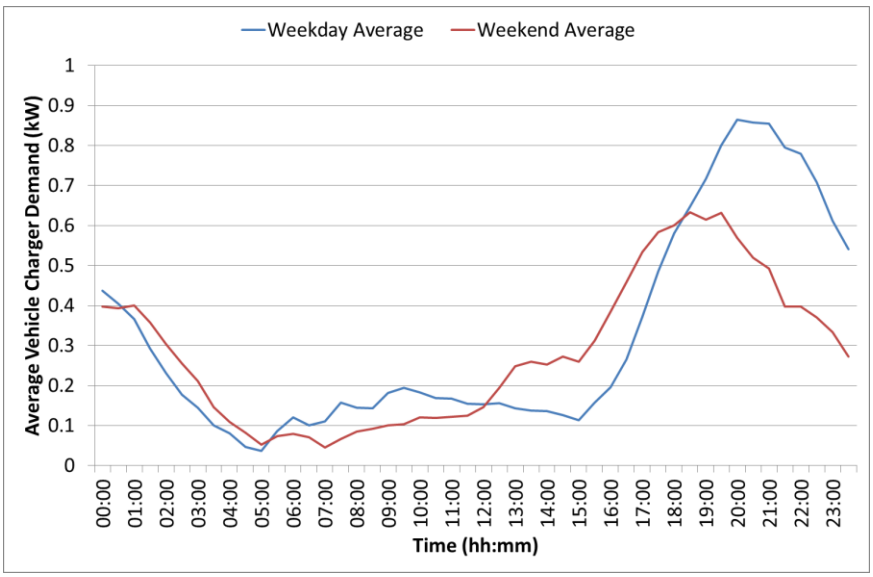

Figure 4: February 2014 EV Charger Weekday and Weekend Average Diurnal Profile

We observe the difference between weekday and weekend EV charging that is a consistent trend over a year. Interview data indicates that work regimes significantly influence when and how people charge the vehicle and how the new practice fits within the current patterns of energy use.

3.3 Seasonality

It can also be seen clearly that EV charging is seasonal; this is reflected in the daily electricity load profiles, which show lower average demand during the summer months. The quantitative analysis clearly indicates the seasonal difference in peak demand and charging times, increased in winter months. The seasonality of EV car use in winter is also mirrored in the ways people drive the electric car in order to preserve battery charge, such as pre-heating the car at home and/or switching the heating off to maximise the range.

The demand is lower in summer months. This trend could be explained by socio-demographic factors such as holiday season when people do not commute to work hence do not need to charge their car. The missing load can be explained by a simple fact that the car is not being used.

KEY MESSAGES

The analysis revealed that charging is very much concentrated in the evening, coinciding with the household peak. The EV charging curve closely follows the household demand curve, so we can assume that it is strongly correlated with household occupancy.

The EV charging practices are diurnal, weekly, monthly or seasonal patterns of activities.

The analysis suggests that the owners are charging opportunistically, but also when the battery is less than half-full.

Weekend charging is lower than weekdays; this seems to correlate with the conventional weekday work pattern of the household and the predominant use the EV as a week-day car.

This finding suggests that the EVs the drivers rarely change their daily/weekly commuting routines.

4. EV driving, range anxiety & large-scale adoption

The 'range anxiety' is an established term that describes fear that a vehicle has insufficient range to reach its destination. This research shows that the range anxiety seems to be one of the key factors that determine and affect the driving and charging practices.

This had been reflected in the qualitative part of the survey some respondents reported they would charge the car every time they finished using it, daily regardless of battery status, always on arrival at home or after every journey. Others would charge '**opportunistically**' that means whenever they can have access to a car park charging point. The tendency to 'top up' the miles and to increase the range whenever possible is illustrated below:

> *I charge it whether it needs it or not. Just to max up the miles. [...] There is always this unknown thing if you wanna go somewhere else. Just to put it charging it up, you've got that flexibility. And it takes two seconds to charge up, to plug it in. (Martin)*

The limits of battery are reflected in other household practices, most notably **planning** longer journeys ahead or trying to undertake round trips such as commuting to work, school runs and shopping trips that are within their vehicle range as illustrated in quote below:

> *We just plan a lot more, and I look at distances a lot more than I used to. I think our confidence of the range now is that if we are the North East, we not gonna get stuck. We know we gonna get there and we get back. (Alice)*

The electric vehicle is becoming a 'weekday car' and used mainly to make routine home-work and back round trips. During the weekend, when the family plans a longer, leisure trip, the EV is replaced by a conventional petrol or diesel fuelled car:

> *We went to the lakes [Lake District] at Easter. And we took the diesel car. I'd have consider taking the Leaf if there was more infrastructure but obviously with the charge points, there is a load of them in the North East so I'm pretty confident around here. If you start going a little bit down towards the Lake District, [to south] there is a very few charge points. ... I probably would have [use the EV] if I could plan the route but it's a little bit worrying and you obviously have the family in the car. (John)*

No surprise that some of participants identified the range anxiety as one of the reasons to discontinue the usage of an EV in the future. The 'range anxiety' is clearly driven by technological limits and subsequently the perceived unreliability of the EV technology. The presence of reliable **charging infrastructure or new battery technology** would enable to use the EV as a primary car and possibly replace current gas powered cars as described by one of the respondents:

Yes, it's the infrastructure (that's let the car down for me). We can't charge it. And if they put the infrastructure in and I gonna get to flee on the M3 find this ten people waiting for an hour charge and then you know ... There was this really high-tech talk in California where they're developing a liquid battery. They are developing a liquid battery that can charge a full charge in fifteen minutes or five minutes. And they say that if they can get this liquid battery to charge as quick as filling the car then people would just go to plug station, plug in, bang, five minutes! (Mark)

The development of a reliable charging infrastructure would manage the 'range anxiety' and impact on the **practices of personal mobility, domestic charging, and the large scale transition to EV technology**. Although the dataset only included domestic data and cannot report on commercial customers, presence of infrastructure would likely be an important factor in adoption of electric vehicle technology in commercial sphere as well as in public transport.

KEY MESSAGES

Several factors seem to be the key to enable a large-scale adoption of the EV technology. One of the obvious factors is the initial investment people have to make when purchasing the car. Making the technology affordable and reliable and the development of a new battery technology such as replaceable batteries and/or charging infrastructure are the basic assumptions.

The successful adoption of EV technology would also include the development of services associated with having and driving the electric car. Those include car insurance, maintenance, driving schools, and in general training how to use and maintain the EV vehicle.

5. Peak demand & network planning

From the network's viewpoint, the winter weekday peak demand of an **EV-enabled household is about equivalent to 2 normal households on average**. This can be seen from the household and charger demands in Figure 2 and Figure 4 respectively, where the charger peak is about the same as that of the household.

Figure 5 (below) shows a comparison of the EV owner group annual household demand with TC1a customers grouped by Mosaic category (the EV group shown by the red bar). The EV owners group exhibits a very ordinary annual consumption figure of 3397 +/- 208kWh / year. The EV owners in this group have a higher peak-to-daytime consumption than the average TC1a customer; this means that for a customer with a similar peak winter evening demand, the EV driver's daytime demand is likely to be lower, and so their total daytime energy use will be lower. Across the year therefore the EV driver's annual consumption is likely to be less than that of a customer who has a similar peak winter evening demand.

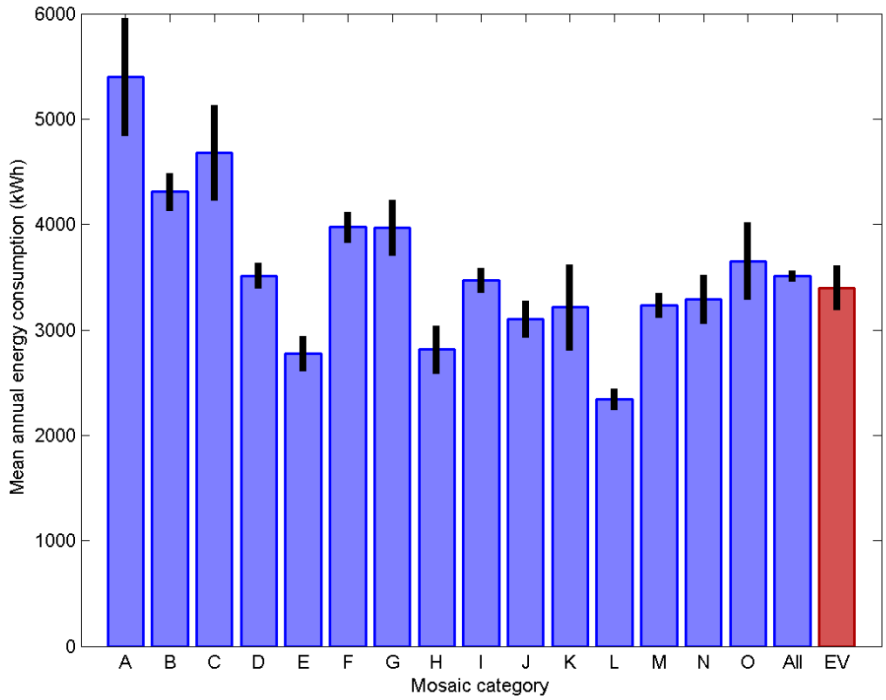

Figure 5: Comparison of mean annual energy consumption for EV owners' households with Mosaic Categories from TC1a

At the moment, electric vehicles present a marginal technology and so from the network planning perspective they do not present a serious constraint. This is true unless EV technology becomes mainstream and adopted on a large scale. Extensive future EV take up may only be precipitated by vehicles with longer range and the ability to charge these batteries quickly. We can only speculate that for uptake to increase, chargers and batteries may need to increase in size which would cause a

much larger than currently seen increase in EV loading and a more extensive strategy for managing distribution (and perhaps higher level) networks.

KEY MESSAGES

From the peak demand perspective, the EVs present a fairly inflexible yet predictable load. All of the charging curves show evening peaks, which shows that people are probably coming in from work and putting the car on charge. Hence, the biggest issue we identified is the lack of diversity and flexibility in EV charging times.

EV users do not seem to be using timers or delayed charging. People make sure their car is charged, they cannot afford for their vehicle not to be charged because they rely on it to get to work.

For enquires about the project
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