WESTERN POWER DISTRIBUTION
INNOVATION

NEXT GENERATION NETWORKS

Customer Research and Trial Update Report
Electric Nation

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Contents

Glossary

Abbreviation	Term
BEV	Battery Electric Vehicle
EV	Electric Vehicle
E7	Economy 7
HV	High Voltage
NIA	Network Innovation Allowance
PIV	Plug-In Vehicle
PHEV	Plug-In Hybrid Electric Vehicle
REX	Range Extender Vehicle

1 Introduction

This report provides an update on the customer-facing aspects of Electric Nation ("the Project") – both the customer research questionnaires and trials of smart charging. As detailed below the project aims to show the technical feasibility and benefits of smart charging and customer acceptance of the concept.

The Project has now completed its recruitment and installation stage. It has installed 673 domestic smart charging units in properties across the Midlands, South West and South Wales. This report will provide a final analysis of the Recruitment survey, completed by trial participants shortly after their smart charger has been installed.

The report authors would like to thank Impact Utilities, who are providing customer research expertise to the Electric Nation project, for their input and insight into Sections 2, 3, 4 and 5 of this report and for providing the graphics in these sections.

Participants received their first survey (the Recruitment survey) a fortnight after installation of their charge point. Participants who received the Baseline survey were sent it between two and six weeks later to establish routine charging behaviour. Trial participants were then surveyed again after they had experienced at least four weeks of demand management in Trial 1. Customer research industry insight, provided by the project's highly experienced customer research contractor Impact Utilities, suggests that participant response rates to surveys (92%, 96% and 90% respectively) are very good when compared to industry averages for this type of research. This is likely due to respondents being highly engaged with the project overall, and after the trial surveys, respondents receive a £10 Amazon voucher for each survey completed. However, they are only eligible for the incentive if the recruitment and baseline surveys have been completed. Consequently, the Project has already received a significant amount of data about EV drivers, their attitudes, and their charging habits, highlights of which are included in this report.

This report also provides an update on the progress of the customer trial in terms of the latest insights into charging behaviour (time of day, energy consumed, frequency of charging, plug-in durations and use of timers), moving customers into demand management, and the results of management to date on both a group and individual participant basis. Since the last milestone report the second smart charging algorithm has been rolled-out to some CrowdCharge, and all GreenFlux participants. This report provides an update on this process and the level of usage of the high priority app by GreenFlux participants.

1.1 The Electric Nation Project

Electric Nation is a Western Power Distribution and Network Innovation Allowance funded project. WPD's collaboration partners in the project are EA Technology, DriveElectric, Lucy Electric GridKey and TRL.

Electric Nation, the world's largest domestic smart charging electric vehicle (EV) trial, is revolutionising domestic plug-in vehicle charging. By engaging 500-700 plug-in vehicle drivers in trials, the project is answering the challenge that when local electricity networks have 40% - 70% of households with electric vehicles, at least 32% of these networks across Britain will require intervention.

The project is developing and delivering a number of smart charging solutions to support plug-in vehicle uptake on local electricity networks. A key outcome will be a tool that analyses plug-in vehicle related stress issues on networks and identifies the best economic solution. This 'sliding scale' of interventions will range from doing nothing to smart demand control, from taking energy from vehicles and putting it back into the grid, to traditional reinforcement of the local electricity network where there is no viable smart solution.

The development of the project deliverables is being informed by a large-scale trial involving plug-in vehicle drivers that will:

- Expand current understanding of the demand impact of charging at home, on electricity distribution networks, of a diverse range of plug-in electric vehicles - with charge rates of up to 7kW, and a range of battery sizes from 6kWh to 100kWh (All-Electric Ranges from 10 miles to 250+).
- Build a better understanding of how vehicle usage affects charging behaviour.
- Evaluate the reliability and acceptability to EV owners of smart charging systems and the influence these have on charging behaviour. This will help to answer such questions as:
    - Would charging restrictions be acceptable to customers?
    - Can customer preference be incorporated into the system?
    - Is some form of incentive required?
    - Is such a system 'fair'?
    - Can such a system work?

The results of this project will be of interest and will be communicated to the GB energy/utility community, to UK government, to the automotive and plug-in vehicle infrastructure industry and to the general public.

To be eligible to participate in the project Electric Nation participants are required to already have an EV, or to be about to take ownership of an EV. They must live in the WPD licence area (the Midlands, South West and South Wales). In return for taking part in the project the participants receive a smart charger. Trial participants are recruited via a recruitment campaign that has utilised social media, internet presence, traditional PR, attendance at EV events and creating links with EV retailers.

1.2 Purpose and Structure of Report

The purpose of this report is to provide an update on the progress of the trial aspects of Electric Nation, both the smart charging roll-out and customer research. It also sets out the next steps for the project.

The structure of the report and the contents of each section is as follows:

- Section 1: an introduction to the document and its purpose.
- Section 2: the customer research approach, the surveys which customers will complete and data collected by the trial to date.
- Section 3: final analysis of the Recruitment survey, showing the demographic data for Electric Nation trial participants.
- Section 4: insight into results of the baseline survey to date, showing participants reported charging behaviour.
- Section 5: insight into the results from the survey of customers who have experienced the first demand management algorithm
- Section 6: details early findings on the charging behaviour of Electric Nation participants including the time of day and frequency of charging, the amount of energy consumed, length of time they are plugged-in and use of timers.
- Section 7: provides an update on progress with moving all participants into demand management, and the results of demand management to date for both CrowdCharge and GreenFlux.
- Section 8: describes the next algorithms which will be deployed into the trial, progress with rolling these algorithms out, and use of the app by GreenFlux participants.
- Section 9: the next steps for both customer research and the smart charging trial, including a description of the third smart charging algorithm iterations.

2 Customer Research and Data Collection

2.1 Customer Research

Customer research is one of the many data sources being gathered by the Electric Nation trial (others include vehicle telematics data, charge point data, data from apps or demand control preference systems and participant enquiries). This research is being undertaken by Impact Utilities. These sources of information will be used to provide an answer to the overall customer objective of the trial:

> To prove which, if any 'Managed EV Charging to Support Local Electricity Networks' regime applied to trial participants is most likely to be satisfactory to all customers.

A condition of taking part in the Electric Nation trial[1] requires participants to complete a number of surveys during the course of the Project to enable the Project to understand participants' attitudes toward charging their EVs and their level of acceptance of varying degrees of managed charging. As the trial progresses and the level of managed charging/systems used to manage charging changes, the customer research will map any alterations in the participants' attitudes towards charging their vehicles and managed charging.

Participants contact details are collected by DriveElectric, the project partner responsible for participant recruitment and associated data protection[2], as part of the enrolment process. DriveElectric clearly explain to trial participants before they enrol in the Electric Nation trial that they are obliged to complete customer research surveys. The graphic overleaf demonstrates the exchange of participant data between DriveElectric and Impact Utilities.

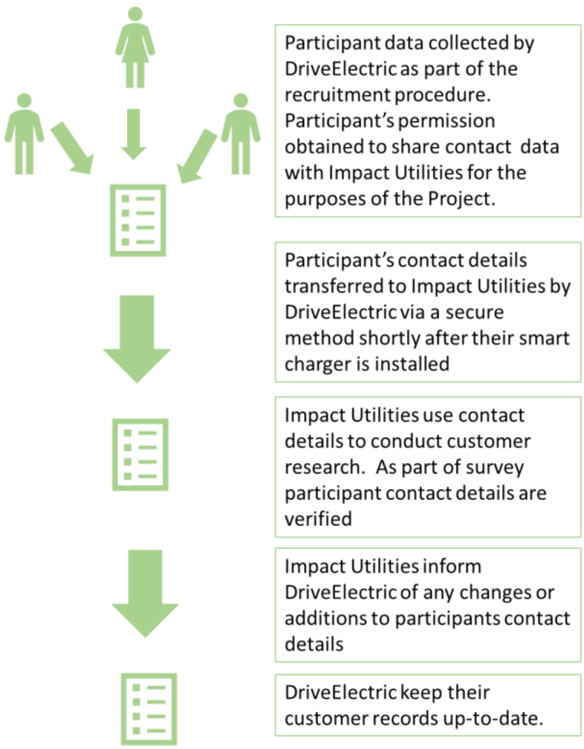
Shortly after the installation of a participant's smart charger they are asked to complete the Recruitment survey (see Appendix 1). This survey concentrates on collecting demographic and socio-economic data, information about the participants, their household, their plug-in vehicle (PIV) and their level of satisfaction with their smart charger installation experience. Until May 2018 participants were then (between 4 and 6 weeks after having their charger installed or after receiving their EV, whichever is later) asked to complete a Baseline survey (see Appendix 2) to obtain data on their charging behaviour, their satisfaction with this and their attitude towards having their charging managed. After May 2018 a large enough sample size (i.e. more than 100) of the Baseline survey was collected, to be statistically comparable, so participants were moved into demand management as soon as stable communications had been proven with their charge point.

[1] This condition is highlighted in project publicity literature, such as the Project website and brochure (which can be accessed via the Project website http://www.electricnation.org.uk

[2] The Projects Data Protection Strategy can be found at: http://www.electricnation.org.uk/wp-content/uploads/2016/11/NIA_WPD_013-CarConnect-Data-Protection-Strategy-FINAL.pdf -this is in the process of being updated to be compliant with GDPR.

Further surveys are conducted towards the end of each managed charging cycle, and then a final survey will be conducted at the end of the trial. The first survey to ask participants about their experiences under managed charging was issued in mid-January 2018. The findings from this survey will be discussed in future Trial Update reports. The content of this survey is very similar to the Baseline survey in Appendix 2 to allow direct comparison.

Figure 1: Exchange of participant data between DriveElectric and Impact Utilities



2.2 Surveys investigating attitudes to managed charging trials

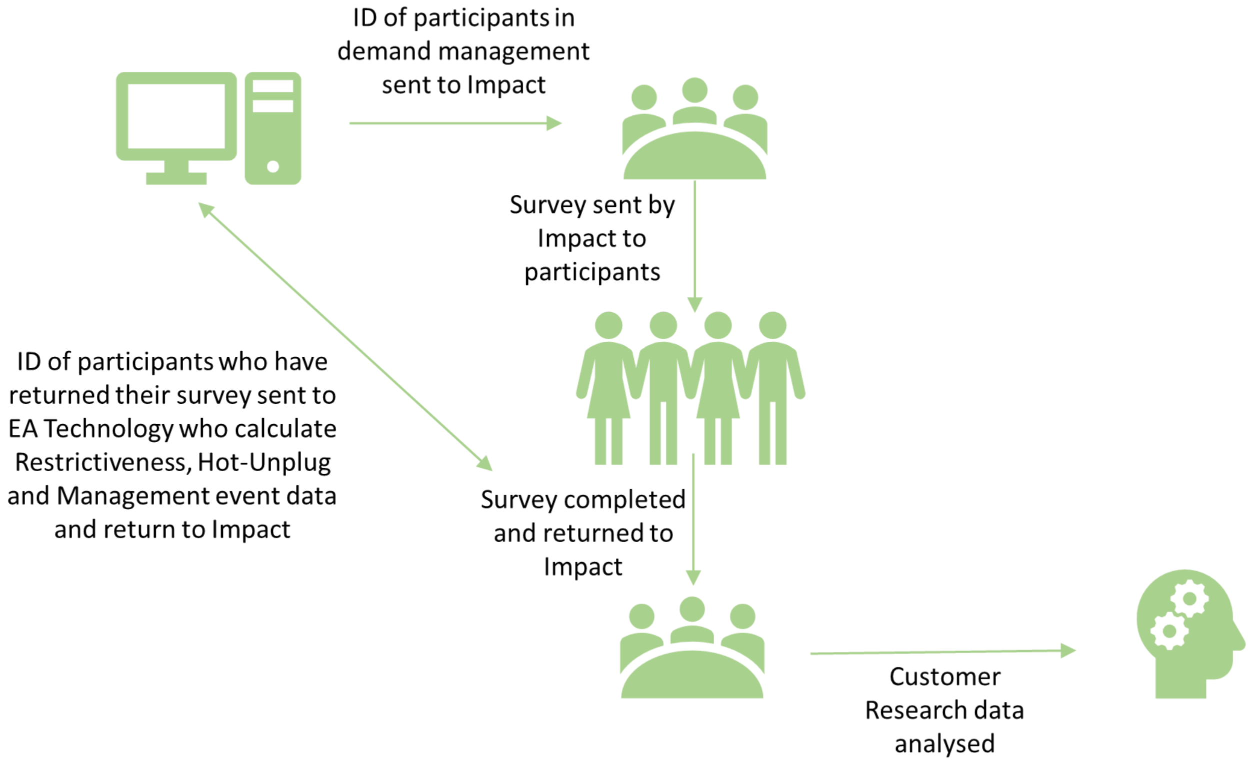
A selection of participants have progressed to the demand management trial: GreenFlux 267/342 installed and CrowdCharge 244/325 installed, overall 77% of chargers are in demand management at time of writing this report. Not all project participants have been part of this demand management trial to date, either because of technical issues with their smart charger (mainly communications not working or configuration issues which cannot be resolved remotely – in most cases this does not prevent the customer charging, but would prevent demand management)[3], because their smart charger has not been installed for a sufficient length of time (approx. two/three weeks to assess communications reliability) or they have not started using their charger because they are waiting for delivery of their EV. Further details of this process are given in Section 7.

[3] These technical challenges have implications for future potential roll-out of smart charging. The experience gained in this trial is potentially valuable for future research, product development and future roll-out of smart charging. Findings of this type will be summarised and incorporated into the project's final reports.

An important aspect of the Electric Nation trial is to monitor how participants' attitudes to demand management are altered by their experiences of demand management in the project. Therefore, it is important that the survey results are analysed in the context of the individual participants' experience of demand management. It should be noted that some of the trial participants (the number will be reported once movement of customers into demand management is completed) will experience a period of unrestricted home charging (so called "charge at will"), charging data and survey results for these participants will act as a baseline for charging behaviour. These results can then be used for comparison against charging behaviour and attitudes for participants who go quickly into managed charging from the start of their participation in the trial. Over 200 participants were moved into demand management after they had experienced approximately 90 days of unconstrained charging. For comparison, other participants were moved straight into demand management after it had been ascertained that their charger was working correctly. This group would not have had the opportunity to experience and become accustomed to unconstrained charging. After a participant had been subject to demand management for around four weeks they were issued a survey by Impact Utilities. This survey is nearly identical to the Baseline survey issued to participants when they had completed 90 days of unconstrained charging.

The flow of information and precise data that Impact Utilities will require to judge the impact of demand management on participants has been considered by the project team. This data and information flow is illustrated in the diagram below:

Figure 2: Data flow for trial 1 survey



Impact Utilities are informed by EA Technology of the ID of participants who have been subject to managed charging for at least four weeks for them to be included in a second baseline survey (for comparison against the first baseline survey). Impact Utilities then issue survey links to the relevant participants and encourage them to complete the survey, either online or by telephone according to the participant's choice. Impact Utilities will then inform EA Technology when a participant has completed their survey, so data can be generated about the impact of demand management on the participant. Impact Utilities will then use this data to inform their analysis of the survey responses that they receive.

2.3 Data Collection

Recruitment for the Electric Nation trial (and, so, installations of smart chargers into participant's homes) started in January 2017. The final installations were completed in July 2018.

This report is based on the data collected from the Recruitment surveys of trial participants in the weeks after the installation of their Electric Nation smart charger and data collected from the Baseline and Trial 1 surveys. The table below summarises the number of Recruitment surveys completed as of 20th July 2018.

	Surveys Sent	Surveys completed
%	100%	92%
N	673	634

Table 1: Recruitment surveys completed

The table below summarises the number of Baseline surveys completed.

	Surveys Sent	Surveys completed
%	100%	96%
N	529	498

Table 2: Baseline surveys completed

Trial survey 1 investigates participant attitudes to the first managed charging trial. This survey started 15th January 2018 and has involved over 300 trial participants who have been under managed charging for at least 4 weeks. Response rates to this survey are summarised in the table below.

	Surveys Sent	Surveys completed
%	100%	90%
N	310	279

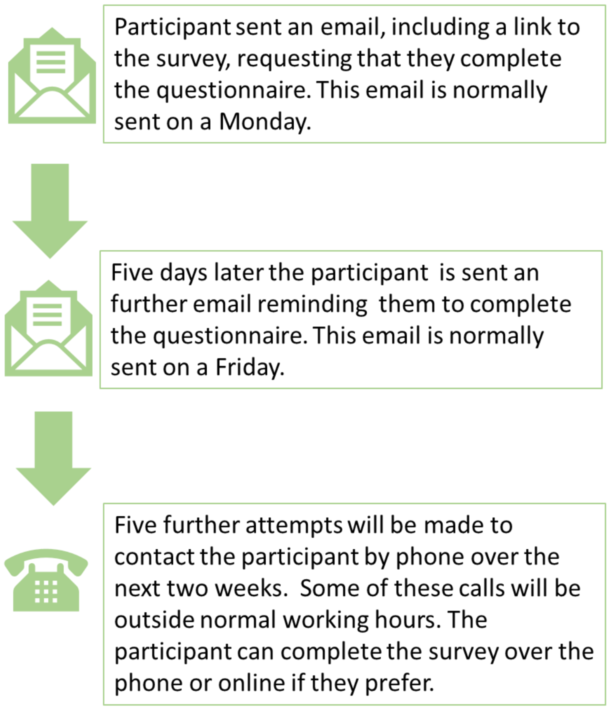
Table 3: Trial 1 surveys completed

The high level of survey responses can be attributed to a number of factors and process put in place by the project team:

- Newsletters were sent to all participants reminding them of:
    - The importance of the customer research
    - Their obligations as trial participants
    - The details of the customer research contractor (Impact Utilities)
    - The incentive they will receive for completing some surveys
    - Asking them to expect the Trial 1 survey soon
- Tweets to remind participants to complete the surveys
- DriveElectric reminding participants during the enrolment that under the terms of the trial, in return for the installation of a free “smart” EV charger at their home, they are asked to participate in customer research surveys (trial participants can, of course, withdraw from the trial at any time or just not participate in a survey)
- DriveElectric are ensuring that participants are expecting communication from Impact as part of the trial
- DriveElectric are collecting personal email addresses from participants rather than work addresses that are more likely to reject Impact Utilities emails as Spam. They are also encouraging participants to put Impact Utilities email address into their contacts list, again to reduce the chance that emails will be rejected as Spam or being blocked by servers which are likely to be more sensitive in their places of work.
- Participants are given the flexibility to take part over the phone or online and with/without the assistance of a professional interviewer
- Impact Utilities proactive attempts to contact participants who have not completed their surveys. This procedure is outlined in the graphic below. If this is unsuccessful, then Impact Utilities and/or DriveElectric send a personalised email to ensure communication has been received and check participant has been given ample opportunity to participant in the research
- The high response rates and active communication from participants demonstrate that participants are enthusiastic about participating in the trial and completing the surveys.
- Impact Utilities have designed the surveys so they are not unduly onerous for participants to complete.
- Surveys are kept succinct to prevent survey fatigue and to encourage future participation (surveys should take roughly 10 minutes or less to complete), response rates tend to follow an asymptotic curve with 80% of respondents replying within two weeks of a survey being sent to them, the remainder taking up to 6 weeks to respond with reminders. This pattern can be disrupted by holiday seasons.

It should be noted that surveys do not highlight the charging algorithm, or provide too much information about being managed, which is to avoid biasing the results as we are testing consumer behaviour and acceptance (which includes what changes are noticed/unnoticed by EV owners)

Figure 3: Procedure used to encourage participants to complete questionnaires



For all trial surveys, the participant is sent a link to the questionnaire by email (Appendix 3 and 4). If they fail to complete the survey within an allotted period, then the link will be re-sent with a further email reminding them to complete the questionnaire. If the participant still does not complete the survey, then the survey company will attempt to contact the participant by telephone. The participant will be telephoned several times over the following weeks.

Participants will receive a £10 voucher for an online store (Amazon) for completing each of the trial surveys. This excludes the Recruitment survey and Baseline survey. Completion of the Recruitment survey and the Baseline survey are an obligatory condition of trial participation and therefore not rewarded. Participants will not be eligible for the vouchers above if they do not complete the Recruitment and Baseline surveys.

3 Recruitment Survey Results - Participant Demographics

The Recruitment survey provides demographic and socio-economic data about the trial participants. This survey provides the Project with a survey population and frame of reference against which all future survey measurements will be compared. It should be noted that:

- The survey population is representative of the population **who have had their smart charger installed to date.** Project recruitment is now complete. The final smart chargers were installed in July 2018. This report contains the final snapshot about the Electric Nation trial population.
- As seen below, the population recruited is skewed towards affluent males, aged 36-55, so is not representative of the WPD regional customer base.
- The survey population demographic is also unlikely to be representative of the wider population of car owners, but may be of electric car owners, perhaps more correctly this should be "new car buyers/leasers", this will be investigated further when trial recruitment is complete within the constraints of availability of data (currently, there are limited statistics available regarding EV owners, therefore Electric Nation cannot commit to being able to do this analysis, unless new data becomes available).
- Surveys completed by participants after each demand management trial will be matched demographically to the Baseline survey population, so that the Project is always comparing a like for like population.
- The Electric nation sample shows some characteristics of Early Adopters, however we do not have enough information to confirm this. According to Rogers'[4] early adopter curve, early adopters 'have a higher social status, financial liquidity' which is what can be seen in the survey population. It is worth noting that with early adopters they need to have both the interest in the technology and the necessary funds

These points should be taken into consideration when drawing conclusions from the survey data.

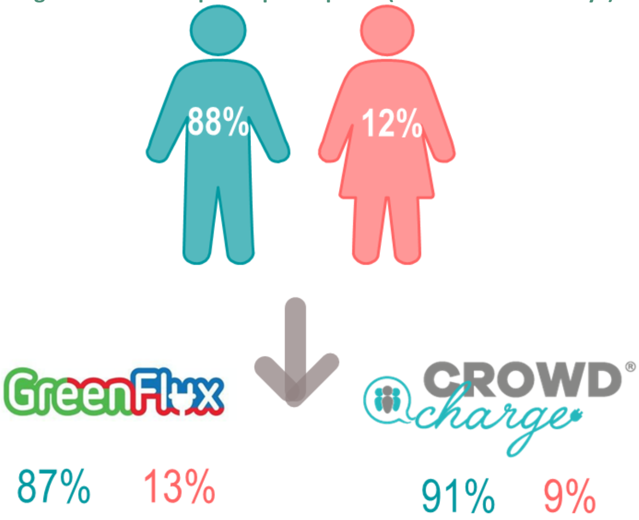
Data provided in this section is for the whole project population who have responded to the Recruitment survey.

[4] Rogers, Everett M. (2003). Diffusion of innovations. Free Press. ISBN 0743222091.

3.1 Gender

There is a pronounced gender split amongst participants. Of the 634 participants who have completed the Recruitment survey 88% are male, compared with 12% females.

Figure 4: Gender split of participants (based on 634 surveys)



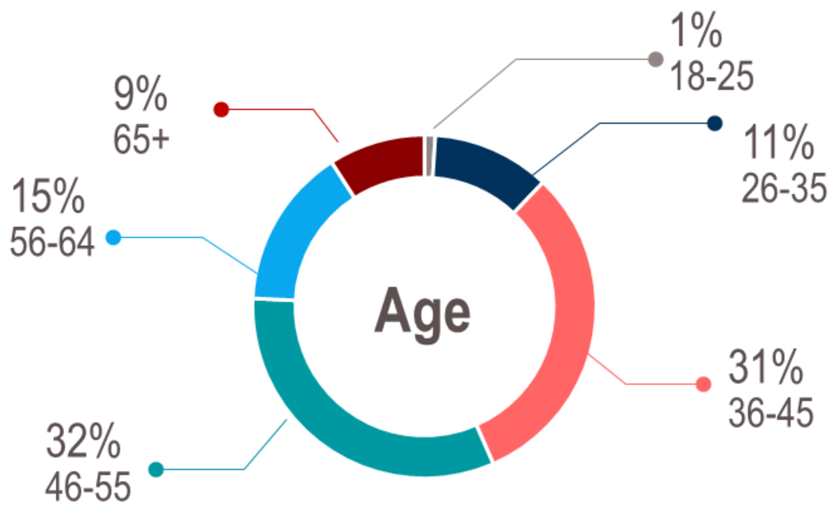
The trial population is not representative of the general UK driving population. Although a larger proportion of men hold driving licenses compared with women, the difference is not as large as the split within the participant group, as shown below.

Figure 5 Percentage of population that hold a Driving License

3.2 Age

The chart below demonstrates the age split of participants. The majority of participants are aged between 36 and 55 however the trial does include participants from all age groups eligible to drive a vehicle.

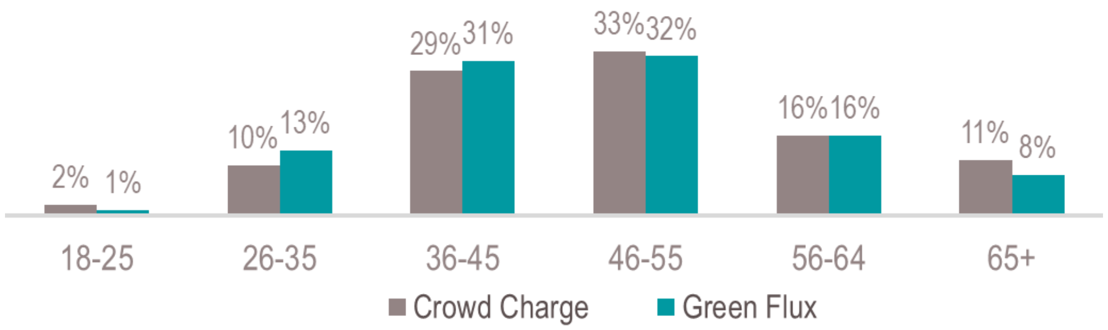
Figure 6: Age split of participants (based on 634 surveys)



The average age of a participant is 48. The youngest participant is 21 and the oldest is over 80.

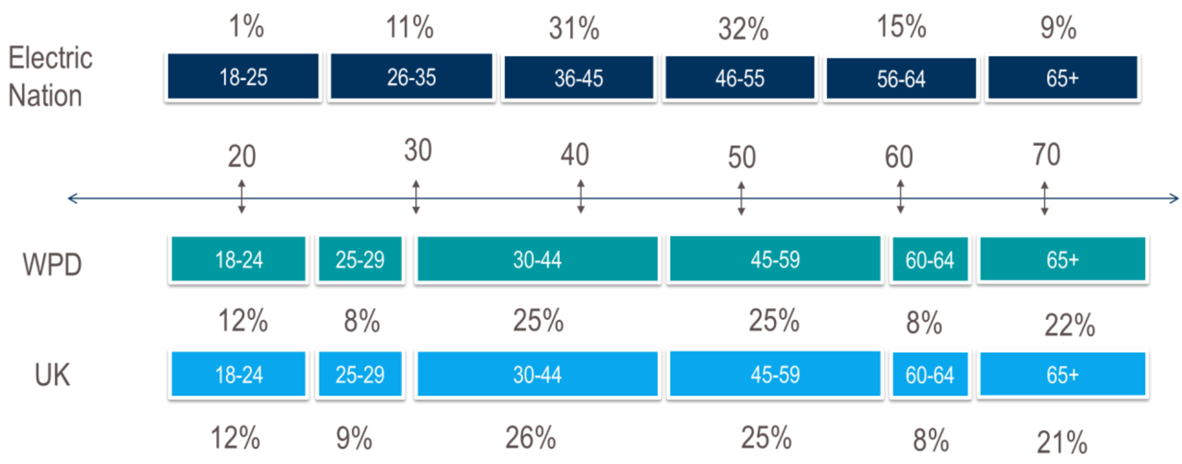
The chart below shows that the GreenFlux and Crowd Charge cohorts have a similar age profile.

Figure 7: Comparison of the age profiles of the GreenFlux (322) and Crowd Charge (293)



The spread of participant age profiles is dissimilar to both the WPD and UK populations.

Figure 8: Comparison of participant age breakdown to national and WPD license areas (based on 634 participants, 2011 UK Census data used for UK and WPD comparison)

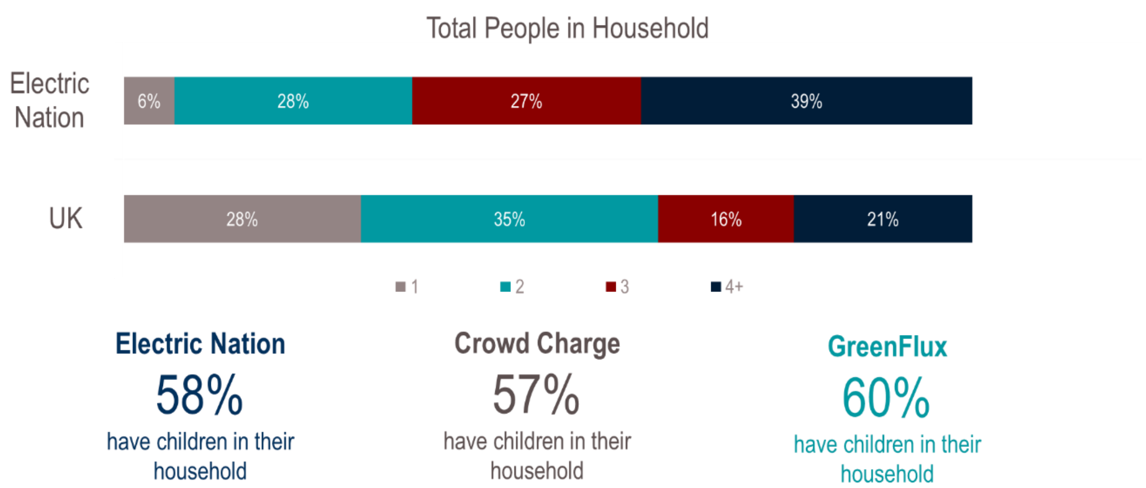


The age spread of trial participants is not representative of UK or WPD age distribution residents.

3.3 Household sizes

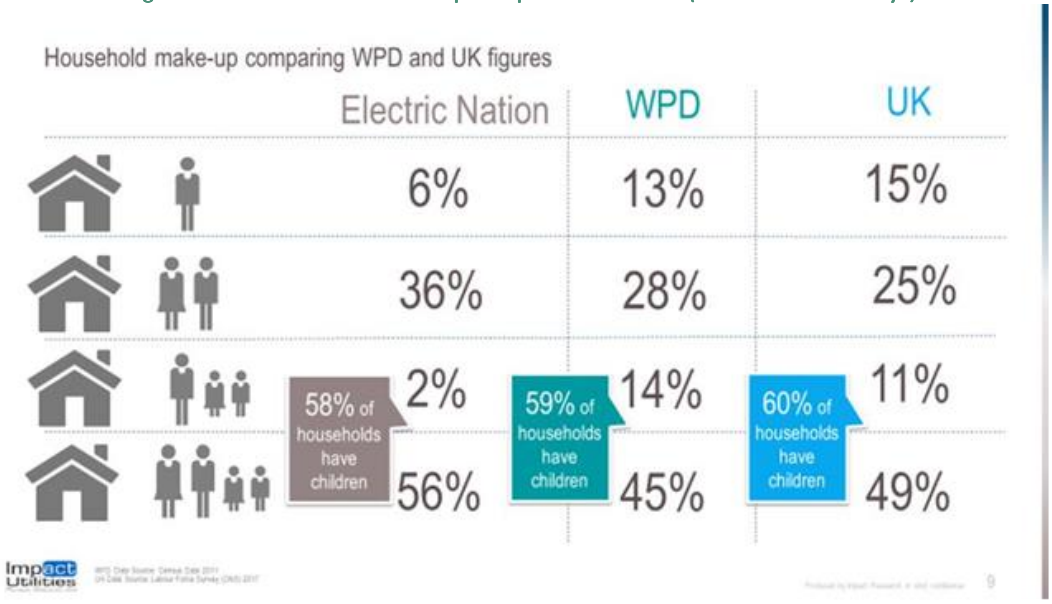
Electric Nation participants represent a range of different household sizes (including adults and children). This is demonstrated in the chart below:

Figure 9: Participant household size (based on 634 surveys, 596 of whom have children, compared with 2011 Census data)



Electric Nation project participants are more likely to be from households with multiple occupants than the UK norm. The number of children in participant households is illustrated below:

Figure 10: Number of children in participant households (based on 634 surveys)

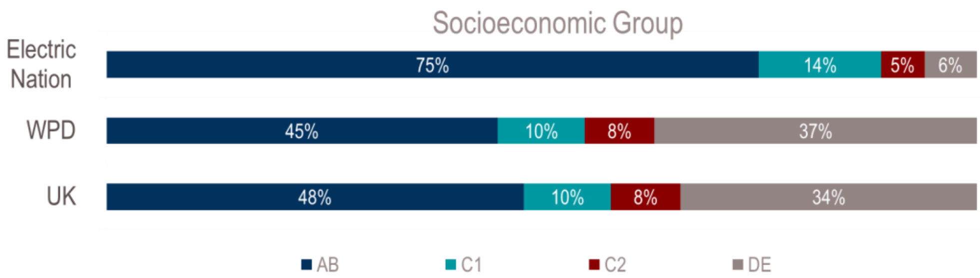


These figures demonstrate that the project has a spread of participants representing different household sizes, including smaller households with no dependent children and households with multiple children. Project participants are more likely to live in households with two adults than the WPD or national norm.

3.4 Socio-economic and employment data

The chart below shows the socioeconomic characteristics of project participants and compares this to the groupings for WPDs licence area and national figures.

Figure 11: Socio -professional category of participants (based on 634 surveys, UK and WPD comparison data from 2011 Census data)



The table below provides a breakdown of the socio-economic segmentations of the categories above.

Category	Definition
A	Higher Managerial, administrative, and professional
B	Intermediate Managerial, administrative, and professional
C1	Supervisory, clerical and junior managerial, administrative and professional
C2	Skilled manual workers
D	Semi-skilled and unskilled manual workers
E	State pensioners, casual and lowest grade workers, unemployed with state benefits only

Table 4: Socio-professional categories

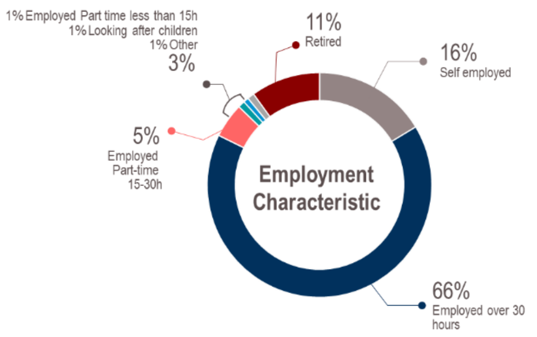
Trial participants are more likely to be from higher socioeconomic categories that both the UK and WPD population. This may be explained by the cost of EVs being higher than a traditional car, and the relative lack of EVs on the second-hand market amongst other factors.

Most trial participants are engaged in Higher or Intermediate professions however trial participants have been recruited from all socio-economic categories. Only 17% of respondents have a household income between £6,499 and £39,999, 18% of households have an income of between £40,000 and £59,000, while 25% have an income between £60,000 and £89,000. Over a quarter of trial participants have a household income over £90,000 per annum.

The chart below demonstrates the employment characteristics of participants. Most participants work full time however the trial has over 11% of participants who are retired. The number or self-employed participants is similar to the national rate[5].

[5] According to the Office of National Statistics approximately 14.9% of people in employment were self-employed in 2016 https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/trendsinselfemploymentintheuk/2001to2015

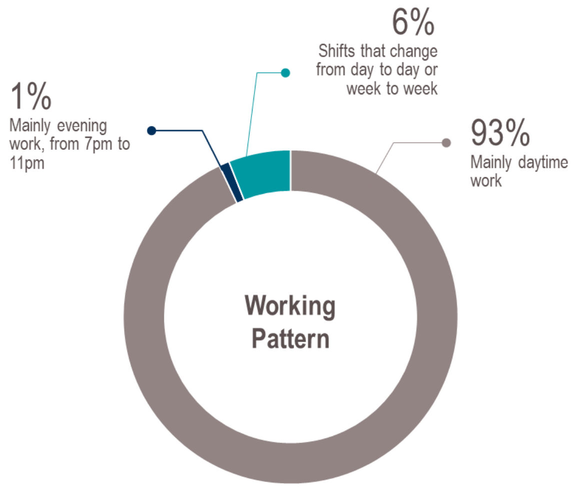
Figure 12: Participant employment characteristics (based on 634 participants, WPD and UK source Census data 2011)



Those working aged 16-74	WPD	UK
Full Time	37%	39%
Part Time	14%	14%
Self employed	9%	9%
Retired	15%	14%
Unemployed	7%	4%
Student	9%	9%
Other	9%	11%

The chart below illustrates the working pattern of those participants who are in employment.

Figure 13: Working time characteristics of participants in employment (553 participants)

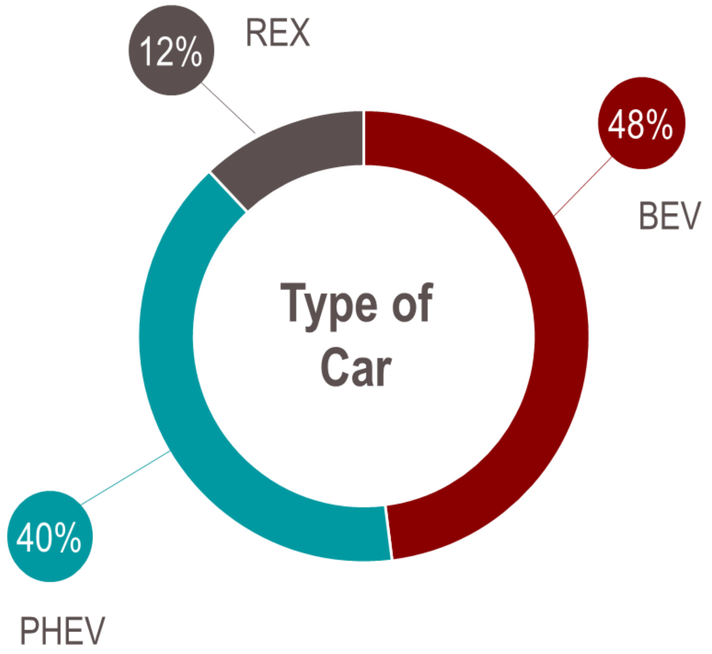


This demonstrates that 9 in 10 work during the daytime. It may suggest that these participants may have little flexibility about when they charge their vehicles, if they charge them at home, because they are not at home during the daytime. They may be more likely to charge their vehicle during the evening, or overnight. See section 4.2 for insight on where trial participants charge their cars.

3.5 Car type

The chart below shows a near equal split among participants who own Battery Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs).

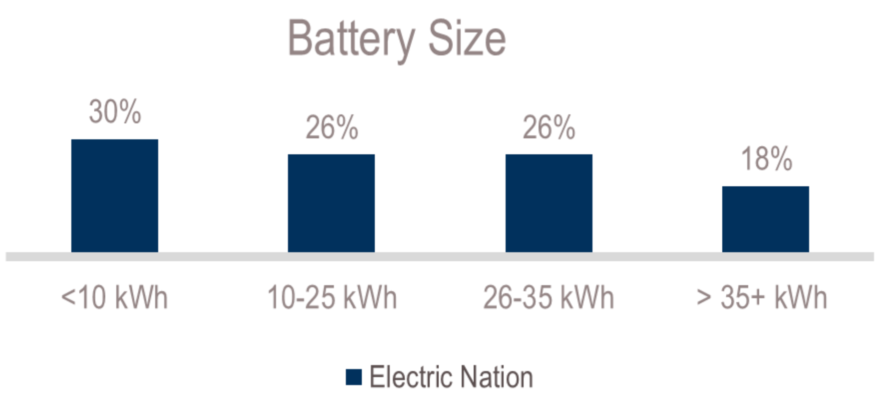
Figure 14: Vehicle type split amongst participants (based on 634 surveys)



Participants with a PHEV can drive their vehicle despite the battery being empty (discharged). These participants may therefore be less concerned about completing a charge and therefore having their charge managed. This will be explored later in the report.

The chart below shows the range of different battery sizes within the trial.

Figure 15: Spread of different battery sizes within the trial (based on 634 participants):



The table below shows the spread of participants with different battery size and types of EV across rural, suburban and urban regions, and the spread of GreenFlux and Crowd Charge cohorts.

	Battery Size				Fuel Type			Charger Type	
	<10 kWh	10-25kWh	26-35 kWh	>35 kWh	BEV	PHEV	REX	GF	CC
Urban	35%	26%	18%	21%	47%	43%	10%	44%	52%
Suburban	32%	24%	30%	13%	46%	42%	12%	54%	45%
Rural	24%	30%	25%	21%	50%	37%	13%	57%	43%

Table 5: Characteristics by rural, urban and suburban setting (based on 634 participants)

Urban participants are slightly more likely to own a smaller battery sized vehicle than participants who live in suburban or rural areas.

Participants are more likely to have two or more cars than the general population.

Figure 16: Electric Nation other car ownership compared to England and Wales (based on 634 responses, compared to census data 2011):

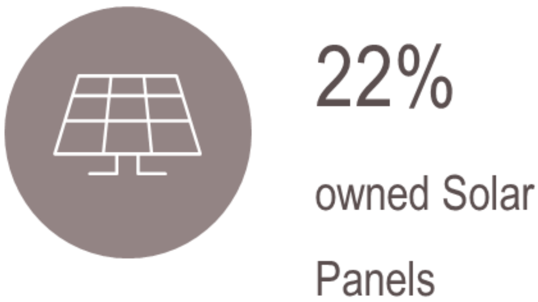
	Urban					Rural				
	0	1	2	3	4+	0	1	2	3	4+
Electric Nation	0%	20%	61%	16%	4%	0%	18%	42%	30%	10%
England and Wales	29%	43%	22%	5%	2%	12%	40%	35%	9%	4%

81% of Electric Nation participants have two or more vehicles, compared to 33% of households across England and Wales

3.6 Ownership of solar PV panels

Over one fifth of participants have solar PV panels fitted to their properties.

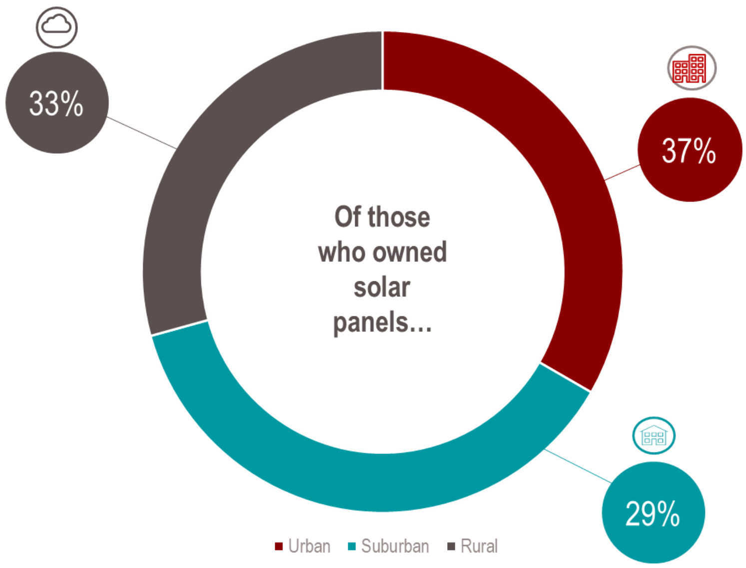
Figure 17: Trial participants with solar panels (based on 634 surveys)



This is a larger proportion than the general population[6]. It **may** suggest that Electric Nation participants, as a whole, are more environmentally minded than the general population, have the financial means to invest in solar PV panels or have seen them as a good investment opportunity. The general shift towards renewable energy generation where households install small scale generation sources such as PV could also suggest that the project participants are representative of a future customer base where these technologies are more prevalent.

The ownership of solar panels was split between participants who lived in rural, suburban and urban area, as is demonstrated in the chart below.

Figure 18: Split of participants with solar PV between rural, suburban and urban (based on 137 participants with solar panels)

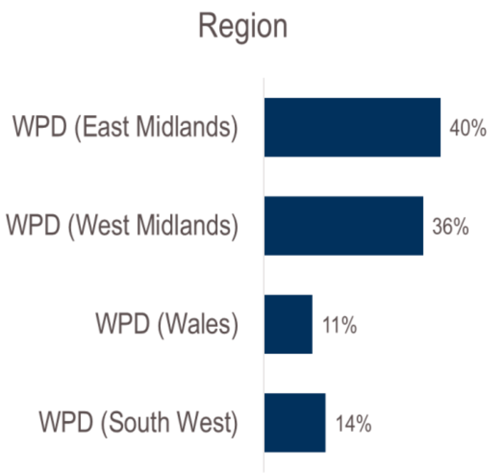


3.7 Where do you live?

Participant postcodes have been used to analyse where they live.

[6] There were 886,000 households in England, Scotland & Wales with MCS certified Solar PV FIT installations by May 2017 (ONS). There are roughly 26.3 million households in the UK (ONS 2016). So, approximately 3% of households in England, Scotland & Wales have solar panels.

Figure 19: Breakdown of participant location based on WPD license area (based on 634 participants)



Participants mainly are drawn from the more densely populated license areas in the Midlands.

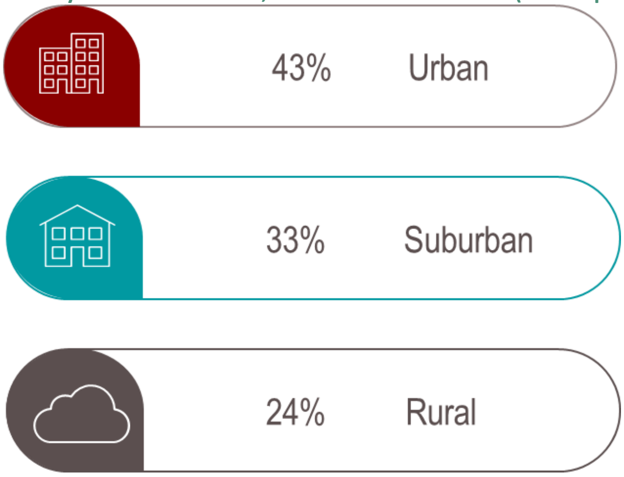
Figure 20: Breakdown of participant location by city (based on 634 participants)

Coventry	13%	Gloucester	5%
Birmingham	12%	Newport	4%
Nottingham	10%	Milton Keynes	4%
Bristol	7%	Northampton	3%
Derby	6%	Stoke-on-Trent	3%
Leicester	5%	Cardiff	3%

The city with the highest number of participants in the trial is Coventry, followed closely by Birmingham. It is unclear why Coventry is particularly well represented among participants. The city was not highlighted in the recruitment campaign. It could be due to the cities links with the automotive trade or that the city has a higher than normal proportion of off road parking.

Trial participants were asked to classify whether they live in an urban, suburban or rural area.

Figure 21: Do you live in an urban, suburban or rural area? (634 respondents)



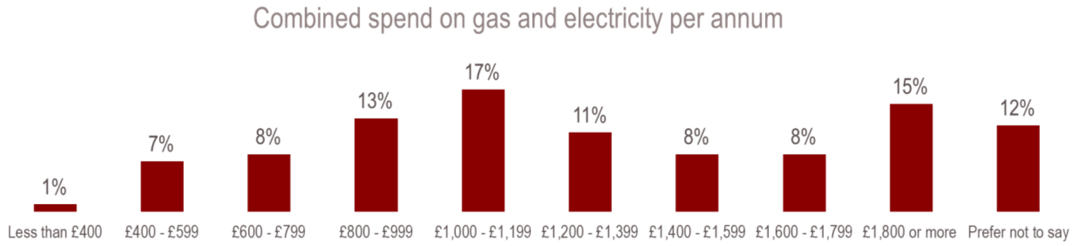
Location	WPD	England & Wales
Urban	74%	81%
Rural	26%	19%

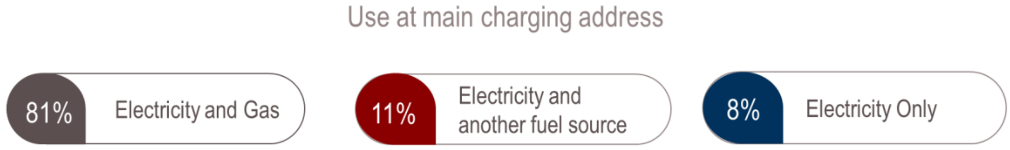
Respondents are most likely to state that they live in an urban area, however a quarter say that they live in a rural area. The license area covered by WPD has a higher rural population than the rest of England and Wales, and this is reflected in the participant population.

Participant who live in a suburban area are statistically (at 90% confidence level) more likely to have a 25-35kWh battery car.

3.8 Participant spend on gas and electricity

Participants were asked about their average spend on gas and electricity per year (before they bought an EV).





The average spend was £1,065 per annum however there is a large variation between households. It has been estimated that across England and Wales 11% of households do not have access to mains gas[7]. This suggests that Electric Nation participants are more likely than the national average not to have access to mains gas.

The recruitment survey results suggest that the trial population is skewed towards affluent males aged 36 to 55 in higher or intermediate professions. A proportion of the group are environmentally minded. Participants cover a cross section of other attributes such as vehicle type, household size, number of children and rurality. They are not representative of the UK or WPD population as a whole. Given project timescales to recruit and complete the trial, and the current demographics of EV ownership, it is not be possible to remove the influence any recruitment bias via targeted enrolment.

[7] Sub-national gas consumption data, Department of Energy and Climate Change, 2012 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/267774/sub_national_gas_consumption_factsheet_2012.pdf P22

4 Baseline Survey Results

The Baseline survey was conducted approximately four to six weeks after a participant has had their smart charger installed – the purpose of the survey is to capture an understanding of participants' charging behaviour, once they have been driving their plug-in vehicle for sufficient time to get used to it and overcome any immediate range anxiety issues they may have suffered as a new plug-in vehicle driver.

The survey questions will also be used to identify any changes in the participants' charging habits once they experience demand management. It will also be used to reference the acceptability of demand management as opposed to unconstrained charging.

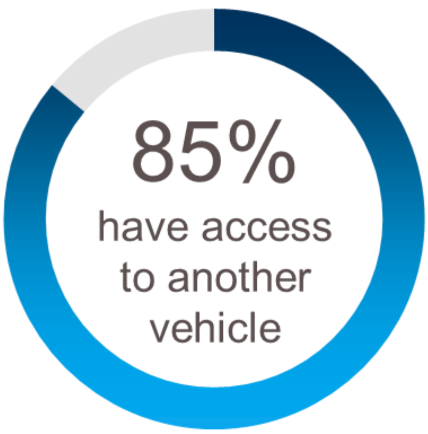
Participants are split between a 'charge at will' group (at least 90 days period where their charger will not be managed) and 'straight into demand management' group (see Section 6 for further details). The baseline survey results of these populations can be compared to show any difference in initial satisfaction between those who are allowed a period of unrestricted charging vs. those who are very quickly put under demand management. Comparison of participants who have experienced these two pathways at the analysis stage will help to reduce the effect of anomalies such as experience or knowledge levels and reduce the impact of Hawthorne effects (the alteration of behaviour by the subjects of a study due to their awareness of being observed).

This section of the report is designed to provide an insight into the interim survey results at the point of writing. The data does not distinguish between the "charge at will" and "straight into demand management" groups at this time - a full analysis, including distinguishing differences between these two groups and levels of statistical confidence of the survey results, will be provided later in the trial.

4.1 Do you have access to another vehicle?

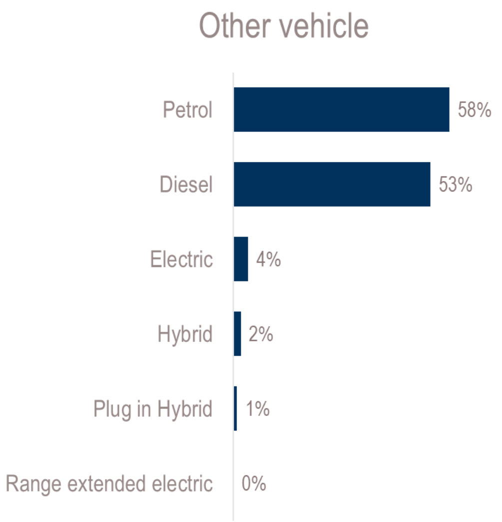
Participants were asked if their household has access to another vehicle(s).

Figure 22: Do you have access to another vehicle? (498 responses)



The participants with access to another vehicle were then asked how the other vehicles(s) were powered (please note that some households have access to multiple other vehicles).

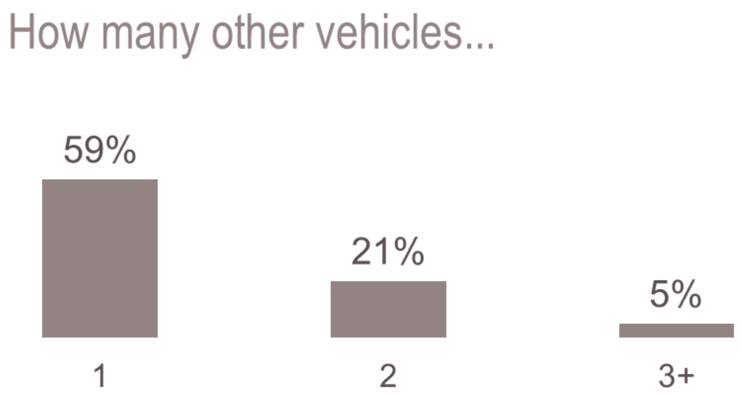
Figure 23: What type of alternative car does your household have access to (424 participants have access to another vehicle)



At time of writing, over 20 participant households have more than one plug-in vehicles.

Those households who have another vehicle, many have more than one vehicle as is demonstrated in the figure below.

Figure 24: How many other vehicles in participant household (498 responses)



Participants who have two cars in their household are statistically less likely to live in a rural area (42% in comparison to 56%). Those who have 3 (19%) or 4+ (5% total) cars in their household are statistically more likely to live in a rural area (30% for 3 cars and 10 % for 4+ cars).

4.2 How do you use your vehicle?

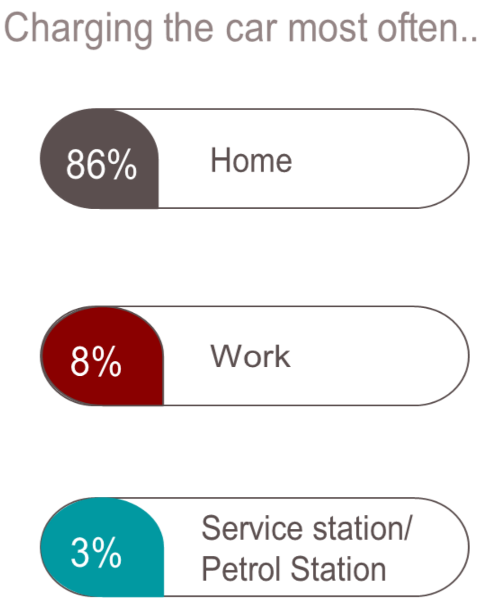
Participants were asked how they used their EV.

Figure 25: How do you use your EV? (498 responses)

4.3 Where do participants usually charge their EV?

Participants were asked where they charge their EV most often. Most participants usually charge their EV at home.

Figure 26: Where do you charge your EV most often? (498 responses)

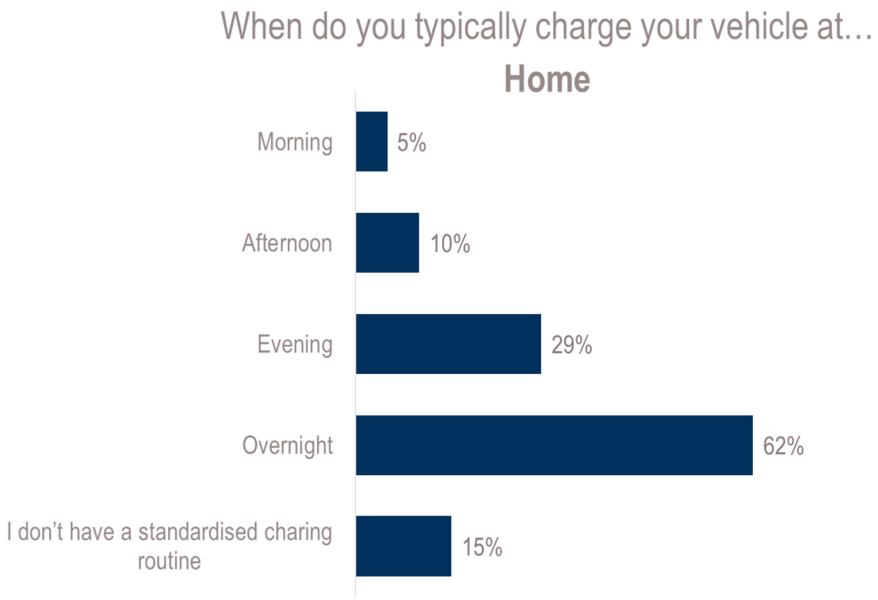


Nine participants (2%) stated that they do not charge their vehicle at home – however, there is still value in gathering their attitudes to charging data because it may be useful to understand why people do not charge (or do so infrequently) at home where a charger is available to them. Two of these participants use Tesla superchargers at motorway service stations, six charge their vehicle at work and one uses the free charger at a Nissan dealership.

4.4 When do you usually charge your EV at home?

Participants were asked what time of day they usually charged their EV, when they charge it at home. Participants were given the option to choose more than one answer.

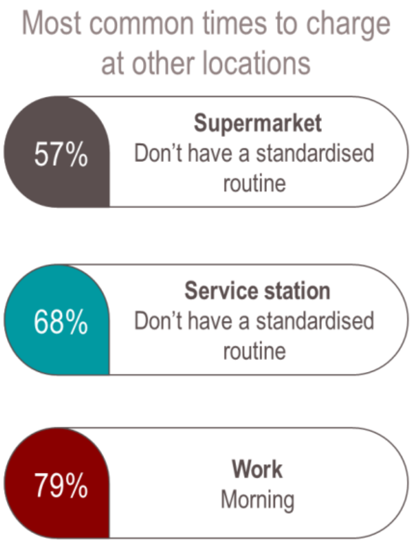
Figure 27: When do you usually charge your EV when you charge at home? (490 participants)



Most participants stated that they charge their EV either in the evening or overnight. This data will be compared to data gathered from smart chargers at a later point in the trial. The chart below provides insight into how frequently participants charge their EVs at other locations and when they are likely to use these chargers.

Participants were also asked about their charging behaviour when they used charge points at other locations.

Figure 28: Frequency that participants charge their EVs at locations other than home (All (490), Supermarket (113), Work (119), Service (140))

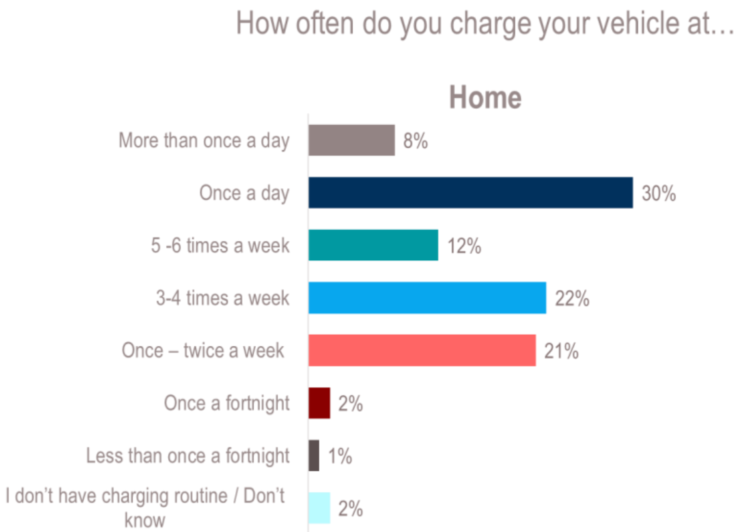


Participants who charge their EV's at other locations are less likely to have a standardised routine, except those who regularly charge their vehicles at work. This may indicate that there could be the risk of a 'morning charging peak' in business districts as EV ownership becomes more prevalent.

4.5 How frequently do you charge your EV?

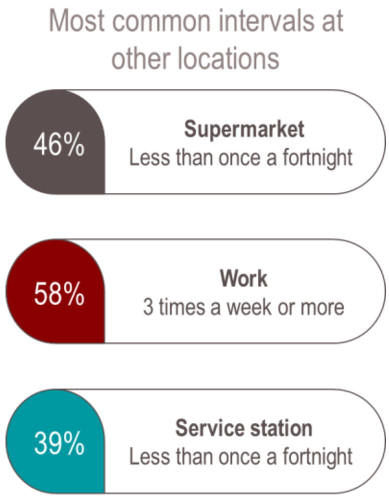
Participants were asked to indicate how frequently they charged their EV at home.

Figure 29: How frequently do you charge your EV? (490 participants)



Over a third of participants charge their EV at least every day. This data will be compared to charging transaction data gathered by the project in due course.

Figure 30: Most common charging frequency at other locations (All (470), Supermarket (112), Work (114), Service (137))



Participants are more likely to use other charge point locations less frequently.

4.6 Are you concerned about having your charging managed?

Respondents were asked about their level of concern about the upcoming charge management trials (at the time they receive this survey most will not have experienced demand management; some may have just entered demand management – timing of survey returns will be compared with date of entering demand management later in the trial).

Trial participants are made aware that the Electric Nation project will be trialling managed charging and that as trial participants' their EV charging will be subject to demand management in a broad sense, however they have not been given precise information about the nature of the trial. Only 6% of the participants who completed the survey were quite concerned and 2% were very concerned.

4.7 Summary

To conclude, the Baseline survey suggests that most trial participants who have completed this survey usually charge their EV at home, either in the evening or overnight. More than half of participants do not use their charger every day. Most are satisfied with the current, uncontrolled charging experience. This is significant because all future measurements of satisfaction will be compared to this level of acceptability. Most are not concerned about the upcoming charge management trial. Many have access to another vehicle other than their EV. It is worth noting that even at this early stage of EV ownership there are some households with multiple plug-in vehicles.

These are preliminary results based on data that is subject to change as more participants complete the Baseline survey. Further analysis and statistical testing of this data will be carried out as the Electric Nation trial progresses.

5 Acceptability of the first demand management trial

The first managed charging trial started in December 2017. The trial is fully explained in Section 6. Over two hundred participants were moved into demand management after they had experienced approximately 90 days of unconstrained charging. For comparison, other participants were moved straight into demand management after it had been ascertained that their charger was working correctly. This group would not have had the opportunity to experience and become accustomed to unconstrained charging. After a participant had been subject to demand management for around four weeks they were issued a survey by Impact Utilities. This survey is nearly identical to the Baseline survey issued to participants when they had completed 90 days of unconstrained charging. If a participant had completed the Recruitment and Baseline survey they are eligible for a £10 online voucher for completing this survey.

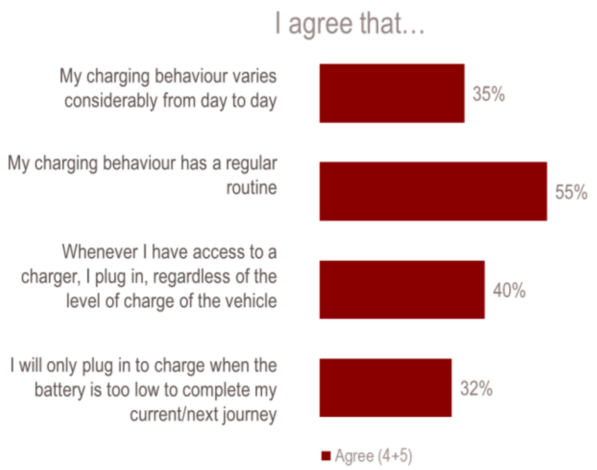
Trial participants were not informed of any movement into demand management, in effect the trial participants were blind to the change, but may have noticed changes to their EV charging sessions as a consequence of demand management.

As with previous section of the report, this section is designed to provide an insight into the interim survey results at the point of writing. This data does not distinguish between the "charge at will" and "straight into demand management" groups at this time - A full analysis, including distinguishing differences between these two groups and levels of statistical confidence of the survey results, will be provided later in the trial.

5.1 Reported change in charging behaviour

Participants were asked about their charging behaviour. Comparison of their responses to the baseline data suggests that it has stayed relatively similar. The chart below shows a breakdown of the responses across the whole cohort and by vehicle type.

Figure 31: Reported charging behaviour by whole cohort and type of vehicle (279 survey responses)

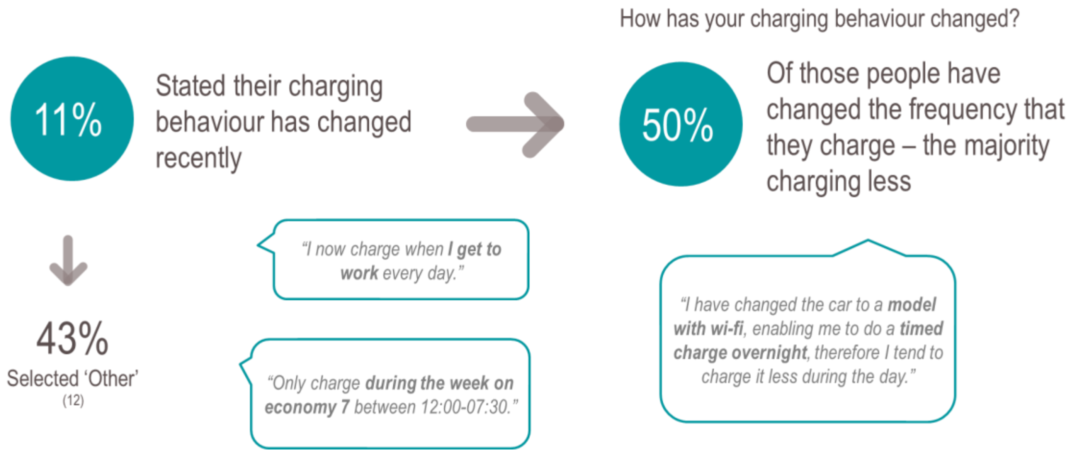


Fuel Type		
PHEV (102)	BEV (138)	REX (39)
29%	42%	26% (21% baseline)
69%	44%	56% (64% baseline)
53%	30%	38% (24% baseline)
29%	36%	26% (33% baseline)

The only noticeable change in behaviour is that the charging patterns for participants with REX vehicles has become more irregular compared to the Baseline survey.

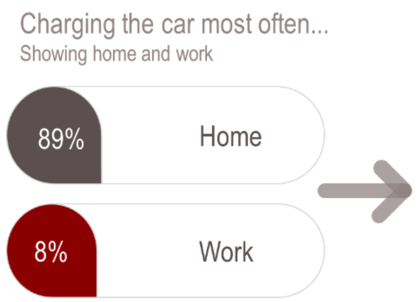
When asked if they have actively changed their charging behaviour, 11% (30 participants) of respondents stated that they had. The majority of these (50%, or 16 participants) stated they had changed the frequency of their charging, of which 10 people charged less.

Figure 32: Stated changed in charging behaviour (30 respondents out of 279 surveys)



Participants reported that they have not changed where they are likely to charge their vehicle. Charging at home is still the most popular location.

Figure 33: Where do participants charge their vehicle most frequently (based on 279 responses)



Charging car most often by Home vs. Work

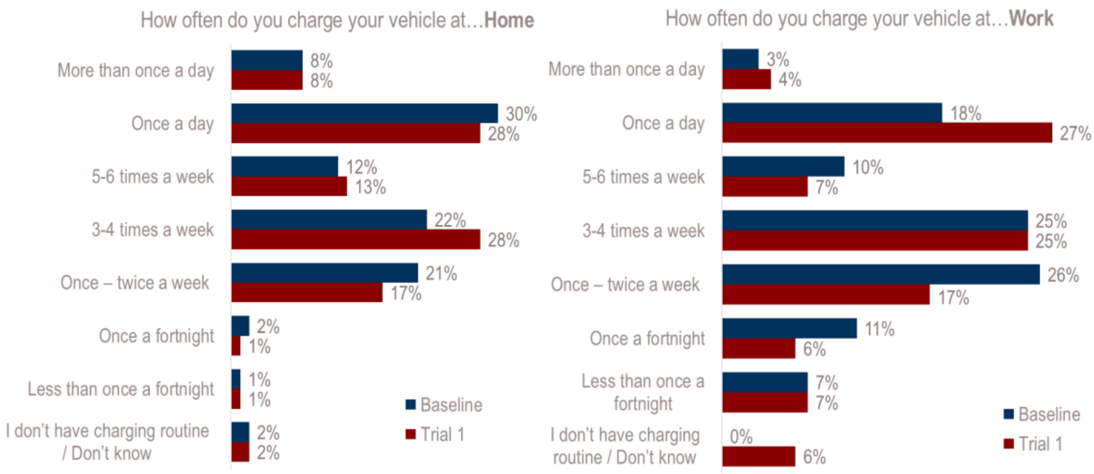
Battery Size				Fuel Type			Charger Type	
<10 kWh	10-25kWh	26-35 kWh	>35 kWh	PHEV	BEV	REX	GF	CC
96% (64)	95% (77)	89% (76)	67% (30)	96% (98)	82% (113)	92% (36)	90% (130)	87% (116)
3% (2)	2% (2)	10% (9)	20% (9)	3% (3)	12% (16)	8% (3)	6% (9)	10% (13)

Participants with larger batteries, or whose vehicles are BEVs are more likely to charge their vehicle at work than other participants however behaviour around charging location has remained unchanged.

5.2 Frequency of charging

Participants were asked how frequently they charged their vehicle at their favoured charging location. These responses were compared to the replies received in the baseline survey.

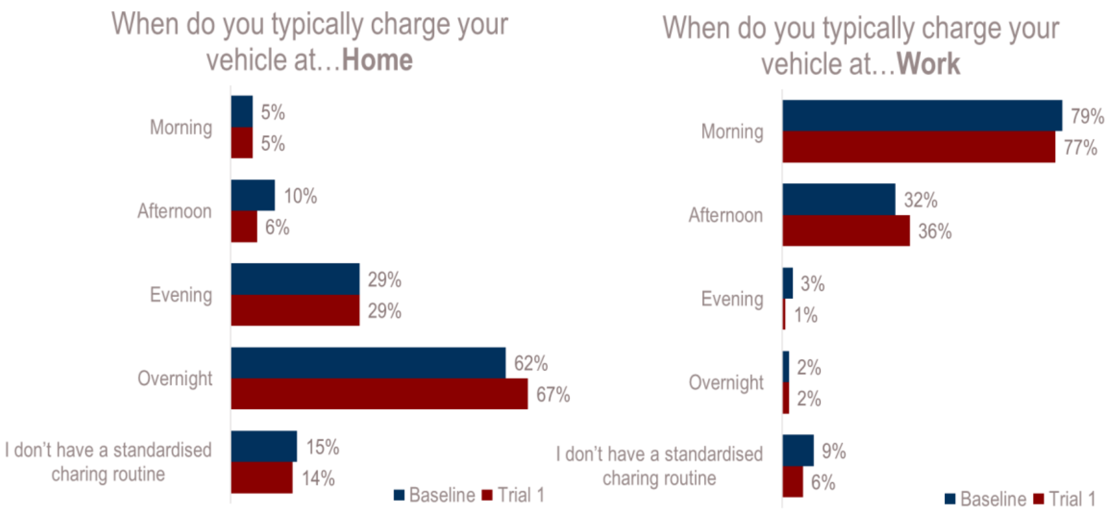
Figure 34: Reported frequency of vehicle charging (Home: 274, baseline 490, Work: 81, baseline 119)



Survey responses indicate that there may have been a slight shift during Trial 1 to participants charging their vehicles more frequently at work.

Participants were asked when they typically charge their vehicle, and this was also compared to the Baseline responses.

Figure 35: When participant typically charge their vehicles at their favoured location (Base: Home (274), Baseline Home (490), Work (81), Baseline Work (119))

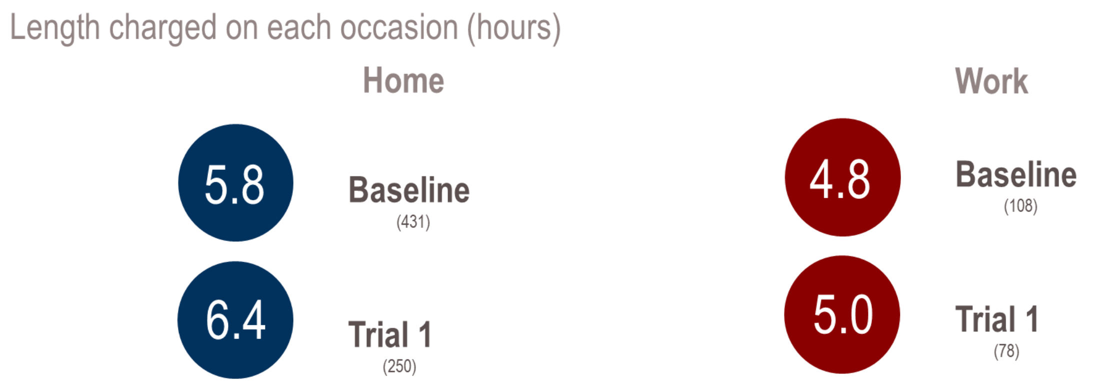


There have been limited changes to participant behaviour, the most noticeable being a slight increase in the number of participants charging their vehicles overnight. The statistical significance of these changes will be investigated when final analysis is undertaken.

5.3 Reported length of charge duration

Participants are asked about the length of time that they charge their vehicle for. Analysis will also be completed using transaction records from.

Figure 36: Comparison of reported average length of charging (Base: Those who selected location (250))



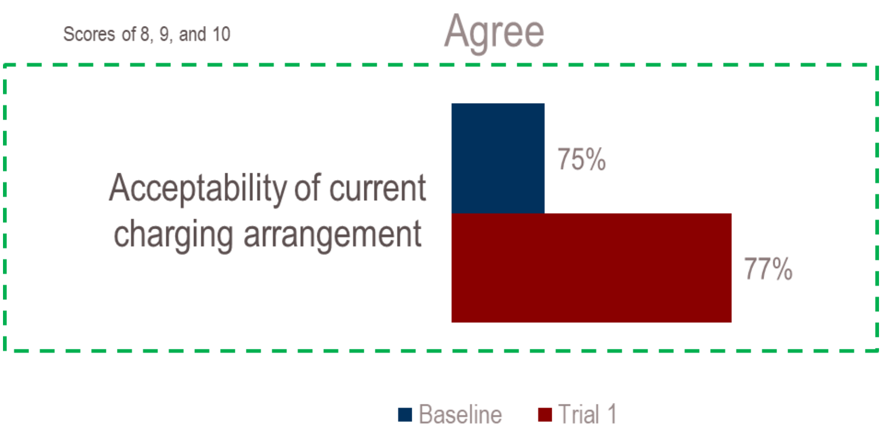
Home	Charger Type	
	Green Flux	CrowdCharge
Trial 1	6.8 (144)	5.8 (134)

There has been a slight increase in the average length of time that participants report that they charge their vehicle compared to the Baseline data.

5.4 Acceptability and satisfaction with charging arrangements

Participants were asked whether the current charging arrangements were acceptable, by providing a score between 1 and 10. Acceptability of current charging arrangements has increased (77% after trial 1 compared to 75% in the baseline survey). This score is a combination of scores 8, 9 and 10.

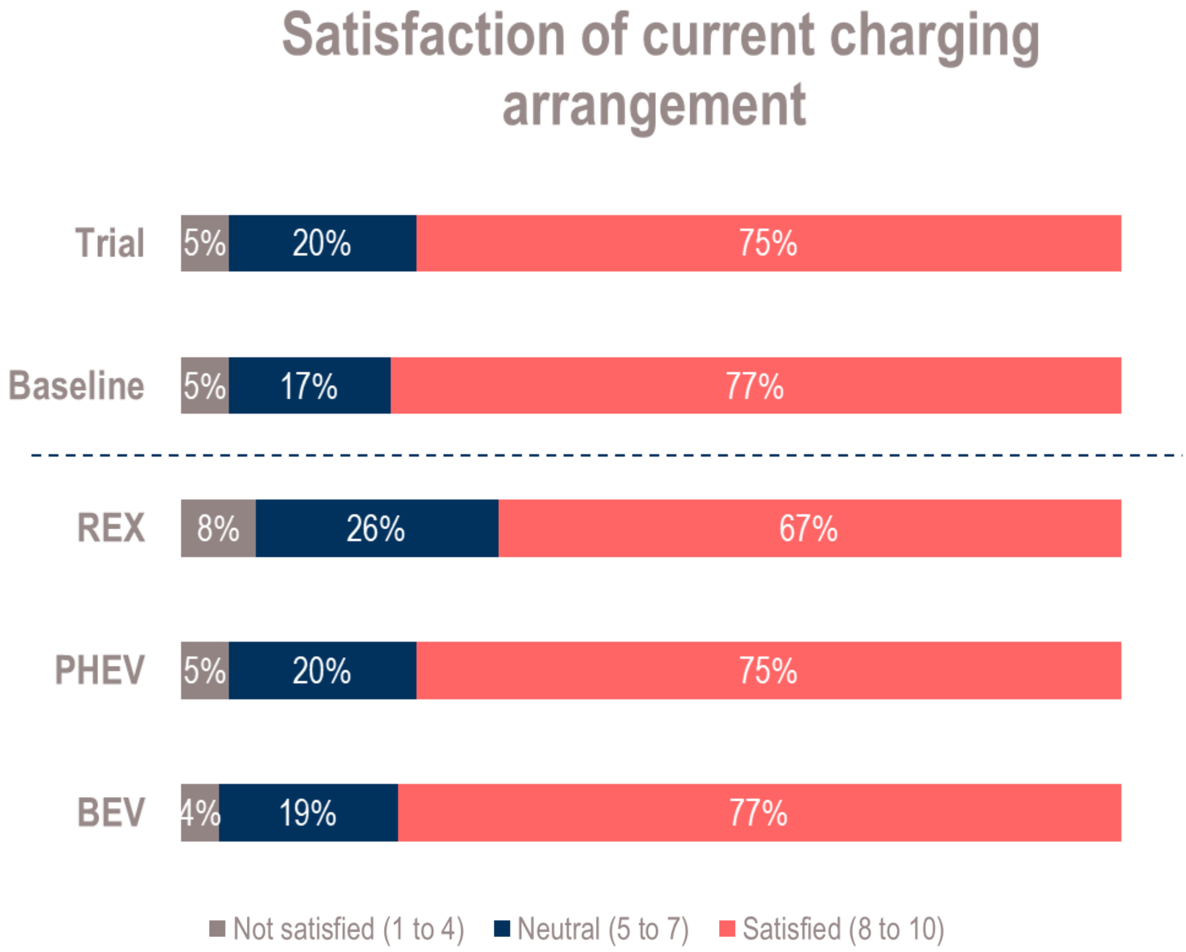
Figure 37: Acceptability of current charging arrangements (Base: All Trial (279), Baseline (498))



Participants with a battery size between 26-35kWh had a slightly higher than average acceptability rating at 84%.

The level of satisfaction with current charging arrangements has decreased slightly compared to the baseline survey, and more participants have expressed passivity toward the arrangements.

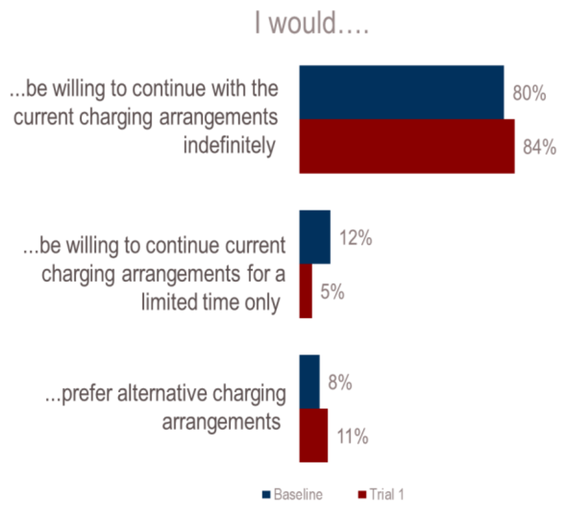
Figure 38: Levels of satisfaction with charging arrangements (Base: All Trial (279), Baseline (498), REX (39), PHEV (102), BEV (138))



Participants with a battery size greater than 35kWh had a lower satisfaction rating (68%) than the general trial population as did REX owners. The REX category in this project is populated of owners of a single model of car (BMW i3) that only has a range, when using the battery, of 110miles.

There has been a slight increase in the percentage of participants willing to continue with demand management indefinitely, however on the whole sentiment remains very similar to the Baseline survey.

Figure 39: Willingness to continue with current charging arrangements (Base: All Trial (279), Baseline (498))



There are slight variations in **trial** charging behaviour between charger types and fuel types

Charger Type		Fuel Type		
Green Flux (144)	Crowd Charge (134)	PHEV (102)	BEV (138)	REX (39)
87%	81%	80%	86%	82%
5%	6%	6%	4%	10%
8%	13%	14%	10%	8%

Thirty-one respondents provided reasons for their stated preference for alternative charging arrangements. These can be grouped into three categories:

1. Charger issues with the communications system or other technical issues with their smart charger[8]:

   "Your demand control leaves me with a low battery at times and I end up using battery capacity instead of mains power when trying to pre-heat the car on a morning."

2. Many wanted more readily available charging facilities at work/supermarket/petrol station

   "Access to charge points at work is more challenging due to increase in number of electric & hybrid cars. . . "

3. Difficulty managing the physicality of the actual charger and it not being suitable for their needs:

   "I'd prefer an induction charger at home and at service-stations. I'm a disabled driver it's not that easy to connect and stow a charging cable."

   "The charging point is too far from the vehicle, so the cable is fully stretched and very difficult to fit."

Participants were asked whether they were concerned about having their charging managed as part of the trial.

[8] This category consists mainly of participants who are having technical issues with their charger but also some who are adjusting to demand management

Participants with a battery size greater than 35kWh were statistically more concerned than average in the trial (22% combining 'quite' and 'very' concerned). 60% of the Crowd Charge cohort were 'not at all concerned' about having their charger managed compared to 50% of GreenFlux.

To conclude, participants have expressed a very slight increase of acceptability of charging arrangements compared to those expressed in the Baseline survey, but a slight move toward passivity in their satisfaction ranking of charge arrangements. The vast majority of participants have very few concerns about having their charge managed. Average reported charge duration has increased slightly for some participants. There are some interesting differences in satisfaction and acceptance amongst different subsections of participants that will be investigated further.

6 Early Insight into Charging Behaviour

Electric Nation is collecting data from up to 673 smart chargers and includes a wide range of different makes and models of EVs, and different customer types (e.g. those in full-time work, different demographics, EVs used for commuting etc.). This data can be used to predict the additional electricity demand which will be created from domestic EV charging in the future. This allows a better prediction to be made of the reinforcement requirements this may lead to, alongside the smart charging element of the trial showing whether such a solution can mitigate this.

The smart chargers for the project are generating substantial quantities of data, at two different levels of detail:

- Transaction records: showing the time at which the vehicle was plugged and unplugged, and the amount of energy transferred in the charge session.
- Meter values: a record of the amount of current (amps) made available from the charge point and drawn by the vehicle, either for each minute, or every three minutes. This allows more detailed analysis, for example showing the time at which charging began (as distinct from when the vehicle was connected, showing participants using timers) and when charging was complete. Meter values are crucial to showing the impact of demand management, as they show both the restrictiveness of a transaction and whether a vehicle was 'hot unplugged' (had the charge session finished before the vehicle was unplugged?).

This section presents some early findings based on the data received to date, and various analysis techniques. The quantity of data available will continue to increase in the rest of the trial, and analysis methods will be refined, and results presented in future reports. A full dataset will be made available at the end of the project.

6.1 Total Demand from EV Charging – Heat Maps

Charge events will occur throughout the day, the timing of which is driven by the time when the vehicle is plugged in (depends on the lifestyle of the participant) and the time taken to refill the battery (depends on the distance driven since last charge and the rate of charging). The total additional demand on distribution networks will be a result of the charge events for a group of chargers. So, for example, if charging was evenly spread throughout the day and night, rather than clustered and overlapping at particular times of day then this would be of less concern to network operators.

Preliminary analysis has been undertaken to show how charge events are spread over the course of each day, and how this varies through the year. This is based on early transaction data, and the methodology used is described below:

- Days are modelled in 48 half hour periods. Loads must be considered either 'on' or 'off' for each whole half hour period. The transaction data has been assigned to half hour periods as follows:

- Plug-in time is rounded down to the nearest half hour – e.g. a plug-in at 10:20 will be considered 'on' for the whole 10:00 – 10:30 block.
- Timers are not considered and all charging is assumed to begin as soon as the vehicle is plugged in. This will tend to overestimate peak load as some vehicles delay charging until later in the evening (see Section 6.2.5).
- The length of time a charging event lasts is estimated based on the consumed energy and knowledge of the car type registered to each Electric Nation participant. For example, a transaction where 21kWh was consumed on a charger registered to a participant with a 7kW car lasts three hours (21kWh / 7kW). This is a simplification that will tend to underestimate the charging time, as many vehicles charge slightly below their maximum rate, and charge significantly more slowly at the end of the charge cycle. This also neglects the impact of any demand management, where the actual charge rate would be reduced.
- The end time is calculated based on the approximate start time and the time required to charge. This is rounded up, so a charge event which ended at 17:10 would be 'on' for all of the 17:00 – 17:30 block.
- Examples of this are shown below:

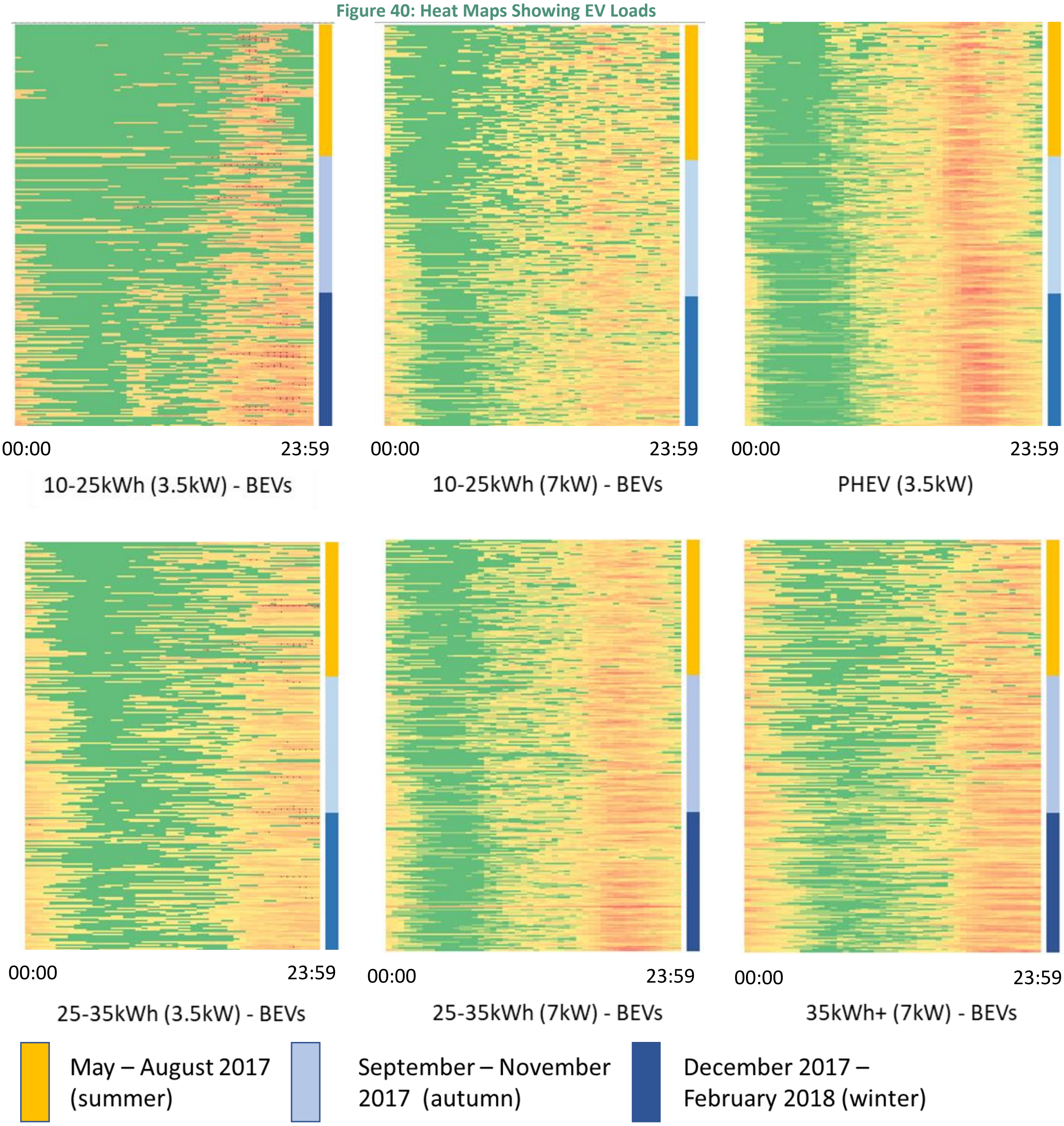
Plug-In Time	First ½ Hour Block Recorded as 'On'	Energy Consumed (kWh)	Car Rating (kW)	Time Required to Charge	Estimated Finish Time	Last ½ Hour Block Recorded as 'On'
10:10	10:00 – 10:30	16.3kWh	7	2 hours 20 minutes	12:20 (i.e. 10:00 plus 2 hours 20 minutes)	12:00 – 12:30
12:05	12:00 – 12:30	9.6 kWh	3.5	2 hours 45 minutes	14:45	14:30 – 15:00

Table 6: Examples of Charging Time Estimation Methodology

- An approximation of the total load for all chargers in the trial can then be made using a summation of the individual charger loads in each half hour.
- One of the purposes of this analysis is to compare the load across seasons. However, throughout 2017 and 2018 the number of chargers providing data increased substantially, so, for example, the total load in May 2018 would be much higher than May 2017. This is due to the increase in the size of the trial population rather than any other effect. This has been accounted for by determining the number of 'active' chargers in each week. This is defined as the total number of distinct charger IDs providing transaction records in each week.
- The total load in each half hour is compared to the maximum possible (based on the number of 'active' chargers each drawing 3.5 or 7kW depending on the car they are associated with).
- This generates a figure for each half hour period of each day of the trial, based on the estimated total load divided by the maximum.

These figures have been separated into different charging rates, PIV types and battery capacities and converted to a heat map. The x axis (left to right) indicates time of day (00:00 to 23:59), with each row showing a day of data, moving through the year from May 2017 downwards on each chart. Colours can be compared within each diagram, but not between categories (i.e. a red area in the 'PHEV' diagram does not necessarily indicate a higher load than an orange area on the '35kWh+ (7kW) – BEVs' diagram). These heat maps are shown below.

Figure 40: Heat Maps Showing EV Loads



This shows a predictable pattern of higher demand in the evening peak period for all vehicle types, at all times of year. For smaller batteries (i.e. the top three diagrams) this higher power consumption period has generally finished by mid-night, as shown by the green area beginning near the left-hand side of the diagram. However, for larger batteries (or 25 – 35kWh, 3.5kW vehicles) charging continues into the early hours of the morning. This is particularly true for the largest battery capacities, as it is likely that more energy will be consumed for each charge cycle as drivers can travel further between charges.

Weekend demand appears to be lower than weekdays, with shorter, less intense high demand periods appearing at regular intervals through the chart. This aligns with the findings reported in Section 7.5 showing less demand management at weekends.

The trend through the year (down each chart) appears to indicate longer charging durations in the winter months, as the orange/yellow/red area is wider. The demand during the peak period is also higher in winter, as indicated by a more intense red/orange colour in the lower portion of the charts. This is likely to be caused by decreased vehicle efficiencies (miles/kWh) during the winter months due to additional loads for heating etc.

This analysis technique will be further developed for future reports to include the effect of timers and take account of actual current drawn in a transaction to estimate the time at which charging was complete. As more data is gathered during the remainder of the customer trial, these analyses will become clearer, further the PHEV heatmap will be compared with an "all BEV" heatmap for increased clarity. A comparison could also be made between the profiles for 'managed' and 'unmanaged' transactions, which is likely to show slightly longer charge sessions in the 'managed' group, as demand is decreased to remain within the network's capacity.

6.2 Charging Behaviour

As described above, chargers in the Electric Nation project send data to the demand management providers for each charging session (when online). This data can be used to show the charging behaviour of the participants – such as the frequency of charging, energy consumed, time of charge sessions, use of timers etc. Early insights are presented in this section, based on 74,644 transactions where more than 0.5kWh of energy was consumed. These records come from 573 different participants, with various makes and models of PIV. The records span the period between April 2017 and June 2018. Further data will be added as the trial progresses and final results will be presented in the project reports to be published during 2019.

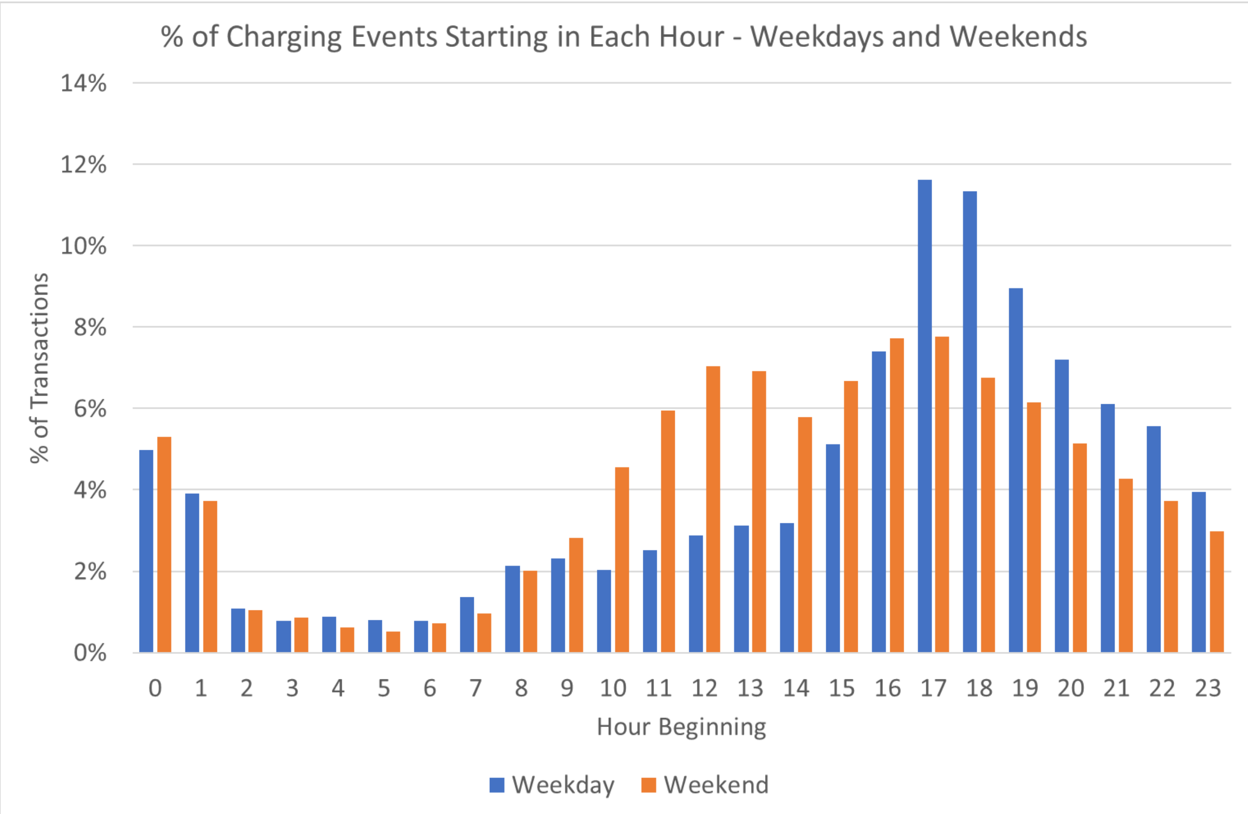
6.2.1 Time of Day

The time at which EVs charge will determine the impact on distribution networks – if the additional from charging adds to existing peaks then this is more likely to lead to a requirement for network reinforcement or other solutions, such as smart charging. If charging loads occur at a time of day when there is sufficient spare network capacity, then the reinforcement requirements would be much lower.

Transaction records (see description at the start of this section) record the time the vehicle was plugged into the charger, and then unplugged. The majority of PIVs have a facility within the vehicle, or via an app, which allows the user to programme a timer which determines when their vehicle charges. If this has been used, then the start of charging will be after the plug-in time. It is only possible to determine this by using the meter values sent by the smart charger. These values are only sent for charge events which occur when the charge point is online, therefore the analysis below is based on the 58,205 records for which a 'start of charging' time can be determined.

The % of all transactions beginning in each hour are shown below, separated by whether the transaction began on a weekday or weekend (i.e. a plug-in at 20:00 on a Sunday is counted as 'weekend', even if it was unplugged on Monday morning).

Figure 41: Start of Charging - by Weekday and Weekend

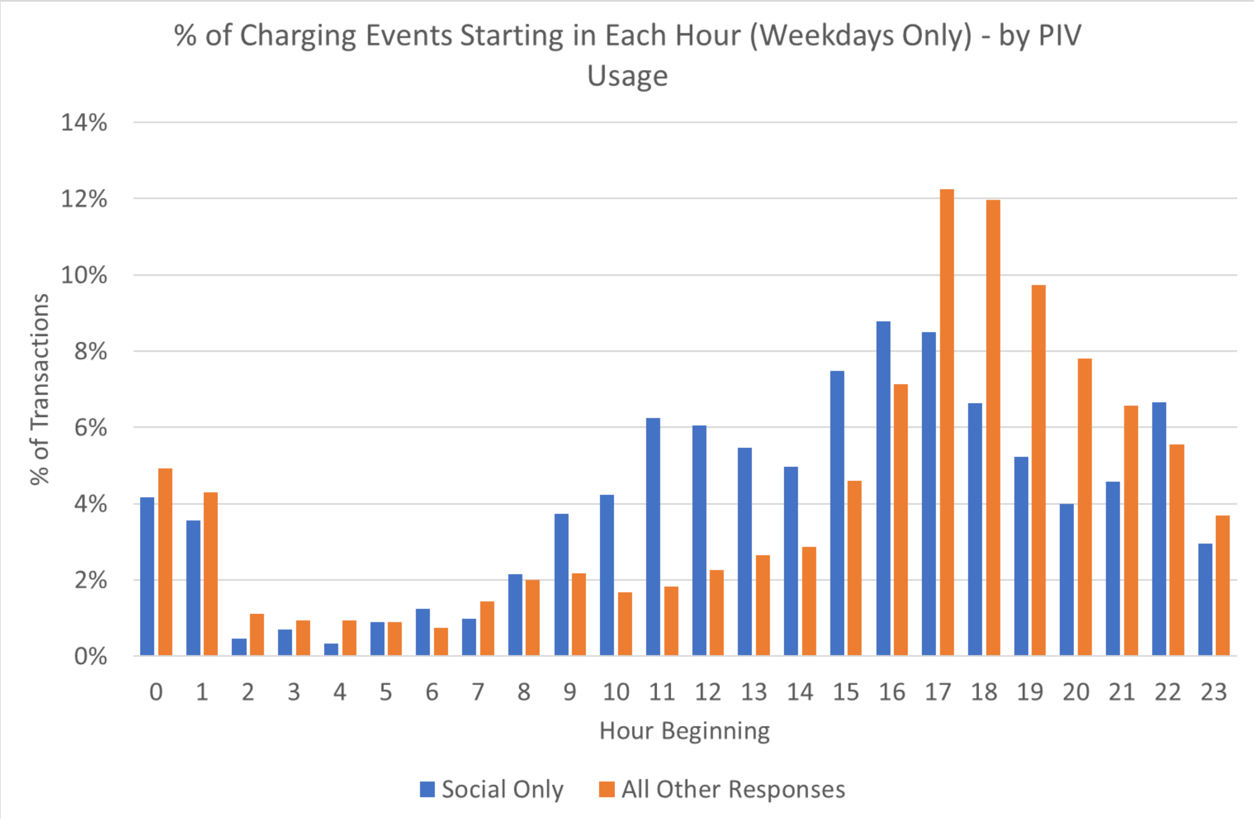


The weekday pattern shows a pronounced increase in charge events beginning the evening peak period. Charge sessions which begin in the early hours of the morning are likely to be because of drivers using a timer, this is explored in more detail in Section 6.2.5 below.

Charging behaviour during the day at weekends is different, with a much larger proportion of events starting during the day, and a lower evening peak. This aligns with the lower levels of demand management observed at the weekend.

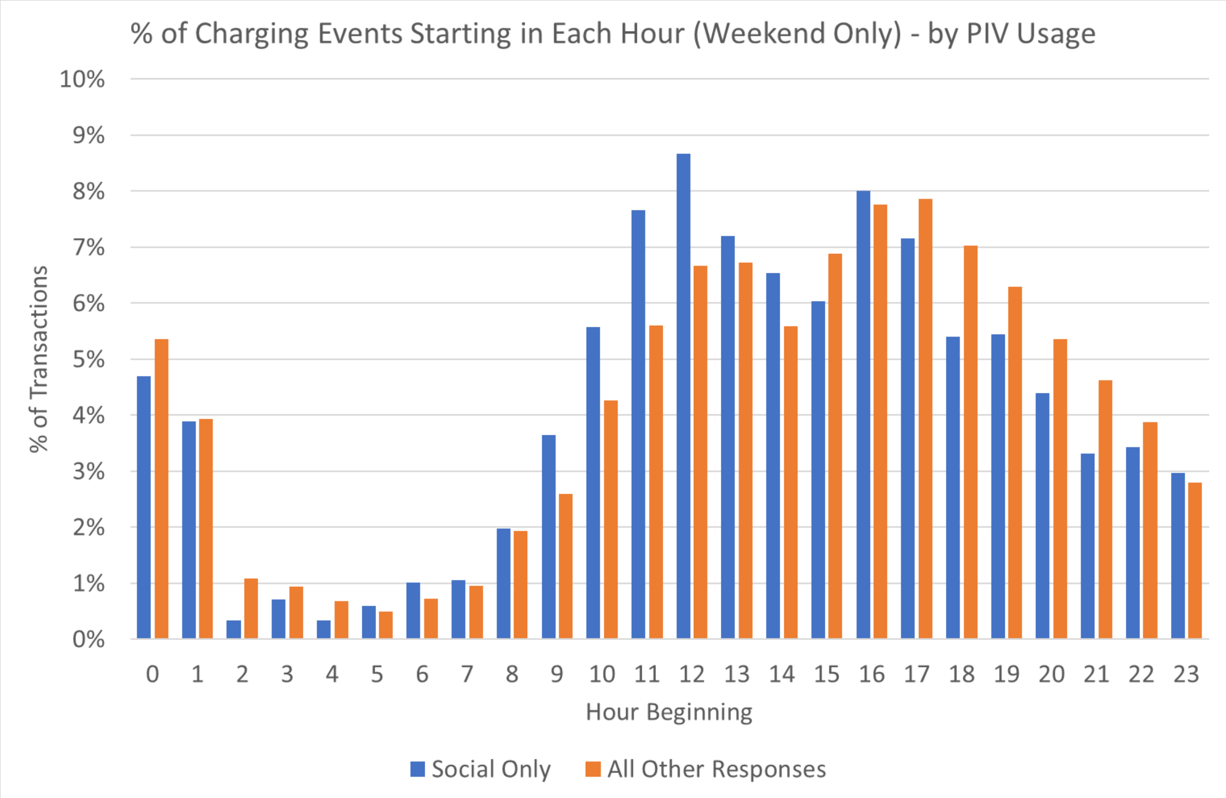
As part of the baseline survey drivers are asked what type of journeys they use their PIV for (commuting, social and business). This is may affect the time of day at which the vehicle is parked at their home address and so may be charging. The graph below shows the % of transactions beginning each hour, based on weekday charge events. The blue series relates to transactions from participants who use their PIV for social journeys only, with transactions from all participants who have responded to the survey shown in orange.

Figure 42: % of Charging Events Beginning in Each Hour (Weekdays Only) - by Type of PIV Usage



This shows much more charging during 'work hours' for the 'social only' group. The late afternoon/early evening peak also occurs earlier in the afternoon – from 15:00 to 17:00. This is likely to result in these participants experiencing less demand management. The weekend pattern for the start of charging is much more similar between the two groups, as shown below.

Figure 43: % of Charging Events Beginning in Each Hour (Weekend Only) - by Type of PIV Usage

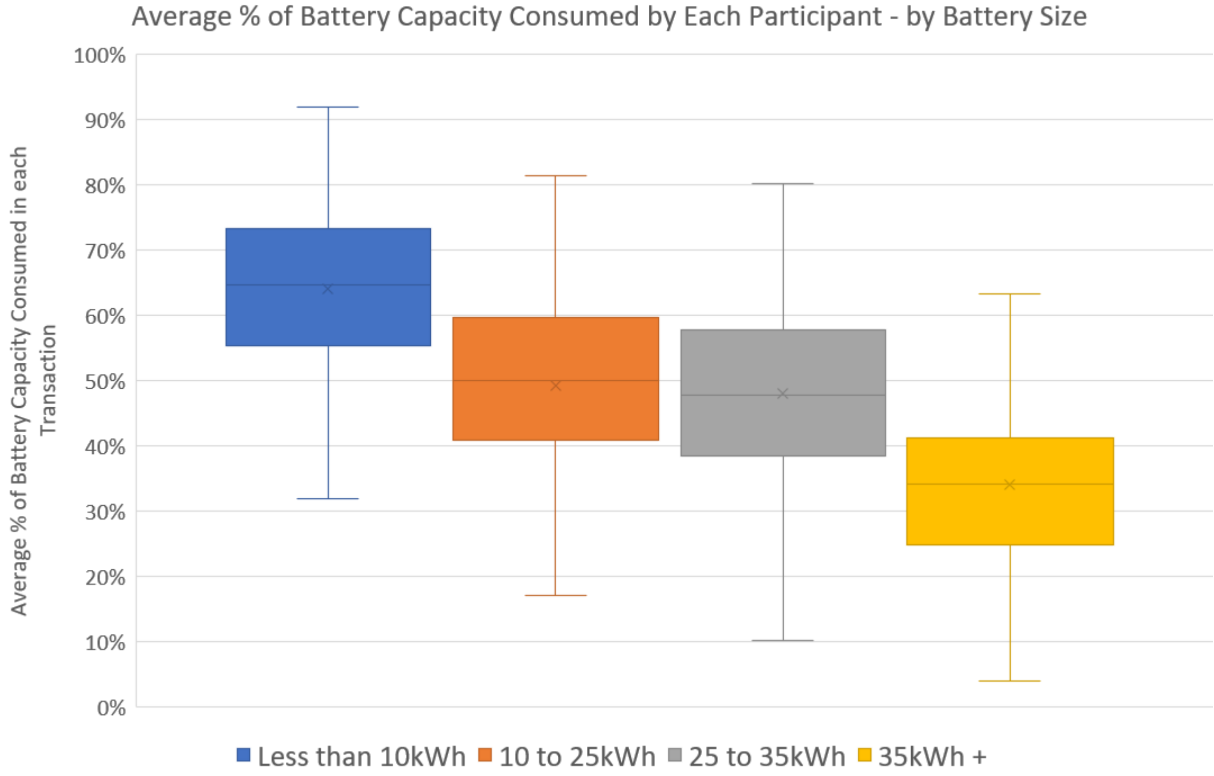


6.2.2 Energy Consumed

If a vehicle is left to charge until the battery is full (i.e. not 'hot unplugged') then the energy consumed, and the time taken to charge, will be determined by the energy consumed (primarily affected by the distance driven) since the last charge and the battery capacity (as this dictates the maximum value). Time taken to charge is also affected by the EV's maximum charge rate (3.5 or 7 kW)

The vehicle registered as part of the trial, and its battery capacity is known for each Electric Nation participant, and this can be associated with the charger ID. It is therefore possible to calculate the percentage of the battery capacity consumed for each transaction (e.g. if 15kWh is consumed during a transaction for a charger registered to a participant with a 30kWh Nissan Leaf then 50% of the battery capacity has been refilled). The average of this value has been calculated for each participant. The spread of these values is shown in the box and whisker plot below, split by the battery capacity category. Start and end of charging EV state of charge data is not available currently and is only ever likely to be available for a very small number of trial participants vehicles.

Figure 44: Average Energy Consumed by Participants - by Battery Size[9]



This shows that participants with the smallest batteries are generally refilling a greater percentage of their battery capacity each time they charge. This is to be expected, as the range of these vehicles is much lower. Participants with the largest battery capacities tend to consume a lower proportion of their battery capacity. However, this will still be equivalent to more energy than smaller batteries. The average battery capacity in the 'less than 10kWh' category is 8kWh, so the median value of 65% is equivalent to consuming 5.2kWh. In the '35kWh+' group the average battery capacity is 76kWh, so the median value of 34% is equivalent to 26kWh. Vehicles in the largest category are therefore likely to charge for longer – 26kWh at 7kW would require 3 hours 40 minutes, compared to 1 hour 30 minutes for 5.2kWh at 3.5kW. This aligns with heat maps presented in Section 6.1, where the times of highest demand last longer for vehicles with larger battery sizes.

6.2.3 Frequency of Charging

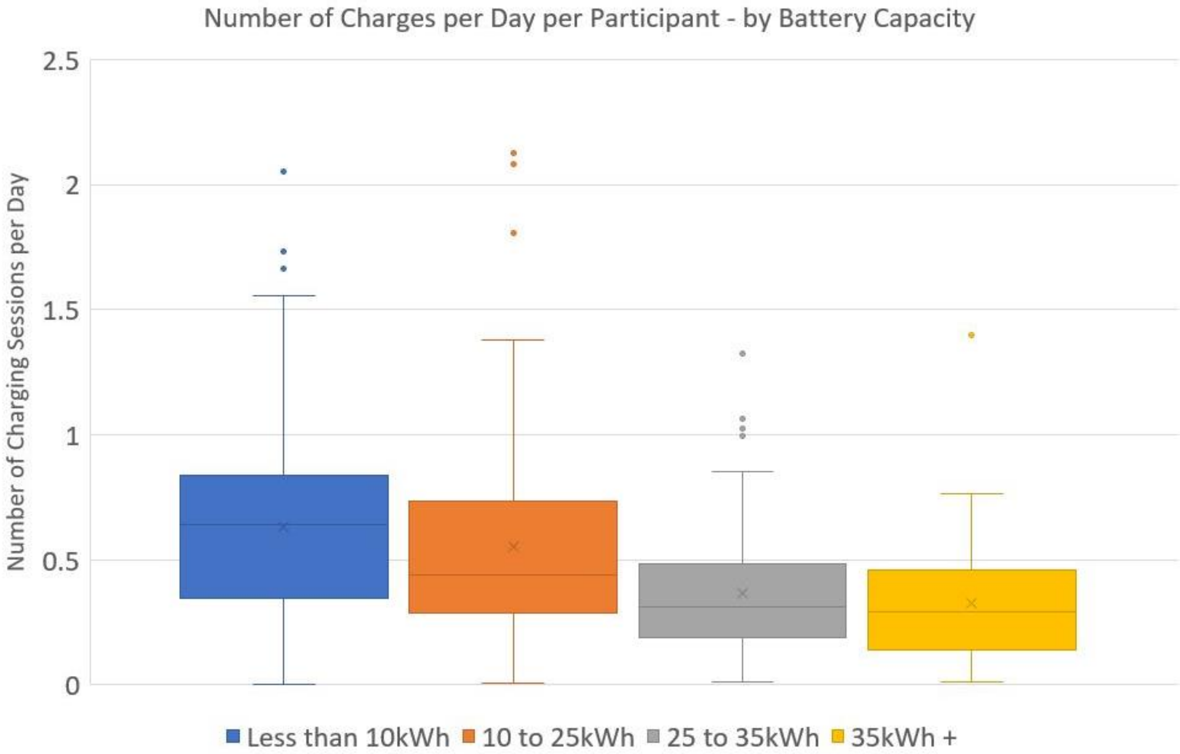
Transaction records received from chargers to date has been analysed to determine the typical frequency with which trial participants charge their vehicle. This is shown below,

[9] Box and whisker diagrams show the spread of data using the minimum, maximum, median and interquartile range of the data. For example, for participants with a registered battery capacity of less than 10kWh:

- The lowest average energy consumed (as a percentage of battery capacity) is 32%.
- 25% of participants with this battery capacity consume, on average, less than 55% of their battery capacity each time they charge.
- The median value is 65%
- Only 25% of participants with this battery capacity consume, on average, more than 73% of their battery capacity each time they charge.
- The highest average energy consumed (as a percentage of battery capacity) is 92%.

based on the number of transaction records (where greater than 0.5kWh of energy was consumed) received from each charger since the date it was first used by the customer. Records for chargers with less than 50% communications reliability are excluded as this can lead to a falsely low charging frequency due to missing records. These figures are therefore based on 474 chargers. On average participants are charging 0.48 times per day, or between three and four times a week. This is shown by battery capacity in the box and whisker plot below.

Figure 45: Charging Frequency by Battery Capacity - Box and Whisker Plot



This shows that participants with smaller batteries tend to charge more frequently – with a median value of 0.64 charges per day for the smallest battery capacity category, compared to 0.29 for the largest batteries. Charging every day is relatively unusual, particularly for the large battery sizes which are likely to dominate in the future. Across all battery sizes only 39 of 474 participants charge at least once a day (8%), 26 of these are in the 'less than 10kWh' category (137 participants of the 474 have a vehicle with a battery capacity of less than 10kWh).

The table below summarises the average charging frequency for a number of different variables within the trial population:

Variable	Category	Average Number of Charging Sessions Per Day	No. of Participants in Category (with comms >50%)
All Participants	All	0.48	474
PIV Type	PHEV	0.64	185
	REX	0.43	65
	BEV	0.37	224
Battery Capacity	Less than 10kWh	0.63	137
	10 to 25kWh	0.55	122
	25 to 35kWh	0.36	133
	35kWh+	0.32	82
Uses of PIV	Social Only	0.46	60
	All Other Uses	0.46	292[10]
Employment Type[11]	Employed over 30 hours a week	0.48	296
	Employed part time	0.48	30
	Retired	0.46	40
	Self employed	0.50	68
Area Type	Urban	0.45	173
	Mixed/Semi-Rural	0.52	139
	Rural	0.52	88
Access to at least one other vehicle	No other vehicle	0.50	52
	Yes – another PIV	0.49	22
	Yes – not a PIV	0.45	278

Table 7: Average Charging Frequency for Various Participant Characteristics

These figures suggest that of the variables considered above, PIV type and battery capacity have the strongest influence on charging frequency.

6.2.4 Plug-In Duration

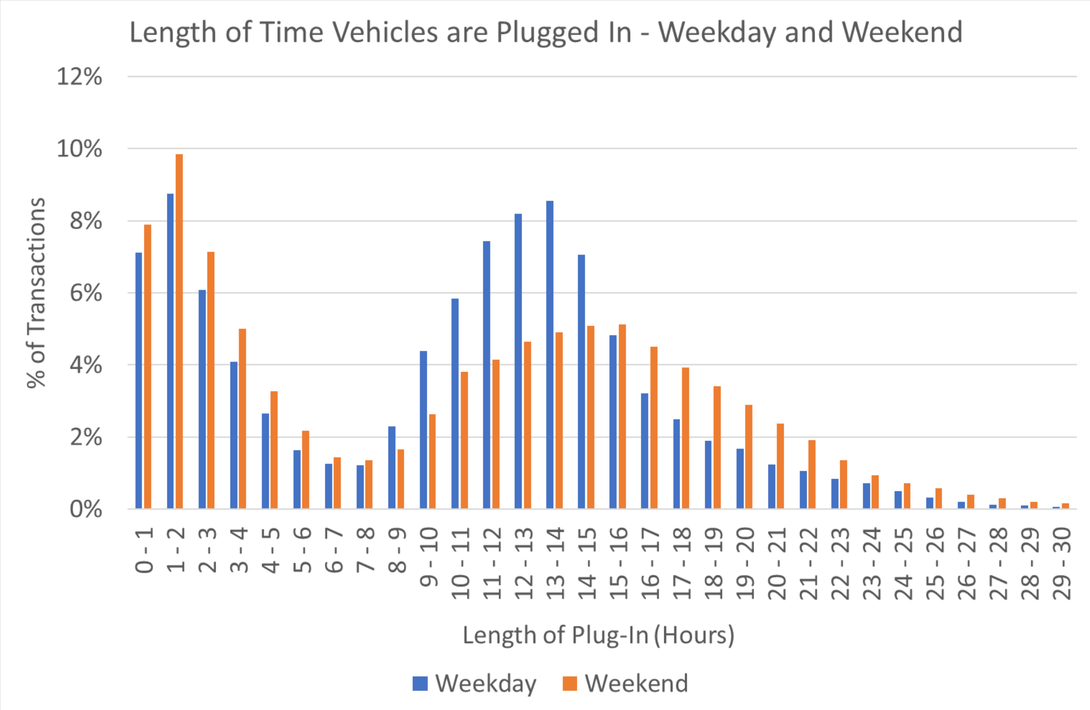
In theory, the energy required to recharge a vehicle can be delivered at any point when it is plugged in. For example, a 7kW vehicle requiring 21kWh of energy to fully re-charge and plugged in for nine hours could be charged at 2.4kW throughout the plug-in and still meet the its energy requirements. Smart charging for DNO purposes is unlikely to require such a long restriction – in reality, the charge rate may be reduced for two/three hours during the

[10] Participants who have not responded to the Baseline survey are excluded from this analysis
[11] Participants who are 'looking after the home/children' and 'unemployed' have been excluded from this analysis due to very small sample sizes.

evening peak, but the vehicle could charge at 7kW throughout the rest of the night. In contrast, if the same 7kW vehicle requiring 21kWh was only plugged in for three hours then it must charge at the maximum rate to meet the requirement. The plug-in duration therefore gives some indication of the amount of flexibility that is available.

The graph below shows the % of transactions in the trial where a vehicle is plugged in for different durations. Transactions with a plug-in duration of over 30 hours are not shown and make up 4.2% and 6.2% of weekday and weekend transactions respectively.

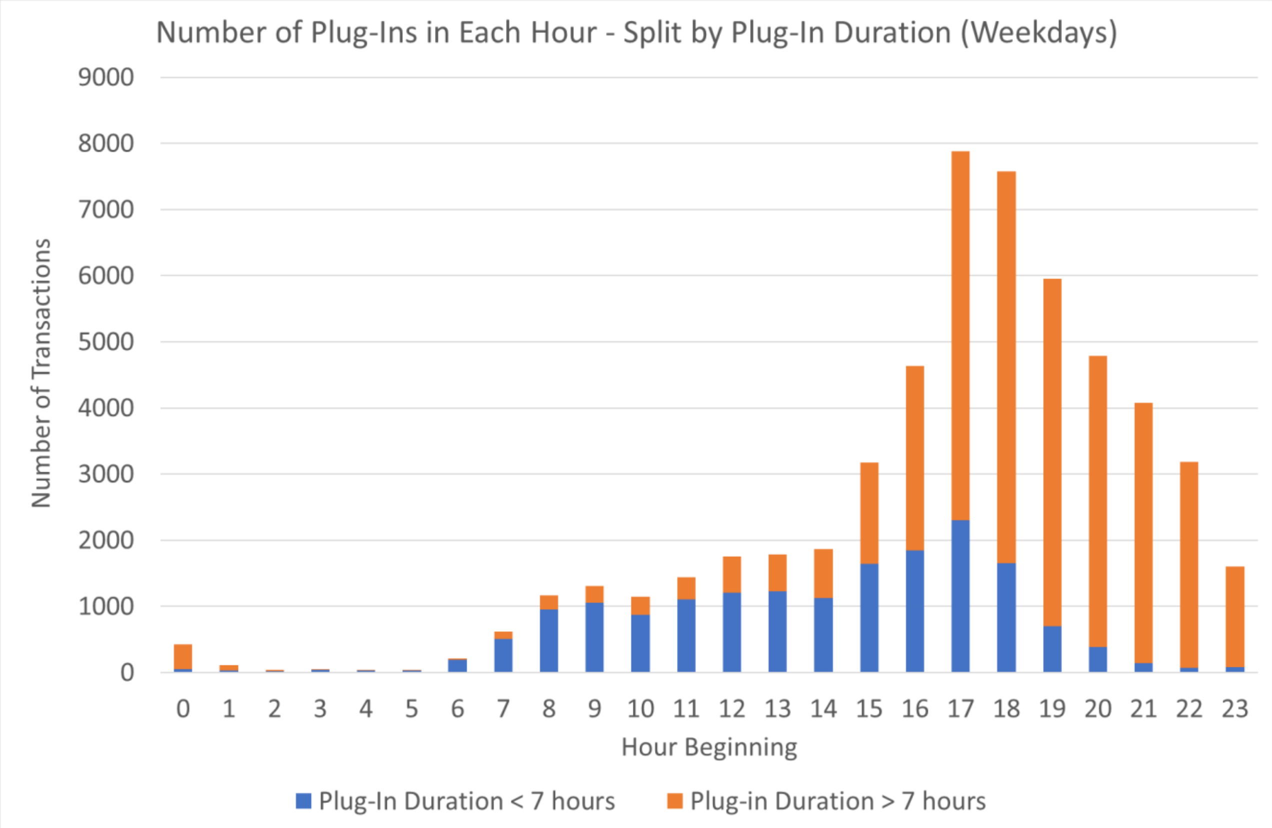
Figure 46: Length of time vehicles are plugged in (weekdays and Weekends)



Shorter plug-in durations are more common at weekends. This may be due to drivers only requiring short 'top-up' charges in between activities at the weekend, rather than plugging in overnight during the week. On weekdays there is a clear split between either short duration (less than 7 hours) or longer duration events. A similar split exists for the weekend, but the plug-in durations are longer, possibly as drivers leave the house later on a weekend morning compared to during the working week. The split in length of plug-in time is likely to be a function of plug-in time, as vehicles which are plugged in during the evening will either be unplugged within a couple of hours or left plugged in until the next morning.

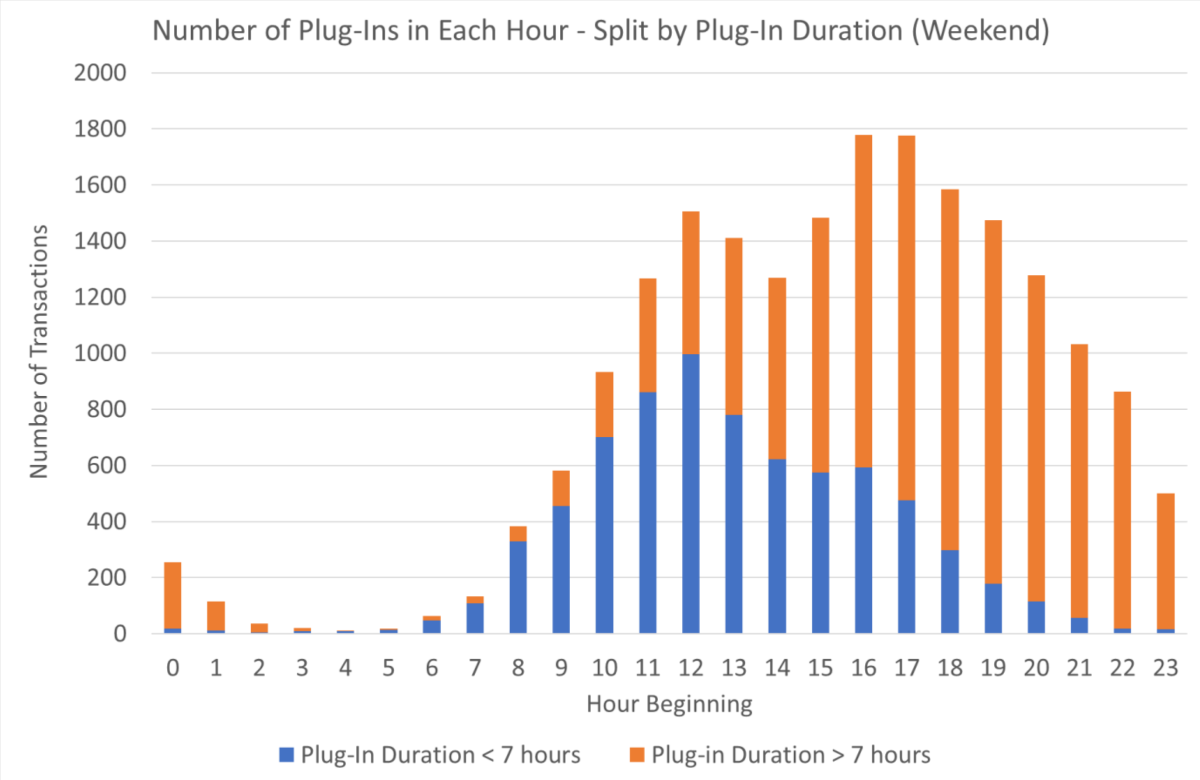
The graphs below show the number of transactions which began in each hour, split into those plug-in durations of less than, or more than, 7 hours. Weekdays and weekends are shown separately.

Figure 47: Number of Transactions beginning in Each Hour, split by Plug-in Duration - Weekday



The overall height of each column is in line with expectations, with a peak in vehicles being plugged in during the evening peak, as drivers return home (17:00 to 19:00). Shorter plug-in durations (less than 7 hours) dominate during the daytime. From 16:00 onwards the majority of plug-ins have a duration of more than 7 hours. From the point of view of demand management this means that for the majority of plug-ins which occur after 16:00 there is at least 7 hours in which the energy required could be delivered, indicating a degree of flexibility for smart charging.

Figure 48: Number of Transactions beginning in Each Hour, split by Plug-in Duration - Weekend



The pattern differs at weekends – the evening peak in total number of plug-ins does not occur. The switch to the majority of plug-ins lasting more than 7 hours also occurs earlier at the weekend, at 14:00.

6.2.5 Use of Timers

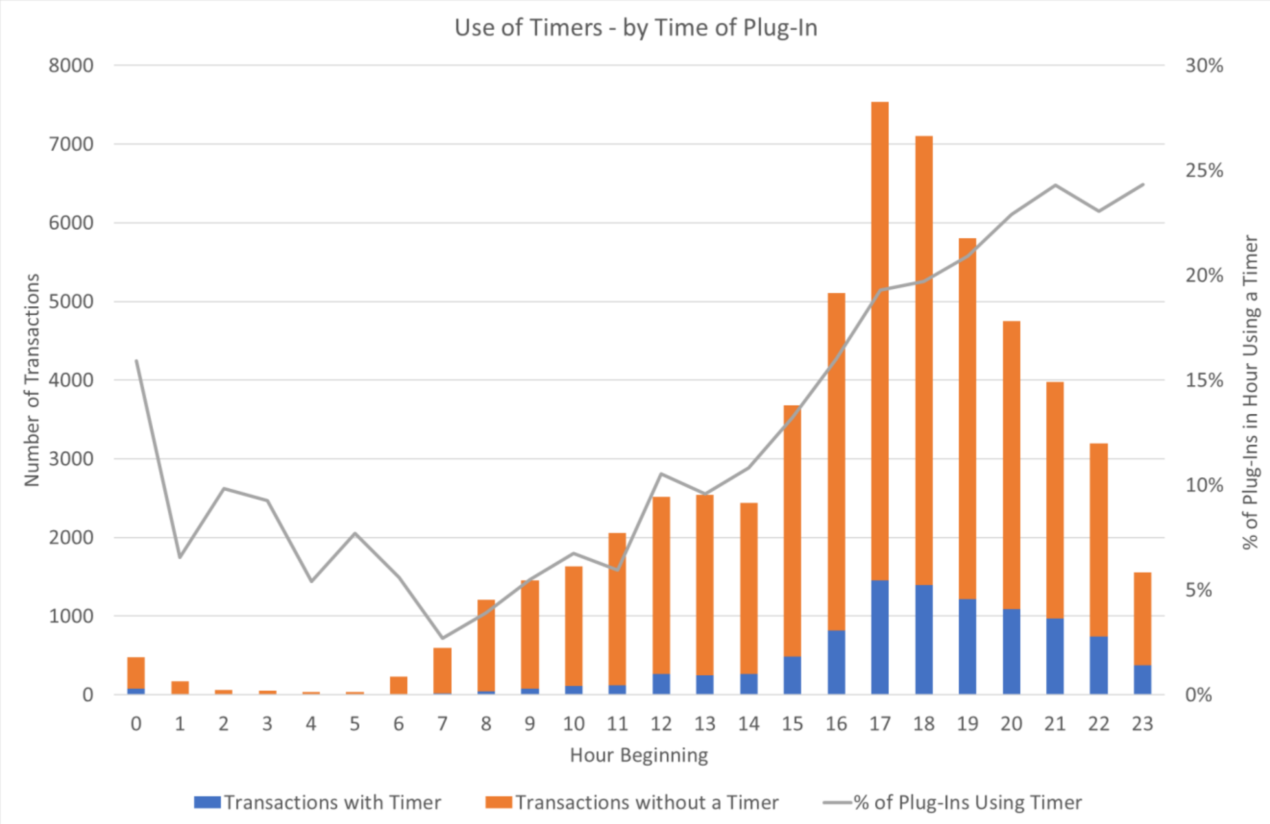
Many makes and models of PIV include a timer function to control when charging occurs (i.e. delaying start of charge from the plug-in time). In the absence of a timer, and without demand management, an EV will begin charging almost immediately when plugged in and continue to charge until the battery is full, or the vehicle is unplugged. Timers typically function in one of two modes:

- Off-peak timing window (e.g. Mk1 Nissan Leaf): the user pre-programmes times when charging should take place (e.g. 00:00 to 7:00). The vehicle begins to charge at the start of this window.
- Departure time (e.g. BMW i3): the user pre-programmes details of their off-peak tariff, and a time when they intend to unplug the vehicle and begin their next journey. The vehicle evaluates its state of charge and expected charge rate and determines the time to start charging to be ready shortly before the departure time.

PIV owners may use timers for a variety of reasons including; taking advantage of existing time varying tariffs (e.g. Economy 7), matching their charging with their own electricity generation (midday charging with PV generation) or due an awareness of network capacity issues and a desire to minimise this (even in the absence of tariff incentives). This sub-section explores the data collected as part of the Electric Nation trial to date, showing the prevalence of the use of timers, and ways in which these are being used. This analysis is based on the 58,089 records in the database where a 'start charge' time (as distinct from plug-in time) is available. These records span the period from April 2017 to June 2018, and involve 565 different chargers. Of these, 368 have used a timer[12] at least once. 9,732 of the 58,089 transactions used a timer – 17%.

Use of a timer is more likely when the vehicle is going to be plugged in for a longer period of time, as there is more flexibility in when the energy can be delivered (compared to a situation where the driver wants to recharge as quickly as possible before their next journey). The graph below shows the proportion of plug-in events in each hour where a timer is used.

Figure 49: Use of Timers - by Time of Plug-In



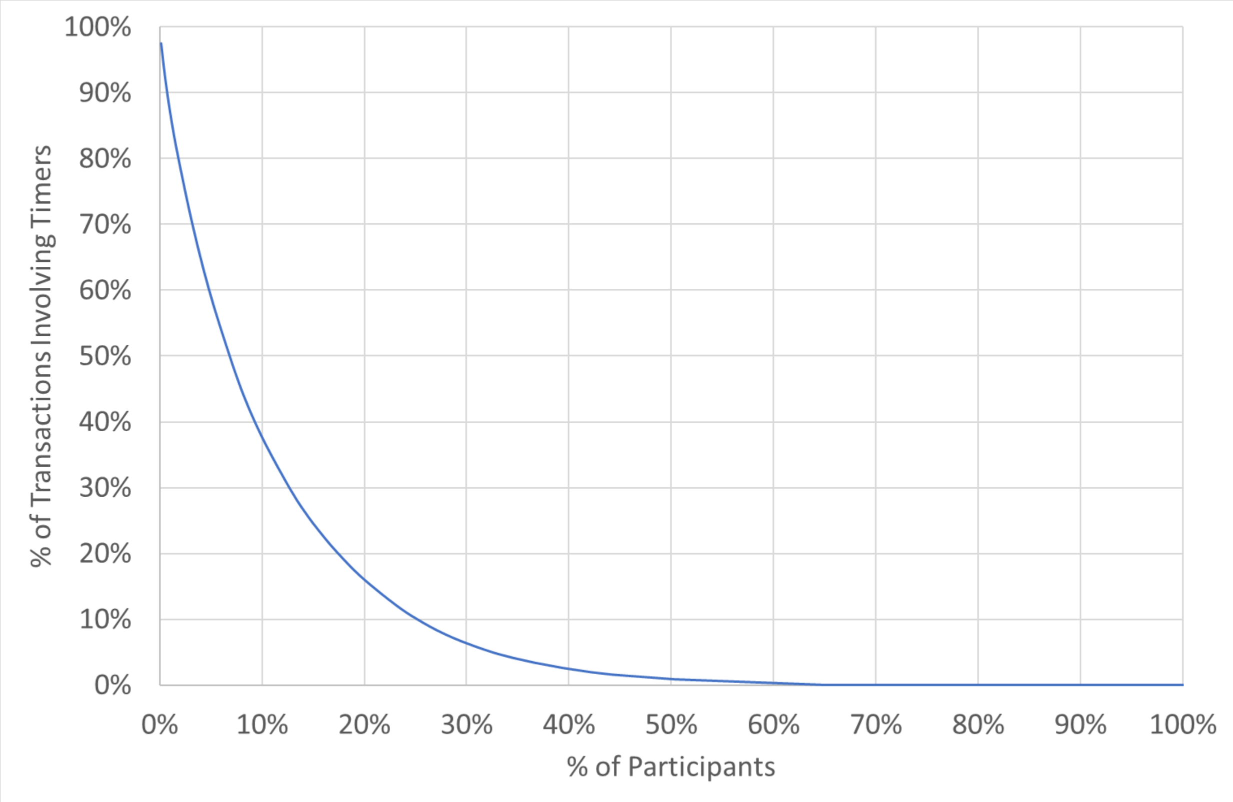
As shown the grey line, the proportion of plug-ins using a timer increases through the day and evening. In terms of raw number of transactions, the largest contribution comes from plug-ins during the evening peak.

Drivers can have varying patterns for their use of a timer – from one extreme, never use a timer to always delaying charging. Other possibilities include using a timer for overnight charging, but occasionally charging during the day. The graph below shows the contribution of individual participants to the total number of transactions with timers. This indicates

[12] Use of a timer is defined as any transaction where there is a delay of more than 15 minutes between plug-in and current being drawn. A value of 15 minutes has been chosen due to the functionality of the GreenFlux demand management system which can insert a short pause at the start of charging cycles.

that approximately 20% of the participants are responsible for 85% of all transactions involving timers.

Figure 50: Contribution of Individual Participants to Total of Transactions involving Timers



Off-peak electricity tariffs, such as Economy 7 (E7) are one potential motivation for use of a timer, and this has been reported anecdotally to Drive Electric during customer technical support calls. During the recruitment process customers provide their MPAN number, from which their meter type (single rate or dual-rate) can be determined, giving an indication of their tariff type. This information has been used below to show the spread of timer use between the 'flat rate' and 'dual-rate' populations.

Figure 51: Timer Use by Participants - Flat Rate and Dual Rate Meters

This shows a much higher use of timers by those participants with a dual-rate meter. This is to be expected as they can take advantage of cheaper electricity rates to charge their vehicle overnight. For example, prices for the 'cheapest' (based on 4,300kWh per year) E7 and single rate electricity only tariff in 2017 were reported as 15.2 p/kWh (peak rate E7), 7.1 p/kWh (off-peak E7) and 12.6 p/kWh (single rate)[13].

The median of the two populations (2% of transactions on a timer for single rate meter participants compared to 38% for the dual rate population) shows a clear difference in timer use. However, there are participants in both groups across the full rate, including 6% of participants with a single rate meter who are using a timer for more than 80% of their transactions.

The effect of time of use tariffs on EV charging load will be explored in more detail as part of the third algorithm iteration.

[13] Money Saving Expert. https://www.moneysavingexpert.com/utilities/economy-7/ Accessed July 2018.

7 Trial Design and Update on Demand Management Roll-Out

7.1 Introduction

A core part of the Electric Nation project is a large trial of smart charging (demand management) which will encompass all project participants (where reliable communications are established). The aim of this trial is to evaluate the reliability and acceptability to EV owners of a smart charging system and the influence this has on charging behaviour.

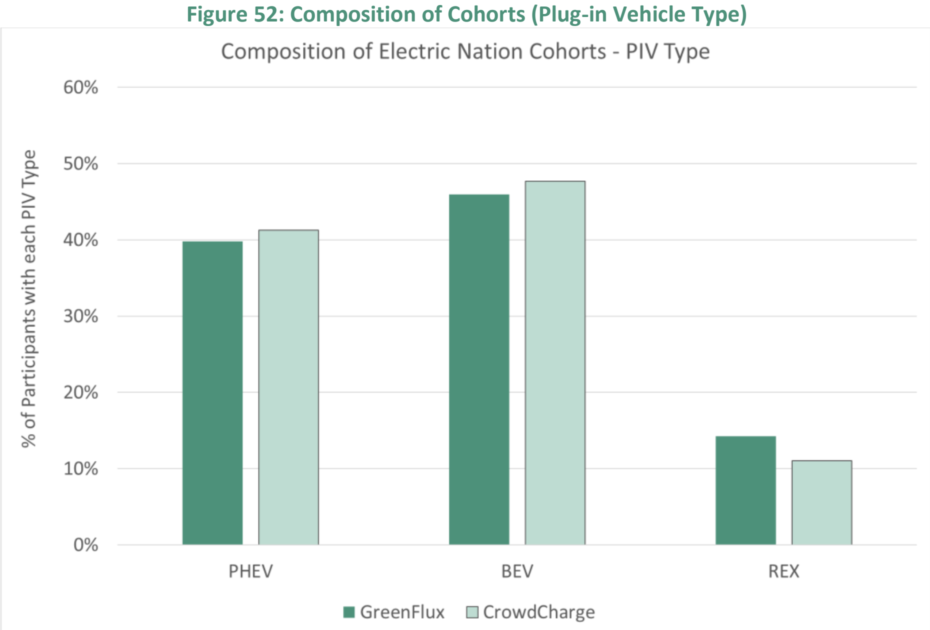
This section describes the trial design in more detail, building on the information included in the Algorithm Development and Testing Report, and the previous trial update reports (published in November 2017, January and April 2018). It also reports on the progress with moving all the trial participants into routine demand management.

7.2 Electric Nation Cohorts – GreenFlux and CrowdCharge

Two demand management providers are being used within Electric Nation, GreenFlux[14] and CrowdCharge[15]. Trial participants are allocated to each group during the recruitment process. Each company uses different algorithms to allocate current to individual chargers. As the project has now moved into 2nd algorithm (see Section 8 for details) the way that participants can interact with their system also differs between the two providers.

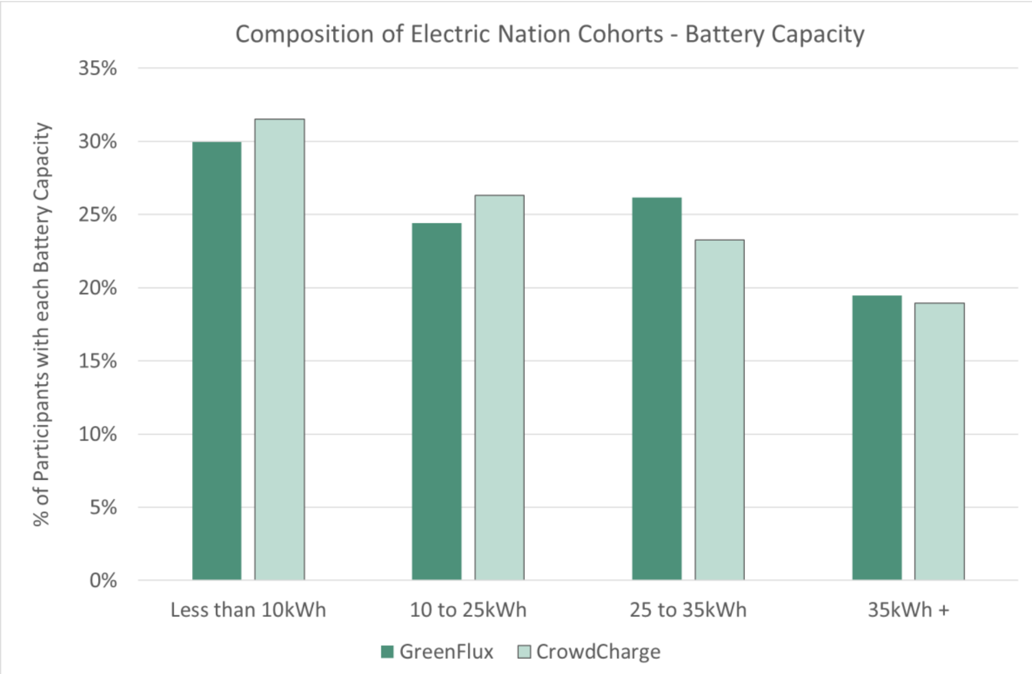
The two cohorts were managed during the recruitment phase to ensure a consistent mix of vehicle type and battery sizes. The current balance of the two cohorts is shown in Figure 52 and Figure 53, based on all chargers installed up to 16th July 2018 (671 chargers).

Figure 52: Composition of Cohorts (Plug-in Vehicle Type)



[14] https://www.greenflux.nl/en/
[15] http://crowd-charge.com/

Figure 53: Composition of Cohorts (Battery Capacity)



These indicate that the two groups are well balanced. The Electric Nation cohort can be compared to recent UK sales, and this is shown below:

Year	PHEV Registrations		BEV Registrations		Total
2016	74%	*(28,798)*	26%	*(10,246)*	39,044
2017	72%	*(34,660)*	28%	*(13,678)*	48,338
2018 (to end May 18)	74%	*(17,134)*	26%	*(5,894)*	23,028
Total	73%	*(80,592)*	27%	*(29,818)*	110,410

Table 8: PIV Type - UK Sales in 2016 - 2018[16]

This does not contain a separate category for range extended vehicles, but as these have an alternative (non-battery) means of propulsion they can be included as plug-in hybrid electric vehicles for the purposes of comparison with UK data. The Electric Nation group is made up of 53% plug-in hybrid vehicles and range extenders, and 47% full battery vehicles (compared to 73%/27% for 2016 to 18 UK sales).

The same data source can be used to compare the composition of battery sizes in Electric Nation to recent UK sales. For each vehicle type, the sales of the five highest models are provided, alongside an 'other' category for all other makes and models[17]. These are shown for BEVs and PHEVs below.

[16] Data from: http://www.eafo.eu/content/united-kingdom Accessed 18/07/2018
[17] 'Other' could include a vehicle which had appeared in the Top 5 in a previous year.

Model	Battery Capacity (kWh)	2018	2017	2016	Total
Nissan Leaf	2018 – 40kWh 2016 and 2017 – 30 or 24kWh	2,971	5,620	4,649	13,240
Tesla Model S	60, 70, 75, 85, 90 or 100kWh	705	2,447	2,453	5,605
Renault Zoe	2017 and 2018 – 40kWh 2016 – 22kWh	614	1,157	1,760	3,531
Tesla Model X	90kWh	389	2,040	0	2,429
Hyundai ioniq (electric)	28kWh	385	-	-	385
BMW i3	22 or 33kWh	-	1,135	593	1,728
Mercedes B250e	28kWh	-	-	281	281
'Others'	Mixed – composition unknown	830	1279	510	2,619

Table 9: BEV Sales by Make and Model - UK Sales in 2016 - 2018[18]

Model	Battery Capacity (kWh)	2018	2017	2016	Total
Mitsubishi Outlander	12	3,100	7,384	9,449	19,933
Mercedes 350e	6.2	1,123	2,916	5,394	9,433
BMW 330e	7.6	2,316	5,864	3,510	11,690
BMW i3 REX	2017 and 2018 – 33kWh 2016 – 22kWh	-	2,259	1,925	4,184
Golf GTE	8.7	1,419	2,422	1,893	5,734
BMW 530e	7.6	1,814	-	-	1.814
'Others'	Mixed – composition unknown	7,362	13,815	6,627	27,804

Table 10:PHEV Sales by Make and Model - UK Sales in 2016 – 2018

This can be converted into the battery capacity sizes used within Electric Nation. For some makes and models, and the 'Other' category, the individual vehicles sold could fall into multiple categories (e.g. a 1st generation Nissan Leaf purchased in 2016 or 2017 could be either a 24kWh or 30kWh model). Assumptions have been made to estimate the total sales in each category, as detailed below.

[18] Data from: http://www.eafo.eu/content/united-kingdom Accessed 18/07/2018

Battery Size	2018	2017	2016	Total	Models Included
Less than 10kWh	9,126	15,807	13,006	37,939	**All years:** Mercedes 350e, BMW 330e, Golf GTE, BMW 530e and a third of 'Other' PHEV sales
10 to 25kWh	5,554	15,367	17,964	38,885	**2018:** Mitsubishi Outlander and a third of 'Other' PHEV sales **2017:** Mitsubishi Outlander, a third of 'Other' PHEV sales, half of Nissan Leaf sales, half of BMW i3 BEV sales **2016:** Mitsubishi Outlander, BMW REX, a third of 'Other' PHEV sales, half of Nissan Leaf sales, Renault Zoe, half of BMW i3 BEV sales
25 to 35kWh	3,254	10,881	5,366	19,501	**2018:** Hyundai ioniq, half of 'Other' BEV sales and a third of 'Other' PHEV sales (could be 2017 model year BMW i3 REXs) **2017:** Half of Nissan Leaf, half of BMW i3 BEV, half of 'Other' BEV sales, BMW i3 REX and a third of 'Other' PHEV sales **2016:** Half of Nissan Leaf, half of BMW i3 BEV, half of 'Other' BEV sales, Mercedes B250e, and a third of 'Other' PHEV sales
35kWh+	5,094	6,284	2,708	14,086	2018: Nissan Leaf, Tesla Model S and X, Renault Zoe, half of 'Other' BEV sales 2017: Tesla Model S and X, Renault Zoe, half of 'Other' BEV sales 2016: Tesla Model S and X, half of 'Other' BEV sales

Table 11: UK Sales - totals by Electric Nation Battery Capacity Categories

Using these assumptions, the breakdown for total sales in 2016, 2017 and 2018 can be compared to Electric Nation in the table below.

Battery Capacity Category	Approximate % of UK Sales (2016 – May 2018)	% of Electric Nation Trial Participants
Less than 10kWh	34%	31%
10 to 25kWh	35%	25%
25 to 35kWh	18%	25%
35kWh+	13%	19%

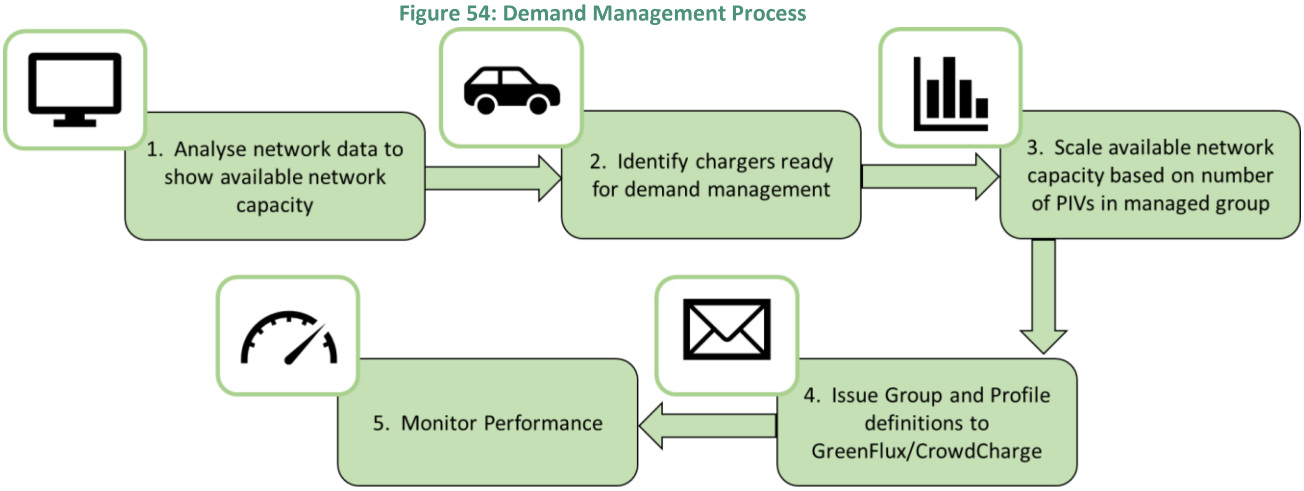
Table 12: Comparison of Battery Capacity Composition - UK Sales and Electric Nation

This shows that the Electric Nation cohort is made up of a greater proportion of vehicles with larger batteries (as well as full battery vehicles as shown above) than recent UK sales. *However, this is likely to be representative of the future scenarios as the cost of larger batteries decrease.*

7.3 Demand Management Process Update

From July 2017 onwards, participants are being moved into demand management through a series of group expansions, following the process illustrated below.

Figure 54: Demand Management Process



Further details of each of these stages were given in the October 2017 trial update report[19]. This text is reproduced in Appendix 5 of this report, with the bullets below summarising developments in the period between the end of April 2018 and the time of writing.

- **Analysis of network data to show available network capacity:** profiles of available capacity for EV charging were developed for use in the project. These are based on real network loading data for an HV feeder in the East Midlands, with profiles set to be equivalent to the level of curtailment that would be required when 30% of passenger cars are plug-in vehicles. A spring profile was implemented in early April. However, monitoring of this profile showed that no management was occurring. A decision was made to modify the profile to ensure some curtailment of charging continued. This would still be realistic for some networks in a scenario where 30% of vehicles are a plug-in variety (i.e. those with less spare capacity than the specific East Midlands example chosen), or on the specific network used but with higher PIV ownership levels. This also ensures that the project can continue to test the acceptability of smart charging solutions. The new profile matches the spring profile outside of the evening peak period but reverts to a modified winter profile in the peak. The modification is applied to increase the available capacity slightly compared to winter, therefore reducing the levels of management slightly. The resulting amounts of management are shown in Section 7.5 and Section 7.6.
- **Identify chargers ready for demand management:** the process set out in the October 2017 version of the report has continued to be followed. A further 57 participants are now in routine management. Further details of this are provided in Section 7.4 below.

[19] https://www.westernpower.co.uk/docs/Innovation/Current-projects/CarConnect/Electric-Nation-Customer-Research-and-Trial-Update.aspx Accessed 05/01/2018

- **Scale available network capacity based on number of PIVs in the managed group:** a scaling factor continues to be applied to account for communications reliability in the managed group. This is adjusted each time the group is expanded based on current performance.
- **Issue group and profile definitions to GreenFlux/CrowdCharge:** no change to the process.
- **Monitor Performance:** The level to which demand management has occurred, and the impact of this on participants is under review and this is discussed in more detail in Section 7.5.

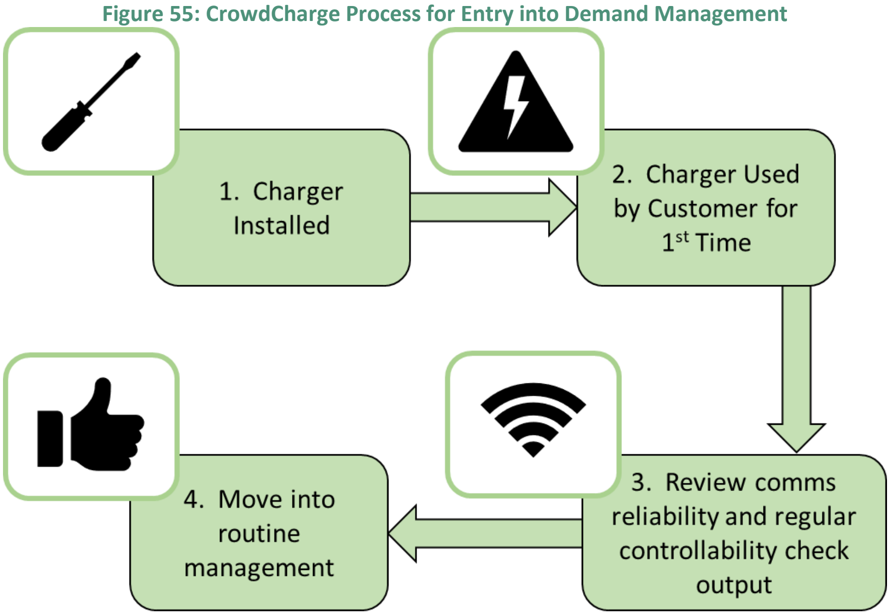
7.4 Progress with the roll-out of Demand Management to Participants

For participants to enter routine management they must pass a number of tests. At any of these stages it is possible for an issue to occur which could delay a charger entering management. This section outlines the detailed process by which chargers pass through these stages for both GreenFlux and CrowdCharge and the progress made to date with moving participants into routine management.

7.4.1 CrowdCharge

The diagram below shows the stages by which CrowdCharge participants enter demand management:

Figure 55: CrowdCharge Process for Entry into Demand Management



The number of chargers at each stage is shown in the following table. The 'route' to demand management is excluded, as this can only be accurately assigned once a customer has moved into routine management.

Stage	Number Passed Stage	Notes
1. Charger installed	325 (based on information until end w/c 25th June)	
2. Charger used by participant for 1st time	296 of 325 (last reviewed 10th July)	A transaction record is not currently available for the remaining 29 chargers. There are a variety of potential possible causes for this: • Communications reliability – if chargers are not communicating with all parts of the back office then no transaction records will be available. • Charger not yet in use – e.g. car not yet delivered.
3. Review communications reliability and controllability	244 of 296 'used' chargers	52 chargers have been used but cannot be transferred into routine management • 24 are only communicating with part of the CrowdCharge system or have configuration problems with one part of the system. This prevents a controllability check taking place. • 21 either have no communication to any part of the CrowdCharge system, or the reliability of this is poor. • 5 have improving reliability to all parts of the system and should move into routine management in the coming weeks. • 2 are communicating with all parts of the back-office system but haven't been used for a significant period of time. If this continues then the participant will be contacted to clarify the situation.
4. Move into routine management	244	244 chargers have moved into routine management (or will be during w/c 16th July), and this will continue to expand as other charge points moved through the preceding stages.

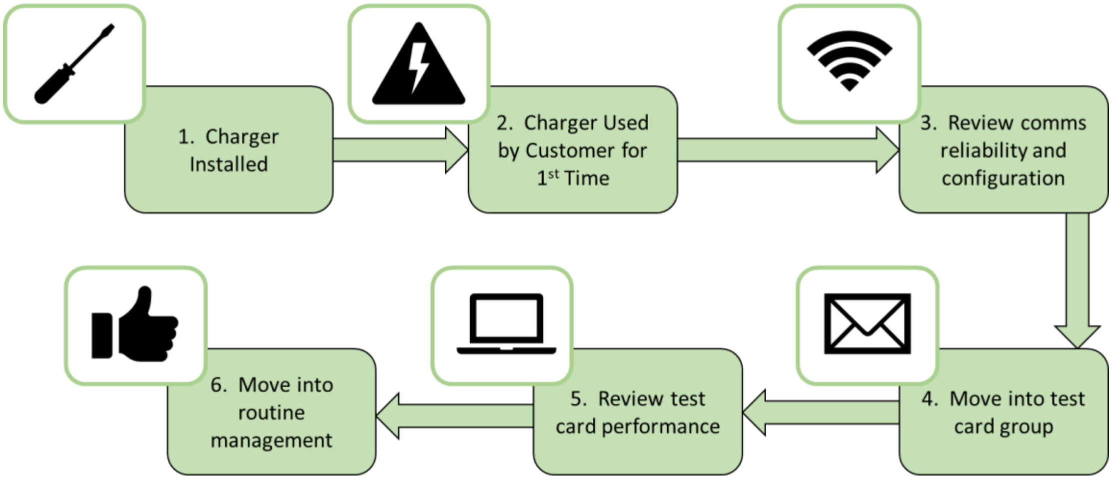
Table 13: Roll-Out of Demand Management to CrowdCharge Participants

Two forms of communications failures remain the dominant reason for delays entering routine management. This is either due to unreliable communications between the charger and all of the CrowdCharge system, or a specific configuration error which results in some chargers not communicating with part of the back office. Chargers which are not communicating with all parts of the system cannot be controlled and so cannot move into routine management. Chargers which are not communicating to all parts of the back-office system have been highlighted to CrowdCharge for this to be investigated and remedied. The Tech Factory (the systems integration specialists for the project) will continue to visit chargers with unreliable communications, with the aim to bring as many chargers are possible into routine management.

7.4.2 GreenFlux

The diagram below shows the stages by which GreenFlux participants enter demand management.

Figure 56: GreenFlux Process for Entry into Demand Management



The number of chargers at each stage is shown in the following table.

Stage	Number Passed Stage	Notes
1. Charger installed	342 (based on information until end w/c 25th June)	
2. Charger used by participant for 1st time	328 of 342 (last reviewed 10th July).	Of the 14 chargers without a transaction record, only two are online, suggesting that the main cause of the lack of transaction records is communications. Once communications are restored these records will be sent to the back office.
3. Review communications reliability and configuration	288 passed (of 328 which have been used)	288 chargers have passed a review of their communications performance and configuration. Of the remaining 40 chargers (i.e. those that have been used but are not yet ready for the test card phase): • 32 have not yet passed a check of their communications performance. • 6 have a variety of configuration problems which will be highlighted to GreenFlux • 1 charger has only recently been installed so further data is required before moving this participant to the test card phase. • 1 participant has left the project

<table>
<tr><td>4. Move into test card</td><td>285 into test card
(3 more to follow in w/c 16th July)</td><td>285 chargers have entered the test card phase since early July 2017. Three have passed the previous stage and will be transferred to the test card phase early in w/c 16th July.</td></tr>
<tr><td>5. Review test card performance</td><td>267 passed of 285 reviewed</td><td>The causes for failure or a delay at the test card phase are:
Charger offline (5 of 18): this prevents meter values being sent to the online portal, therefore the test card performance cannot be evaluated.
Delayed meter values from charger (5 of 18): delayed meter values indicate a communication problem whereby chargers can send information out but may not receive charging profiles from the back office. This can lead to problems with smart charging and so these participants are not transferred into routine management until these issues are resolved.
Lack of transactions in test card phase (2 of 18): successful transactions are required to pass this phase. These transactions must occur when communications are working. Where a participant uses their charger infrequently the test card phase may last longer.
Failure at test card phase due to BMW issue (2 of 18)
Unusual behaviour in test card phase (2 of 18): these cases are referred to GreenFlux and/or Alfen for investigation before customers move into routine management.
Prior use of a timer (1 of 18): earlier in the trial the GreenFlux algorithm required an adaptation to allow maximum current to be allocated to vehicles which have used a timer. Whilst this algorithm was in development some participants were removed from smart charging. The majority of these have now consented to return to the test card phase and have passed through to routine management. One customer remains.
Dropped out of the trial (1 of 18): this participant no longer owns an EV.</td></tr>
<tr><td>6. Move into routine management</td><td>267 chargers</td><td>267 chargers have moved into routine management (or will do early in w/c 16th July).

To date, 17 participants have either left the project or been removed from the smart charging group for various reasons:
10 due to an issue with vehicles which enter a hibernation state when paused, but do not restart</td></tr>
</table>

		when current is made available again. This group is dominated by participants with BMW 330es. This was investigated on the Electric Nation test rig. A combination of settings was found which resolved all the issue in all the tests carried out. However, when deployed on vehicles in the field it was not successful in all transactions, so these participants have been removed from the trial. • 6 where unreliable communications have resulted in chargers being repeatedly 'stuck' at 13A and this is insufficient for the customer. • 1 participant has left the project

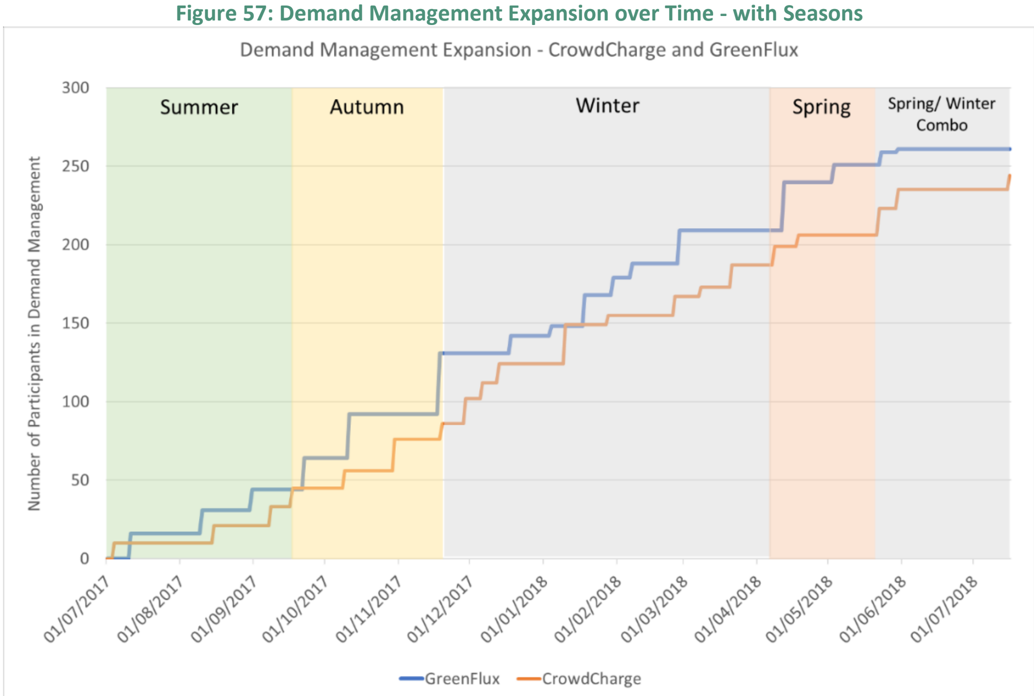
Table 14: Roll-Out of Demand Management to GreenFlux Participants

As summarised in the table above the main reason preventing chargers moving through all stages of the demand management initialisation process is a lack of reliable communications. A total of 54 chargers are delayed at various stages due to a communications problem. Alfen (charger manufacturer for chargers managed by GreenFlux) have engaged Siemens to carry out site visits to these units to ensure they are updated to the latest firmware version and brought online if possible.

7.5 Results of Demand Management to Date

The first 'routinely managed' groups were established in July, and these have been expanded multiple times over the last year. These group expansions are shown by the steps on the graph below.

Figure 57: Demand Management Expansion over Time - with Seasons



As described above a new 'demand limit' is provided to CrowdCharge/GreenFlux each time the routinely managed group expands. The profile will also be adjusted throughout the year to reflect varying levels of 'spare' network capacity across seasons. Summer profiles were used until mid-September, before all participants were transferred into autumn from mid-September, and winter from mid-November. A spring profile was applied in mid-April. As described above (see Section 7.3) the spring profile resulted in no curtailment being required between April and mid-May. A combined spring/winter profile was applied from mid-May onwards which ensures some management is still required, as shown in the sections below.

7.5.1 Occurrence of Demand Management at a Group Level

The level of demand management which occurs is a function of the demand limit profile and the charging diversity of the managed group. As increasing numbers of participants in the group plug-in at the same time then it becomes more likely that demand management will occur. Management (curtailment of available current from chargers) also becomes increasingly likely as the seasons change through the year, as the 'spare' network capacity available for EV charging decreases due to increases in other loads. The current allocated to a group of chargers can be compared to the limit which applies to the group to show whether management (curtailment) was active **at a group level.** The effect of this curtailment on individual chargers requires a secondary level of analysis and this is presented below and in Appendix 6. This sub-section shows the level of management which has occurred for CrowdCharge and GreenFlux since a combined winter/spring profile was enacted in mid-May.

7.5.2 CrowdCharge Group Level Management

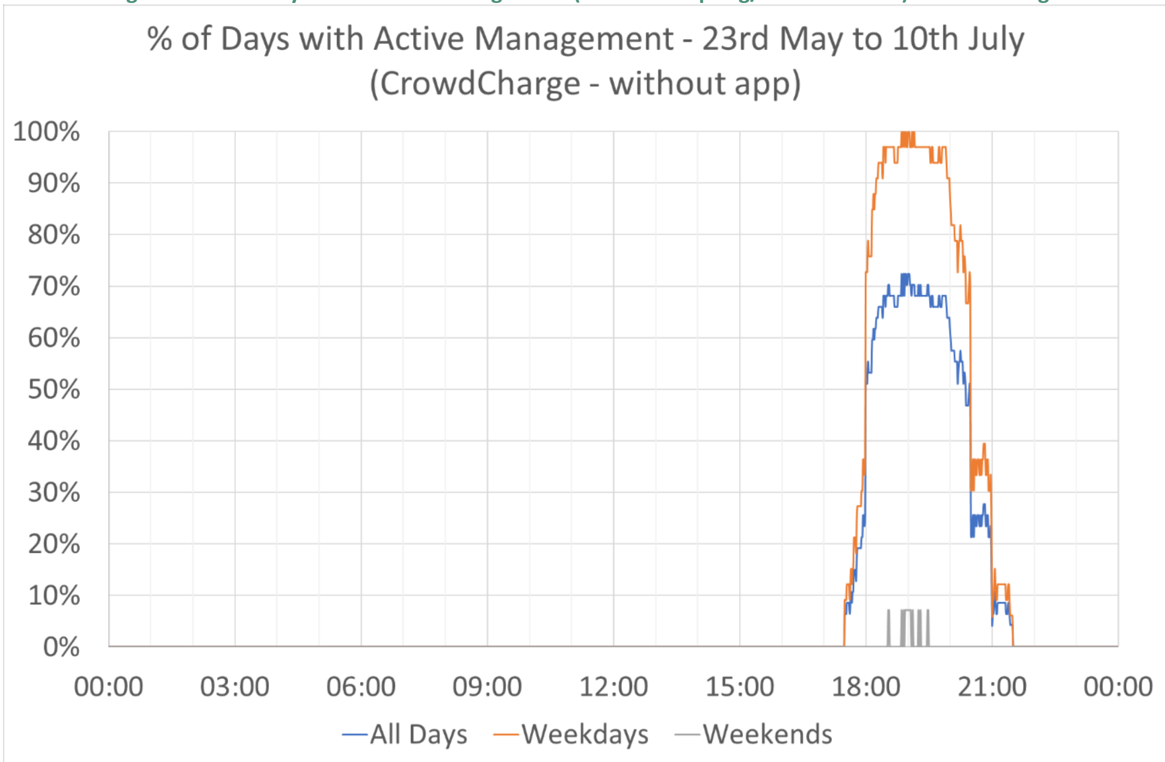
CrowdCharge begins to curtail the current available from active chargers when there is insufficient capacity available to allocate all active stations at 32A. For example, if the group limit is 300A then no management occurs with nine active chargers, but curtailment will apply once a 10th charger becomes active.

The previous report[20] showed the level of management which occurred at a group level over the winter period (20th November 2017 to 6th April 2018). A spring profile was enacted on 8th April and ran until 23rd May, during which time no curtailment was required. As described above a 'combined' spring/winter profile was developed to ensure that management continued to occur. This follows the spring profile outside of the evening peak but then decreases the available capacity to close to winter levels during the peak. This sub-section sets out the group level management which has occurred between 23rd May and 10th July 2018, on this 'combined' profile.

[20] Customer Research and Trial Update Report. April 2018. Available from: https://www.westernpower.co.uk/docs/Innovation/Current-projects/CarConnect/Electric-Nation-Customer-Research-and-Trial-Up-(1).aspx Accessed July 2018

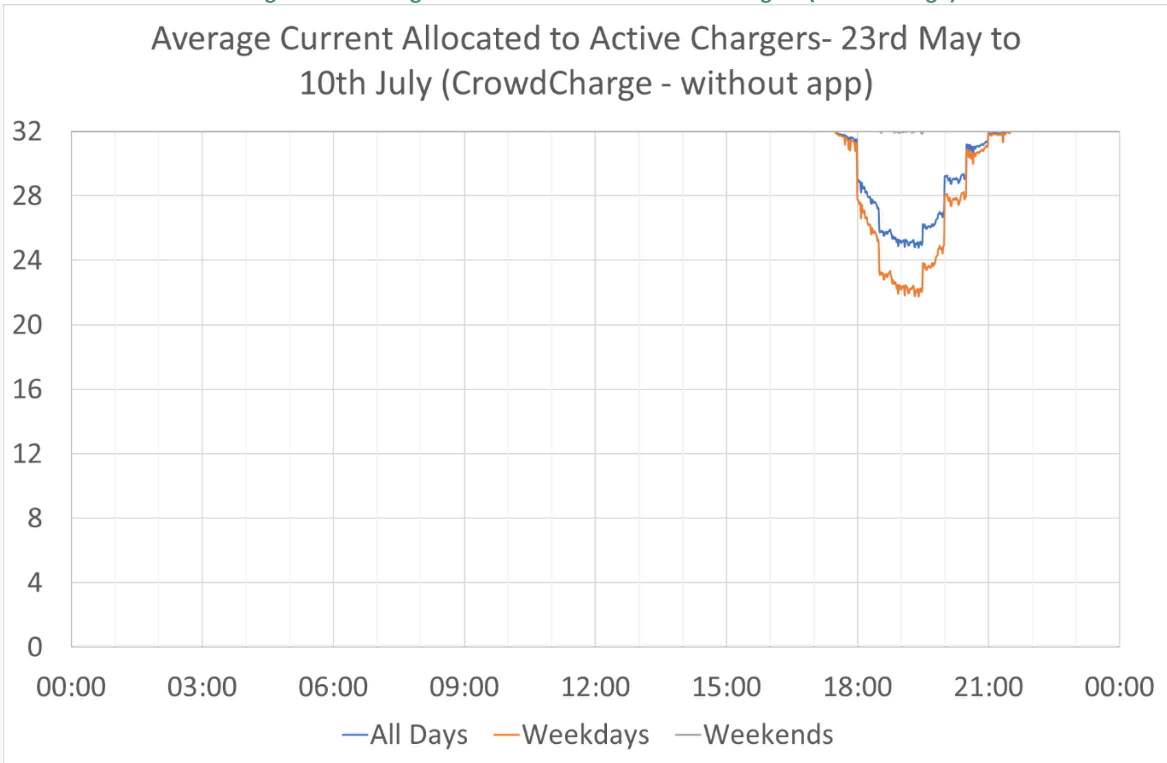
Figure 58, below, shows the number of days with active management for CrowdCharge against the time of day (x axis).

Figure 58: % of Days with Active Management (Combined Spring/Winter Profile) - CrowdCharge



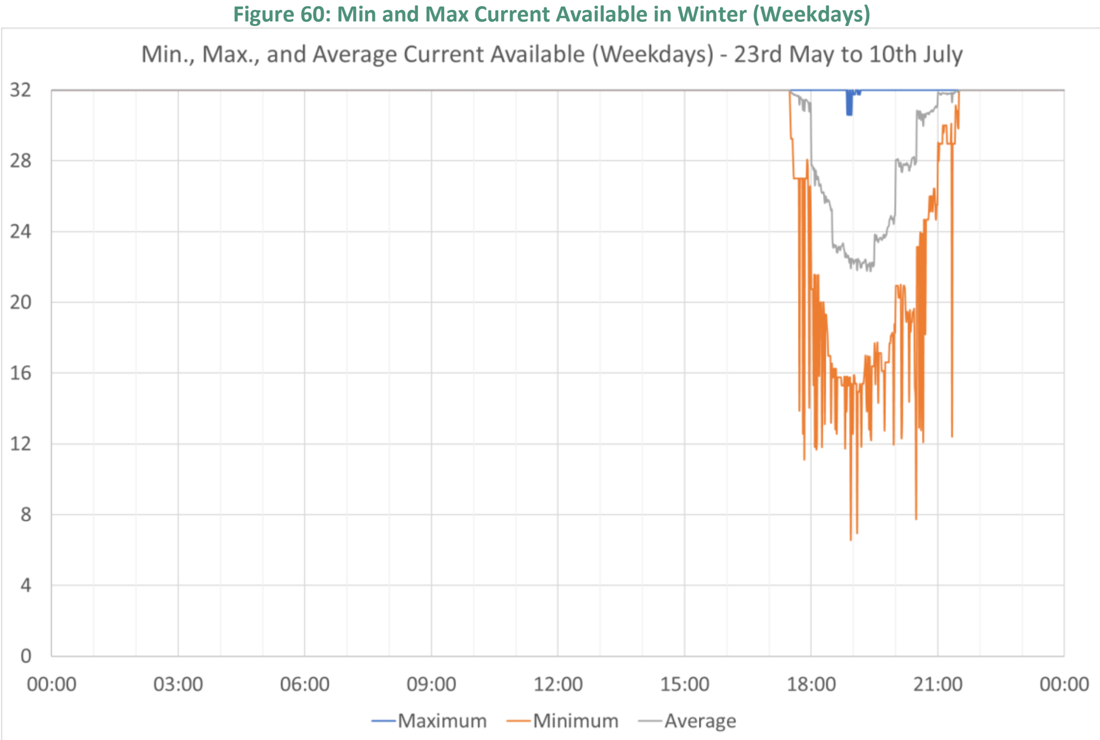
As expected this shows that management has only been required over the evening peak period. Management is unlikely to occur at weekends. The duration of management events, and the likelihood of management at weekends has reduced compared to the winter profiles shown in the April 2018 report. The level of curtailment required is shown below, both as an average value and minimum and maximum current available.

Figure 59: Average Current Allocated to Active Chargers (CrowdCharge)



The minimum average current available is 21A on weekdays at 19:24. This is higher than in winter, where the minimum average available was approximately 18A. The minimum, average and maximum values for weekdays is shown below. Weekends have been excluded due to the minimal amount of management which has occurred.

Figure 60: Min and Max Current Available in Winter (Weekdays)

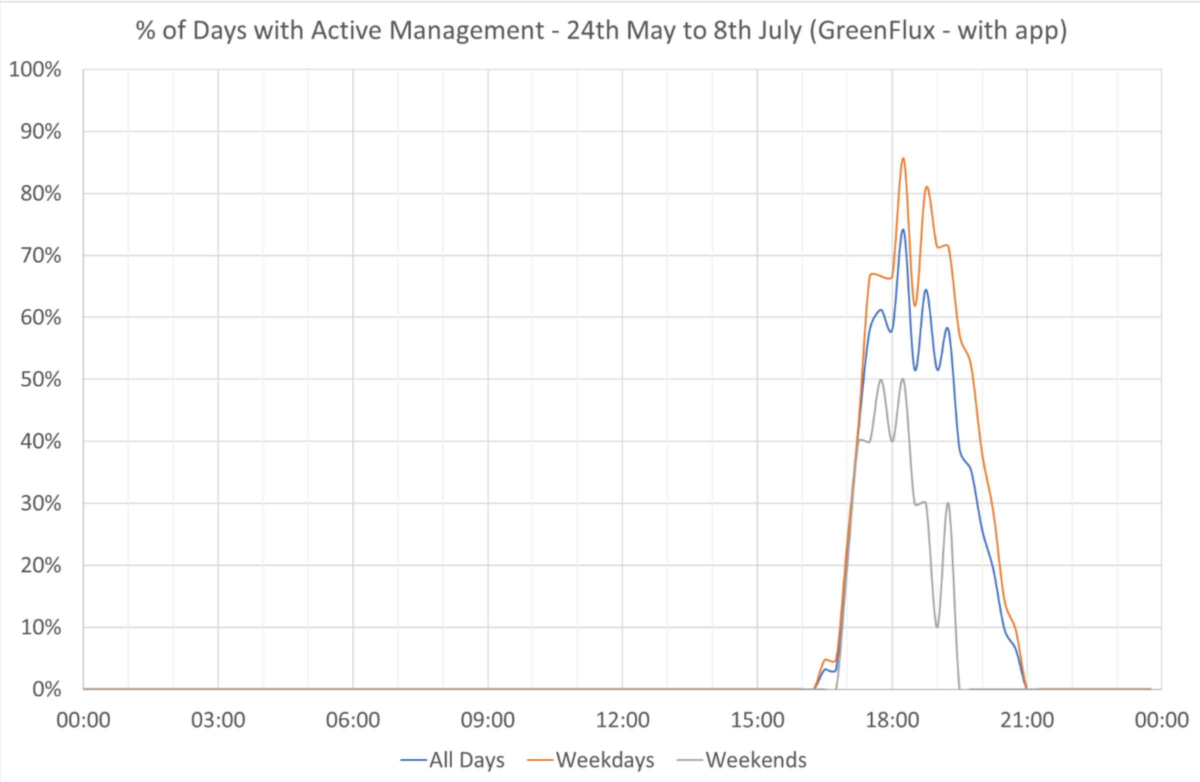


This shows that on 'average' days owners of plug-in hybrid vehicles (and BEVs rated at 16A) would not have been affected by demand management. The impact of these group level events on individual transactions is explored in more detail in Section 7.6.1.

7.5.3 GreenFlux Group Level Management

The graph below shows the % of days when group level management has occurred for the GreenFlux cohort, again split by all days, weekdays and weekends. In this case, during the period shown below the vast majority of participants had access to the app and so results are presented for the 'with app' group.

Figure 61: % of Days with Active Management (GreenFlux)



The timing of management events are similar to the CrowdCharge cohort – only occurring in the evening peak period. Weekend events are more common in the GreenFlux group than for CrowdCharge, but are still shorter and less frequent than during the working week. Management occurs less frequently in the GreenFlux group (maximum of 85% of weekdays, as opposed to 100% for CrowdCharge), probably because of a more efficient distribution of available current amongst active chargers. This is due to a distinction being made between 32A and 16A vehicles at the start of each charge cycle.

7.6 Occurrence of Demand Management for Individual Charging Events

The graphs above indicate the periods when a group of chargers was subject to some curtailment. However, it is easy to imagine scenarios where this management event did not actually impact the charging of an individual car, for example:

- During the most restrictive part of the event all chargers in a group were limited to 20A. However, a PHEV was charging at a nominal rate of 16A.
- The restriction began at 17:30 and was over by 20:30. A vehicle was plugged in at 17:00 but was using a timer so did not charge until 23:30.

Further logic is therefore required to identify whether any individual charger was affected by a group level management event. Appendix 6 describes this logic in detail for both CrowdCharge and GreenFlux. Preliminary results of this analysis are presented for CrowdCharge and GreenFlux in the sub-sections below.

7.6.1 CrowdCharge – Management of Individual Chargers

The logic used to identify management of individual transactions is set out in detail in Appendix 6. This has been applied to the winter (20th November to 6th April) and 'combined spring' profile (23rd May to 26th June) period. This covers the following number of transactions:

- Winter Profile (20th November to 6th April, excluding 20th December to 10th January): 8,695 transactions from 179 different chargers which were part of the managed group during this period. A total of 1,919 (22%) of these transactions experienced some constraint, involving 147 different chargers.
- Spring Combo Profile (23rd May to 26th June): 3,644 transactions from 201 different chargers which were part of the managed group. A total of 402 (11%) of these transactions experienced some constraint, involving 102 different chargers.

Using the current analysis technique transactions are marked as either 'managed' (i.e. the charging rate was reduced for any part of the active charging cycle) or 'unmanaged'. Further developments to the analysis approach will review the relative degree of restriction and this will be included in future reports.

Proportion of Charge Events Managed

Whether an individual transaction is managed is a function of the profile in place at the time (varies by season and weekday/weekend) and the number of other vehicles charging at the same time. This can be seen in graphs such as Figure 58, where a transaction which occurred during the middle of the day would not be managed, whereas charging in the evening peak may be.

The graphs below show the % of transactions on each day which were managed, for the 'winter' and 'combined spring/winter' profiles.

Over the Christmas period an unrestricted profile was used to limit the potential for customer support requests to the project. In reality, demand management may be required over the Christmas and New Year period, further analysis will be undertaken to evaluate whether this period is more like a string of weekend days or has a character of its own.

Figure 62: % of Transactions Managed on Each Day (Winter Profile)

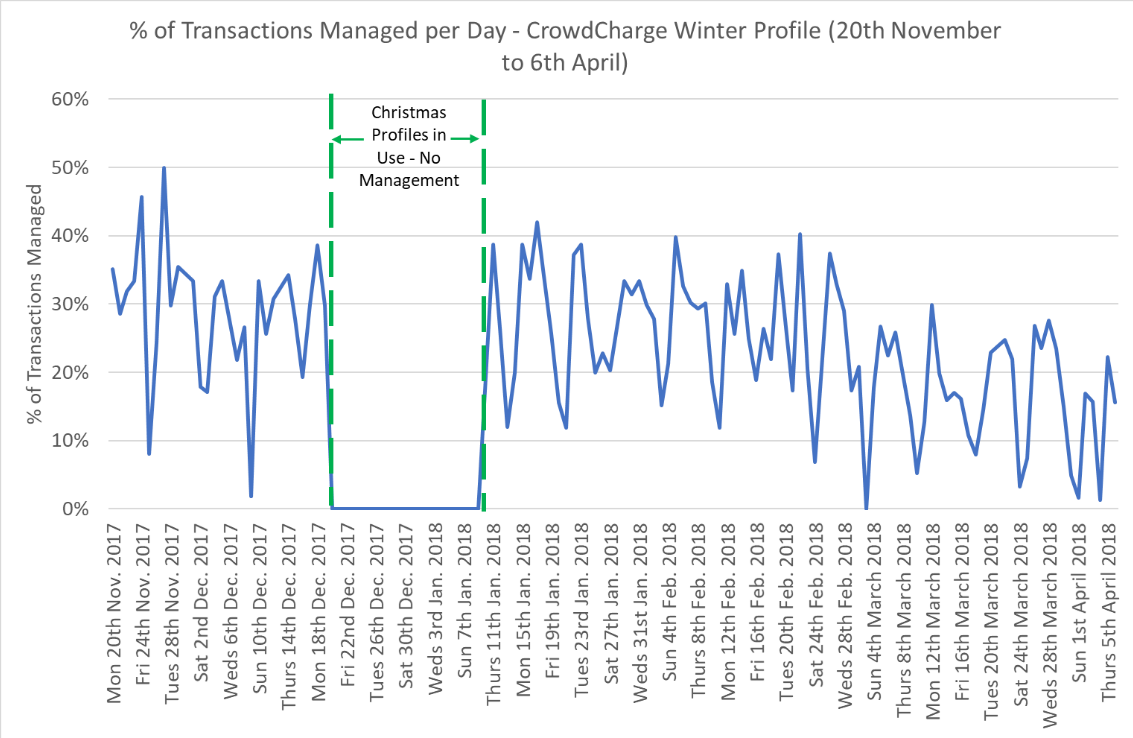
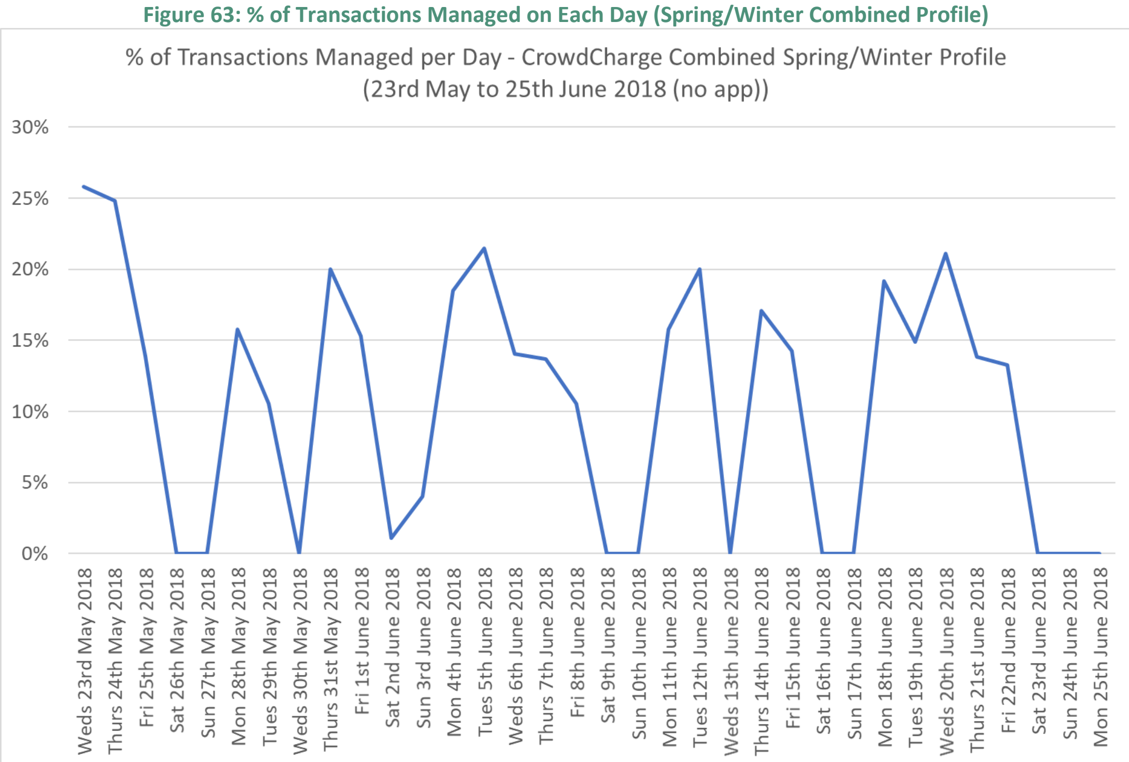


Figure 63: % of Transactions Managed on Each Day (Spring/Winter Combined Profile)



Management occurred regularly on both profiles, although always for less than 50% of transactions. It should be noted that the situation above replicates the management that would be required for a representative network in the East Midlands to remain within capacity limits when 30% of vehicles are PIVs (mix of PHEV and BEV). In this scenario the majority of transactions can occur without curtailment. The proportion of transactions being managed declines towards the end of the winter profile, potentially as the energy requirements of vehicles reduced as temperatures began to increase. Management occurs for a lower proportion of transactions whilst the spring/winter combined profile has been in place, compared to winter. For the combined spring/winter profile very little management occurs at weekends, which aligns with the weekend pattern shown at group level in Figure 58. The average % of transactions which are curtailed is summarised in the table below.

Profile	Weekday/Weekend	Average % of Transactions Managed
Winter	Weekday	28%
	Weekend	14%
Spring/Winter Combined	Weekday	15%
	Weekend	1%

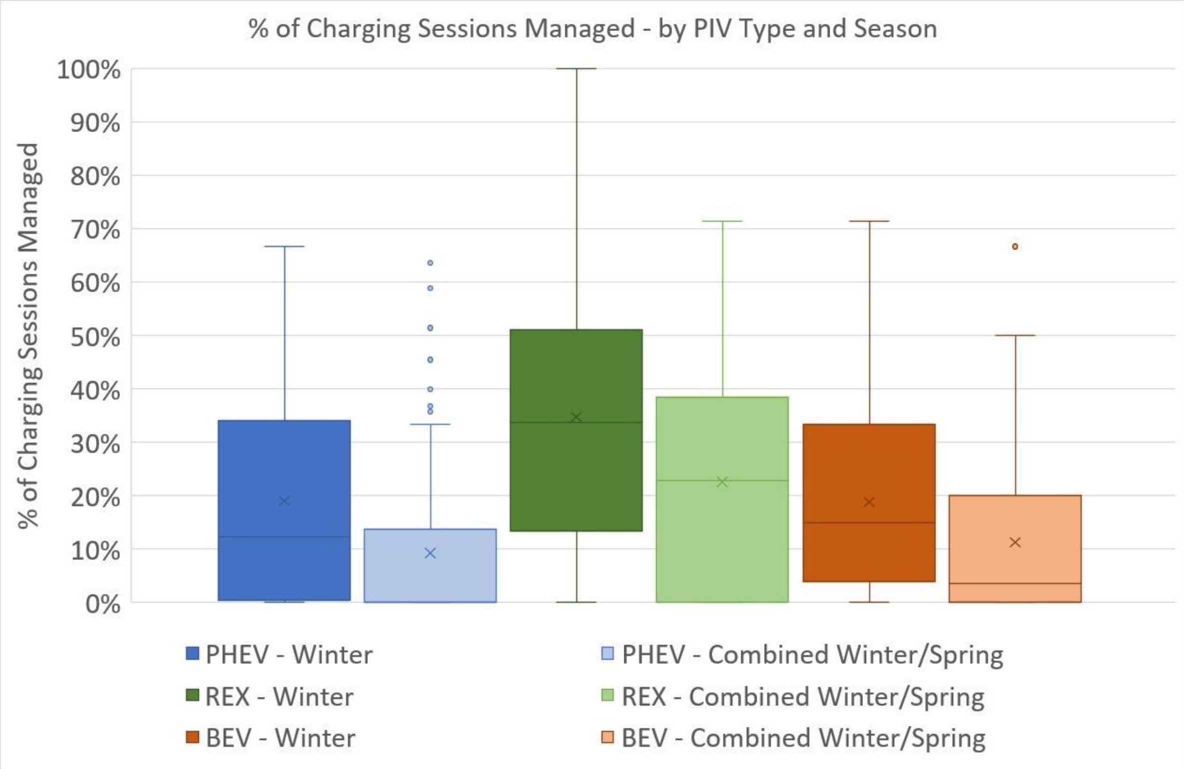
Table 15: Average % of Transactions Managed by Profile and Day of Week

Participants' Experience of Management

The section above explores the proportion of transactions at a population level which have been managed. Through the trial, customer acceptability of smart charging will be judged by each individual participant based on their own experiences, such as whether their own charging is management, whether they notice this occurring, and whether it results in any inconvenience. The aim of the analysis below is to show the amount of management individual participants have experienced. This will be expanded in future reports to include the degree of management (e.g. restriction which delays the end of charging by five minutes is less restrictive than a thirty-minute delay). This is based on both the winter and combined spring/winter profile periods, for customers without access to the app.

The box and whisker plot below shows the effect of both the change in season, and the vehicle type, by showing the spread of % of charging events which were managed across the three different PIV types, for the winter and combined winter/spring periods.

Figure 64: % of Transactions Managed for CrowdCharge Participants by PIV Type and Profile



The median of the groups in each scenario is shown below for clarity.

PIV Type	Profile	Median % of Transactions Managed
PHEV	Winter	12%
	Combined Winter/Spring	0%
REX	Winter	34%
	Combined Winter/Spring	23%
BEV	Winter	15%
	Combined Winter/Spring	4%

Table 16: Median % of Transactions Managed (CrowdCharge, by PIV Type and Season)

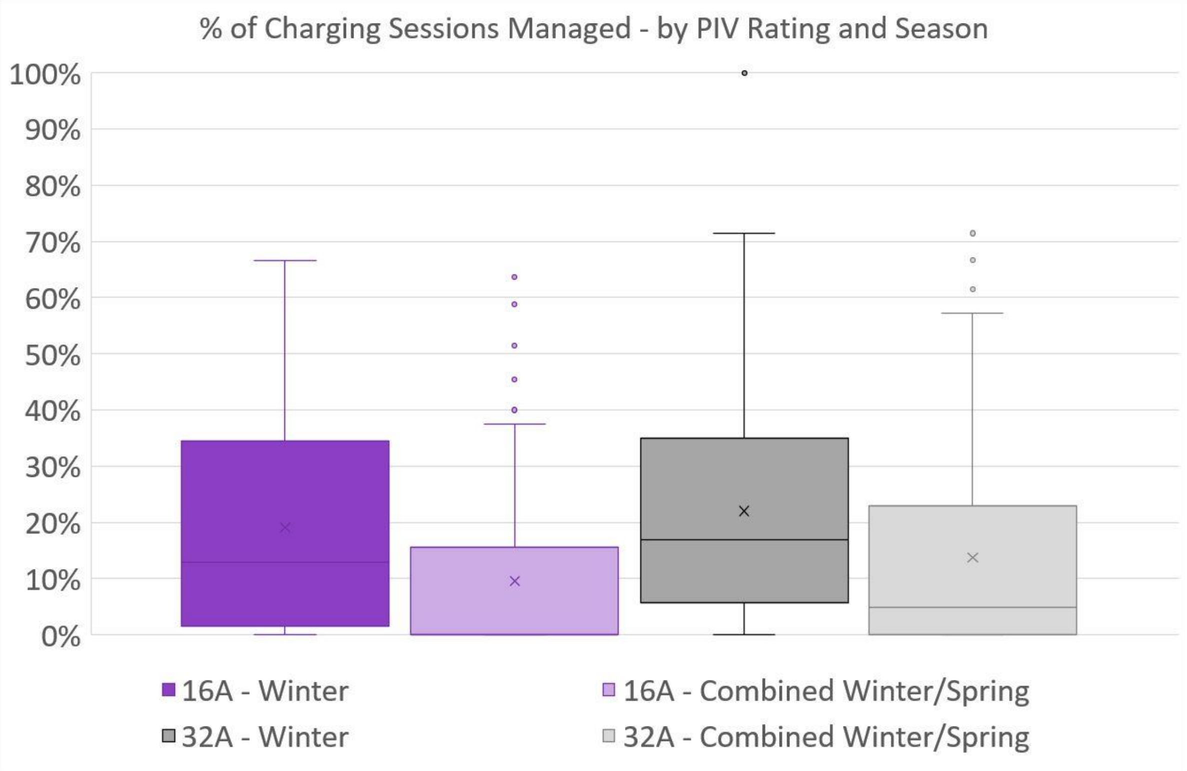
This shows a decrease in the % of transactions which are being managed between the two seasons for all PIV types. This is to be expected as slightly more capacity is available in the combined winter/spring profile than winter. The lowest proportions of transactions are managed for PHEVs in both seasons. This is likely to be linked to the nominal rating of the vehicles involved in the groups. Vehicles can either be nominally rated at 16A, or 32A. In a management event where the allocation is reduced, but not below 16A, then vehicles which are rated at 32A will be curtailed, whereas 16A vehicles will not. The composition of the vehicle ratings in each of the three PIV type groups are shown below:

- PHEV: 95% 16A and 5% 32A.
- REX: 100% 32A (all BMW i3 REX vehicles)

- BEV: 18% 16A and 82% 32A.

The box and whisker diagram below shows the same data, but split by PIV rating and season.

Figure 65: % of Transactions Managed for CrowdCharge Participants by Nominal Vehicle Rating and Profile

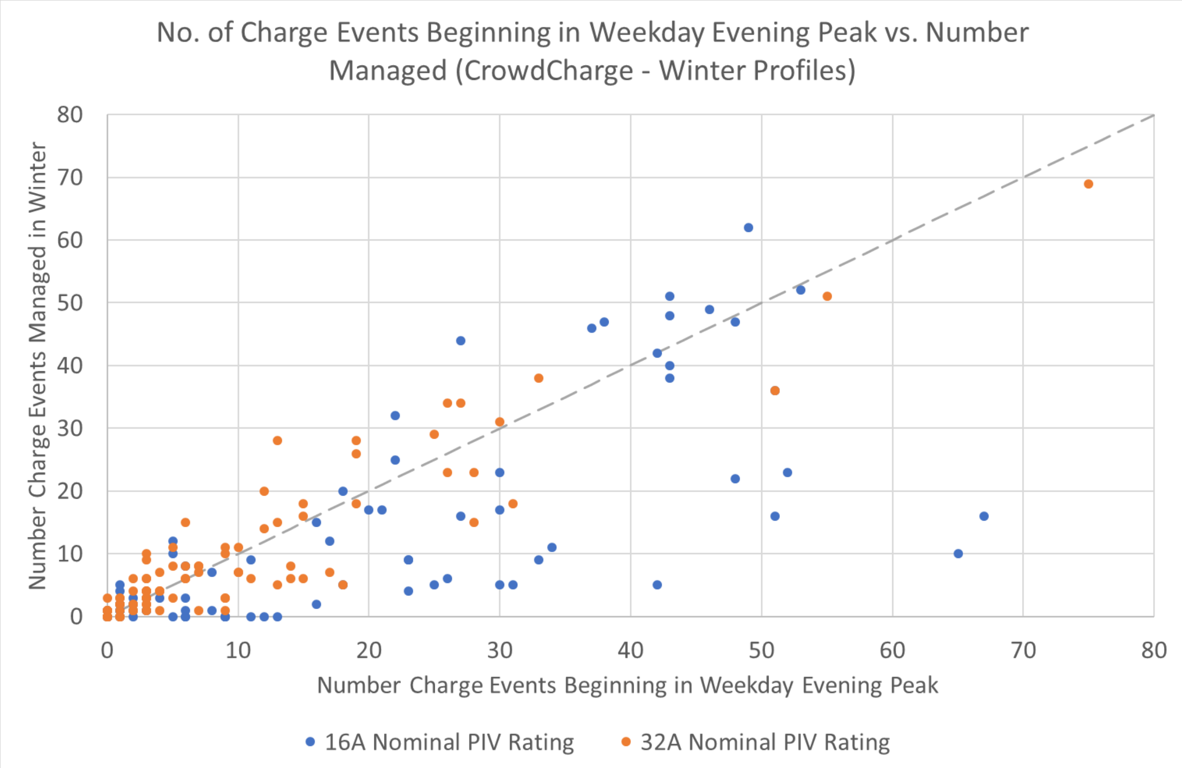


This shows a larger proportion of transactions are managed for 32A vehicles than 16A. This is to be expected, as the vast majority of management events will affect all nominally 32A vehicles, whereas only a proportion will be restrictive enough to impact upon 16A vehicles. In winter the difference between the two vehicle ratings is lower, with the 'most managed' 25% of participants both experiencing management on more than 35% of their charging events. The difference is more pronounced on the combined winter/spring profile, where a smaller proportion of management events involve curtailment of the current available to below 16A. This can be shown by the group level restriction information in Figure 60. For both ratings, a lower proportion of transactions are being managed on the combined winter/spring profiles.

The other factor which will strongly influence the proportion of a participant's charging events which are managed is the timing of these events. A participant who only charges on weekdays, and always begins charging when they get home from work at 6p.m. would experience much more management than another participant who uses a timer for all their transactions to take advantage of a time of use tariff, so begins charging at midnight.

For each participant, the number of their charge events which began in the weekday evening peak has been calculated (16:00 – 19:59, using only those events where the time when charging began is known). This has been used in preference to use of timers, as it will include both the effect of timers, and charge events which begin immediately, but outside of the evening peak. This is shown in the graph below, compared against the number of their transactions which have been managed, split by PIV rating. Each dot is representative of a single participant and the grey dashed line is included to indicate a 1:1 relationship (i.e. the position of a marker on this line indicates that their number of charge events beginning in the evening peak is equal to the number which were managed).

Figure 66: % of Charge Events Starting in Peak Time vs. % Managed



There is considerable scatter in the graph above, with participants who begin charging in the evening peak the same number of times experiencing considerably different numbers of managed events – e.g. the three participants with 16A vehicles who each began charging in the evening peak 30 times during winter.

Points above the dashed line represent participants who were managed for a greater number of charge events than just those which began in the evening peak, there are various potential reasons for this:

- Their charge events began outside of the evening peak (e.g. 15:30, or 20:15) but the vehicle was still involved in a management event (i.e. still charging when it began, or the event lasted beyond the end of the evening peak).
- Some of their charge events which occurred at the weekend were also managed. The data above represents the period when winter profiles were active, during which time management also occurred during the weekend.

Points below the dashed line relate to participants who were managed fewer times than the number of times their charge events began in the evening peak. Potential explanations for this include:

- Management events where the level of curtailment was not sufficient to impact the charge event – e.g. a management event where the lowest current available was 20A, but the vehicle was rated at 16A. This is shown in the data – 82 participants are 'below the line' (i.e. fewer charge events were managed than began in the weekday evening peak), 61% of these had a 16A nominal rating. This can be compared to the 63 participants 'above the line', where only 31% had a 16A vehicle.
- Charge events were very short and although they may have begun in the evening peak, they had finished before the management event began.

Further analysis will be undertaken to understand the factors affecting the number of times an individual participant has been managed.

The figures above are based on a provisional analysis of whether transactions are managed as a yes/no value. It will also be expanded to quantify the extent of management. This is likely to show further trends – e.g. even where a 16A vehicle has been curtailed, the degree of restriction will be lower than for a 32A vehicle.

7.6.2 GreenFlux – Management of Individual Chargers

Preliminary logic which can be used to identify management of individual transactions is set out in detail in Appendix 6. This is still under development at the time of writing, with further records to be added to, and processed by, the database. This section of the report provides an indication of the amount of management experienced in the winter period only (20th November to 6th April).

During this period (including the Christmas break, as shown below) 14,448 transactions where more than 0.5kWh of energy was consumed took place for chargers in the managed group. A management flag (yes/no) can currently be calculated for 7,514 of these. The figures below are based on these 7,514 transactions only (i.e. where it is currently possible to determine whether the transaction was managed). Further development will be undertaken on the project database to ensure a management flag can be calculated for all transactions and this will be included in subsequent reports, alongside the incidence of management in other seasons. The 7,514 transactions involved 197 different participants. 6,832 transactions took place outside of the Christmas break, so could have been managed. Of these, 1,795 were managed (26%), from 159 different participants.

Using the current analysis technique transactions are marked as either 'managed' (i.e. the charging rate was reduced for any part of the active charging cycle) or 'unmanaged'. Further developments to the analysis approach will review the relative degree of restriction and this will be included in future reports.

Proportion of Charge Events Managed

As above for CrowdCharge, whether an individual transaction is managed is a function of the profile in place at the time (varies by season and weekday/weekend) and the number of other vehicles charging at the same time. However, as GreenFlux differentiate the current allocations between vehicles which are nominally 16A and 32A and share restrictions equally there is no reason why a 16A vehicle would be managed less often than a 32A one with the same charging behaviour. The table below shows the average % of transactions which were managed, for weekdays and weekends during winter.

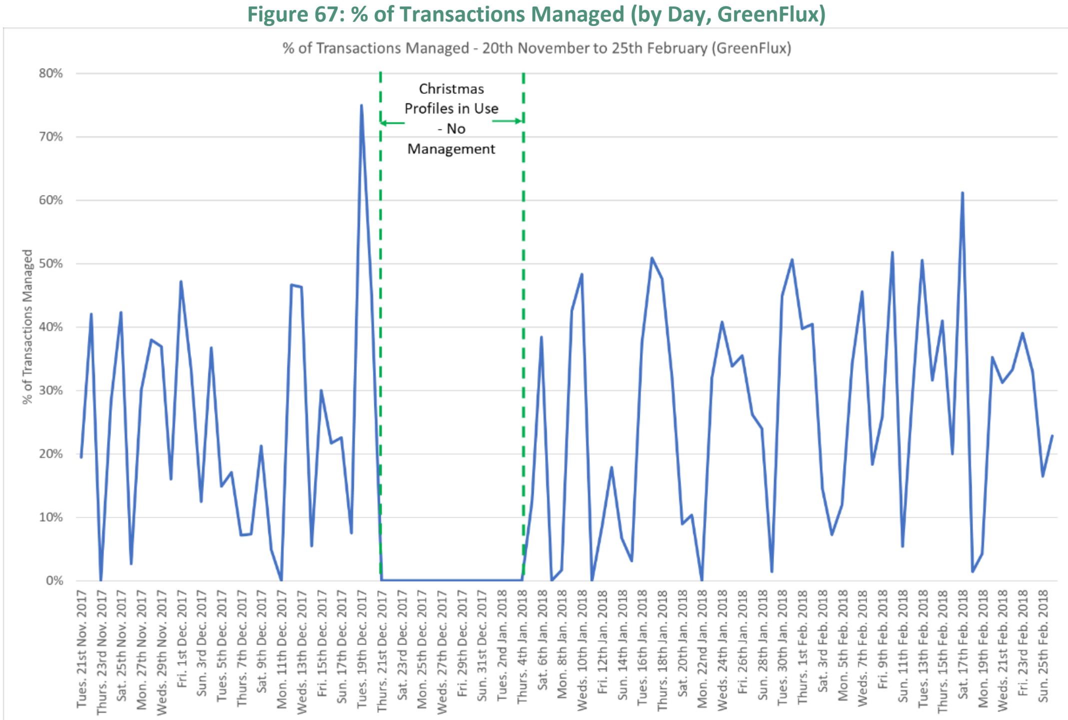
Profile	Weekday/Weekend	Average % of Transactions Managed
Winter	Weekday	32%
	Weekend	11%

Table 17: Average % of GreenFlux Transactions Managed (Winter, excluding Christmas)

In common with the CrowdCharge data above, management occurs less frequently at weekends – this is combination of a peak charging load (see charging behaviour in Section 6.2) and slightly more capacity being available due to lower levels of ‘non-EV’ load. The percentage of transactions managed is comparable between the two demand management providers (CrowdCharge in winter was an average of 28% and 14% for weekdays and weekends respectively).

The graphs below show the % of transactions on each day which were managed, for the period between the end of November and the end of February.

Figure 67: % of Transactions Managed (by Day, GreenFlux)



This shows variability between days, with a general trend towards less management at weekends, as shown in Table 17 above. Variations between weekdays will be caused by differences in the number of vehicles charging during the evening peak (where the current available is lowest) from day to day.

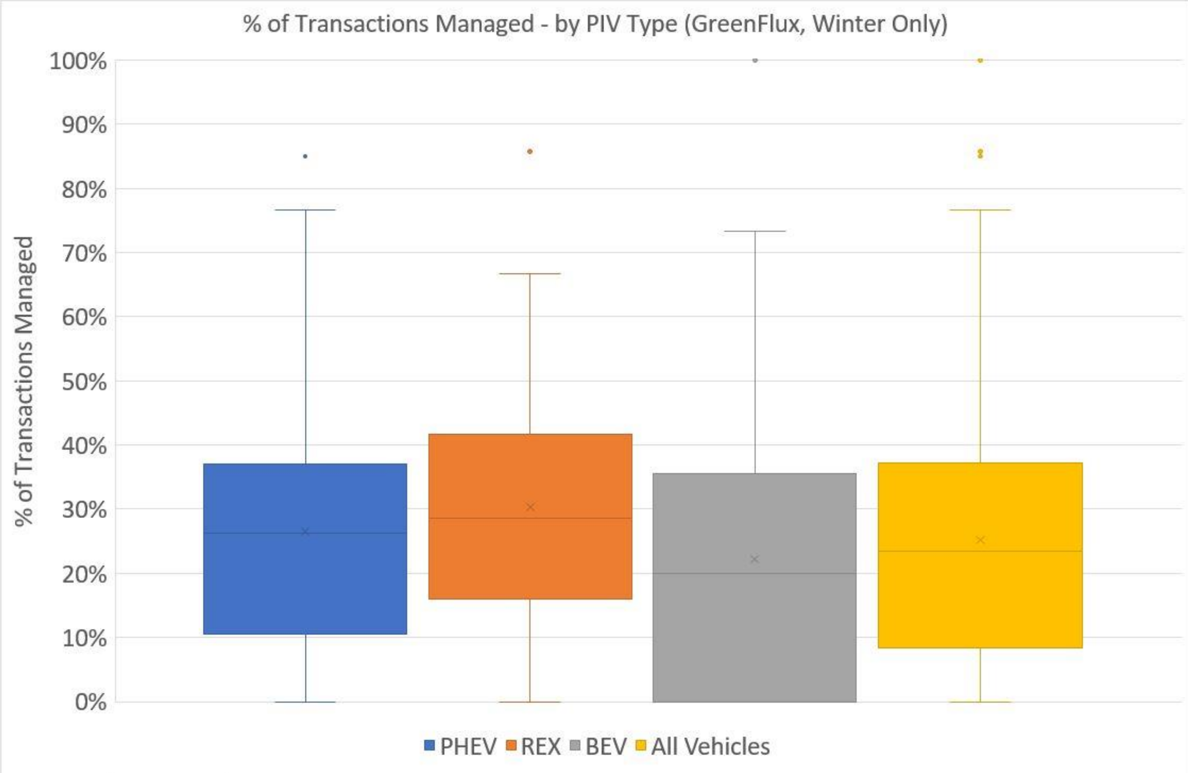
Participants' Experience of Management

As described for CrowdCharge above, individual participants will judge the acceptability of smart charging based on their own experiences. This sub-section therefore explores the factors which affected the percentage of transactions which were managed. The difference in the way CrowdCharge and GreenFlux share out available current during a management event (i.e. when the capacity available is insufficient to allow all vehicles to charge without restriction) will lead to differences in these factors between the two systems. The two main differences were as follows, based on the first algorithm iteration:

- GreenFlux restrict a proportion of active chargers (either with a reduced or zero allocation) in a series of discrete time windows, before changing the chargers which are restricted in the next time window. CrowdCharge allocate the same current to all active chargers, re-evaluating this restriction each time the limit or number of cars connected changes (e.g. if 300A is available and ten chargers are active, they each receive 30A).
- GreenFlux always detects the current required for each vehicle at the start of each transaction (16 or 32A). Once this evaluation has taken place a 16A vehicle is only ever allocated a maximum of 16A during the transaction. It is as likely to be restricted during the process described in the bullet point above. In contrast, if a demand management event for CrowdCharge involves the allocation per charger only being reduced to 20A (or any other value more than 16A) then 16A vehicles are unaffected – hence the difference observed in Figure 65, particularly for the combined winter/spring profile where restrictions are less harsh than winter.

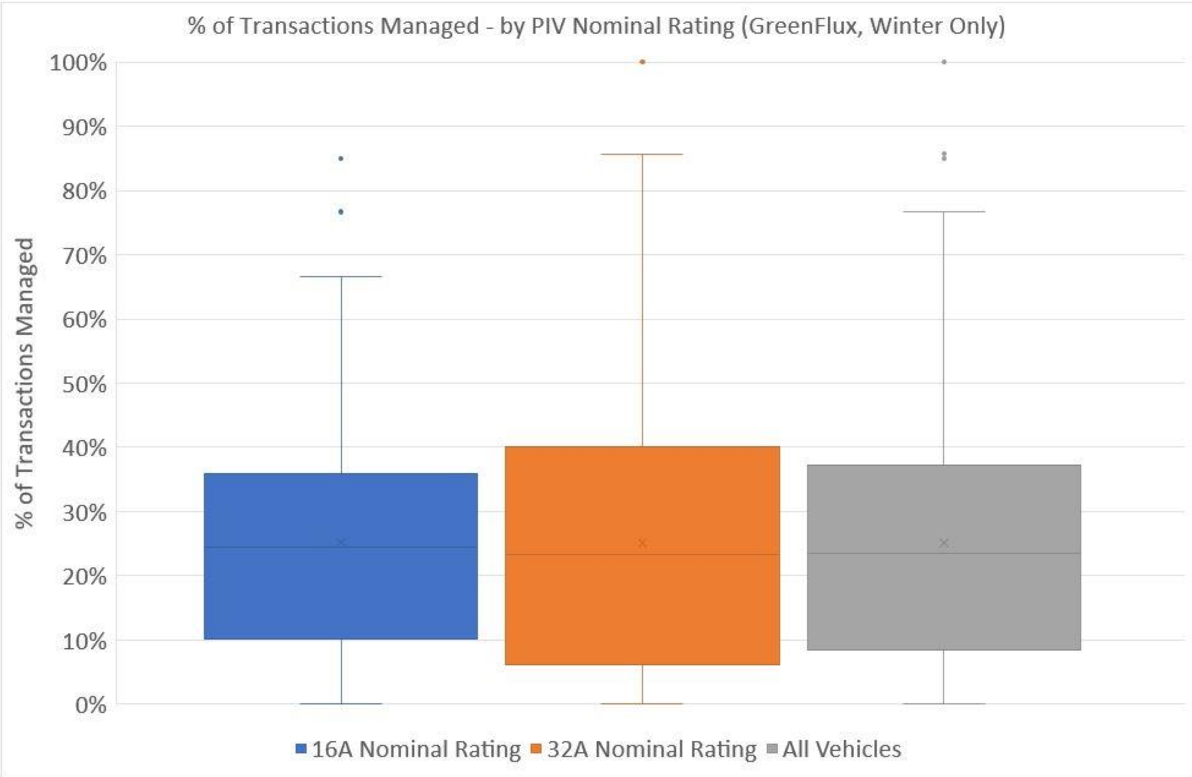
The graph below shows the distribution of number of % of transactions managed by PIV type, and for all vehicles.

Figure 68: % of Transactions Managed by PIV Type (GreenFlux, Winter)



The median values are 26%, 29%, 20% for PHEV, REX and BEV respectively. This shows less variation than the equivalent graph for CrowdCharge (see Figure 64), this is to be expected due to the differences between the two algorithms – a charge session for a 16A vehicle is as likely to be reduced or interrupted as a 32A vehicle in the GreenFlux system. This is confirmed in the graph below, which divides population by PIV rating.

Figure 69: % of Transactions Managed - by PIV Nominal Rating (GreenFlux, Winter)

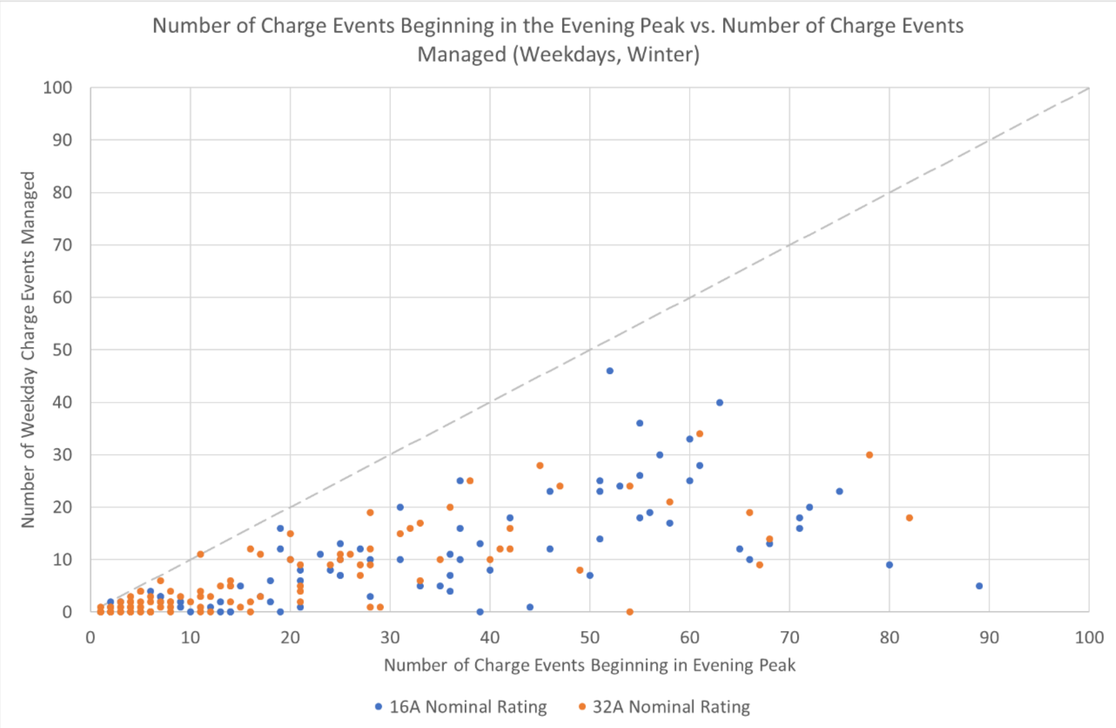


The median value is similar (24% and 23% for 16A and 32A respectively). There is a larger spread of data for participants with 32A vehicles and this will be explored in more detail in future reports.

The other key factor influencing whether a charging event is managed is the time of day in which it takes place, as management is much more likely to occur during the evening peak, particularly on weekdays (see Table 17). The data has been analysed to explore the trends between the time of day participants charge, and their experience of management.

The graph below shows the number of charging events which began in the weekday evening peak, plotted against the number of weekday charge events which were managed, for each participant. The grey dashed line is included to show where the two values are equal.

Figure 70: Number of Charge Events Beginning in the Evening Peak vs. Number of Charge Events Managed (GreenFlux, Weekdays Only, Winter)



This shows that in all cases, fewer transactions were managed than began in the evening peak. This is to be expected, as not all participants will experience a restriction during a management event. For example, in a scenario where ten 32A vehicles are charging (therefore requiring 320A), but the capacity limit is 288A then one charger will be paused in each time window to prevent the limit being breached – i.e. in each time window, each participant has a one in ten chance of being restricted. If the management event only lasts for four of the time windows, then not all of the vehicles which are charging will be paused, so some are unaffected by the group level management event.

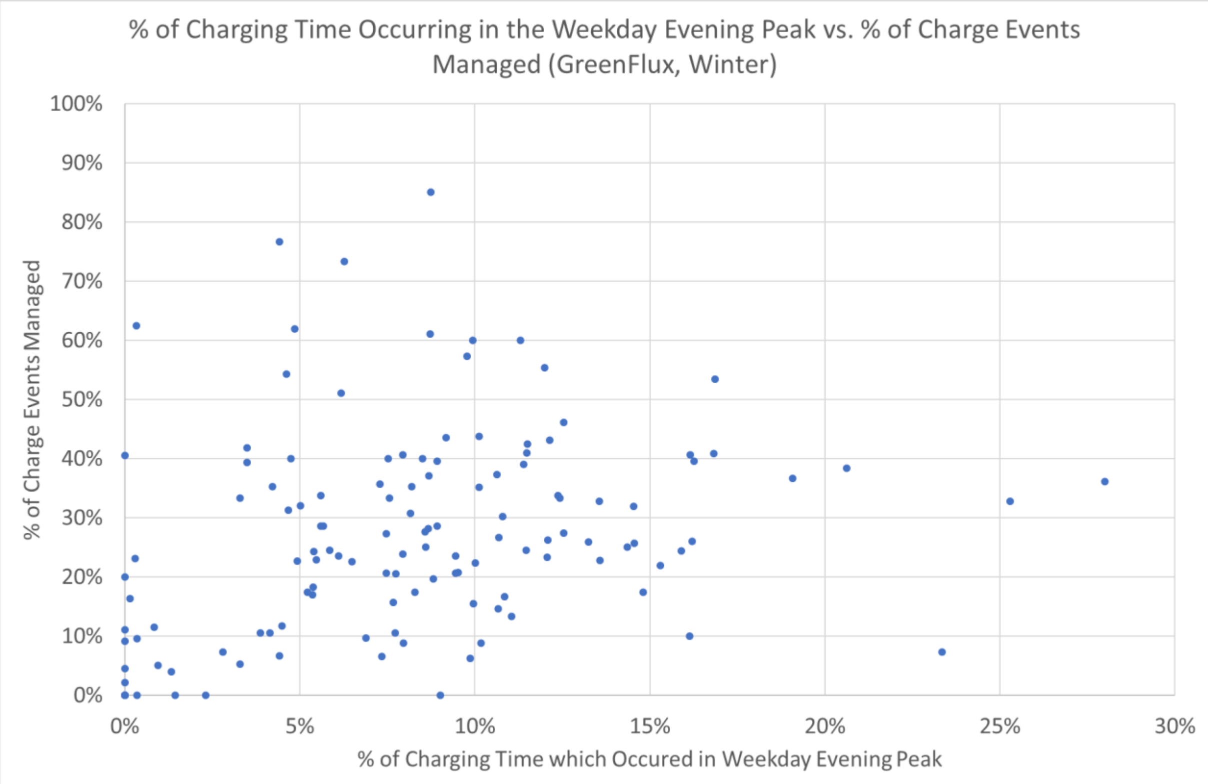
However, there is still considerable variation in this data – for example, there were 11 participants who were managed for ten of their weekday transactions during winter. The number of their charge events which began in the evening peak ranges from 20 to 107[21]. One potential reason for this variation is the amount of time which was spent charging in the evening peak. In the hypothetical example above, a charge event which was only active for one time window is less likely to be restricted than one which is active for a larger number of sessions. The analysis below attempts to correct for this affect. For each charge event the time spent charging has been estimated using either the vehicle's nominal rating, or the maximum allocation to the charger during the event (whichever is smallest). The duration of charging, and the start charge time has then been used to determine the amount of charging which took place during the weekday evening peak (16:00 to 20:00), for example:

[21] A small number of participants who charged greater than 100 times are excluded from the graph above for clarity.

- Start charge of 15:00, rating of 7kW, 21kWh consumed: vehicle charged for three hours (21kWh/7kW) and so finished at 18:00. It therefore charged for two hours during the evening peak.
- Start charge of 19:15, rating of 3.5kWh, 12.25kWh consumed: vehicle charged for three and a half hours (12.25kWh/3.5kWh) and so finished at 22:45. It charged for 45 minutes of the evening peak.

The total time spent charging by each participant during the weekday evening peak has been calculated and compared to the total time spent charging (during winter). The graph below shows this percentage plotted against the % of transactions which were managed (excluding participants with fewer than 10 weekday charge events).

Figure 71: % of Charging Time Occurring in the Weekday Evening Peak vs. % of Charge Events Managed (GreenFlux, Winter)



There is considerable variation in this data. For example, 11 participants did not do any of their charging during the weekday evening peak but have been managed for between 0 and 41% of their winter charging events. Possible explanations for this include the timing of their weekend charging, as this could be causing the management. The factors affecting this will be explored in more detail in future analysis. Introducing a measurement of the degree of restriction may also clarify this trend, as using the current method a charge event with a single, short pause would be treated equally to one with multiple pauses where the average charge rates are considerably different between the two examples.

8 Algorithm Iteration 2 Update

As shown above, the project team are in the process of moving all participants into routine demand management. This will continue during the next quarter as the later installations move into management, and where possible, long standing issues preventing the roll-out of management are resolved.

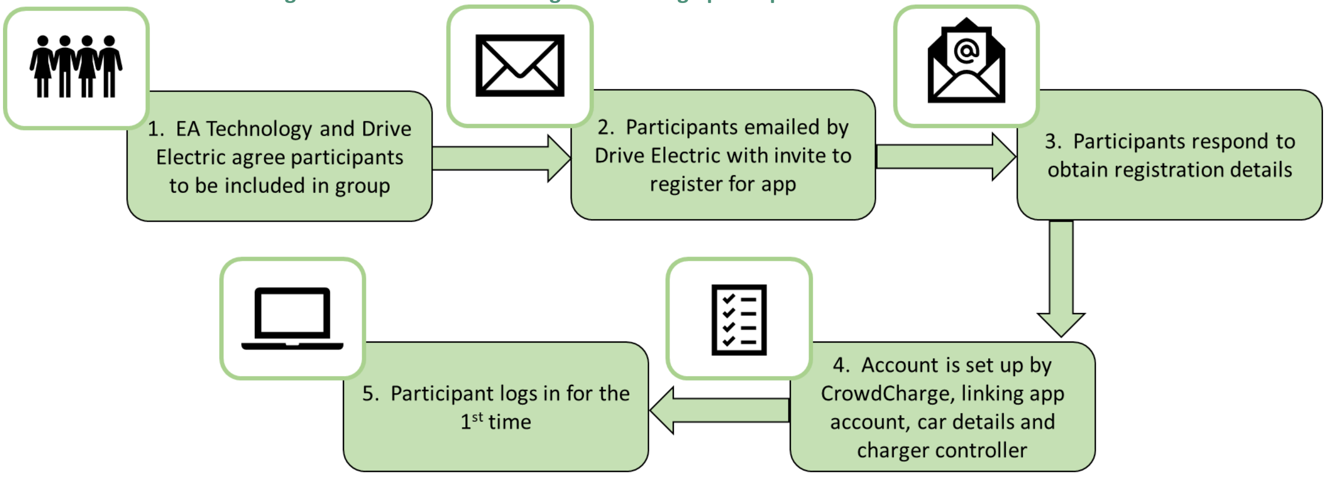
The 1st algorithm iteration from both smart charging providers did not provide a means by which participants could interact with the smart charging systems. From July 2017 participants were moved into 'trial 1' (algorithm iteration 1). Testing of this algorithm was reported in the Algorithm Development and Testing Report[22]. Relatively simple algorithms have been used by both CrowdCharge and GreenFlux to share the available current between active chargers. The majority of participants who have experienced this type of management have been surveyed to assess the customer acceptability of this type of system and results are reported in Section 5 of this report.

This section of this report briefly describes the 2nd algorithm iteration for each demand management provider and summarises progress with moving customers into the 2nd part of the trial, where app has been made available to trial participants. These apps enable customers to interact with the demand management systems (described below). Early insights are provided into the use of the app by GreenFlux participants.

8.1 CrowdCharge

The 2nd iteration of the CrowdCharge algorithm aims to estimate the energy requirements of vehicles to prioritise them when constraints become necessary. Final testing of this 2nd algorithm was completed in late May 2018. The process for enrolling each batch of customers into trial 2 is as follows:

Figure 72: Process for moving CrowdCharge participants into Trial 2



[22] Available from: https://www.westernpower.co.uk/docs/Innovation/Current-projects/CarConnect/CarConnect-Algorithm-Development-and-Testing.aspx Accessed April 2018.

All participants who are invited to register for the app (i.e. those identified in Step 1) are moved into a separate 'Trial 2' management group. Reminder emails will be sent to participants who do not respond at Step 2 to encourage them to register, however, these will be limited to understand the proportion of customers who do not wish to engage with such a system. Issuing many reminders could give a falsely high enrolment figure.

This process is being undertaken in batches. The table below summarises the current position, and the plan for the final batches.

<table>
<tr><th></th><th>Batch 1</th><th>Batch 2</th><th>Batch 3</th><th>Batch 4</th><th>Batch 5</th><th>Batch 6</th><th>Batch 7</th></tr>
<tr><td>Number of Participants in Batch:</td><td>21</td><td>20</td><td>30</td><td>40</td><td>40</td><td>38</td><td>38</td></tr>
<tr><td>Batch Defined in w/c:</td><td>4th June</td><td>9th July</td><td>23rd July</td><td>30th July</td><td>6th August</td><td>13th August</td><td>20th August</td></tr>
<tr><td>Controller Updated</td><td>21</td><td>20</td><td>30</td><td>40 (updates in w/c 6th Aug.)</td><td>40</td><td>38</td><td>38</td></tr>
<tr><td>App/Account Setup Ongoing (or delayed due to technical difficulties)</td><td>3</td><td>2</td><td>1</td><td colspan="4" rowspan="3">Invites to be issued and setup process followed over period from 6th August. The process is due to be completed by the end of August</td></tr>
<tr><td>No Response from Customer</td><td>8</td><td>7</td><td>23</td></tr>
<tr><td>Setup and Fully Operational</td><td>10</td><td>11</td><td>6</td></tr>
</table>

Table 18: Roll-Out of Algorithm 2 to CrowdCharge Participants

The batches identified above are based on all those who are currently in routine management, and the controller is online. Offline units must be brought back online before they can be transferred into the 'app' group, as an update to the controller software is required. These participants, along with any who enter routine management for the first time will continue to enter trial 2 during early September.

Once the process of linking participants with the app is complete they have the option to enter various pieces of information:

- Regular journey plans (e.g. entering a Monday – Friday commute)
- Occasional journeys for a particular date/time
- State of charge information on each login

The amount of information entered by each participant, alongside number of logins will be used to determine the level of engagement which can be obtained with such a system and this will be detailed in future reports.

8.2 GreenFlux

The 2nd algorithm iteration introduces a customer app. The app is a simple interface which allows the user to request 'high priority' for the current charge session. Available current is allocated to high priority chargers first, before trickling down to 'normal' and 'low' priorities respectively (low priority occurs at the end of a charge cycle, or where a vehicle is on a timer and not yet actively charging). Therefore, if all the participants with active sessions choose to enact the request for high priority, all chargers will have the same priority and will be treated equally.

Participants were transferred from 'trial 1' (routine management, no app) to 'trial 2' in a series of five batches during April and May.

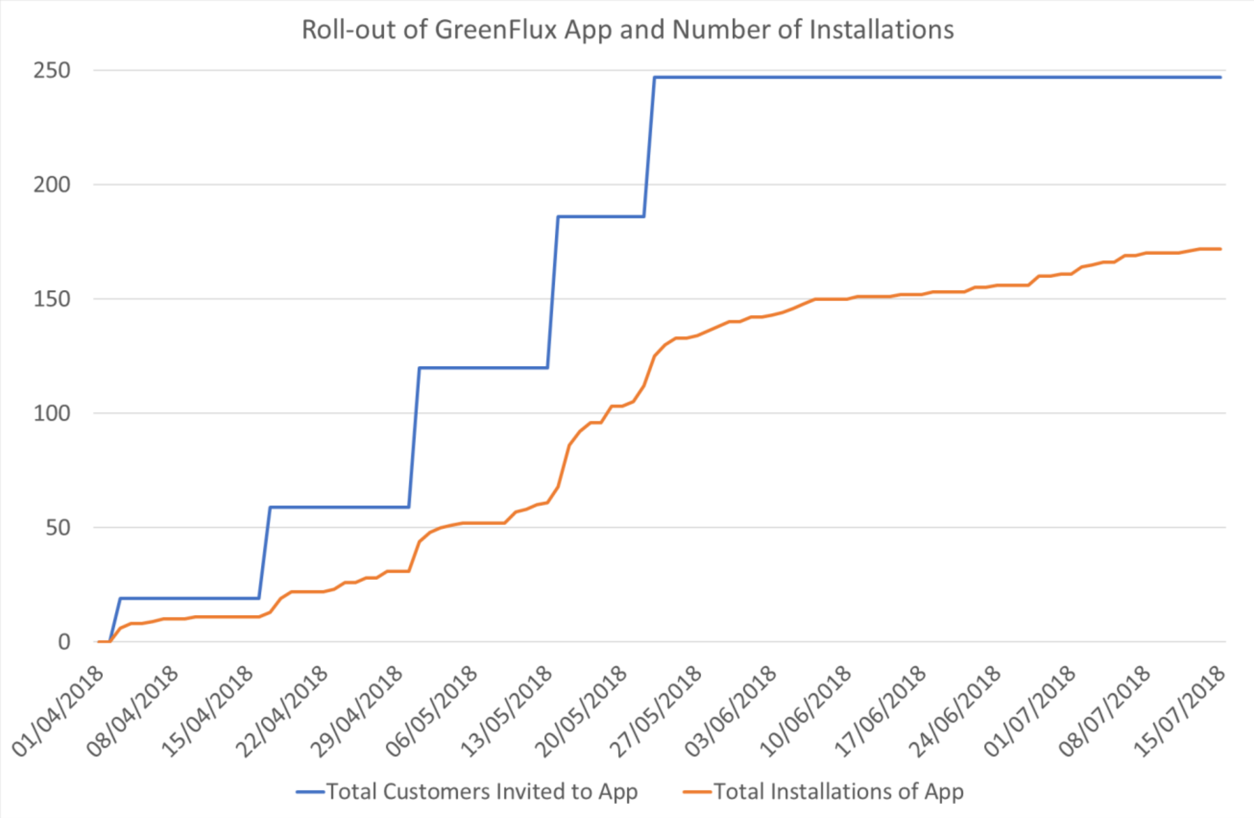
All GreenFlux participants in routine management have now been invited to the app. Participants entering routine management for the first time will go straight into the 'with app' group.

8.2.1 Downloads of the App

Batches of GreenFlux participants were emailed by DriveElectric inviting them to download the app and providing login details and a link to instructions. Participants who had been removed from smart charging (e.g. due to the BMW 330e issue – described in section 7.4.2) were not invited to download the app, as it is only relevant to those participants who are under demand management.

The app is available for both Android and iOS devices. Participants can choose whether they want to download the app. The number of downloads during the course of trial 2 is shown below.

Figure 73: Downloads of GreenFlux App - April to July 2018



The number of participants who had been invited to download the app is shown in blue – clearly showing each batch of invites at intervals of approximately two weeks. The resulting running total of app installations is shown in orange. Increases are shown with align with each batch of invitations, suggesting that most participants either respond quickly to the invitation, or not at all. In early July an additional reminder was issued to all participants, which resulted in another slight increase. From the download information it is not possible to determine which participants have downloaded the app without ever requesting high priority.

At the time of writing, the app has been downloaded 172 times, compared to 248 invitations (69%). There are several potential causes for the discrepancy, including:

- Participants who are not concerned about the effect of smart charging, and so have no interest in an app which allows them to select high priority.
- Lack of access to a smartphone or tablet
- Not receiving the invitation (incorrect email address, 'junk' filters etc.)

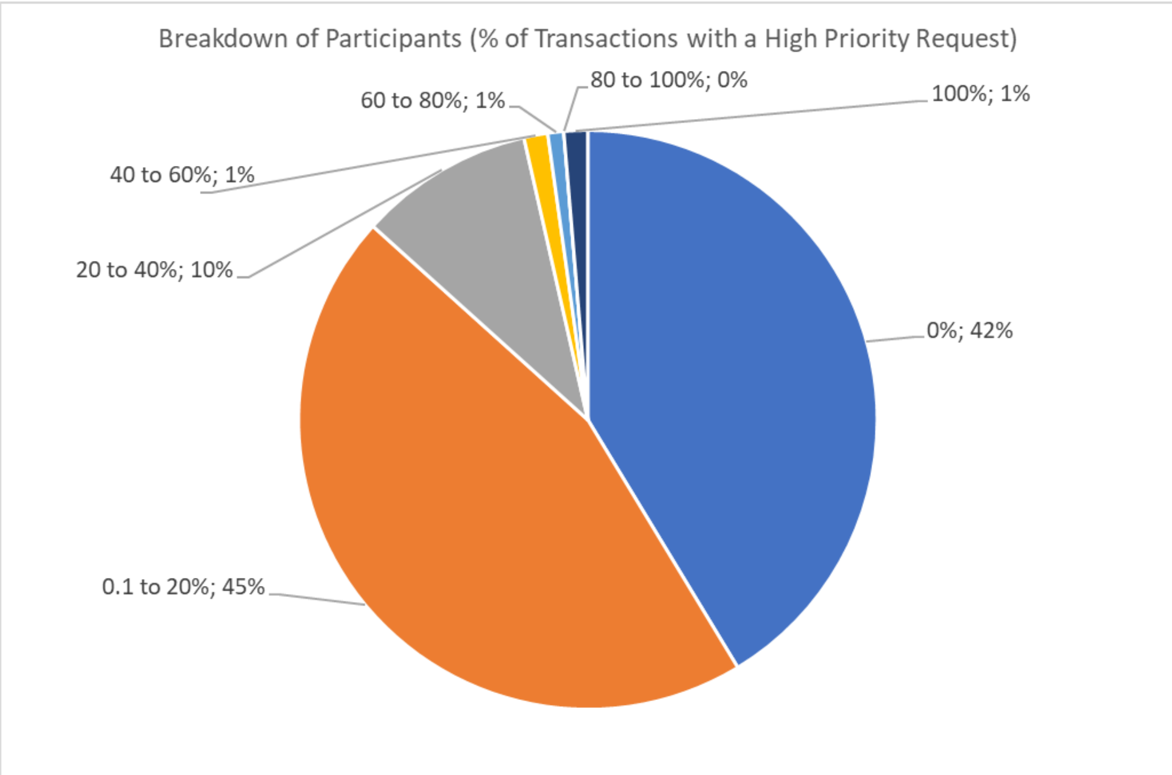
The customer research survey for the 2nd trial period includes questions to determine a) if each participant has downloaded the app and b) if not, why this is. Results of this survey will be included in future reports.

8.2.2 High Priority Requests

Once participants have downloaded the GreenFlux app they are able to request 'high priority' for their current charge session. At a group level current is made available to all 'high priority' chargers first, before any remaining current (relative to the demand limit) is trickles down to 'normal' and then 'low' priority charging sessions. Selecting 'high priority' therefore greatly reduces the potential of an individual charging session being affected by demand management.

248 participants were transferred to the app group in batches during April and May, as shown in Figure 73. At least one transaction record exists for 225 of these participants since they moved into the app group. The remaining 23 chargers may be offline, or not using their charger. A total of 8,499 transactions have occurred where the participant had access to the app, and a request was made for 499 of these charge events (5.9%). App use by an individual participant may occur occasionally (either to experiment with the new feature, or when their journey plans mean that demand management would be particularly inconvenient) or become habitual. The breakdown of the proportion of participants who have requested high priority for varying proportions of their transactions is shown below.

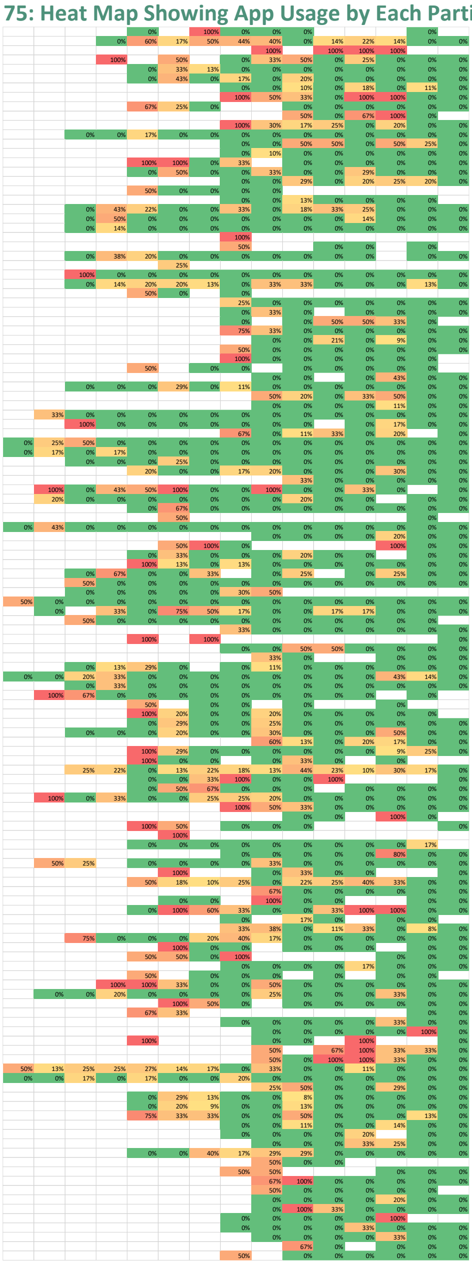
Figure 74: Use of High Priority Requests by GreenFlux Participants



This shows that the majority (87%) of participants with the app have either never used it or have used it for less than 20% of the charge events when they have had access to it. Only 1% of the participants have used it on every transaction.

It is possible that some participants use the app for a short period and then lose interest, or through viewing the information in the app determine that their charge sessions are not being managed. The heat map below shows a row for each participant, with the weeks of the trial since participants began to be transferred into the app group shown from left to right. The percentage of transactions with a high priority request has been calculated for each week and colour-coded, so that weeks with high app usage are red, compared to weeks with no app usage in green. No fill is applied before the participant had access to the app, or where no transactions occurred in a given week. Participants with no transactions since they were offered access to the app, or those who have never used it are excluded from the diagram.

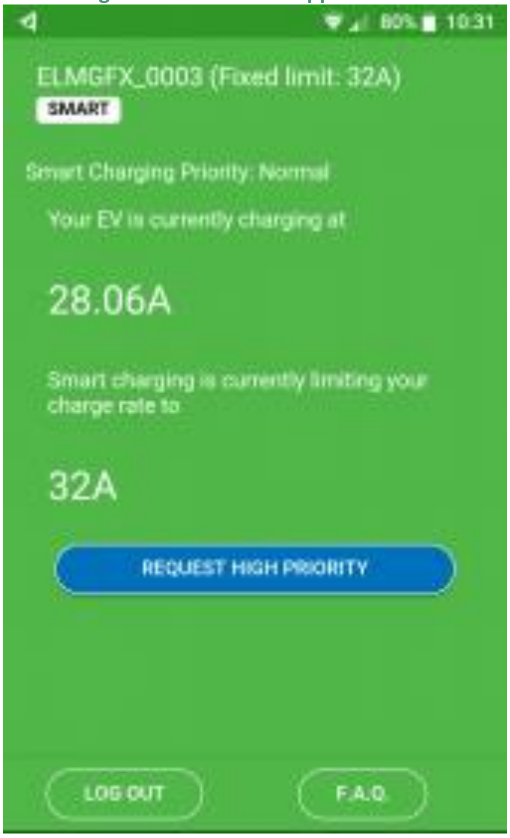
Figure 75: Heat Map Showing App Usage by Each Participant



This shows that for the majority of participants, for the majority of weeks, the app is rarely used, as the majority of the chart is green. App usage appears to be higher in the early weeks of trial 2, shown by larger yellow/orange/red areas on the left of the chart.

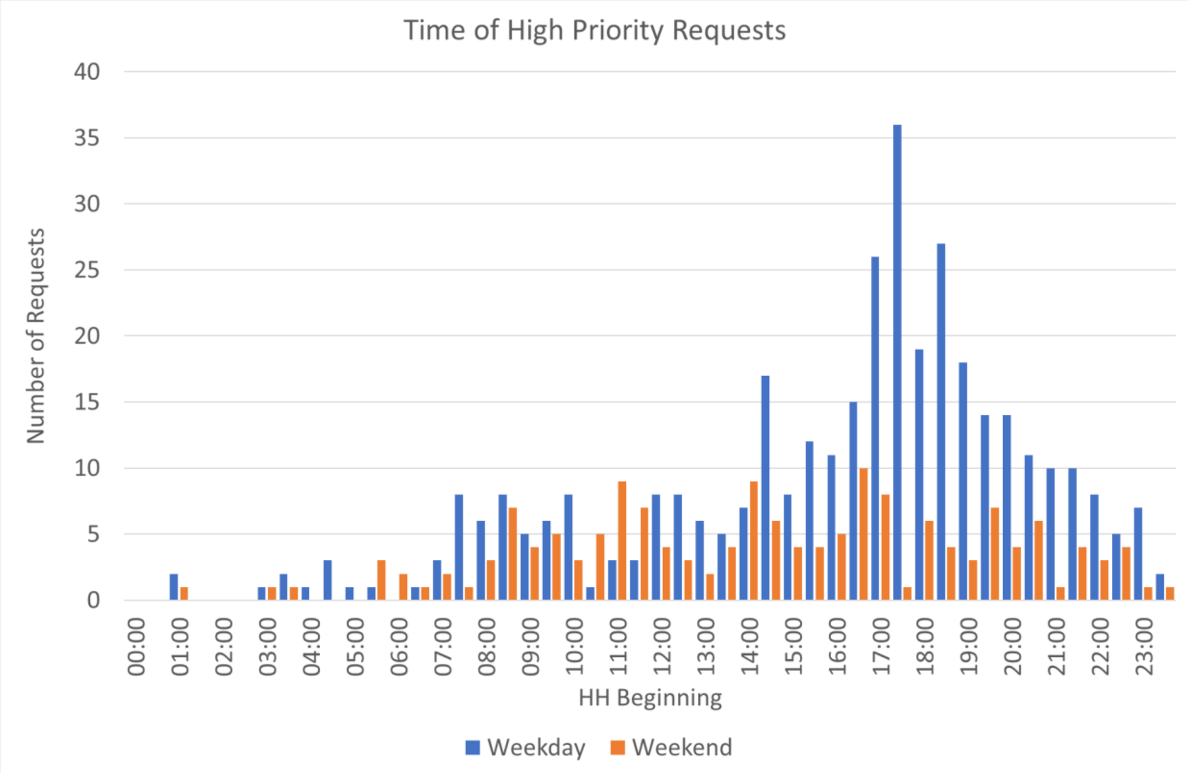
The app interface shows participants the current that their vehicle is drawing, and the amount available from their charger in real time. It also allows them to request high priority, as shown below:

Figure 76: GreenFlux App Interface



Participants may be requesting high priority either in response to demand management being active (i.e. observing that smart charging is reducing the current available), or in anticipation that management may occur during the charging session. The timing of the requests can provide some insight to this, particularly when compared to the times of day when management is active.

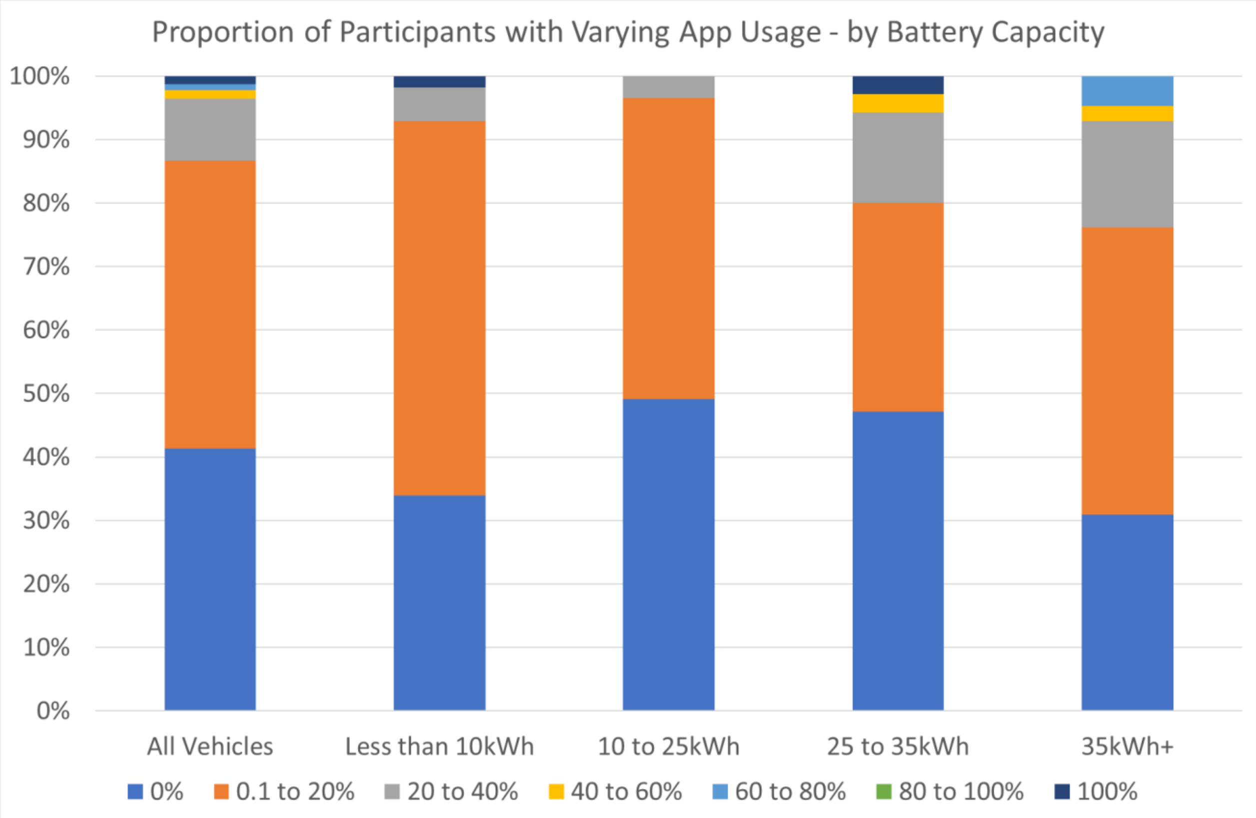
Figure 77: Time of High Priority Requests



This shows a clear increase in high priority requests in the times when demand management is more likely to be active (weekdays, evening peak). Fewer requests are received at the weekend, but this may be due to fewer transactions occurring as well as a lower likelihood of demand management, or fewer time pressures on drivers. A significant proportion of participants are requesting high priority for charging sessions which are unlikely to be constrained – as shown by the number of requests received during the daytime.

Demand management reduces the average current available to a car across a charging session (e.g. instead of 32A being available for three hours there may be two 15-minute pauses, reducing the average rate to 27A). In most cases the reduced rate is still sufficiently fast to fully recharge the vehicle before it is unplugged. However, this may not be the case during shorter transactions, or where a large amount of energy is required. The second of these scenarios is more likely to occur for participants with vehicles with larger batteries. The app usage has therefore been analysed based on the vehicle type assigned to each participant.

Figure 78: Proportion of Participants with Varying App Usage - by Battery Capacity



This shows a slight trend towards increased use of the app by participants with vehicles with larger batteries (25 to 35kWh and 35kWh+). However, app use remains relatively rare for most participants – even the in the 35kWh+ group only 7% of participants use the app for more than 40% of their charging events.

Further analysis of app usage will be conducted in later reports, including linking use of the app to the results of the 2nd trial survey.

9 Next Steps

9.1 Customer Research

Impact Utilities have updated the Baseline survey to include a section asking participants about their interaction with the apps that they trialled as part of Trial 2. This survey is designed to discover if participants have used the apps, which functions they have used and whether use of the apps has placated any concerns that the participants may have had about managed charging. It is expected that this survey will be circulated to the first set of participants in mid-July 2018.

Final analysis of the Baseline survey will be included in the next Customer Research Milestone report.

Final analysis of the customer acceptance of the demand management experience from trial 1 will be undertaken once the impact of demand management on individual participants has been identified and statistically quantified.

9.2 Smart Charging Trials – Algorithm Iteration 2 Activity for August to October 2018

9.2.1 CrowdCharge and GreenFlux

The remaining 'non-managed' participants in both groups will be transferred into trial 2, where this is possible. In some cases, communication problems will prevent this. Although these participants provide little valuable data to the trial it does provide an indication of the likely overall reliability of similar solutions in a Business as Usual scenario. It is likely that a Business as Usual system would differ from that deployed as part of Electric Nation, partly because of the learning developed by the project. Discussions will be held with both CrowdCharge and GreenFlux, and the Tech Factory to determine improvements which could be made. These will be included in the final project reporting.

9.2.2 CrowdCharge

Transfer all remaining CrowdCharge participants from 'trial 1' to 'trial 2'. This will be achieved in the first part of the quarter, with the batch sizes increasing as confidence grows in the ability to deploy new groups and complete all the back-office changes required. The level of customer engagement with the app will be monitored and where necessary reminder emails may be sent – e.g. via participant newsletters.

9.2.3 GreenFlux

Any customers entering management for the first time will go straight into trial 2 (with app). The project team will continue to monitor customer engagement with the app via downloads and high priority requests.

9.3 Smart Charging Trials – Algorithm Iteration 3

9.3.1 CrowdCharge

CrowdCharge have begun preliminary development work on the third iteration of their algorithm and back office system. This will mix the group current limit (capacity profile based on spare network capacity) with time of use pricing. A meeting was held between CrowdCharge and EA Technology in early August to agree details of the improved CrowdCharge Algorithm and timescales for development testing and customer trial roll-out.

Briefly, the improved CrowdCharge algorithm will incorporate an economy 7 style time of use tariff that allows customers using the app to request cost-efficient or time-efficient charging – those selecting cost efficiency alongside their EV's state of charge and next journey plans will have their charging delayed, where possible, to minimise charging costs. Those that select time-efficiency will be charged as quickly as possible, all within the constraints of group current availability.

Trial participants would be rewarded for participating in this part of the trial through a voucher scheme. Initially they will be awarded a nominal amount, for example, £20 (to be agreed). The value of this reward will increase or decrease depending on the times at which the customer choses to charge their vehicle (based on meter value data from the smart charger) – consistently charging overnight will increase the value.

9.3.2 GreenFlux

Preliminary discussions were held between GreenFlux and EA Technology in June 2018 regarding the aims of the 3rd algorithm iteration and the features to include. The third iteration will aim to show whether time of use tariffs in combination with smart charging will encourage EV drivers to allow smart charging system managers to move charging away from period demand periods. By introducing a time of use element this may encourage customers to naturally move consumption away from the peak, reducing the need for curtailment actions. However, this is also a risk of a "feed forward" effect, where the unit price drop stimulates additional demand, creating new peaks at times when demand traditionally falls.

A time of use tariff will be developed consisting of a small number of rates, applying at different times of day. This will include a gradual tapering down from the peak price in the evening peak to the overnight rate, to prevent a sudden increase in demand when the overnight rate begins. This will be 'virtual' tariff and will only relate to a reward value based on the customer's charging behaviour and will not involve a change in supplier or tariff. The new tariff will not result in customers incurring additional expense (consistently charging at the most 'expensive' time will only erode the reward voucher value, rather than costing the customer any additional amount).

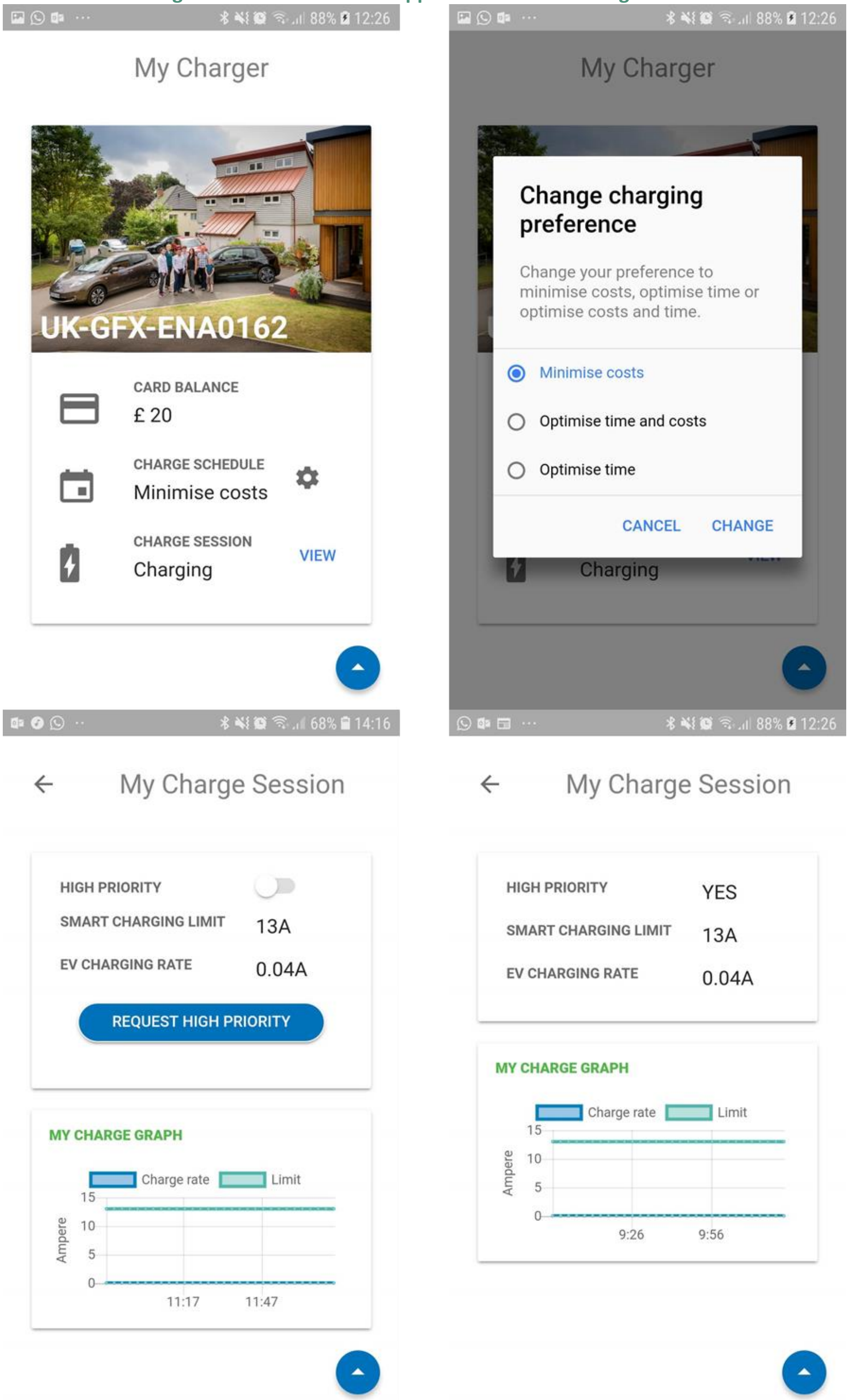
Trial participants would be rewarded for participating in this part of the trial through a voucher scheme. Initially they will be awarded a nominal amount, for example, £20 (to be agreed). The value of this reward will increase or decrease depending on the times at which the customer choses to charge their vehicle (based on meter value data from the smart charger) – consistently charging overnight will increase the value. Participants could use the timer function on their vehicle to ensure the charge at particular times – as some participants do already (see Section 6.2.5). Alternatively, trial participants can opt to use the GreenFlux app and system to manage their charging automatically. They would express a preference for their charging (saved setting for all future charging events, but can be changed at any time), potentially using three options:

- To “minimise charging cost” (default setting)
    - In which case system will pause charging during peak and taper tariff period
- Or “optimise time and cost”
    - In which case the system only pauses during peak tariff period but will bring a charger on to charge during taper tariff
- Or “optimise time”
    - In which case system treats charger as normal priority and charging starts immediately and is not paused at any time (except where WPD capacity limit smart charging action is required)

At all times the GreenFlux system would still operate the group to ensure that total demand remains with network limits. Customers would still have access to a high priority button to request high priority for an individual charge event.

GreenFlux are developing an update to the existing app which will allow users to select their preference for charging (minimise cost, optimise time, optimise time and cost) and display information about their reward balance. The screenshots below show the changes to the app design.

Figure 79: Screenshots of App for 3rd GreenFlux Algorithm



The app will be testing during August and early September, before deployment into the customer trial in the autumn.

Appendix 1 – Recruitment Survey

Electric Nation Recruitment Questionnaire

December 2016

568 Electric Nation	ONLINE SCRIPT DRAFT 14/12/16	Susie Smyth, Michael Brainch, Lucy Upshall, Helen Rackstraw

INTRODUCTION TO THE RESEARCH AND ADHERENCE TO MRS CODE OF CONDUCT

CATI ONLY: Hello, may I speak to **NAME FROM SAMPLE** please?

C1. I am calling from Impact Research about the Electric Nation project that you recently agreed to take part in. We recently sent you a survey link by email, can I check whether you received that email?
Yes
No – **CONFIRM EMAIL ADDRESS WITH RESPONDENT MATCHES SAMPLE**

C2. We would be really grateful if you would be able to complete this survey as soon as possible, I can take you through the questions now on the phone, or if you prefer you can complete it online? The survey should take no longer than 10 minutes.
Phone - **CONTINUE**
Online – **CHECK IF NEED LINK RE-SENDING, THANK AND CLOSE.**

Thank you for agreeing to participate in this important project about the future of electric vehicles. This is the first of a number of surveys you will be asked to take part in during the trial and should take no more than 10 minutes to complete, depending on the answers you give us. The purpose of this survey is to check the information we hold about you and gather some background about your household before you start the trials. This information will be used in combination with that from the other trial participants to understand how perceptions might vary by different groups.

This is a genuine market research study and no sales call will result from our contact with you. The interview will be carried out in strict accordance with the Market Research Society's Code of Conduct. Your identity and any information you provide to us will be kept confidential and will not be used for any purposes other than this research. Your details were provided to us by DriveElectric and only Impact Research and DriveElectric will have access to your personal contact information so that we can keep in touch with you throughout the trials.

SAMPLE CONFIRMATION

We already have some details about you that were passed to us by DriveElectric that we would like to check all are correct before we continue.

S ASK ALL
A1 Can we check your full name is **INSERT FROM SAMPLE** ....
Correct
Wrong – **INSERT NAME HERE**

S ASK ALL
A2 And is this your home address where your charging point is installed? **INSERT FROM SAMPLE** ....
Correct
Wrong – **INSERT CORRECT ADDRESS HERE**

Is your postcode?
INSERT FROM SAMPLE ....
Correct
Wrong – **INSERT CORRECT POST CODE HERE**

QHIDDNO
AUTOCODE DNO FROM POSTCODE LIST:

1) WPD (East Midlands)
2) WPD (South West)
3) WPD (Wales)
4) WPD (West Midlands)
5) Electricity North West
6) Guernsey Electricity
7) Jersey Electricity
8) Manx Electricity Authority
9) Northern Ireland Electricity
10) Northern Powergrid
11) Scottish Hydro
12) Southern Electric
13) SP Distribution
14) SP Manweb
15) UKPN

S ASK ALL

A3 Is this the best telephone number on which we can contact you on for the duration of the trials?

Correct
Wrong – **INSERT CORRECT NUMBER HERE**

S ASK ALL

A5 And is this your preferred email address?
Correct
Wrong – **INSERT CORRECT EMAIL ADDRESS HERE**

A6 And can I confirm your vehicle is…
FROM SAMPLE:
FULL EV OR HYBRID
CAR MAKE AND MODEL

(ALLOW EDITING FOR ANY FIELDS THAT ARE WRONG)

S ASK ALL
A7 Does your household have regular access to any other vehicles apart from the electric/hybrid vehicle registered for this trial?
Yes **(SPECIFY MAKE AND MODEL)**
No

S ASK IF YES AT A7
A8 How many other vehicles does your household have regular access to?
1
2
3+

S ASK ALL
A9 Which of these best describes how you personally use the electric/hybrid vehicle registered for this trial?
I am the main driver
I drive the car regularly but am not the main driver
I rarely or never drive the vehicle **CONFIRM WITH RESPONDENT, CLOSE, AND CONTACT IMPACT AS ALL DRIVERS SHOULD BE REGULAR DRIVERS OF THE VEHICLE.**

M ASK ALL
A10 Apart from you, who else is likely to drive the electric/hybrid vehicle registered for this trial?
Please select all that apply.

My partner

Another household member
Someone who does not live in the household
Only me EXCLUSIVE

Thank you for confirming that information. We will now ask you some questions about your household.

DEMOGRAPHICS AND HOUSEHOLD INFORMATION

S **ASK ALL,**
B1 Please record your gender below.

1) Male
2) Female

S **ASK ALL**
ADD VALIDATION RULE NO YOUNGER THAN 16 AND UP TO 99 YEARS OLD
B2 Please record your age below.
……. Years old

AUTOMATICALLY CODE INTO THE FOLLOWING AGE BREAKS (HIDDEN VARAIBLE]

IF CODE 1 CLOSE

QHIDAGE Please record **age** below

1) Under 18
2) 18-25
3) 26-35
4) 36-45
5) 46-55
6) 56-64
7) 65+

S **ASK ALL**
B3 Which of the following best describes ***your*** employment?

1) Self employed
2) Employed over 30 hours a week
3) Employed part time, 15-30 hours a week
4) Employed part time, less than 15 hours a week
5) Full time Student
6) Unemployed- seeking work
7) Unemployed- other
8) Looking after the home/children full time

9) Retired
10) Unable to work due to sickness or disability
11) Other (please specify)

S **ASK IF CODE 1, 2, 3, 4 AT B3**
IF CODE 5, 6, 7, 8 SKIP TO B5

B4 Is your work…
1. Mainly daytime work
2. Mainly evening work, from 7pm to 11pm
3. Mainly night work, 11pm to 5am
4. Shifts that change from day to day or week to week

B5 How many people (including children) are there in your household altogether (that is currently living at home with you)?
Please include yourself in the total.
ENTER NUMBER 1-20

IF 2 OR MORE AT B5 ASK B6
B6 How many children live permanently in your household?
ENTER NUMBER 0-20

S ASK ALL
B7 Which ONE of the following categories best describes the employment status of the ***Chief Income Earner*** (CIE) in your household?

1) Semi or unskilled manual *worker (e.g. Caretaker, Park keeper, non-HGV driver, shop assistant etc)*
2) Skilled manual worker *(e.g. Bricklayer, Carpenter, Plumber, Painter, Bus/ Ambulance Driver, HGV driver, pub/bar worker etc)*
3) Supervisory or clerical/ junior managerial/ professional/ administrative *(e.g. Office worker, Student Doctor, Foreman with 25+ employees, salesperson, etc)*
4) Intermediate managerial/ professional/ administrative *(e.g. Newly qualified (under 3 years) doctor, Solicitor, Board director of small organisation, middle manager in large organisation, principle officer in civil service/local government etc)*
5) Higher managerial/ professional/ administrative *(e.g. Doctor, Solicitor, Board Director in a large organisation 200+ employees, top level civil servant/public service employee etc)*
6) Student
7) Casual worker – not in permanent employment
8) Housewife/ Homemaker
9) Retired and living on state pension

10) Retired and not living on state pension
11) Unemployed or not working due to long-term sickness
12) Full-time carer of other household member

S ASK IF CODE 10 AT B7

B8 Which ONE of the following categories best describes the employment status of the Chief Income Earner ***before*** they retired?
SHOW THE SAME LIST AS B7, EXCLUDING CODES 9 AND 10

AUTOMATICALLY CODES OF QUESTIONS B7 AND B8 INTO SOCIAL ECONOMIC GRADE AS FOLLOWS:

CODE 1	**D**
CODE 2	**C2**
CODE 3 OR 6	**C1**
CODE 4	**B**
CODE 5	**A**
CODE 7 OR 8 OR 9 OR 10 OR 11 OR 12	**E**

S GRID ASK ALL

B9 Which of these best represents your **total** household income before tax and other deductions, either per month or per year.

This information will only be used to check that we have surveyed a mixture of different customers.

ONLY ALLOW ONE ANSWER IN ONE COLUMN

	PER MONTH	PER YEAR
1	Up to £539	Up to £6,499
2	£540 - £789	£6,500 - £9,499
3	£790 - £1289	£9,500 - £15,499
4	£1290 - £2079	£15,500 - £24,999
5	£2080 - £3329	£25,000 - £39,999
6	£3330 - £4999	£40,000 - £59,999
7	£5000 - £7499	£60,000 - £89,999
8	£7500 and over	£90,000 and over
98	Don’t know	Don’t know
99	Prefer not to say	Prefer not to say

S ASK ALL

B10 Which of the following do you have in your main charging address?

Mains electricity only
Mains electricity and mains gas
Mains electricity and another fuel source such as oil

S ASK ALL
B11 Do have solar panels (photovoltaics) at your home address?
Yes
No
Not sure

S GRID ASK ALL
B12 On average, how much is your combined spend, on gas **and** electricity?

ONLY ALLOW ONE ANSWER IN ONE COLUMN

	PER MONTH	PER YEAR
1	Less than £35 per month	Less than £400 per year
2	£35 - £49	£400 - £599
3	£50 - £65	£600 - £799
4	£66 - £85	£800 - £999
5	£86-£100	£1,000 - £1,199
6	£101 - £115	£1,200 - £1,399
7	£116 - £130	£1,400 - £1,599
8	£131-£149	£1,600 - £1,799
9	Over £150 per month	£1,800 or more per year
98	Don't know	Don't know
99	Prefer not to say	Prefer not to say

QHIDFUELPOV:
1 FUEL POOR – IF MORE THAN 10% OF INCOME SPENT ON FUEL BASED ON RESPONSE AT B9 AND B12
2 NON-FUEL POOR – IF LESS THAN 10% OF INCOME SPENT ON FUEL BASED ON RESPONSE AT B9 AND B12

C1 Finally, have you experienced any technical difficulties while taking the survey?

1. No
2. Yes (Please specify)

Thank you for the information you have provided today. We will be in touch again once you have had your vehicle and been charging it for a few weeks to understand a little more about how you use and charge you vehicle.

If you have any questions in the meantime about the survey you have just done, or future surveys, please contact Impact Research on 01932 226 793 and ask for a member of the Electric Nation team. Our full contact details and those of the Electric Nation project partners such as DriveElectric were provided to you in your welcome pack. Please do not hesitate to get in touch if you have any questions.

Thank you.

Appendix 2 – Baseline Survey

Electric Nation Recruitment Questionnaire

February 2017

568 Electric Nation	ONLINE SCRIPT FV 22/02/17	Susie Smyth, Michael Brainch, Lucy Upshall, Helen Rackstraw

INTRODUCTION TO THE RESEARCH AND ADHERENCE TO MRS CODE OF CONDUCT

CATI ONLY: Hello, may I speak to **NAME FROM SAMPLE** please?
C1. I am calling from Impact Research about the Electric Nation project that you recently agreed to take part in. We recently sent you a survey link by email, can I check whether you received that email?
Yes
No – **CONFIRM EMAIL ADDRESS WITH RESPONDENT MATCHES SAMPLE**

CATI ONLY: C2. We would be really grateful if you would be able to complete this survey as soon as possible, I can take you through the questions now on the phone, or if you prefer you can complete it online? The survey should take no longer than 5 minutes.
Phone - **CONTINUE**
Online – **CHECK IF NEED LINK RE-SENDING, THANK AND CLOSE.**

ASK ALL
Thank you for agreeing to participate in this important project about the future of electric vehicles. This is the second survey that you will be asked to take part in during the trial and should take no more than 5 minutes to complete, depending on the answers you give us. The purpose of this survey is to gauge how you are currently charging your electric vehicle. This information will be used in combination with that from the other trial participants to understand how behaviour might vary by different groups.

This is a genuine market research study and no sales call will result from our contact with you. The interview will be carried out in strict accordance with the Market Research Society's Code of Conduct. Your identity and any information you provide to us will be kept confidential and will not be used for any purposes other than this research. Your details were provided to us by DriveElectric and only Impact Research and DriveElectric will have access to your personal contact information so that we can keep in touch with you throughout the trials.

USE

We have some details about you we would like to check are correct before we continue.

M ASK ALL

A1 Firstly, what do you use your electric vehicle for? Please select all that apply.

1) Social
2) Business
3) Commuting

S ASK ALL

A2 Does your household have regular access to any other vehicles apart from the electric/hybrid vehicle registered for this trial?

1) Yes
2) No

S ASK IF A2=YES

A2a How many other vehicles does your household have regular access to apart from the electric/hybrid vehicle registered for this trial?

1) ……. **(SPECIFY MAKE AND MODEL FOR EACH)**

M ASK IF A2 = YES PLEASE SHOW ON SAME PAGE AS A2

A3 Is your other vehicle(s)… Please select all that apply.

1) Electric
2) Range extended electric
3) Plug in Hybrid
4) Hybrid
5) Petrol
6) Diesel
7) Other (please specify)

Thank you for confirming this information. We will now ask you some questions about your electric vehicle.

CHARGING BEHAVIOUR

M ASK ALL, ROTATE ALL

B1 To what extent do you agree or disagree with the following statement, where 1 is strongly disagree and 5 is strongly agree.

1) My charging behaviour varies considerably from day to day
2) My charging behaviour has a regular routine
3) Whenever I have access to a charger, I plug in, regardless of the level of charge of the vehicle
4) I will only plug in to charge when the battery is too low to complete my current/next journey

M **ASK ALL, MULTICODE**

B2 Where do you charge your electric vehicle? Please select all that apply.

3) Home
4) Service station (motorway) / Petrol station
5) On street charge point
6) Work
7) Supermarket/Shopping centre car parks
8) Other Car parks (please specify)
9) Friend/relative's house
10) Other (please specify)
11) Don't know

S **ASK ALL, SINGLE CODE**

B3 And, where do you charge your electric vehicle most often?

INSERT ALL SELECTED AT B2

S **ASK ALL, SINGLE CODE BY ROW**

B4 How often do you charge your electric vehicle in the following locations?

	1)	2)	3)	4)	5)	6)	7)	8)
Location	More than once a day	Once a day	5 -6 times a week	3-4 times a week	Once – twice a week	Once a fortnight	Less than once a fortnight	I don't have charging routine / Don't know
INSERT ALL SELECTED AT B2								

M **ASK ALL, MULTICODE**

B5 When do you typically charge your electric vehicle at the following locations? Please select all that apply to each location.

	1)	2)	3)	4)	5)
Location	Morning	Afternoon	Evening	Overnight	I don't have a standardised charging routine
INSERT ALL SELECTED AT B2					

S **ASK ALL**
B6 Thinking about when you charge your electric vehicle in the following locations, how long do you charge your electric vehicle for on each occasion?

	1)	2)
Location	**PROGRAMMER: NUMERIC BOX** ___________ hours	I don't have a charging routine / Don't know
INSERT ALL SELECTED AT B2		

S **ASK ALL**
B7A How do you tend to judge when to charge your electric vehicle?

1) Number of miles left
2) Percentage of battery left
3) Other (please specify)

S **ASK IF B7A = 1**
B7B At what point would you feel like you need to charge the battery of your electric vehicle?

1) 10 miles or below
2) 20 miles or below
3) 50 miles or below
4) 100 miles or below
5) 150 miles or below
6) More than 150 miles

7) Other (please specify)

S ASK IF B7A = 2

B7C At what point would you feel like you need to charge the battery of your electric vehicle?

1) Below 75% charge
2) Below 50% charge
3) Below 25% charge
4) Other (please specify)

S ASK ALL

B8 On a scale of 1 – 10, where 1 is completely unacceptable and 10 is completely acceptable, how **acceptable** are your current charging arrangements?

1) 1 – Completely unacceptable
2) 2
3) 3
4) 4
5) 5
6) 6
7) 7
8) 8
9) 9
10) 10 – Completely acceptable
11) Don't know (Please specify why)

S ASK ALL

B9 On a scale of 1 – 10, where 10 is very satisfied and 1 is very dissatisfied, how **satisfied** are you with your current charging arrangements?

1) 1 - Very dissatisfied
2) 2
3) 3
4) 4
5) 5
6) 6
7) 7
8) 8
9) 9
10) 10 – Very satisfied
11) Don't know

S ASK ALL

B10 Which statement best describes your attitude to changing your charging behaviour

1) I am very willing to continue with this current charging arrangement indefinitely
2) I am willing to continue with this current charging arrangement for a limited time only
3) I would prefer alternative charging arrangements
4) I cannot continue with these current charging arrangements

OE **ASK IF CODES 2 – 4 SELECTED AT B10**
B11 Why do you say that?

S **ASK ALL**
B12 How do you feel about having your charging arrangements managed as part of the trial?

1) Not at all concerned
2) Slightly concerned
3) Quite concerned
4) Very concerned
5) Not sure

OE **ASK ALL**
B13 Why do you say that?

INSTALLATION QUESTIONS (DE)

Thinking back to when you had your charge point installed….

G **ASK ALL**
I1 Overall can you tell us what you thought of your experience with DriveElectric in terms of… **ROWS**
a) Contact with DriveElectric
b) Information provided to you about the project
c) Administration of your application for the charger

COLUMNS
1) Very poor
2) Poor
3) Neither poor nor good
4) Good
5) Very good

S **ASK ALL**
I2 How was your experience of the install itself?

1) Very poor
2) Poor
3) Neither poor nor good
4) Good
5) Very good

S **ASK ALL**

I3 Did the installer explain how safety would be managed as part of the installation?
1) Yes
2) No
3) Can't remember

OE ASK ALL
I4 Is there anything you feel you need more information on regarding the project?
OPEN ENDED

Thank you for providing that information. I would just like to confirm your contact information is up to date.

CONTACT INFORMATION

S ASK ALL
C1 Can I confirm that this is still the best number to contact you on?
1) Yes
2) No

S ASK IF C1 = 2
C2 Please provide the best number to contact you on in the future?
____

C3 Finally, have you experienced any technical difficulties while taking the survey?

1. No
2. Yes (Please specify)

Thank you for the information you have provided today. We will be in touch again once the first trial is underway and you have had few weeks to charge your vehicle.

If you have any questions in the meantime about the survey you have just done, or future surveys, please contact Impact Research on 01932 226 793 and ask for a member of the Electric Nation team. Our full contact details and those of the Electric Nation project partners such as DriveElectric were provided to you in your welcome pack. Please do not hesitate to get in touch if you have any questions.

Thank you.

Appendix 3 – Recruitment Survey Invitation

Dear

You are receiving this survey invitation based upon you signing up to the **Electric Nation** research project. Your details were given to us by our project partner **Drive Electric**.

This initial survey will collect some background information about yourself and your electric vehicle, which will be used throughout the duration of the project. All details collected will be kept confidential and only be used for the purpose of this research as outlined in the welcome back. The information you provide for us is important to help us understand how different electric vehicle users' experiences might vary.

To take part in the survey, please read the following and click on the relevant link below:

<SURVEY LINK>

This survey should take approximately 10 minutes to complete. Please aim to complete the survey within the next seven days, after which time we may be in contact with you to remind you to complete the survey as soon as you can.

As part of this research you will be asked to complete up to seven further surveys throughout the next two years as previously explained.

If you have any queries about the Electric Nation surveys we send you please contact us at Impact Research on 01932 226 793 or electricnation@impactmr.com. If you have any other questions about the research then please refer to your welcome pack for relevant contact details. We look forward to receiving your feedback.

Kind regards,

Impact Utilities

Appendix 4 – Baseline Survey Invitation

Email subject: Electric Nation Survey 2

Dear

Thank you for completing the first survey as part of the **Electric Nation** research. **Now you have had your charger for a few weeks** we would like to ask you about your experience so far.

This survey is to understand your initial charging habits before the demand management trial begins. All details collected will be kept confidential and will only be used for the purpose of this research, as outlined in the Welcome Pack. The information you provide for us is important to help us understand how different electric vehicle users' experiences might vary.

To take part in the survey, please read the following and click on the relevant link below:

<SURVEY LINK>

This survey should take approximately 5 minutes to complete. Please aim to complete the survey within the next seven days, after which time we may contact you to remind you to complete the survey as soon as you can.

As part of the Electric Nation project you will be asked to complete up to six further surveys throughout the next two years, as previously explained.

If you have any queries about the Electric Nation surveys we send you, please contact us at Impact Research on 01932 226 793 or electricnation@impactmr.com. If you have any other questions about the Electric nation project then please refer to your Welcome Pack for relevant contact details. We look forward to receiving your feedback.

Kind regards,

Impact Utilities

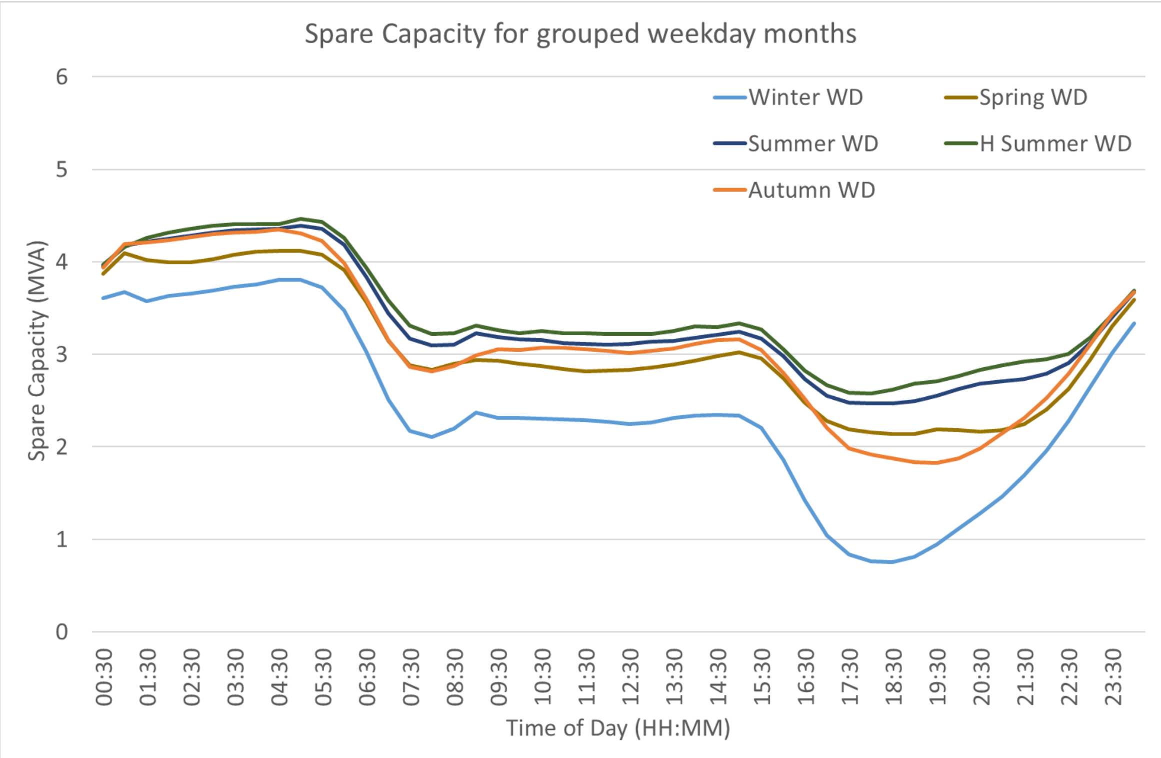
Appendix 5 – Smart Charging Roll-Out Process

Analysis of Network Data to Show Available Network Capacity

Electric Nation is trialling the use of demand management (smart charging) to avoid or defer network reinforcement. To achieve this the additional load from EV charging must be accommodated within 'spare' network capacity. This available spare capacity will vary depending on the network in question and by time of year, weekend/weekday and time of day.

In the first year of the Electric Nation trial 'spare capacity' profiles have been generated for a high voltage (HV) feeder in the East Midlands, for five seasons, for weekdays and weekends. The resulting profile is shown below.

Figure 80: Spare Capacity Profile



In the later stages of the trial alternative profiles may be investigated – e.g. managing based on Low Voltage (LV) network capacity, or for different networks.

This spare network capacity is equivalent to the amount of power which could be drawn by EV charging (or other load growth) on the network without exceeding the networks design limits. However, it requires scaling to be used within the trials – for example, the winter profile above has a minimum spare capacity of 0.75MW in winter at 18:30. This is equivalent to 107 chargers drawing 7kW (or slightly less than a third of each cohort when all participants are under demand management). The project is therefore scaling the capacity profiles so that participants experience a similar amount of demand management as the number of participants under management grows.

Identify Chargers Ready for Demand Management

As set out above, there are two routes in demand management:

- Charge at Will: Approximately 100 participants in each cohort (GreenFlux and CrowdCharge) who will be allowed unrestricted charging for approximately 90 days before demand management is imposed.
- Straight into Management: once the charger is in use approximately two weeks is permitted to prove the reliability of the communications from the charger, then the charger enters the managed group.

By using these routes, it should be possible to show whether there is any difference in the acceptability of demand management depending on whether participants have prior experience of unrestricted charging. The results of the 'baseline' surveys between the two populations can also be compared to show whether participants have different satisfaction levels with their charging at this stage, or whether their charging behaviour changes once they enter routine management (if they are aware of this), or once they have experienced some curtailment. This analysis will be completed later in the trial and the results shown above include participants from both populations.

Regardless of the route to management, chargers must satisfy a number of conditions before they entered the 'managed' group. Prior to this they provide data to the trial which will inform the project's understanding of charging behaviour for different types of PIVs. These criteria are set out below:

- Confirm the charger is in use: the date on which the first significant transaction occurs is recorded for each charger (i.e. excluding small transactions which occur during testing when the charger is installed). There can be delay between charger installation and the first use of the charger, for example if there is a delay in the delivery of the vehicle. For the charge at will group approximately 90 days is required between the date of first transaction and their entry into demand management. This measure is purely based on the time since they start charging, and does not include the number of transactions. However, it is a sufficient period of time for drivers to develop a charging routine.
- Charger configuration is ready for demand management: this is undertaken in conjunction with GreenFlux/CrowdCharge as appropriate and any issues are remedied as necessary.
- Ensure reliable communications: poor communications between the charger and demand control provider could negatively affect the participant's experience of smart charging, or make smart charging impossible (in the case of no communications). If a participant is more harshly affected by demand management due to a communications failure this could be reflected in their acceptability of the concept of smart charging, when it does not represent a realistic scenario. For this reason, participants are only being transferred into demand management after two to three weeks of good (85%+ reliability) performance.

- Test of controllability: this stage confirms that each individual charger is controllable before it is placed in a group. For CrowdCharge participants this is routinely carried out during each transaction and involves a very short reduction in the current available (no participant impact). GreenFlux participants pass through a 'test card' phase in which the charger behaves as it will during management, but full capacity is available at all times. Performance in the test card phase is then evaluated and recorded before the charger passes to routine management.

Batches of chargers which are ready to enter demand management are being identified approximately fortnightly, made up of a mix of participants who have been through the 'charge at will' and 'straight to management' routes. The output from this stage is a list of charger IDs which will form the managed group and the total number of chargers involved. An update on the number of participants which have passed this stage is provided in Section 7.4 below.

Scale Available Network Capacity Based on Number of PIVs in the Managed Group

The profiles of spare capacity (current limit) set out above are scaled based on the number of EVs in the managed group. This scaling factor is applied so that the participants experience a similar level of demand management to that which would apply when 30% of vehicles in the area are electric. This 30% figure was selected based on the findings of My Electric Avenue, and to be representative of a "2030 scenario". The proportion chosen could be altered in one of the later stages of the trial. The level of management that participants experience should stay consistent as the group is expanded (within the same season) as the current limit profile (demand limit) is re-scaled with each expansion.

Issue Group and Profile Definitions to GreenFlux/CrowdCharge

A data format has been agreed between EA Technology and both DCS providers to show the participants who make up a managed group and the weekday/weekend profile they should be managed to. This is issued by EA Technology and then implemented. Participants are not informed when the switch is made into demand management, to avoid prejudicing their survey responses. Impact Utilities are also notified of the date when each participant enters demand management to allow their survey to be issued at the appropriate time.

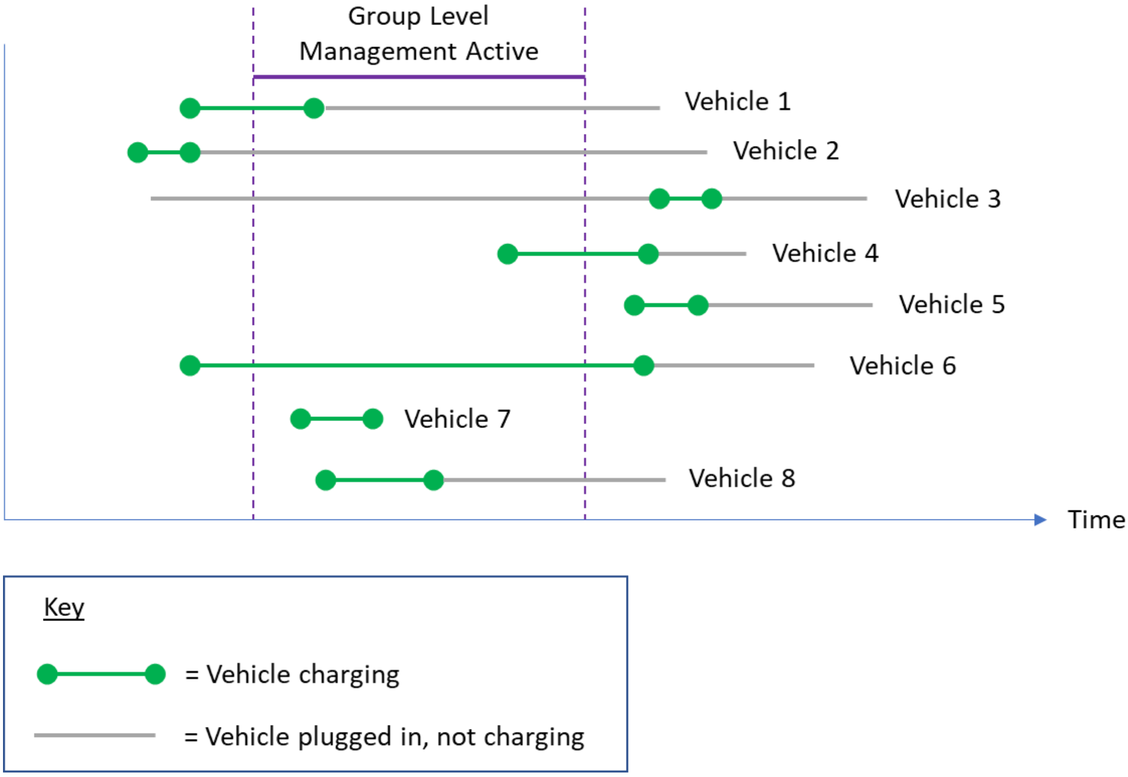
Monitor Performance

Throughout the trial (both before and after the implementation of demand management) all chargers should supply transaction records and meter values (current drawn and current allocated). These are being supplied to EA Technology by both demand management providers.

Appendix 6 – Identification of Management of Individuals Chargers

Regardless of the demand management provider (CrowdCharge or GreenFlux), a plug-in event generally consists of a period of active charging (i.e. car drawing current) followed by an inactive period while the vehicle is still connected to the charger but has completed its cycle and is no longer drawing power. Other combinations are also possible – e.g. inactive before a period charging (using a timer) or no inactive period ('hot unplug' before the battery is full). The timing of this individual charging may or may not overlap with a period when management is active at a group level. Potential permutations are shown below, which aims to capture the majority of charging events. It is also possible that none of the transaction (from plug-in to plug-out) overlapped with a group level management event and this is excluded from the diagram below.

Figure 81: Alignment of Individual Charging with Management Events



These scenarios are described below:

Vehicle Number	Description of Scenario
1	Vehicle began charging before management event began and was still charging towards the start of the management period. It finished charging during the event. It was plugged in until after the event had finished.
2	Vehicle had both started and stopped charging before the event began. It was plugged in throughout the event.
3	The vehicle was plugged in before the event began but was on a timer and didn't draw any current until after the event had finished.
4	The vehicle was plugged in and began charging during the event. It continued to charge after the event had finished.
5	All activity was after the event finished
6	The vehicle began charging before the event started and continued afterwards.
7	Vehicle was plugged in briefly within the event. It was unplugged before it finished charging and before the event finished.
8	The vehicle was plugged in during the event, finished charging before the event was over and was left plugged in.

The aim of the analysis of individual level charging events is to apply a series of queries (questions), the results from which determine whether an individual charging event was affected by management. Based on the scenarios above, and current data availability, the first question to be applied is:

$$\text{Is } t_{\text{Start Charge}} \leq t_{\text{end of management event}}?$$

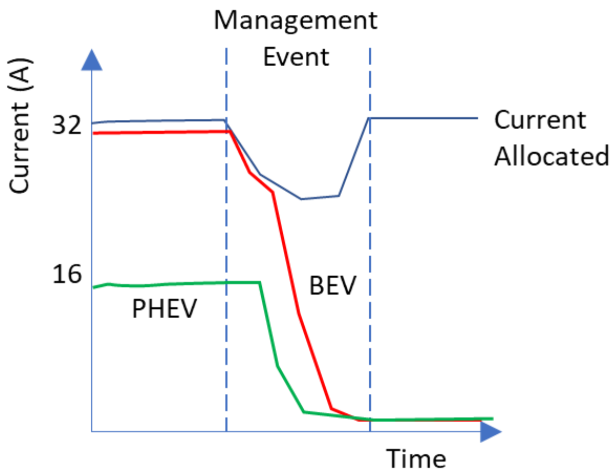
where:

- $t_{\text{start charge}}$ = the time at which the vehicle started charging (not the plug-in time) – indicated by the first green dot in Figure 81 above.
- $t_{\text{end of management event}}$ = the time at which the management event finished – the 2nd dotted vertical line in Figure 81.

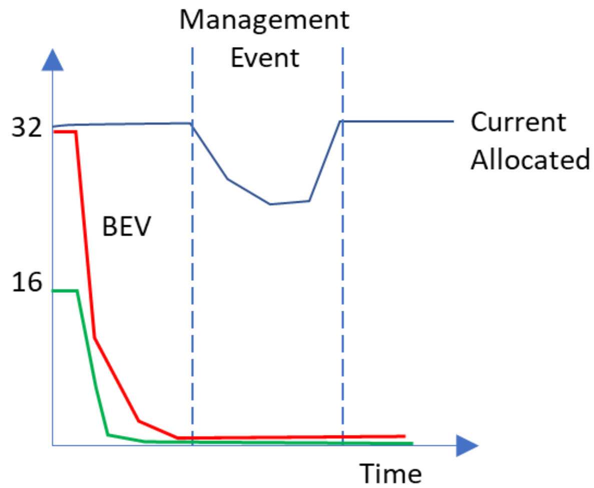
Applying this criterion to the scenarios listed above it is already clear that vehicles 3 and 5 were not affected, these are excluded from the further analysis below. Further queries are required to determine the status of the remaining 6 charging events. These queries will vary between CrowdCharge and GreenFlux because of differences in the control algorithms used and the data being supplied. The sub-sections below describe the logic applied for both providers.

CrowdCharge – Management of Individual Chargers

Illustrative individual charging curves can be drawn up for the remaining customers. These have been separated into an example BEV vehicle (i.e. nominally 7kW) and a PHEV (or other, nominally 16A vehicle).

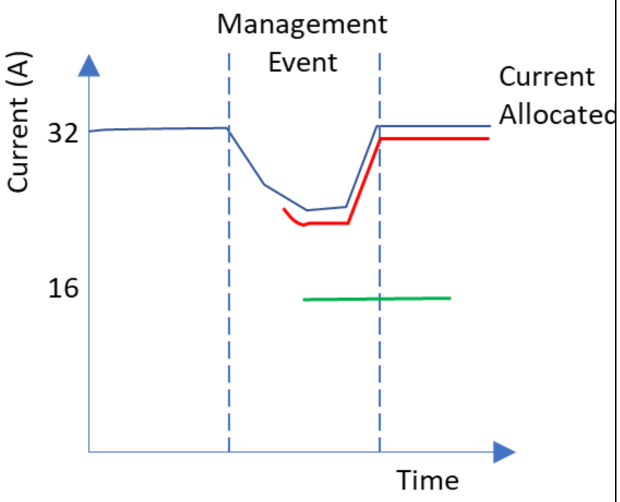
<table>
<tr>
<td>Vehicle 1: Vehicle began charging before management event began and was still charging towards the start of the management period.


As drawn above, the BEV was curtailed by the management event – it is likely that if the allocation hadn't been reduced then it would have continued to charge at 32A for a short while longer.

The PHEV was not curtailed as it was always drawing substantially less current than the allocation.</td>
<td>Vehicle 2: Vehicle had both started and stopped charging before the event began. It was plugged in throughout the event.


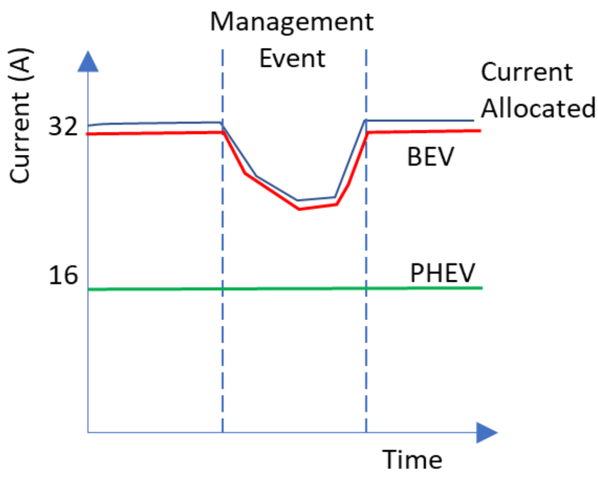
Neither vehicle was curtailed. The current being drawn had already declined prior to the demand management event starting.</td>
</tr>
</table>

Vehicle 4: The vehicle was plugged in and began charging during the event. It continued to charge after the event had finished.



The BEV was curtailed from when it was plugged in until the end of the management event.
The PHEV was unaffected as the allocation remained higher than the nominal charge rate of the vehicle.

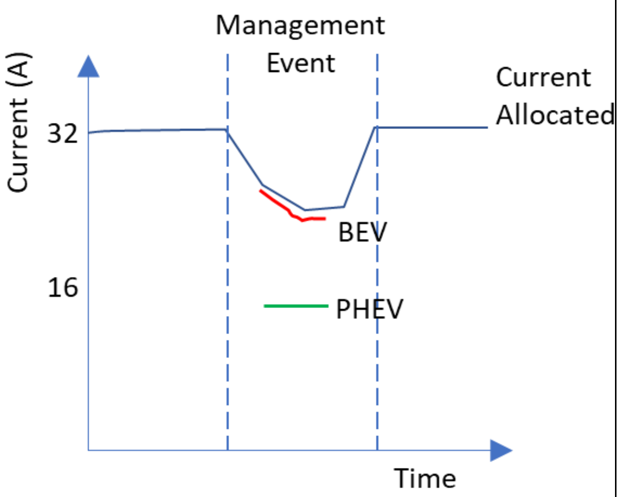
Vehicle 6: The vehicle began charging before the event started and continued afterwards.



The BEV was curtailed throughout the length of the management event.

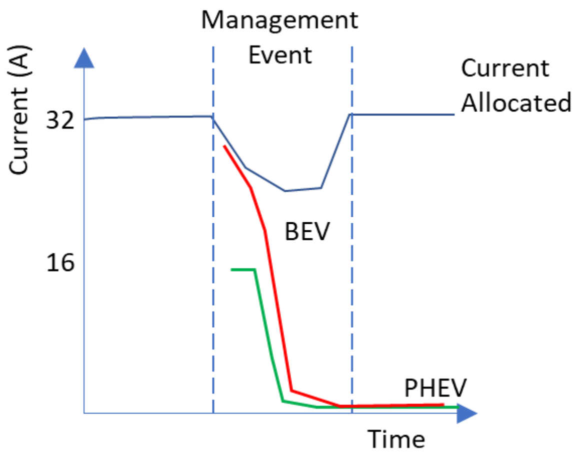
The PHEV was unaffected as the allocation remained higher than the nominal charge rate of the vehicle.

Vehicle 7: Vehicle was plugged in briefly within the event. It was unplugged before it finished charging and before the event finished.



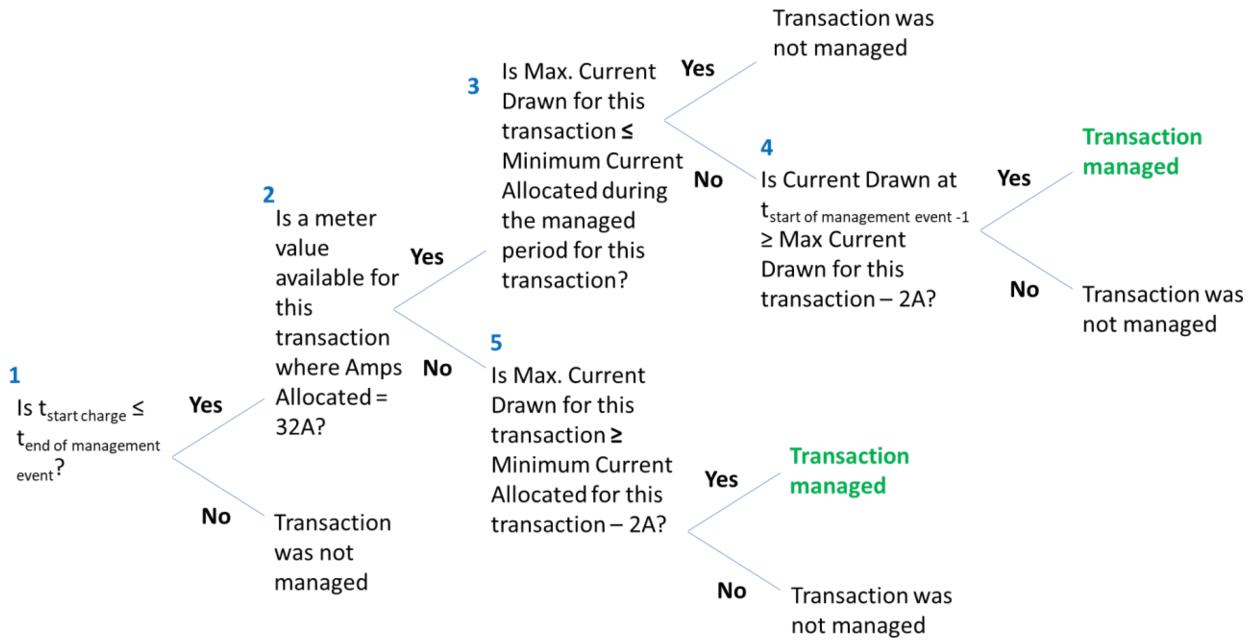
The BEV was curtailed throughout the transaction. The PHEV was unaffected.

Vehicle 8: The vehicle was plugged in during the event finished charging before the event was over and then left plugged in.

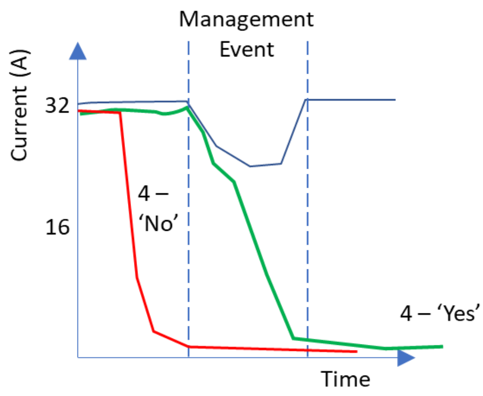


The BEV was affected at the start of the charge event. The PHEV was unaffected.

A series of tests have been developed to determine whether a transaction was affected by a management event. These are shown in the decision tree below.

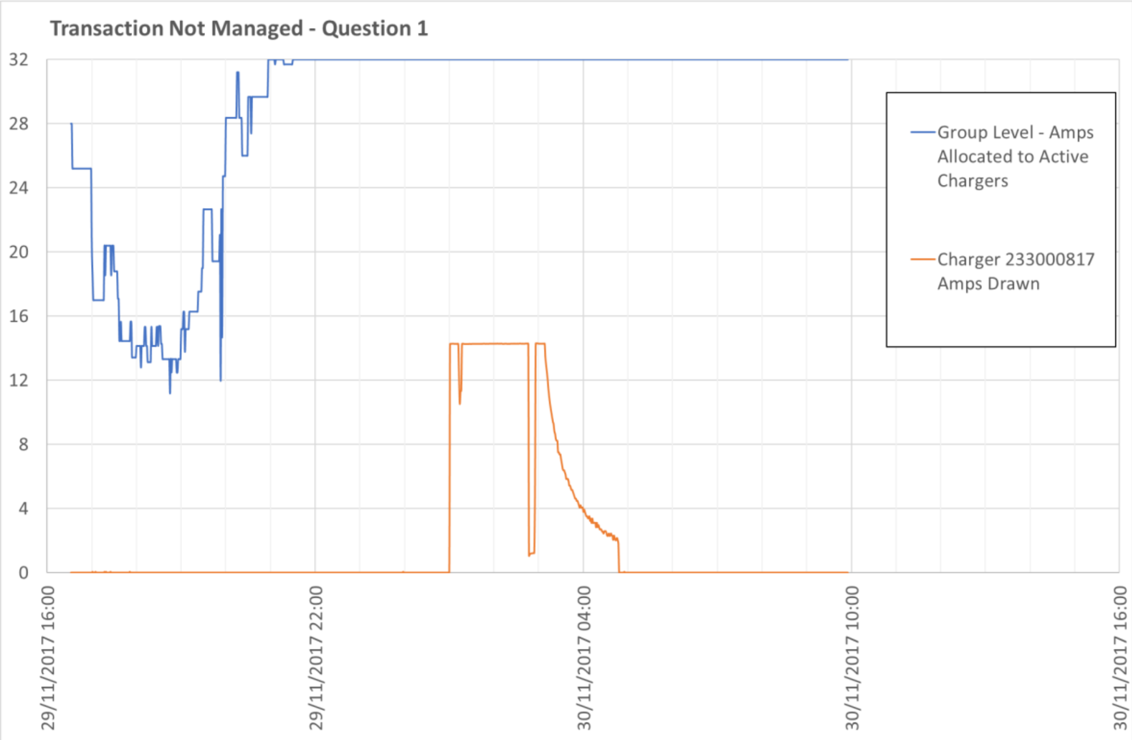


Decision Point	Explanation
1: Is $t_{start\ charge} \leq t_{end\ of\ management\ event}$?	Yes: the vehicle might have been charging during the management event No: charging did not overlap with the management period – e.g. vehicle 3 and 5 above.
2: Is a meter value available for this transaction where Amps Allocated = 32A?	The logic used to determine whether a vehicle was truly curtailed varies depending on the presence of an unconstrained meter value. This value is available in the vehicle 1, 2, 4 and 6 scenarios above.
3: Is Max Current Drawn for this transaction ≤ Minimum Allocated during management for this Transaction	Yes: the maximum current drawn (which will be when the vehicle was offered 32A) is, e.g. 15A compared a minimum allocated of 20A. The vehicle was not affected – e.g. the PHEV in the vehicle 1, 2, 4 and 6 scenarios. No: the vehicle may have been affected, unless the charging event was nearly over before management began – see Decision 4.
4: Is Current Drawn at $t_{start\ of\ management\ –\ 1}$ ≥ Max Current Drawn for this transaction – 2A	Yes: if the current drawn immediately prior to management beginning is still close to the maximum for the transaction then the curtailment is likely to have affected charging. No: the vehicle had begun to finish its charging session. These two scenarios are illustrated below:

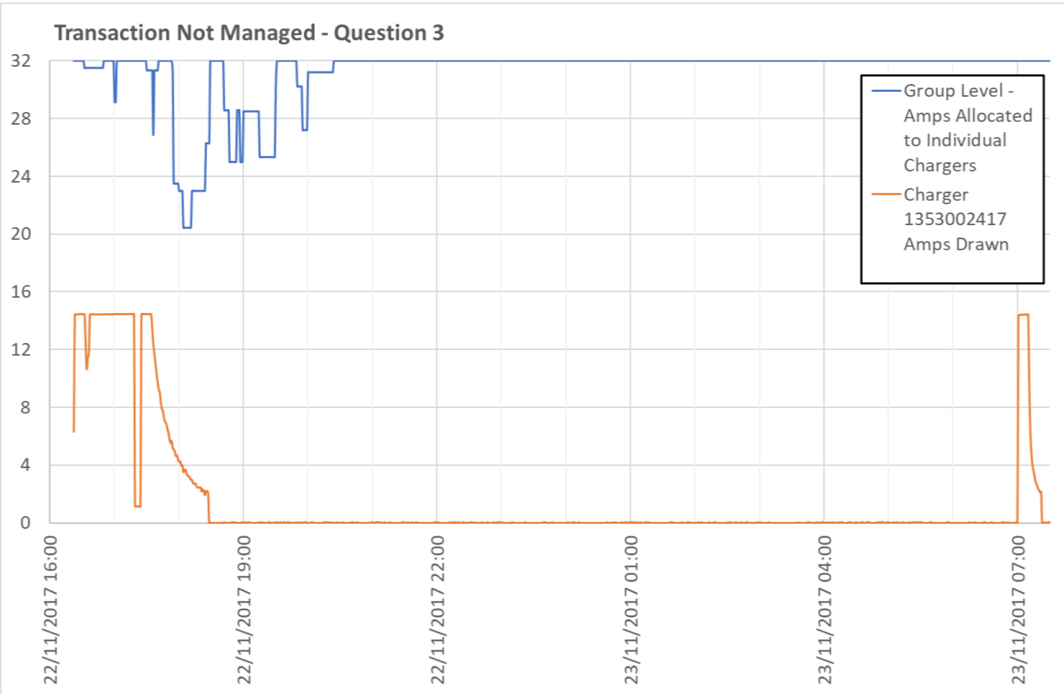
	
5: Is Max. Current Drawn for this Transaction ≤ Minimum Current Allocated for this Transaction -2A?	No: the current drawn was always less than the minimum available current so the transaction was not curtailed – e.g. the PHEV in the Vehicle 7 scenario. Yes: the vehicle was curtailed. A 2A threshold is applied to account for some vehicles which always draw slightly less than the allocation (e.g. a Kia Soul never draws more than 27A).

These queries can be applied to all transaction records (where meter values are available) to show whether each individual transaction experienced some curtailment. Further analysis is required to determine the level of the curtailment, e.g. using the concept of 'restrictiveness' discussed in earlier reports. This will be further developed in the next reporting period and applied to the database.

This logic has been applied to the database and some illustrative examples of 'managed' and 'unmanaged' transactions are shown below (all taken from the 29th November).

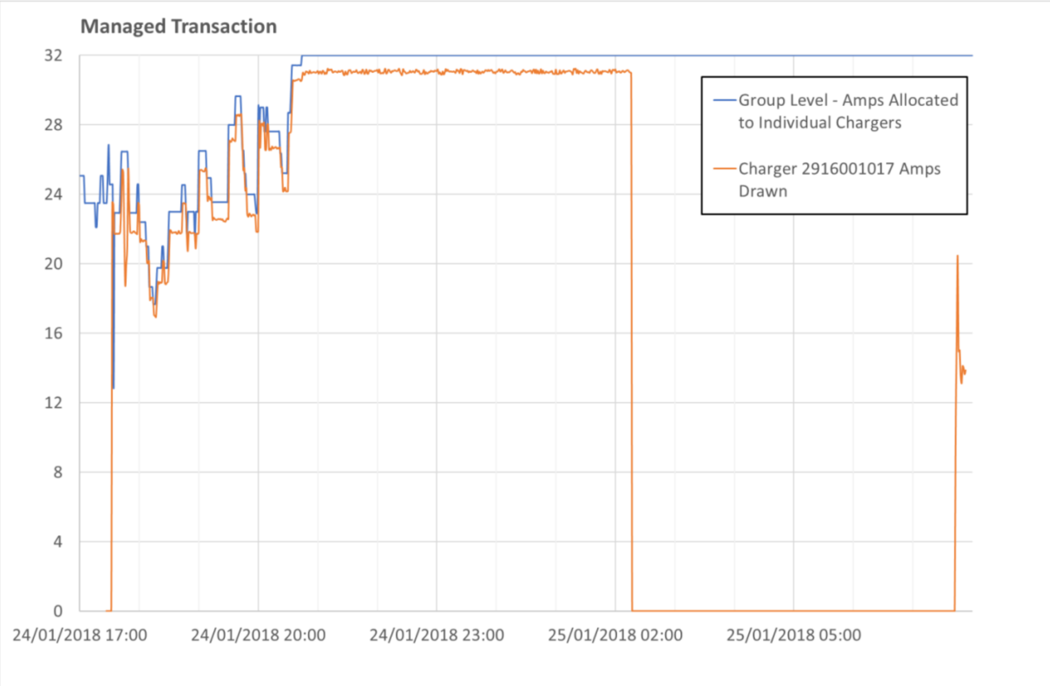


A vehicle was connected to the charger above at 16:32 on 29th November. However, it did not begin charging until 01:00 on 30th November, after the management event was over. This transaction was not managed.



This vehicle was connected at 16:22 on 22nd November. A management event began at 16:32 on this day. Although the vehicle charged throughout the management event it's maximum current drawn was less than the minimum allocated during the event. This transaction was not managed.

An example of a managed transaction is shown below.



The vehicle plugged in during the management event and roughly followed the allocation until the event ended just before 21:00. It continued to charge until the battery was full just after 02:00 on 25th January.

GreenFlux – Management of Individual Chargers

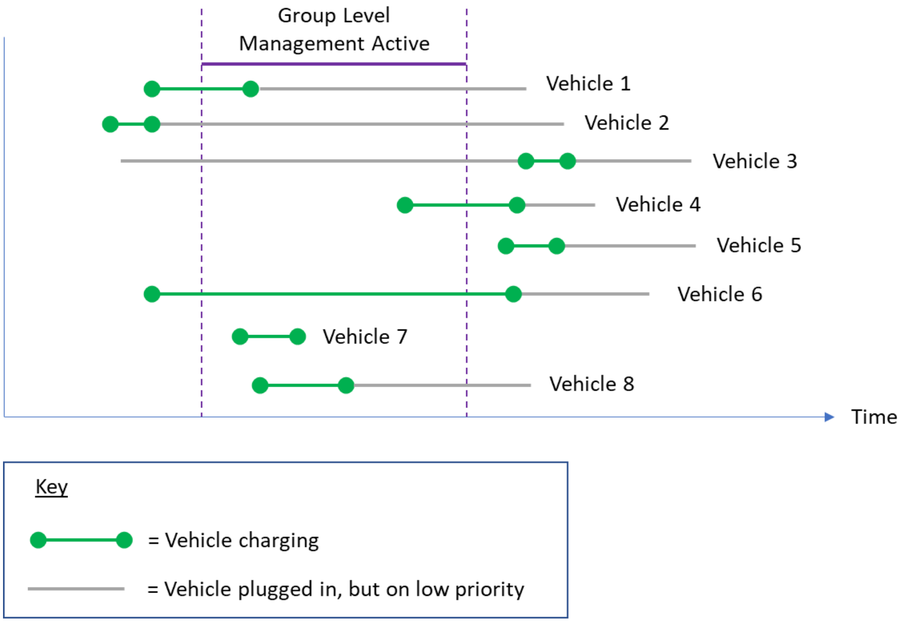
The logic to determine whether an individual charger is affected by demand management needs to be tailored based on both the data available, and the control algorithms used. The following section follows a similar logic to that described above but develops a suitable methodology for GreenFlux chargers.

In the absence of demand management, the GreenFlux system will allocate the following values to active chargers:

- 32A: allocated to a car which is in the main part of its charge cycle, if it draws more than 16A when it first plugs in.
- 16A: allocated to a car which is in the main part of its charge cycle, if it draws less than 16A when it first plugs in.
- 13A: allocated to both 32A and 16A vehicles once they have been transferred to low priority.

Low priority is activated when the current drawn by the vehicle (averaged over a 15-minute period) is less than 25% of the allocated value. For example, a car which has been allocated 32A but draws an average of 6A will be put onto low priority.

The scenarios used for the CrowdCharge individual level management query can be applied to GreenFlux. However, in this case the key period to study is between the start of charging and the time when the charger was switched onto low priority. "Curtailment" (i.e. a reduced allocation) after $t_{low\ priority}$ is a normal part of the algorithm and not as a result of demand management. These scenarios are shown below.



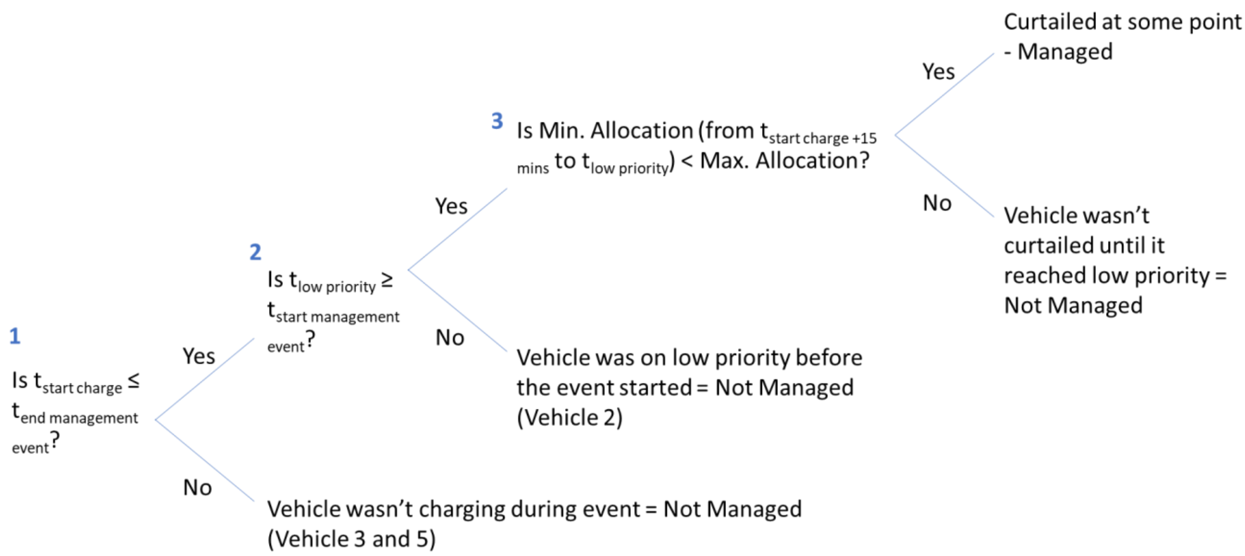
Vehicle Number	Description of Scenario
1	Vehicle began charging before management event began and was still charging (not on low priority) towards the start of the management period. It finished charging during the event. It was plugged in until after the event had finished.
2	Vehicle had started charging and was already on low priority before the event began. It was plugged in throughout the event.
3	The vehicle was plugged in before the event began but was on a timer and didn't draw any current until after the event had finished.
4	The vehicle was plugged in and began charging during the event. It continued to charge after the event had finished.
5	All activity was after the event finished
6	The vehicle began charging before the event started and continued afterwards.
7	Vehicle was plugged in briefly within the event. It was unplugged before it finished charging (before reaching low priority) and before the event finished.
8	The vehicle was plugged in during the event, reached low priority before the event was over and was left plugged in.

Several variables are required to determine whether an individual transaction was managed in the GreenFlux system:

- $t_{start\ management}$: the time the management event started. This is determined using allocation data supplied by GreenFlux, which is compared to the group demand limit.
- $t_{end\ management}$: the time the management event finished.

- $t_{start\ charge}$: the time the vehicle began charging. $t_{start\ charge\ +\ 15\ minutes}$ is also used within the logic – this is 15 minutes after the vehicle started charging. This is explained in more detail below.
- $t_{low\ priority}$: the time at which the charger entered low priority – i.e. the time when the average amps drawn in a 15-minute block was less than 25% of the amps allocated. $t_{low\ priority}$ must be after $t_{start\ charge}$ to account for transaction where a charger is put onto low priority shortly after the plug-in time due to use of a timer.
- Minimum allocation between $t_{start\ charge\ +\ 15\ minutes}$ and $t_{low\ priority}$. The minimum current allocated to the charger between these two time periods. When a vehicle first plugs in (unless on a timer) it will draw current for a minute. This meter value may be enough to trigger a 'start charge' point. However, the allocation data reports a zero allocation until the first time this charger is included within the algorithm calculations. For example, a vehicle which plugged in at 10:05 may report a $t_{start\ charge}$ of 10:05. The allocation data for 10:00 – 10:15 would be 0A, followed by either 16A or 32A at 10:15 – 10:30. The zero value for 10:00 – 10:15 is not indicative of management and so should be excluded from the logic – hence the use of $t_{start\ charge\ +\ 15\ minutes}$.
- Maximum allocation between $t_{start\ charge\ +\ 15\ minutes}$ and $t_{low\ priority}$. The maximum current allocated to the charger between these two time periods.

The logic to be used is shown by the decision tree below.



Decision Point	Explanation
1: Is $t_{start\ charge} \leq t_{end\ of\ management\ event}$?	Yes: the vehicle might have been charging during the management event No: charging did not overlap with the management period – e.g. vehicle 3 and 5 above.
2: Is $t_{low\ priority} \geq t_{start\ management\ event}$?	Yes: the vehicle reached low priority after the event started, so it may have been curtailed. No: the vehicle was already on low priority before the event started – e.g. vehicle 2 above.

3: Is the Min. Allocation (from $t_{start\ charge\ +15\ minutes}$ to $t_{low\ priority}$) < Max. Allocation?	Yes: at some point during the main part of the vehicles charge cycle its allocation was reduced, therefore it was managed. No: the allocation remained at the maximum value throughout the vehicles charge cycle and so it was unaffected by the management event.

This logic is currently being implemented in the Electric Nation database. It may be refined further where necessary.