WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

Electric Nation

WPD_NIA_013

Customer Trial Final Report

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Contents

Glossary

Term	Definition
BEV	Battery Electric Vehicle
BST	British Summer Time
DNO	Distribution Network Operator
ENA	Energy Networks Association
EV	Electric Vehicle
FAQ	Frequently Asked Question
GMT	Greenwich Mean Time
HH	Half Hour
LV	Low Voltage
MCB	Miniature Circuit Breaker
MPAN	Meter Point Administration Number
NAT	Network Assessment Tool
OCPP	Open Charge Point Protocol
OLEV	Office for Low Emission Vehicles
PEV	Plug-in Electric Vehicle
PHEV	Plug In Hybrid Electric Vehicle
PV	Photovoltaic
RCD	Residual Current Device
REX	Range Extender
SoC	State of Charge
ToU	Time of Use
UTC	Co-ordinated Universal Time
WPD	Western Power Distribution

1 Executive Summary

Plug-in Electric Vehicles (PEVs) are becoming increasingly common on UK roads. The growth in PEV ownership could cause challenges for the UK electricity industry if the adoption of electrified transport is widespread, especially if groups of neighbours buy PEVs, creating localised clusters. These clusters could create issues on low-voltage distribution networks – the networks that follow on from the National Grid transmission network and supply homes and businesses with electricity. Previous research by the My Electric Avenue project[1] showed that the impact of PEV charging may result in at least 30% of low-voltage networks requiring upgrades by 2050. This would represent a present-day cost of billions of pounds and inevitably create disruption, affecting all of us.

The objective of the Electric Nation project was to increase understanding of the impact of charging at home on electricity distribution networks by:

- Understanding how the impact will be altered by different types of vehicles with different sizes of battery that charge at different rates;
- Understanding how vehicle usage affects charging behaviour given diversity of charging rate and battery size;
- Evaluating the acceptability of smart charging systems to PEV owners and drivers; and
- Understanding the influence smart charging can have on charging behaviour.

The project recruited volunteers to participate in smart charging trials between January 2017 and December 2018. A total of 673 smart chargers were installed at participants' homes throughout WPD's licence areas. The trials included 40 different types, makes or models of PEV. For the duration of the project, PEV owners were given smart chargers that were capable of reporting when the vehicle was plugged in and when it was actively charging. Additionally, these chargers were also capable of receiving instructions to reduce or pause charging. The charging infrastructure was provided by two specialist companies: GreenFlux and CrowdCharge. These companies used different control algorithms and customer facing systems. Smart charging arrangements were subject to three different charging trials:

1. Management of charger demand without customer interaction;
2. Management of charger demand with customer interaction via an app/web portal, with no financial incentive linked to charging behaviour; and
3. Management of charger demand, customer interaction via an app/web portal, and financial rewards linked to the time of charging.

[1] http://myelectricavenue.info/

The charging trials captured huge quantities of data: over 130,000 charging events, covering nearly two million hours. In addition, EA Technology developed and deployed the Network Assessment Tool (NAT) software. The NAT uses data from the trial, alongside predictions of PEV uptake, to visualise the impact of PEVs across WPD's low voltage network and the efficacy of smart charging as a solution to avoid or delay the need for upgrading or replacing network assets.

The following key facts emerged from the charging trials:

- The most popular time to plug-in is between 17:00 and 19:00 on weekdays.
- During this period, typically 14% of the PEV population are charging their car.
- 75% of PEVs plugged in during this period (17:00 to 19:00) are charging for less than 50% of the time they are plugged in.
- The time of highest network demand aligns well with the time of the greatest available flexibility (i.e. early in the evening peak).
- The median charging frequency is between 3 and 4 times a week.
- A minority of participants (15%) charge at least once a day. This group is dominated by PHEV drivers. Other factors that affect charging frequency include the availability of other charging facilities (particularly at work) and weekly mileage.
- PEVs with smaller batteries (<25kWh) usually re-fill 40% to 80% of their battery capacity on each charge.
- PEVs with larger batteries (35kWh+) usually re-fill about 15% to 50% of their battery capacity on each charge.
- PEVs with smaller batteries (<25kWh) consume 1,800-1,900kWh per year.
- PEVs with larger batteries (35kWh+) consume about 3,500kWh per year.

In addition to technical evaluation, the trials included extensive behavioural analysis and evaluation of customer satisfaction to determine whether managed charging would be acceptable to customers. The trials tested various ways to incorporate customer preferences into the management regime and evaluated whether some form of incentive would be necessary to ensure management was effective.

The key findings of the charging trials were as follows:

1. Every EV charging at home is approximately equivalent (in energy terms) to adding a new home to a network
2. There is significant flexibility in charging – but without an incentive, unmanaged charging may cause demand to exceed network capacity in the evening.
3. Demand management is effective at managing the evening peak, and is acceptable to the majority of trial participants
4. Time of Use incentives are highly effective at moving demand away from the evening peak – especially when supported by smart charging and a suitable app that makes it simple for the user

In summary, this project found that smart charging can successfully manage the evening peak for the PEV uptake scenarios modelled. Smart charging strengthens the response to time-of-use incentives, while ensuring any negative consequences of mass uptake can be managed. Finally, data from smart chargers provides an excellent foundation on which plan for the necessary investment in PEV charging infrastructure.

2 Foreword

When launched, Electric Nation was the world's largest home smart charging trial with nearly 700 EV owners taking part in the 18-month trial. Between them, our trial participants provided data for more than 2 million hours of car charging data. Importantly they also gave us first-hand feedback on what it is like living with an EV in the real world and how they found the smart charging experience.

The results from Electric Nation have global significance and allow electricity distribution network planners to replace high level axioms with statistically robust facts. The lessons from this project will greatly assist local electricity networks in accommodating home Electric Vehicle (EV) charging whilst ensuring that drivers always have the ability to charge when they need to.

Electric Nation provides evidence that a combination of a well-designed EV tariff (offered by an energy supplier) coupled with flexible smart charging have the ability to provide the lowest-cost solution for customers whilst ensuring a high level of customer satisfaction. In short, it delivers a low-hassle customer experience at an acceptable cost.

Further, for network businesses like WPD it means that we have confidence in market-based solutions for moving demand away from peak hours, which in turn reduces the cost of upgrading our network for low carbon technologies such as EVs.

This project has set a new standard for understanding consumer attitudes toward smart charging. The project was delivered by a dedicated team drawn from WPD and our project partners EA Technology, DriveElectric, TRL and Lucy Gridkey. But in addition to recognising the hard work of the project team, I must also acknowledge the amazing support and enthusiasm (and sometimes patience) of our 673 drivers. Without them there would be no project conclusions.

WPD's electricity networks in the Midlands, South–West England and South Wales will not be a barrier to the rapid decarbonisation of the transport sector through vehicle electrification. We look forward to continuing our engagement with stakeholders and delivering innovative solutions to facilitate our nation's net zero aspirations.

Roger Hey, Western Power Distribution DSO Systems & Projects Manager

3 Introduction

3.1 Project Overview

Electric Nation (formerly CarConnect) was a Western Power Distribution (WPD) and Network Innovation Allowance funded project. WPD's collaboration partners in the project were EA Technology, DriveElectric, Lucy Electric GridKey and TRL. The project began in April 2016 and was completed in October 2019.

The project used three 'methods' to enable Distribution Network Operators (DNOs) to identify which parts of their network are likely to be affected by plug-in electric vehicle[2] (PEV) uptake. This included showing whether demand management/smart charging services are a cost-effective solution to avoiding or deferring reinforcement on vulnerable parts of their networks. The three methods used were:

- **Method 1 – Modelling:** an assessment was tool was developed to predict where PEV market penetration may cause network problems. The tool maps Low Voltage (LV) substations and their associated networks (underground cables and overhead lines making up feeders), customer meter points associated with each substation and feeder and known EV charge point installations. Firstly, the tool enables the assessment of all (non-meshed) LV networks in WPD's licence areas to identify those most likely to be affected by PEV penetration. Secondly, the tool enables more detailed assessment of those LV networks identified as being susceptible to PEV penetration to identify the level of uptake that would present a problem and trigger reinforcement. It also allows the assessment of demand management/smart charging as potential solutions to avoid or defer reinforcement. This method was delivered by EA Technology. The images below show example outputs from the completed NAT – at a wide area level, for an example LV network and finally showing the impact of a smart time of use tariff on the need for reinforcement of each feeder;

[2] In this report 'Plug-in Electric Vehicle' is used to mean a vehicle capable of travelling on electric power alone which is recharged by connection to a chargepoint. It covers plug-in hybrid, range extender and battery only vehicles. It does not include 'mild hybrids'.

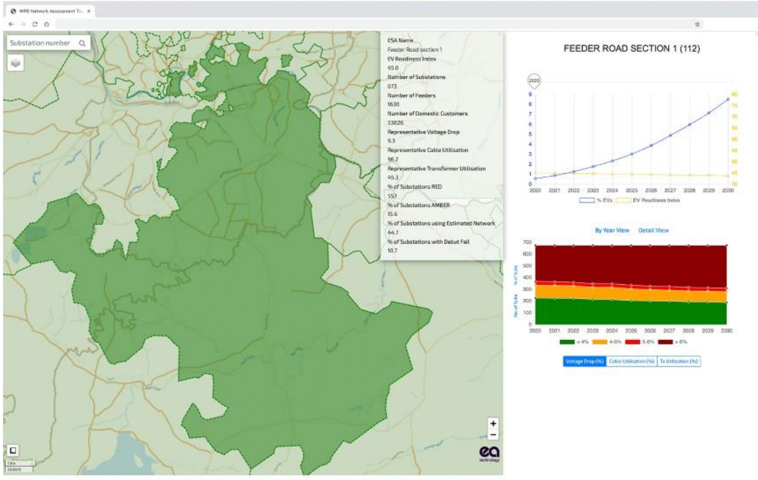


Figure 3-1: Example Output from the NAT - Energy Supply Area View

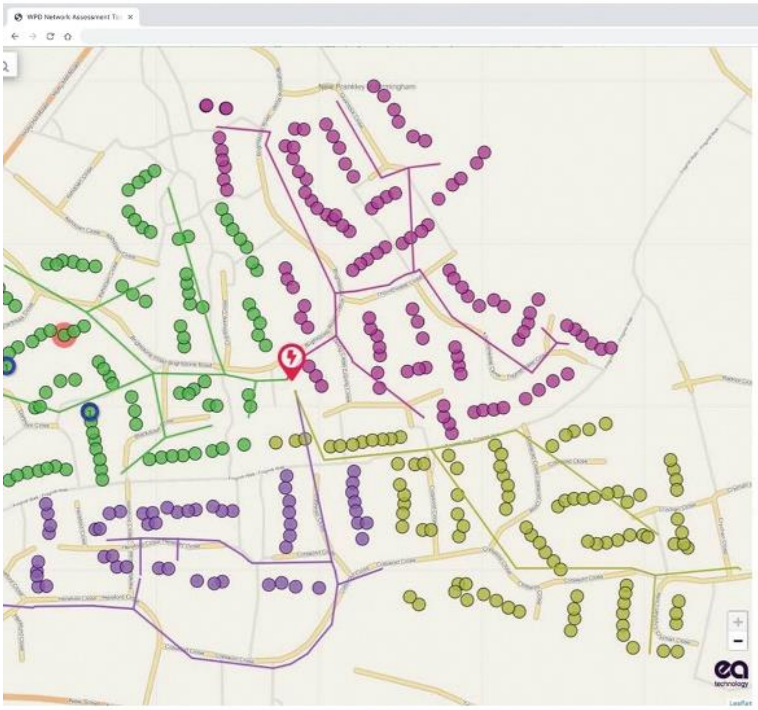


Figure 3-2: Example Output from the NAT - LV Feeders from a Substation

Calculate

Deploy Smart TOU Tariff

No TOU Tariff   Smart TOU Tariff Deployed

	Max Utilisation (%)		Max Volt Drop (%)	
	No Smart ToU Tariff	Smart ToU Tariff	No Smart ToU Tariff	Smart ToU Tariff
Substation	41.6	29.7	-	-
Feeder 10	100	51.6	19.9	5.5
Feeder 20	60	37.3	4	1.6
Feeder 30	96.4	62.1	6.3	3.9
Smart ToU Tariff successfully delays futher intervention				

Figure 3-3: Example Output from the NAT – Cable and Transformer Utilisation and Volt Drop (%), with and without a Smart Time of Use tariff

- **Method 2 – Monitoring:** an algorithm was developed which was designed to be deployed as part of an existing substation monitoring facility. It enables the effect of PEVs on an LV network to be retrospectively analysed and allows the measurable impact to be compared against the modelling tool output. This method was delivered by Lucy GridKey; and
- **Method 3 – Mitigation:** a mass-market customer trial was completed to prove the technical/economic viability of demand management/smart charging to avoid or defer network reinforcement. The customer trial also established whether such systems are acceptable to customers. The customer trial included a wide range of PEVs, with a range of battery sizes and charging rates to prove such systems can be deployed in a future with a diverse PEV market. This method was delivered by EA Technology and DriveElectric.

The outputs from Method 1 and 2 have been reported elsewhere[3], and this report focuses on Method 3 – the customer trial.

[3] Outputs of the Electric Nation project are available via the WPD Innovation webpage: https://www.westernpower.co.uk/projects/electric-nation Accessed August 2019.

3.1.1 The LV Issue

The uptake of PEVs is accelerating. There were 1,039 cars eligible for the plug-in car grant in the UK in Q3 2011. This figure has risen each year to a total of 157,181 cars in Q3 2018. This is a significant increase over a period of just seven years.

While the UK can generate enough electricity to charge these vehicles, charging more PEVs could have a significant impact on low voltage electricity distribution networks, especially if it coincides with existing peaks (e.g. after returning home from work in winter).

This trial is necessary to build an understanding of how different car battery sizes and speeds of charging may impact on this problem and also to trial a potential solution.

3.1.2 Smart Charging as a Potential Solution

By using smart chargers, a demand management provider could communicate with chargers to reduce the charging speed or pause charging. PEV owners will be able to choose their preferred charging regime and this information will be used to charge the car battery at a time or rate best suited to the network while still meeting the car owner's expectations.

Local network operators could make use of this type of service when local networks are stressed as a cost-effective and less disruptive alternative to replacing their equipment (e.g. cables in roads).

Data gathered from the trial will be used to help local network operators identify which parts of their network are likely to become stressed as PEV ownership increases. It will also develop a tool that will aid them to identify the most effective way to ensure the necessary amount of network capacity is available.

3.1.3 Introduction to the Trial

At the start of the project, the Electric Nation trial was the world's largest PEV trial. The aims of the trial were to:

- Expand current understanding of the demand impact of charging at home on electricity distribution networks, including a diverse range of electric vehicles - with charge rates of up to 7kW, and a range of battery sizes from 6kWh to 100kWh;
- Build a better understanding of how vehicle usage affects charging behaviour; and
- Evaluate the reliability and acceptability to PEV owners of smart charging systems and the influence these have on charging behaviour. This was designed to 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?

All participants in the trial were provided with a smart charger and associated communications equipment. These smart chargers sent data to, and could be controlled by, one of two demand management/smart charging providers – either GreenFlux[4] or CrowdCharge[5]. In total 673 smart chargers were installed, throughout WPD's four licence areas.

Figure 3-4 (below) shows a timeline of the customer trial element of Electric Nation.

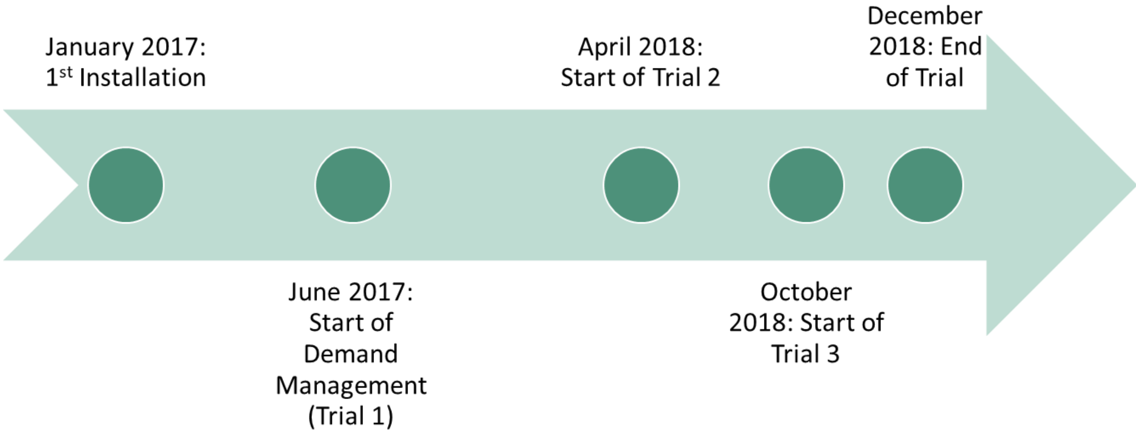


Figure 3-4: Trial Timeline

Smart charger installations began in January 2017 and were completed in July 2018. Demand management began for a small number of participants in June 2017 and continued until the end of the customer trial in December 2018. The demand management trials included three distinct phases:

- Trial 1: management of charger demand without customer interaction;
- Trial 2: management of charger demand with customer interaction via an app/web portal, with no financial incentive linked to charging behaviour; and
- Trial 3: management of charger demand, customer interaction via an app/web portal, and financial rewards linked to the time of charging.

Sections 10, 11, and 12 of this report gives further details of each element of the trial.

[4] https://www.greenflux.nl/en/ Accessed January 2019
[5] https://crowd-charge.com/ Accessed January 2019

3.2 Report Structure

This report provides detailed information on all aspects of the customer trial. It is structured as follows:

- Section 4: provides a description of each distinct phase of the trial, from the selection of smart charging and hardware providers, through recruitment and installations and each of the three trials. For each trial the algorithm used to control chargers is outlined, alongside an example of the testing carried out. Details of when each trial was active are also provided;
- Section 5: focuses on the communications technologies used to connect smart chargers to the smart charging providers (CrowdCharge and GreenFlux). The reliability of each solution is shown alongside details of the issues that occurred during the trial;
- Section 6: describes the different types of data collected including both data from the smart chargers and the customer research completed during the trial;
- Section 7: uses data from the customer research surveys to provide an overview of the participants in Electric Nation including demographic data and household composition, use of the vehicle, early adopter status and motivation for purchasing a PEV;
- Section 8: presents the results from the trial in relation to charging behaviour including; plug-in and start of charging time, charging frequency, annual energy consumption, proportion of the battery capacity refilled during charge events, use of timers, flexibility and profiles of total demand for groups of PEVs;
- Section 9: shows the results of the baseline survey (carried out before participants moved into demand management) and reports on how many participants took part in the demand management trials;
- Section 10: presents results from first demand management trial, when charging demand was managed without a means for participants to interact with the smart charging systems. These results include the amount of management which occurred (both at a group and individual level) and results of the customer research completed at the end of Trial 1;
- Section 11: shows the results of the second demand management trial, once apps had been introduced for participants to use to interact with the smart charging system. It shows how often management occurred, to what extent participants experienced management, use of the apps and the results of the customer research surveys undertaken at the end of Trial 2.
- Section 12: sets out the results of Trial 3, where participants were exposed to a time of use based incentive scheme in order to show to what extent this would change their charging behaviour. This section shows the resulting demand profiles and the extent to which participants changed their charging behaviour (including via use of the apps). The results of the customer research surveys undertaken at the end of Trial 3 are also shown.

- Section 13: describes the results of the final survey which participants completed after the trial was over. This survey included understanding participants attitudes to PEVs in general, and each of the three trials.
- Section 14: sets out the key conclusions from all parts of the project.
- Section 15: describes WPD's next steps in preparing their networks for the uptake of electric vehicles.
- Section 16: provides contact details for any enquiries in relation this report, or the wider Electric Nation project.

Several appendices are included at the end of the document. These are used to show how profiles of available capacity for groups of EV chargers were derived, and also contents of the all customer surveys which were completed by participants as part of the trial.

4 The Customer Trial

This section outlines each element of the customer trial, including the selection of smart charging and equipment suppliers and details of each part of the trial.

4.1 Introduction – what, who, when?

The elements of the customer trial are outlined in the diagram below, including the timescales and details of the project partners involved.

Selection of Smart Charging Providers	• Who: EA Technology • When: During project development (prior to May 2016)
Selection of Hardware	• Who: EA Technology and CrowdCharge/GreenFlux (sub-contractors) • When: May to August 2016
Test System Design and Build	• Who: EA Technology and The Tech Factory and electrical sub-contractors • When: June to September 2016
Development of Installation Procedures	• Who: EA Technology, DriveElectric, The Tech Factory • When: October to December 2016
Pilot Installations	• Who: EA Technology, DriveElectric, The Tech Factory, installation sub-contractors • When: November and December 2016
Recruitment of Participants and Installations	• Who: DriveElectric, installation sub-contractors • When: September 2016 to May 2018
Demand Management Trial 1	• Who: CrowdCharge, GreenFlux and EA Technology • When: June 2017 to May 2018 (GreenFlux), June 2017 to July 2018 (CrowdCharge)
Demand Management Trial 2	• Who: CrowdCharge, GreenFlux and EA Technology • When: July to October 2018 (CrowdCharge), May to September 2018 (GreenFlux)
Demand Management Trial 3	• Who: CrowdCharge, GreenFlux and EA Technology • When: November to December 2018 (CrowdCharge), October to December 2018 (GreenFlux)
Project Learning Dissemination	• Who: EA Technology, DriveElectric, WPD • When: Throughout the project

Figure 4-1: Elements of the Electric Nation Trial

The sub-sections below describe each of these activities in more detail, separated for CrowdCharge and GreenFlux where applicable.

4.2 Selection of Smart Charging Providers

Two smart charging suppliers were included within the project from its inception:

- CrowdCharge: a start-up company under the same ownership as DriveElectric. CrowdCharge were developing a smart charging system based on an EV charger controller and back office system and had been involved in the inception of the project with WPD. CrowdCharge were contracted as a supplier to the project; and
- GreenFlux: a Dutch company with a proven track record of similar smart charging projects in Europe (Holland and Germany). GreenFlux were invited to become suppliers to the project to bring their proven system and international experience to the trial.

This approach allowed two smart charging systems to be tested side by side, though no direct comparison of system performance was intended, and mitigated the risks associated with using a single supplier for the customer trial.

4.3 Selection of Hardware

During the inception of the project it was intended that the customer trial would utilise a range of EV chargers, to mitigate the risk of poor performance or failure of this key component of the smart charging system. As smart chargers were not required for domestic charging in the UK (or elsewhere in Europe as far as is known) at the time the project started, the project had to seek suppliers of commercial charging points, where the smart functionality is required for user access control and billing purposes (and in some cases, charging demand control).

However, at the outset of the project it rapidly became clear that the choice of suppliers of such smart chargers was constrained, primarily by the requirement that the smart chargers to be used in the trial had to be OCPP (Open Charge Point Protocol) 1.6 compliant[6]. At the start of the trial version 1.6 of the standard was the minimum version that supported smart charging. Version 2.0 is the current version at the time of writing. The protocol allowed either the CrowdCharge or GreenFlux back office systems to communicate with, and control, chargers as required by the customer trial (i.e. to record and transmit data and to accept charge management instructions).

The vast majority of UK based, and many European charge point manufacturers/suppliers contacted either had no smart charging capability or those that did, did not meet the OCPP 1.6 requirement, either because they were using an older version of OCPP or a proprietary communication protocol.

[6] See www.openchargealliance.org Accessed August 2019.

A secondary issue then arose: OCPP has a certain amount of flexibility in the structure of commands and messages. This leads to individual manufacturers adapting the protocol (syntax of commands/messages) to, perhaps, simplify communications with their proprietary back offices (say for billing purposes). Both CrowdCharge and GreenFlux had their own interpretation of OCPP 1.6, which would require modification for the purposes of the trials. For example, collection and recording of periodic meter values, which are not normally stored for commercial billing purposes was required for the purposes of the trial and had to be enabled by both CrowdCharge and GreenFlux through OCPP.

This ultimately led to CrowdCharge and GreenFlux recommending a manufacturer and model of charger that they were confident would provide the functionality and reliability required for the customer trial:

- CrowdCharge recommended the APT eVolt EV-WBC-32-Smart charger; and
- GreenFlux recommended the Alfen ICU Eve-Mini charger.

In parallel with selection of the smart chargers, communications methods between the chargers and back office systems had to be selected.

From the project inception the preferred communications method was to utilise participants' home internet connection as the primary communication method. This offered the advantage of being effectively free. In a business as usual deployment the cost of communications and data would form part of the cost of smart charging solutions, and so affect the economic viability of the solution. Using home broadband (if it proved reliable) would therefore be advantageous. Consideration was also made of the fact that most householders would be unlikely to welcome a hard-wired communication installation, involving running an ethernet cable from their charger through their house to their broadband internet router, which was unlikely to be conveniently located close to the charger location. This is opposed to householders' acceptance of satellite and cable TV cables being run through their home, where the drilling of holes, etc. is ignored as the benefit to the householder (i.e. provision of satellite/cable TV) is large. For smart charging it was thought most would be reluctant to allow hard wired connection as smart charging is not so clearly beneficial and there was the possibility that trial participants might want equipment removed at the end of the trial, which could have incurred substantial reparation costs.

The project therefore decided that a wireless connection method was desirable for the project's purposes. The project searched for wireless "Internet of Things" connection methods. At the time of project start-up, the only commercially available offers for such services were mobile (phone system) data modems, either using the public mobile phone network or privately managed networks such as SigFox (which do not have universal coverage of the UK, tending to concentrate on high population density areas). Eventually, CrowdCharge's charger controller manufacturer, The Tech Factory[7], who also supply event Wi-Fi services and have experience in unusual wireless data challenges, identified a solution – a secure Wi-Fi bridge. Further details of the Wi-Fi bridge are given in Section 5.1.

Three different communications methods were used as part of the project:

- Wi-Fi bridge: 549 of 673 installations (82%);
- Hardwired ethernet cable: 89 of 673 (13%); and
- Power Line Carrier Wi-Fi extension units: 31 of 673 (5%).

The GreenFlux system offered an alternative, backup communication method in the form of mobile phone data communications. The Alfen ICU chargers have a mobile data modem built in. The project decided to fit all GreenFlux connected chargers with a mobile data SIM card as a back-up communications option. The chargers were configured to utilise the ethernet/broadband internet communications option where available, switching over to mobile data only when the broadband internet connection was lost. During installations four of the GreenFlux installations were so problematic with regards to connection to the home broadband internet system that the charger was set to mobile data connection permanently.

As previously mentioned, the CrowdCharge system made use of a separate charger controller, designed and manufactured by CrowdCharge. This controller was connected to the charger ethernet port. The controller consisted of a microcomputer board (the controller) and a communications board (ethernet switch and Wi-Fi transmitter). The controller unit interpreted commands received from the CrowdCharge back-office and transmitted them on the charger. It also gathered data from the charger (plug in/out events and meter readings) and transmitted them to the CrowdCharge back-office. This controller did not have a mobile data communication capability and relied solely on the home broadband internet connection.

Further details of the communications method used in the project, their performance and issues experienced are given in Section 5 of this report.

[7] https://rugby-it-support.com/ Accessed August 2019.

4.4 Test System Design and Build

The smart charging algorithms developed by GreenFlux and CrowdCharge were to be deployed into the customer trial, with any errors potentially inconveniencing trial participants and negatively affecting their acceptance of smart charging. A test system was therefore required, which would enable the project team to test each smart charging algorithm to ensure it operated as specified and treated all participants fairly. This also enabled the response of various vehicles to smart charging to be tested (i.e. having the charge rate decreased, increased or stopped and started).

The test system consisted of twelve chargers (six APT eVolt, controlled by CrowdCharge and six Alfen ICU, controlled by GreenFlux) with additional monitoring equipment. The test system had two main purposes, and was used throughout the project:

1. Testing the response of individual cars to changes in the current available (as the chargers were managed) and pauses in charging. This was to confirm that all the vehicles which may take part in a smart charging event would follow the current made available by the charger and return to full rate charging when the constraint was removed; and
2. Confirming the behaviour of smart charging algorithms over multiple cycles to show that current was allocated fairly between chargers (no individual customer was penalised more in a demand management event than others) and that DNO network capacity limits were not breached.

CrowdCharge and GreenFlux provided web portals via which the behaviour of individual chargers during tests could be monitored. Throughout the project EA Technology worked with CrowdCharge and GreenFlux to design, set-up, run and analyse the tests necessary to approve each smart charging algorithm in turn.

In additional to monitoring the behaviour of chargers via web portals, the test system included additional independent monitoring which showed the three key variables for management of charging:

1. The plug-in status of the charger - no car connected, car connected but not charging and car connected & car charging;
2. The current made available from the charger; and
3. The current drawn by the car.

This was achieved via interpretation of the pilot signal from the charger[8] and a current transformer installed around the live feed to the car. This independent monitoring was used during the approval of the algorithms for Trial 1. After this the accuracy of the web portals had been proven.

[8] For details of the pilot pin signal and its use, see Annex A of BS EN 61851-1:2011. Electric Vehicle Conductive Charging System.

A labelled photograph of one of the six 'panels' which made up the test system is shown below (Figure 4-2). Each charger within the test system was connected to both the power supply and an Ethernet cable. These Ethernet cables were fed back to a control room where they were linked to a controller (for CrowdCharge) or directly to a router (for GreenFlux). This mimicked the way that communications were connected in trial participants' homes.

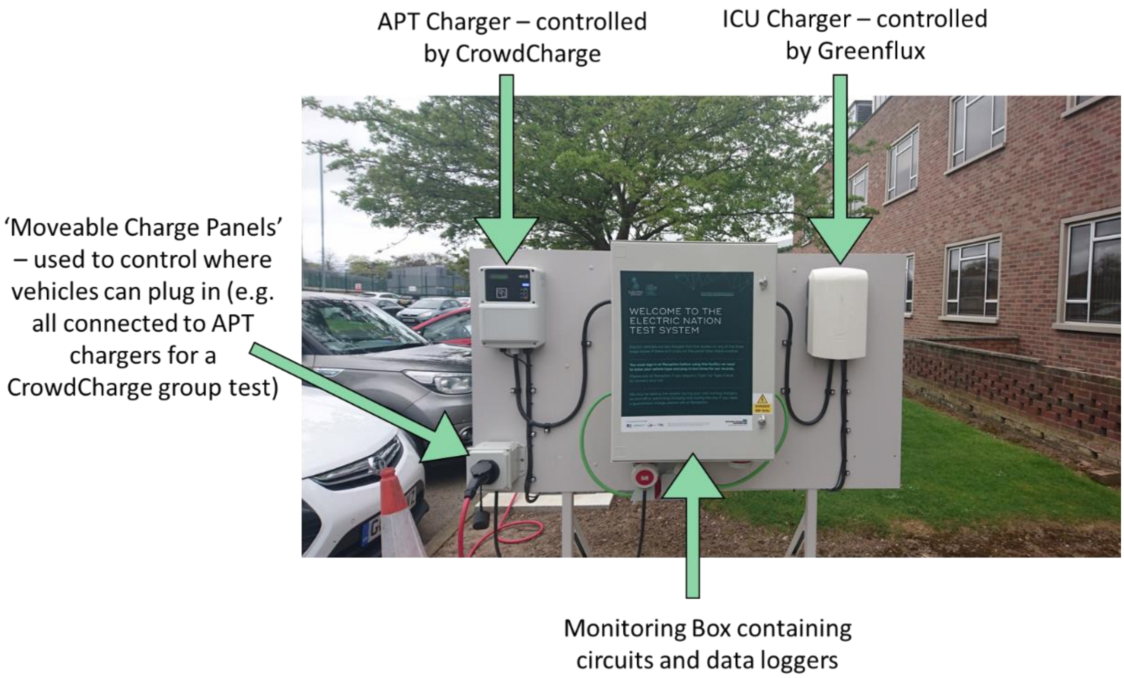


Figure 4-2: Electric Nation Test System

4.5 Development of Installations Procedures and Installer Training

Procedures were devised in order to achieve a consistent high standard for all installations across the project. In addition, a 'pre-installation' self-survey was developed to support participants to collect and share the information necessary for the installers to determine if a 'standard' installation could be completed (e.g. unlikely to be a looped supply, no difficult/long cable runs, sufficient capacity available on the cut-out fuse etc.).

The installation procedures were particularly valuable for the installation of communications equipment, as this was an area outside of the installation partners' prior experience. The procedures also required various pieces of information to be collected for each installation and photographs to be taken and provided to DriveElectric, including the method used to connect the smart charger to the internet (hard-wired, Wi-Fi bridge etc., further details are provided in Section 5.

The procedures were refined further following the pilot installations and were shared with all the installers at a 'training day' held in the Midlands on 13th December 2016. The event covered the following topics:

- Background to the project and explanation of smart charging;
- Overview of system specification (from back offices to smart chargers);
- Health and safety for installations;
- Order and installation procedures;
- Communications installation, commissioning and troubleshooting;
- WPD processes for obtaining a cut-out fuse upgrade and providing notifications of EV charger installations; and
- OLEV HomeCharge scheme application process.

4.6 Pilots

During late 2016, once draft installation procedures had been developed, a series of ‘pilot’ charger installations were arranged. The purpose of these installations was to train installers in the installation and commissioning of the communications equipment, further test this equipment in a variety of homes (e.g. different internet providers etc.) and test the procedures which had been developed.

Ten pilot installations were completed – mainly at the homes of people connected to EA Technology or DriveElectric. Pilot participants were aware that the installation may take longer to complete than a standard installation, and their connection to the project ensured their co-operation.

Following the installation of their smart charger the pilot participants were involved in testing the process of sharing details between DriveElectric and Impact[9], in order to complete the recruitment survey. Due to the size of group of pilot participants demand management was not tested with this group, as groups of five chargers had already been tested using the rig described above. A subset of pilot installations was used to investigate communications problems during the project.

[9] The customer research supplier for the project. More details are given in Section 6.8.

4.7 Recruitment of Participants and Installations

4.7.1 Project Promotion and Trial Participant Recruitment

The responsibility for the recruitment of participants to the Electric Nation project was split between DriveElectric and EA Technology as outlined below:

- DriveElectric:
    - All customer facing activities including attending events to aid recruitment;
    - Receiving and responding to enquiries from potential participants received via email, phone or social media;
    - Processing the application forms and managing the recruitment process;
    - Managing the charge point survey and installation process; and
    - Handling reports from participants about charge point faults and managing the repair process.
- EA Technology:
    - Production of a project communications strategy;
    - Production and management of the project website;
    - Production of written material to support recruitment;
    - Production of project video; and
    - Management of the project Twitter account.

It was recognised that in order to recruit between 500 and 700 participants from within WPD's licence areas (the target at the outset of the trial) the project would require a strong project brand and presence. Following tender submissions, a specialist marketing consultant was employed to provide expert advice on the messaging strategy and to support recruitment and dissemination activity. This advice was especially useful and relevant when communicating with the motoring and EV press and the wider public. A communication strategy was created at the start of the project to help identify key project messages and audiences and to assist the selection of project branding and imagery.

The importance of communicating with PEV drivers at the point that they were purchasing a PEV and therefore organising having their home charger installed was identified as part of the marketing strategy. The project therefore used a targeted marketing approach:

- Project leaflets were distributed to car showrooms – this was especially fruitful for makes of PEV that didn't have links with a charge point manufacturer;
- DriveElectric arranged test drive events;
- DriveElectric posted information about the project on forums visited by PEV owners or potential PEV buyers;
- The project made links to cities participating in Go Ultra Low schemes within the WPD licence area so that it could be represented at events that they organised; and
- DriveElectric mentioned the project to their customers who were leasing a PEV.

The project was launched at the LCV2016 event in September 2016. The project had a stand within the exhibition space and delivered a presentation to the conference about the project. EV celebrity, Robert Llewellyn interviewed members of the project team to feature in his Fully Charged on-line series. Collaboration with the Fully Charged franchise throughout the recruitment stage of the project was very beneficial to the recruitment campaign and mentions in Fully Charged episodes would result in an increase in recruitment enquiries.

Figure 4-3: Project team member Gill Nowell being interviewed by Robert Llewellyn at LCV2016

Press releases were created focussing on the achievement of project milestones (e.g. the first installation) and attendance at events. This helped to keep the project in the motoring and EV press in order to ensure new PEV buyers were aware of the project at the time that they purchased their vehicles.

News items were regularly added to the project website. This was to ensure that the project website received a high ranking by search engines.

4.7.2 Recruitment Material

The project communication strategy identified the need to establish strong external project branding to assist recruitment. It was decided that externally the project would be easier to market if it was known as 'Electric Nation' rather than the initial project name 'CarConnect'. Branding and logos were created that were subsequently used on all project literature and materials.

ELECTRIC NATION
YOUR ELECTRIC VEHICLE YOUR SMART CHARGE

Figure 4-4: Electric Nation Logo

A photo and video shoot was held to create the imagery that would be necessary for the recruitment and dissemination campaign and would complement the project brand. Figure 4-5 shows some of the images.

Figure 4-5: A selection of images from the photo shoot

Prior to the start of the recruitment campaign a set of resources were created which would assist potential participants in making an informed decision about whether to enrol in the project. Literature was designed to answer the questions that potential participants may have at the various steps along the recruitment journey. The literature explained:

- Why the trial was needed;
- What the trial wanted to achieve;
- What the trial would do;
- How participants would benefit through participating in the trial;
- What trial participants would be expected to do; and
- The criteria required to participate in the trial.

This information was put in a number of formats including a short leaflet, an information pack, a brochure and on the project website. The table below shows a summary of the material developed to support recruitment to the Electric Nation project.

Table 4-1: Material produced to aid project recruitment

Resource	Purpose	Link
Website	To provide an easy way for potential participants to contact the project, to provide information about the project to potential participant, and to provide an information source for participants one they have signed up to the project. All recruitment leaflets were hosted on the website.	www.electricnation.org.uk/
Project video	To provide background information to potential participants and other interested parties	https://youtu.be/ZIWe5yKPIfA
Small leaflet	To provide background information to potential participants and other interested parties	https://www.westernpower.co.uk/innovation/projects/electric-nation
Brochure	To provide information to potential participants, allowing them to make an informed decision before they enrolled into it	https://www.westernpower.co.uk/innovation/projects/electric-nation
Information Pack	To provide information to potential participants, allowing them to make an informed decision before they enrolled into it	https://www.westernpower.co.uk/innovation/projects/electric-nation
Welcome Pack	To provide the information that participants may need once they had enrolled in the project.	https://www.westernpower.co.uk/innovation/projects/electric-nation
Twitter	To publicise the project and its attendance at recruitment events	@ElectricNation_ https://twitter.com/ElectricNation_
Pull up banner	For use at recruitment events to draw attention to the project	

4.7.3 Recruitment Events

DriveElectric attended the following events on behalf of the project to promote participation in the Electric Nation project:

Table 4-2: Events attended to aid recruitment

Event	Date
Go Ultra Low Nottingham event, Nottingham	October 2016
Smart Energy Marketplace, Exeter	March 2017
Clean Air Roadshow, Swansea	April 2017
Eco Day, INTU shopping centre, Milton Keynes	May 2017
Go Ultra Low Nottingham event, Nottingham	May 2017
Fully Charged Conference, London	June 2017
FUTURE CAR:DIF	July 2017
Ravesby Festival/ National DriveElectric Week, Lincoln	September 2017
Sustainable travel event, Milton Keynes	October 2017
Fully Charged, Silverstone	June 2018

DriveElectric also hosted PEV test drive events to aid recruitment. The test drive events conducted were as follows:

Table 4-3: Test drive events to aid recruitment

Event	Date
LCV	14th – 15th September 2016
WPD, Pegasus	17th November 2016
WPD, Derby	24th November 2016
WPD, Nottingham	1st December 2016
WPD, Bristol	6th December 2016
WPD, Grantham	15th December 2016
Testdrive the Future Oxford	18th June 2017
Reading University	27th June 2017
Little Wenlock	30th September 2017
LCNI	5th-7th December 2017

4.7.4 Use of Social Media to Aid Recruitment

Social media was actively used to aid recruitment to the project. Three approaches were taken:

- Posts about the project on EV forums: these posts by DriveElectric staff proved to be a very useful and direct way to bring the project to the attention of potential PEV drivers at the point that they were about to purchase a PEV. Care was taken that the post did not appear to be overtly 'selling'. The messages were especially powerful when unprompted testimonials from participants already engaged in the trial were added by customers;
- Social media video: a short video was created to be shared via social media such as Facebook; and
- Project Twitter account: this was used to publicise the project and its attendance at recruitment events. The account audience was increased by 'tagging' key influencers in the EV field.

4.7.5 PR to Aid Recruitment

Throughout the recruitment phase the project maintained a high profile to bring it to the attention of potential participants. Press releases were written in such a way as to ensure that they were accessible to a non-technical audience and that they would be picked up by the automotive and EV media. Some were geographically targeted to be picked up in areas covered by the project (i.e. WPD's licence areas) where there was already a high level of interest in PEVs. The following press releases were circulated during the recruitment phase of the project:

- New Electric Vehicle owners are invited to join the Electric Nation community – September 2016
- Installation of free smart chargers get underway for electric vehicle owners – February 2017
- More electric cars to be unveiled at the Geneva Motor Show, but are the UK's local electricity networks ready? – March 2017
- Free home smart chargers for Electric Vehicle owners are rolled out in Milton Keynes – March 2017
- Electric Nation promotes free smart chargers at Go Ultra Low Nottingham event – May 2017
- Nottingham gets its first Electric Vehicle home smart charger – June 2017
- Research shows that smart charging can be a solution to challenge of network demand from EV's – September 2017
- Electric Nation is on track to achieve its target of 700 trial participants – November 2018
- Final EV Smart Charger is installed for the fully recruited Electric Nation project – July 2018

All press releases were also hosted as news items on the project website. They were published in a number of motoring and EV publications, both in print and on-line. Members of the project team were also interviewed on a number of local radio stations in order to publicise the project.

4.7.6 Recruitment Process

The recruitment to installation process is outlined in the figure below.

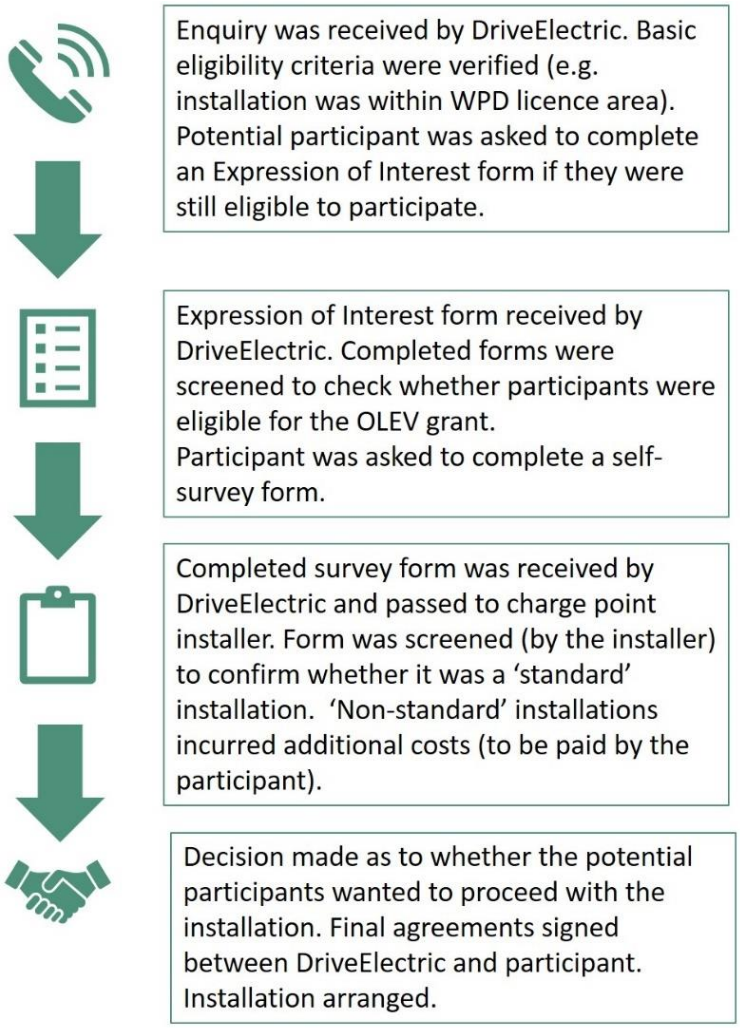


Figure 4-6: Overview of recruitment process

In order to aid the recruitment process, an eligibility checklist was put on the Electric Nation website to allow potential participants to find out whether they lived within a WPD licence area before they contacted DriveElectric. Despite this, many enquiries were received from people outside the area.

4.7.7 Recruitment Timeline

Recruitment for the project started in September 2016. The final installation was completed in July 2018. The chart below shows the correlation between project recruitment and installation.

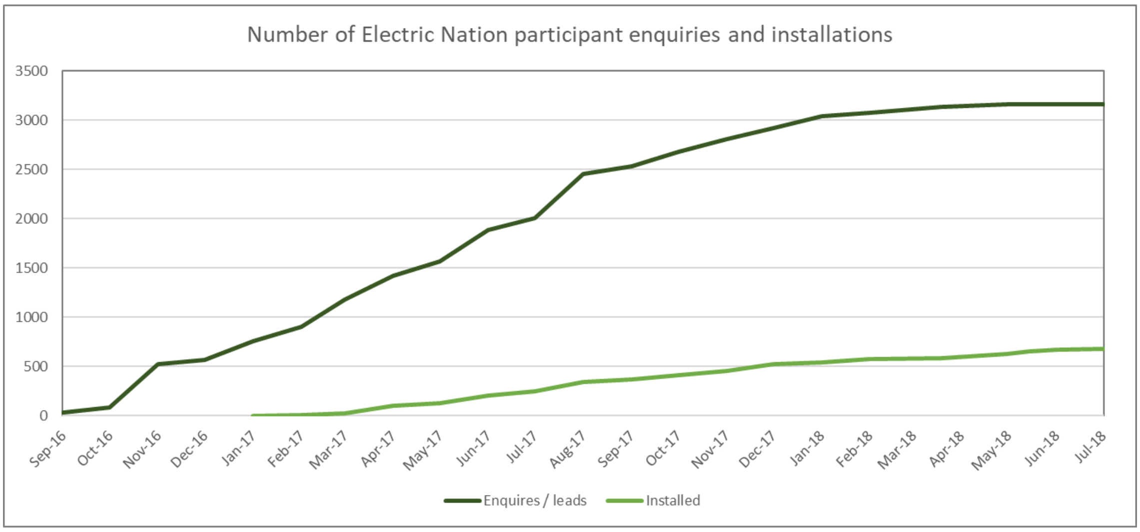


Figure 4-7: Recruitment timeline

The pre-project target for the number of installations was between 500 and 700. A decision was taken, supported by all project partners, to halt installations at 673. This decision was based on the lead time that some potential participants were experiencing when ordering a new PEV. Participants enquiring about the project were having to wait so long for the delivery of their PEV that if they received a project smart charger, they would only be able to participate in a small proportion of the project.

4.7.8 Problems Encountered

The following issues were encountered that made the recruitment process more challenging than anticipated:

- **A large number of enquiries from outside the WPD licence area:** to help reduce the number of enquiries from outside the WPD licence area, a postcode checker was put on the project website. However, this did not prevent DriveElectric receiving out of area enquiries throughout the recruitment campaign;
- **A long lead time between orders for PEVs being placed and cars being delivered:** this was especially relevant towards the end of the recruitment process when applications were being received from applicants who would not be receiving their vehicles for a number of months hence;
- **Low enquiry conversion rate:** many enquiries about project participation were from people who were not eligible to take part in the project or who subsequently decided that they didn't want to take part. It was therefore necessary to generate a considerable number of leads to achieve the number of installations required.

- **OLEV qualification:** part of the funding for the smart charger installations as part of the project came from the Office for Low Emission Vehicle's (OLEV) 'HomeCharge' scheme[10]. Project participants therefore had to be eligible for this grant. Specific OLEV qualification questions were required as part of DriveElectric's qualification call to determine eligibility for the grant. These criteria included off-street parking and no public walkways between the charger and vehicle. This helped to manage the customers expectation of survey approval and reduce the number of cancellations at the installer stage due to OLEV rejecting their application. As a result, this increased the workload per qualification call for DriveElectric;
- **Telematics trial recruitment :** CrowdCharge (one of the providers of smart charging) were intending to use vehicle telematics as part of their control system. This required a small dongle to be installed in the participant's vehicle which would track and inform CrowdCharge the state of charge (SoC) of the participant's vehicle. This helped ensure the participant had the charge they required and was a more accurate measurement then the participants entering the SoC via the CrowdCharge web-based app. The project found it challenging to recruit participants to take part in the telematics trial. This was not a project requirement (like the Baseline and Recruitment survey completion), so it was difficult for the recruitment team to increase the telematics participant figures. In total only 56 participants agreed to be included in this aspect of the trial.
- **Participants switching off their charger/home router:** during the early stage of installations it became clear that some participants were switching off their charger when not in use or switching off their broadband router overnight. This affected the comms uptime and subsequently the projects' ability to control the charger, which was a major issue. Therefore, DriveElectric had to reject applications during the qualification call if they admitted to turning off their router/charger, thus lowering the number of valid applications DriveElectric received.

[10] https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#electric-vehicle-homecharge-scheme Accessed August 2018

4.8 Trial 1

'Trial 1' refers to the first algorithms deployed by CrowdCharge and GreenFlux. During this phase of the trial chargers could be constrained (i.e. PEV charge rate/power reduced), but participants had no way of interacting with the system (e.g. they couldn't override management). It took place between June 2017 and May 2018 (GreenFlux) and July 2018 (CrowdCharge).

During all three demand management trials (1 -3) both demand management providers were provided with 'capacity profiles'. These profiles set out the maximum current which could be drawn by a group of chargers in 48 half-hour blocks, with a separate profile for weekdays and weekends. The profiles were developed using real, historical data for existing (non-PEV) demand on an HV feeder in the East Midlands. The 'spare' capacity (i.e. between the feeders rating and other demand) was then scaled depending on the number of vehicles in the group. Separate profiles were developed for each season, due to changes in underlying demand. An example of this is shown below:

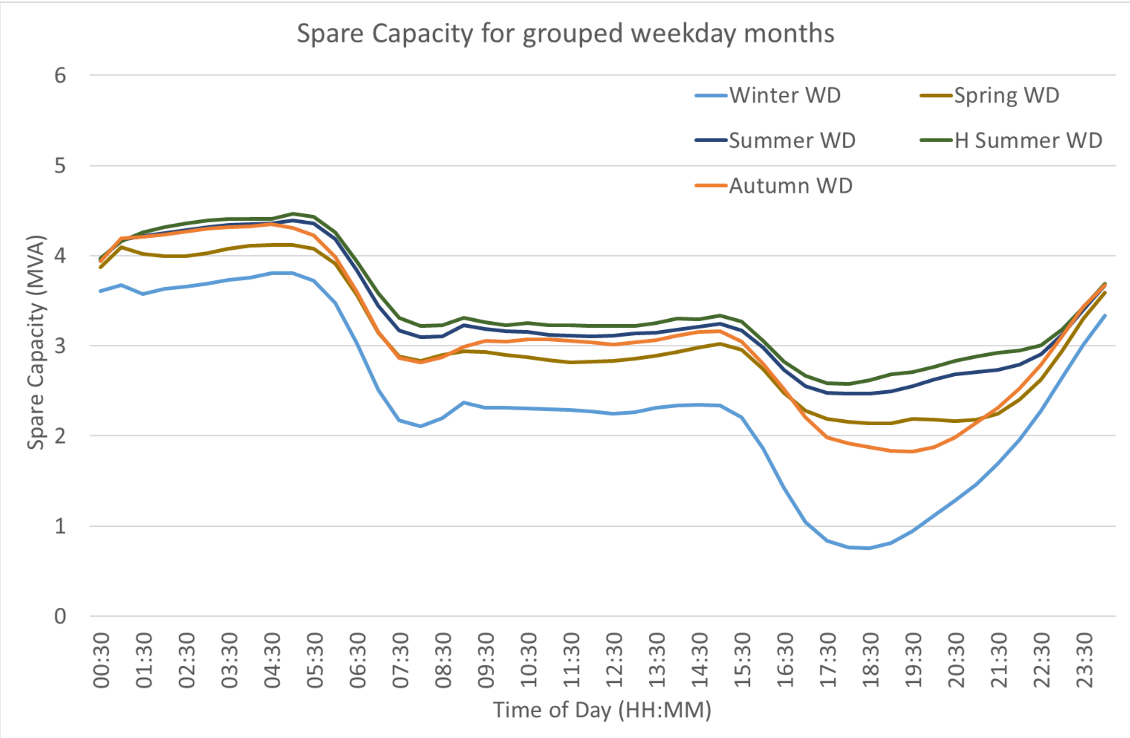


Figure 4-8: Spare network capacity – by season

The sub-sections below describe Trial 1 for CrowdCharge and GreenFlux separately.

4.8.1 CrowdCharge

Trial 1 was deployed to the first group of participants on 4th July 2017 and an increasing number of participants were involved until the start of Trial 2 on 13th June 2018.

Algorithm Description and Testing Example

Trial 1 was the simplest version of control applied during the project. Chargers were constrained when it was not possible to allocate 32A (their maximum rating) to each. When this occurred, the available current was shared equally amongst all active chargers.

For example, if the capacity limit was 300A, when nine chargers were active each was allocated 32A, as 9 x 32 = 288A (less than 300A). When a tenth charger became active it was not possible to allocate 32A to them all without breaching the limit, so each was allocated 30A (300 ÷ 10).

The first algorithm was tested using the Electric Nation test system at EA Technology's offices prior to being released into the field trial. An incremental process was used, stepping through tests of increasing complexity, as follows:

1. Single car, constant capacity limit;
2. Single car, varying capacity limit;
3. Group of chargers, constant capacity limit;
4. Group of chargers, varying capacity limit, all vehicles plugged in throughout the test;
5. Group of chargers, varying capacity limit, car unplugged during the test to confirm capacity is released to other vehicles; and
6. Behaviour during loss of communications.

Steps 3 – 6 are equivalent to the scenario in the main trial – i.e. CrowdCharge or GreenFlux were sent a time varying profile of available current and had to manage demand within this. It should be noted that the profiles used within this testing were not necessarily representative of available DNO capacity. They were designed to test the capability of the demand management/smart charging systems. The profiles used for testing set much lower values of available capacity and changed more quickly than may be necessary for DNO purposes.

An example test result is shown below, from Step 5. In this test a vehicle was unplugged partway through a demand management event. The purpose of this was to confirm that this released capacity to other PEVs. The vehicle was then plugged back in, and should have begun charging again, with the other vehicles allocated less current as the group limit was shared between a larger number of charge points. This was representative of real demand management events within the trial, as cars within the group began and ended charging events at different times. The results are shown in Figure 4-9.

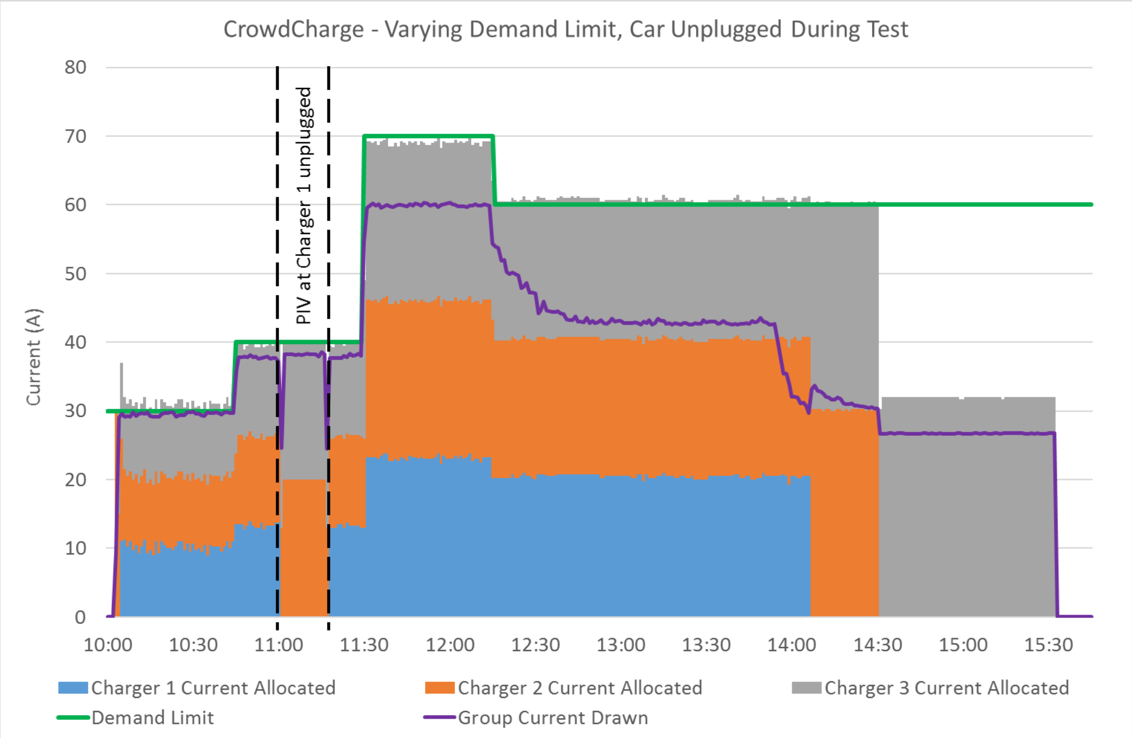


Figure 4-9: CrowdCharge Trial 1 Testing Example

The results showed the correct behaviour. The capacity limit increased at 10:45, and the current allocated to all three chargers increased. When the PEV at Charger 1 (blue area) was unplugged (11:00) the current allocated to the remaining two chargers increased. The PEV at Charger 1 was reconnected at 11:15 and the current allocated to Charger 2 and 3 decreased again.

The behaviour throughout the rest of the test was also as expected. From 12:15 the PEV at Charger 1 was reaching a high state of charge so the current drawn by the group decays. It finished charging at around 14:00, releasing capacity to Chargers 2 and 3.

Customer Trial

The first group of participants to be managed using CrowdCharge Algorithm 1 was established on 04/07/2017 and consisted of 10 participants. Groups of participants were moved into Trial 1 in batches between July 2017 and July 2018. 244 participants took part in Trial 1. Different seasonal profiles were applied, which varied the amount of current available. The process for deriving these profiles is described in Appendix 1.

The number of participants in routine management, and the seasonal profiles applied during Trial 1 is shown below (Figure 4-10). During the period from mid-June 2018 participants were moved from Trial 1 to Trial 2 in batches (see Section 11.1 below).

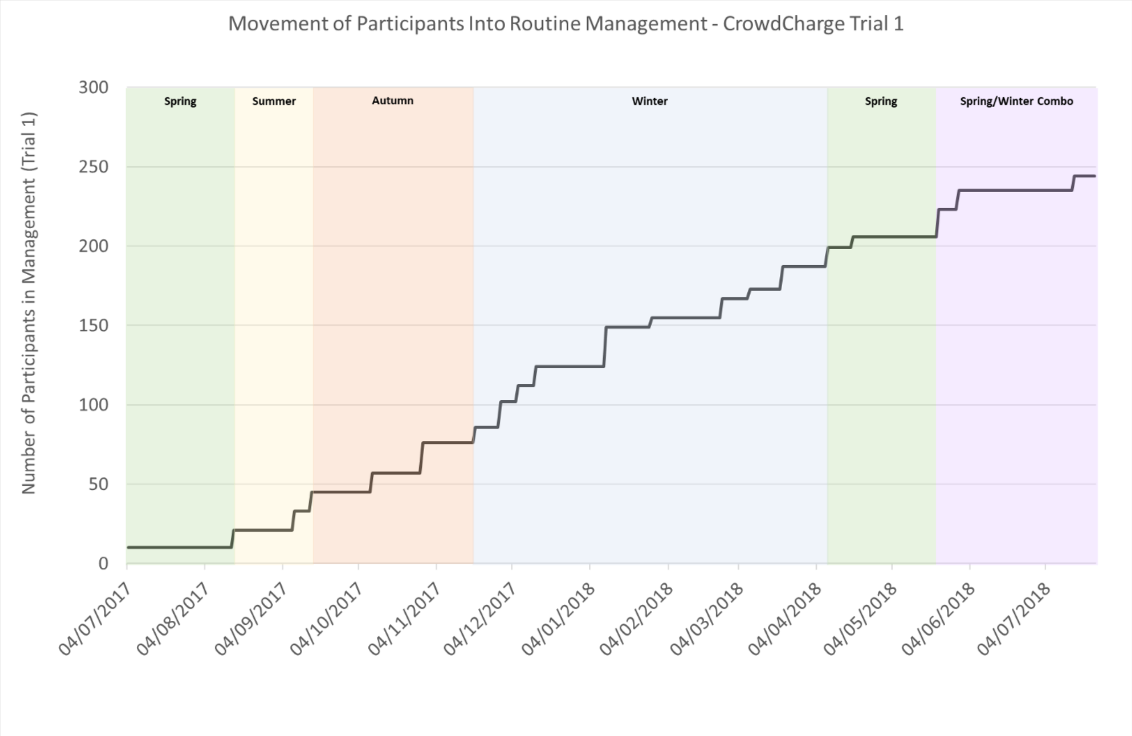


Figure 4-10: Participants in CrowdCharge Trial 1 and Seasonal Profiles

A trial survey was issued to these participants between January and April 2018, in order to assess their satisfaction with their charging arrangements at this stage in the trial. The questions used were identical to those in the baseline, so that changes in satisfaction could be reviewed. Analysis of these survey results can be found in Section 10.1.5.

Management was active regularly during Trial 1, over the evening peak period. Details of the amount of management which occurred at a group level, and which participants were affected by this is contained in Section 10.1 of this report.

4.8.2 GreenFlux

The GreenFlux trial 1 algorithm was the simplest of the GreenFlux systems deployed and did not allow for interaction between the participants and the system (e.g. they could not override a demand management event). It was deployed to the first group of participants on 11th July 2017 and ran until participants began to be transferred to Trial 2 from 3rd April 2018 onwards.

Algorithm Description and Testing Example

Trial 1 was the simplest version of control applied during the project. In each charge session GreenFlux determined whether the vehicle in question was rated at 32 or 16A. Those rated at 16A were then only supplied 16A (thus making the most efficient use of available capacity). Chargers were constrained when it was not possible to allocate 32A (or 16A, where the vehicle is rated at 16A) to each. When this occurred, chargers were constrained in turn to ensure that the total current allocated was less than the available amount. The constraint was shared in a fair manner and periodically reviewed and revised, so that no charger was constrained more than the others.

The first algorithm was tested using the Electric Nation rig at EA Technology's offices prior to being released into the field trial, following the same incremental process as described for CrowdCharge (above).

An example test result is shown below, from Step 5. In this test a vehicle was unplugged partway through a demand management event. Three cars were used during the test (two nominal 7kW (32A), one nominal 3.5kW (16A)). The resulting behaviour is shown below.

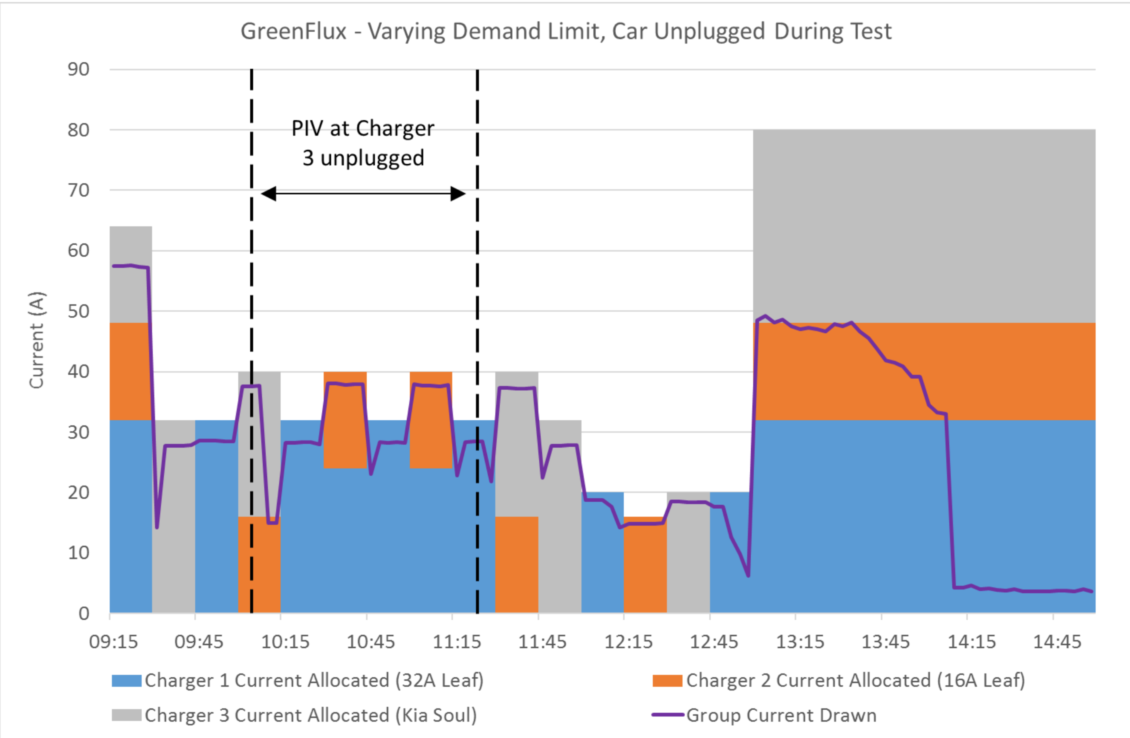


Figure 4-11: GreenFlux Trial 1 Testing Example

The key points to note from this test are:

- When a charger was connected to a nominally 3.5kW (16A) car (Charger 2 in this example, orange area) it was only ever allocated a maximum of 16A. This is due to the algorithm configuration development completed by GreenFlux during the first year of the project;
- Shortly after the car at Charger 3 was disconnected (around 10:05) it was no longer allocated any current, allowing Chargers 1 and 2 to share the available current; and
- After the car at Charger 3 was reconnected (around 11:20) it began to be allocated current again.

These results therefore demonstrated the current allocation algorithm performing correctly. Further examples of the testing of Algorithm 1, for both CrowdCharge and GreenFlux were published during the project[11].

Customer Trial

The first group of participants to be managed using GreenFlux Algorithm 1 was established on 11th July 2017 and consisted of 16 participants. Groups of participants were moved into Trial 1 in batches between July 2017 and April 2018. 241 participants took part in Trial 1. Different seasonal profiles were applied, which varied the amount of current available. The process for deriving these profiles is described in Appendix 1. The number of participants in routine management, and the seasonal profiles applied during Trial 1 is shown below. During the period from mid-April 2018 participants were moved from Trial 1 to Trial 2 in batches (see Section 11.2 below).

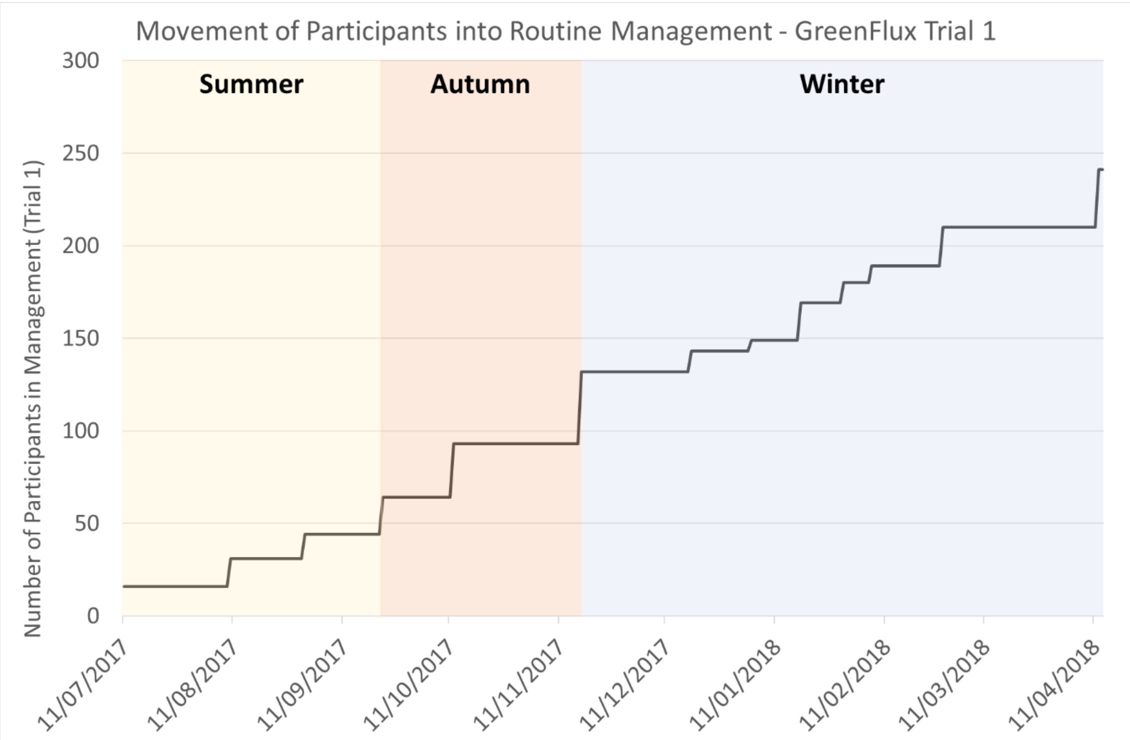


Figure 4-12: Participants in GreenFlux Trial 1 and Seasonal Profiles

A trial survey was issued to these participants between January and April 2018, in order to assess their satisfaction with their charging arrangements at this stage in the trial. The questions used were identical to those in the baseline survey (completed before management began), so that changes in satisfaction could be reviewed. Analysis of these survey results can be found in Section 10.2.5.

[11] Algorithm Development and Testing Report. April 2017. Available from: https://www.westernpower.co.uk/downloads/2242

Management was active regularly during Trial 1, over the evening peak period. Details of the amount of management which occurred at a group level, and which participants were affected by this is contained in Section of this report.

4.9 Trial 2

In Trial 2, both demand control system providers introduced ways in which the participants could interact with the smart charging system, which would allow their charging needs to be prioritised when demand management was required. These systems were developed during spring 2018, tested on the Electric Nation test rig and then rolled out to the customer trial. The sections below describe the updates made by CrowdCharge and GreenFlux, and the process used to roll-out the update to participants.

4.9.1 CrowdCharge

The second and third iterations of the CrowdCharge system used a web-based journey planner ‘app’.

Algorithm Description and Testing Example

Algorithm 1 (described above) allocated the same current to all active chargers when management was required. No distinction was made between 32A or 16A rated vehicles, and no information from users was used to influence the allocation. The web-based journey planning app aimed to estimate the energy requirements of drivers, so that their charging sessions could be prioritised when necessary. Participants could enter three different types of information via the web-based app:

- State of charge of the vehicle – app users were prompted to enter this information each time they opened the app;
- Regular journeys – e.g. a Monday to Friday commute. For both journey types participants entered a start and end point (address), and a departure time. If the participant wanted to make a return trip without charging, then they needed to enter a separate return journey; and
- One off journey – details as above, but for a single date and time of departure.

Chargers would continue to be allocated 32A (or 16A where this was the registered vehicle rating associated with the charger in the app) unless this was not possible without breaching the capacity limit (e.g. 10 active chargers and a capacity limit of 300A). When demand management was required each charger would be given a different current allocation depending on the predicted energy requirement, and the time by which this energy needed to be delivered.

For example, if demand management was required at 18:00 one evening, then a vehicle with a planned journey of 50 miles, departing at 21:00 that evening would receive a higher current allocation than one with a planned journey of 50 miles that was not departing until 7:00 the next morning.

If no information had been entered by the user then the system used an 'assumed' next journey (50 miles, departing four hours later). A conservative assumption of vehicle efficiency (miles per kWh) was used, to ensure that the system delivered enough energy for planned journeys. The system was configured so that changes which were made to journeys during a charge session would affect the charger's current allocation, without the driver re-starting the charge session.

Testing of Algorithm 2 aimed to show:

- Demand management was only implemented when it was not possible to allocate all chargers their full rating (which may be 16A, depending on the registered vehicle);
- Vehicles were prioritised correctly (e.g. as described above);
- Data entries by the user were prioritised above estimates made based on historical behaviour; and
- Behaviour during comms outages.

An example is shown below (Figure 4-13). For this test the following information was entered via the journey planning app:

Table 4-4: App inputs used for CrowdCharge Trial 2 Example Test

Charger	Car	State of Charge Entered via App	Journey Length (miles)	Departure Time
APT 2	16A, 24kWh Nissan Van	49%	20	14:00
APT 4	32A, 30kWh Nissan Leaf	80%	70	14:00
APT 5	32A, 33kWh BMW i3	65%	20	18:00

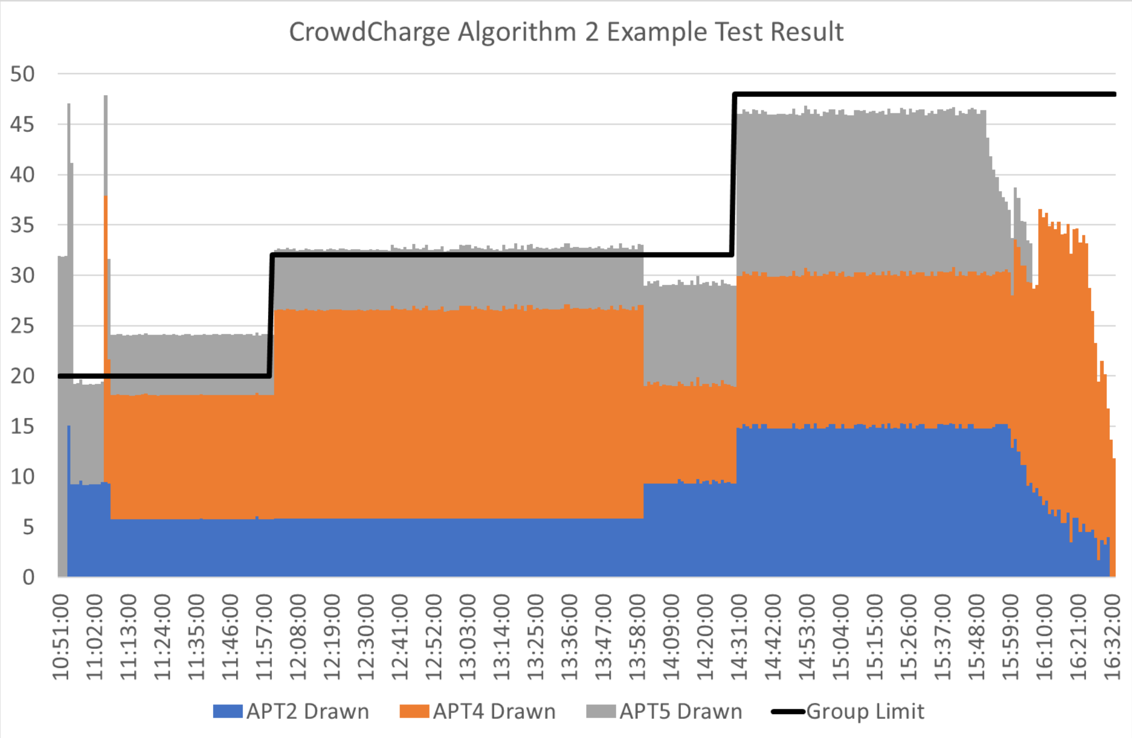
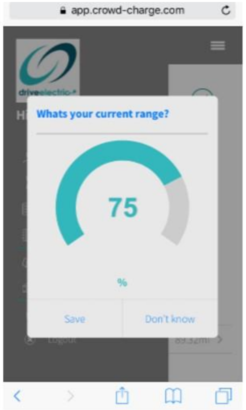


Figure 4-13: CrowdCharge Trial 2 Testing Example

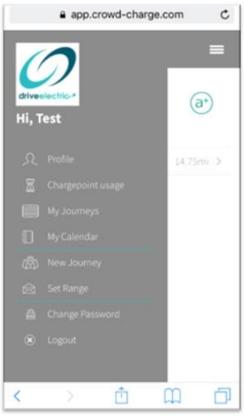
The key points from the test are:

- APT2 (blue area) already had enough energy in the battery to meet the journey requirement, so despite the early departure time (13:00) it received a relatively low allocation of current (approximately 6A from 11:00 – 13:00);
- APT4 (orange area) did not have enough energy in the battery to meet the requirements for the planned journey (using the conservative efficiency assumption). It therefore received the highest priority and the greatest allocation until its planned departure time (14:00). After the departure time the allocation decreased; and
- APT5 (grey area) already had enough energy in the battery to meet its journey requirements, and had the latest departure time, so it was given the lowest priority until additional capacity became available at 14:30.

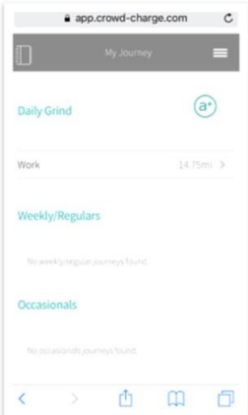
Screenshots from the app are shown below:



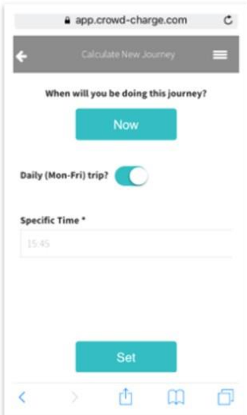
State of Charge Entry Dialogue Box – opened each time the user logs in



Menu options



Summary page showing previously entered journeys



Dialogue box for entering a departure date/time for planned journeys

Figure 4-14: Screenshots of CrowdCharge Trial 2 Web-Based App

Customer Trial

Participants needed to register for a CrowdCharge account in order to use the app. The charger controller software had to have a firmware update in order to take part in Trial 2.

The app was launched to a pilot group of twenty participants in mid-June 2018. Prior to the launch CrowdCharge and DriveElectric developed a user guide and a list of frequently asked questions (FAQs). The pilot group allowed the project team to test the process of updating controller software, registering participants and linking information about their car with the app. It also provided some early feedback on the process which was used to improve the roll-out to the remaining participants.

Between June and September 2018 all participants in Trial 1 were moved to Trial 2 – except for 18 chargers, where it was not possible to complete the required controller software update. All participants were invited to sign-up to the app and they were part of a managed 'Trial 2' group regardless of whether they had completed the registration process. A total of

245 participants were invited to register for an account, including 19 participants who did not take part in Trial 1.

The graph below shows the increase in the number of participants in Trial 2.

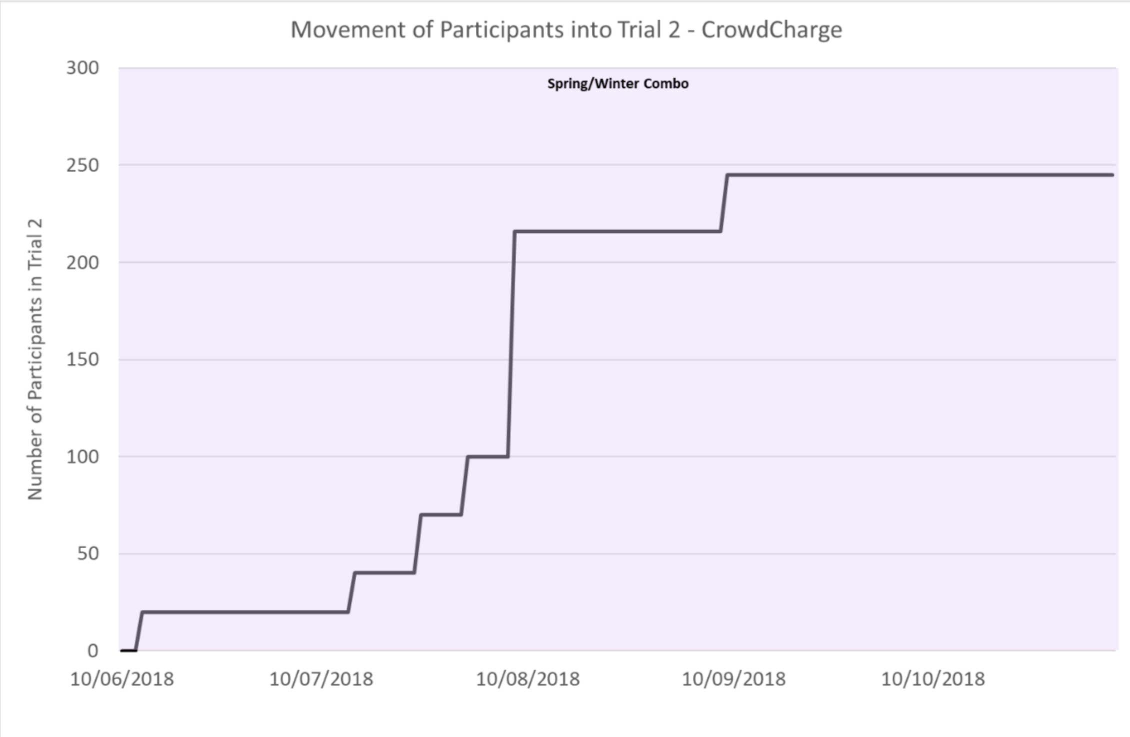


Figure 4-15: Number of Participants in CrowdCharge Trial 2

The 'Spring/Winter Combo' profile (see Section 6.4) of available capacity was used throughout Trial 2. Management was active throughout the trial, over the evening peak, although the frequency of management was slightly lower than during the period when 'winter' profiles were applied in Trial 1. Details of the amount of management which occurred at a group level, and which participants were affected by this is contained in Section 11.1 of this report. The degree of interaction between participants and the app is explored in Section 11.1.5.

A trial survey was issued to these participants between August and November 2018, in order to assess their satisfaction with their charging arrangements at this stage in the trial, and collect feedback on the app, and the degree to which they had used it. Many of the questions used were identical to those in the baseline and Trial 1, so that changes in satisfaction could be reviewed. Analysis of these survey results can be found in Section 11.1.6.

4.9.2 GreenFlux

The second GreenFlux algorithm introduced an Android and iOS app, with a 'high priority' feature.

Algorithm Description and Testing Example

Algorithm 1 used two priority levels:

- 'Normal' priority – charging sessions where the vehicle is still charging at normal rate; and
- 'Low' priority – charging sessions where only a small amount (or no) current is being drawn (i.e. vehicle on a timer and not yet started charging or battery nearly full).

In Algorithm 2 a third priority level was introduced (high priority). High priority could be accessed via requesting priority charging via the GreenFlux app. Current was allocated to those on 'high capacity' first. Therefore, unless a very high larger of participants had requested high priority this effectively acted as an override for demand management for the active charging session.

Testing of Algorithm 2 aimed to show:

- Demand management was only implemented when it was not possible to allocate all chargers their full rating;
- Charging sessions with a high priority request were correctly prioritised;
- Management occurred as expected, including in the 'high priority' group if this was necessary (although this scenario was unlikely to occur in reality);
- High priority only applied for a single charge session and the charger returned to normal priority for the next session; and
- Behaviour during comms outages.

An example test result is shown below.

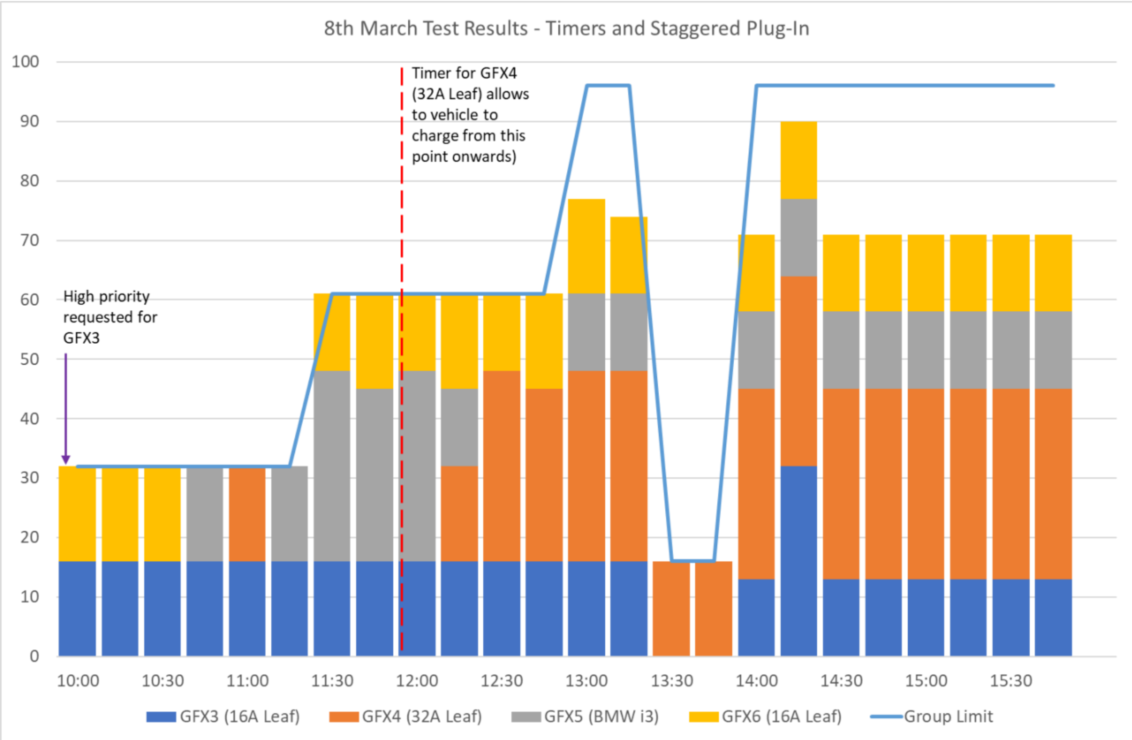


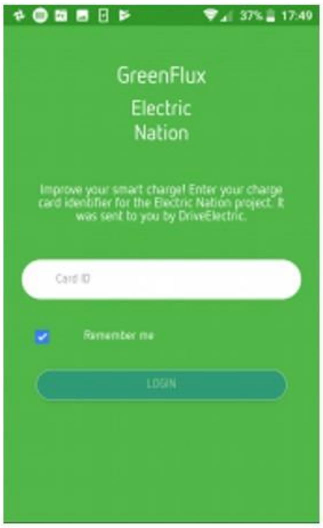
Figure 4-16: GreenFlux Trial 2 Testing Example

The test progressed as follows:

- GFX3 (blue fill) – high priority request was successfully enacted. It was allocated 16A (the vehicle rating) until 13:30, when the current being drawn had declined (battery full);
- GFX4 (orange fill). Current was made available when this vehicle was plugged in at 11:00. As the vehicle was on a timer it was not allocated any current again until the 15 minute block immediately following the point where the timer elapsed (12:15). The vehicle proved it was a 32A model and was then treated equally by the algorithm. As all the other vehicles had finished charging by 13:30 only GFX4 was offered current during the two blocks with only 16A available; and
- GFX5 and 6 (grey and yellow fill): these were both on 'normal' priority and were treated fairly by the algorithm whilst they were actively charging.

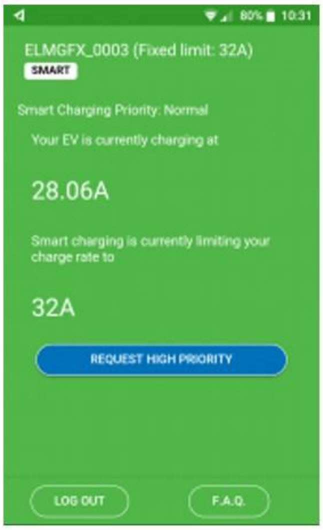
Screenshots from the app are shown below:

Welcome screen (for new app users)



Login screen

App Screen (no active charging session, or charger offline)



App Screen (active session)

Figure 4-17: Screenshots of the GreenFlux Trial 2 App

Customer Trial

In order to use the app participants needed to download the it from either the Google Play Store (Android devices) or the Apple App Store (Apple devices), and log in using an identification code provided to them by DriveElectric (generated by GreenFlux to ensure the correct participant – charger – app linkage).

The app was launched to a pilot group of twenty participants in early-April 2018. Prior to the launch GreenFlux and EA Technology developed a user guide and FAQs. The pilot group allowed the project team to test the process of inviting participants to download the app. It also provided some early feedback on the process, and user instructions, which was used to improve the roll-out to the remaining participants. One participant in this pilot group shared his experience via Twitter:

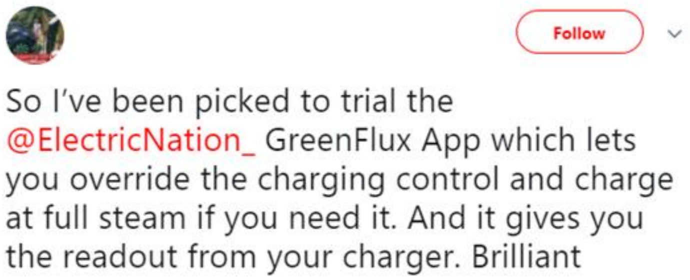


Figure 4-18: GreenFlux Trial 2 Feedback via Twitter

During April and May 2018 all participants in Trial 1 were moved to Trial 2 – except for participants that had been removed from smart charging (further details given in Table 9-8).

All participants who had been invited to download the app were part of a managed 'Trial 2' group regardless of whether they had downloaded the app. A total of 267 participants were invited to download the app, including 42 participants who had not taken part in Trial 1 (i.e. Trial 2 was their first experience of management). During Trial 2 the app was downloaded 183 times (69% if no participants downloaded the app more than once). 241 of these participants used their charger at least once during Trial 2, and 147 made at least one high priority request. This is equivalent to 61% of all participants and 80% of those who downloaded the app.

The graph below shows the increase in the number of participants in Trial 2, including the seasonal profiles used during Trial 2.

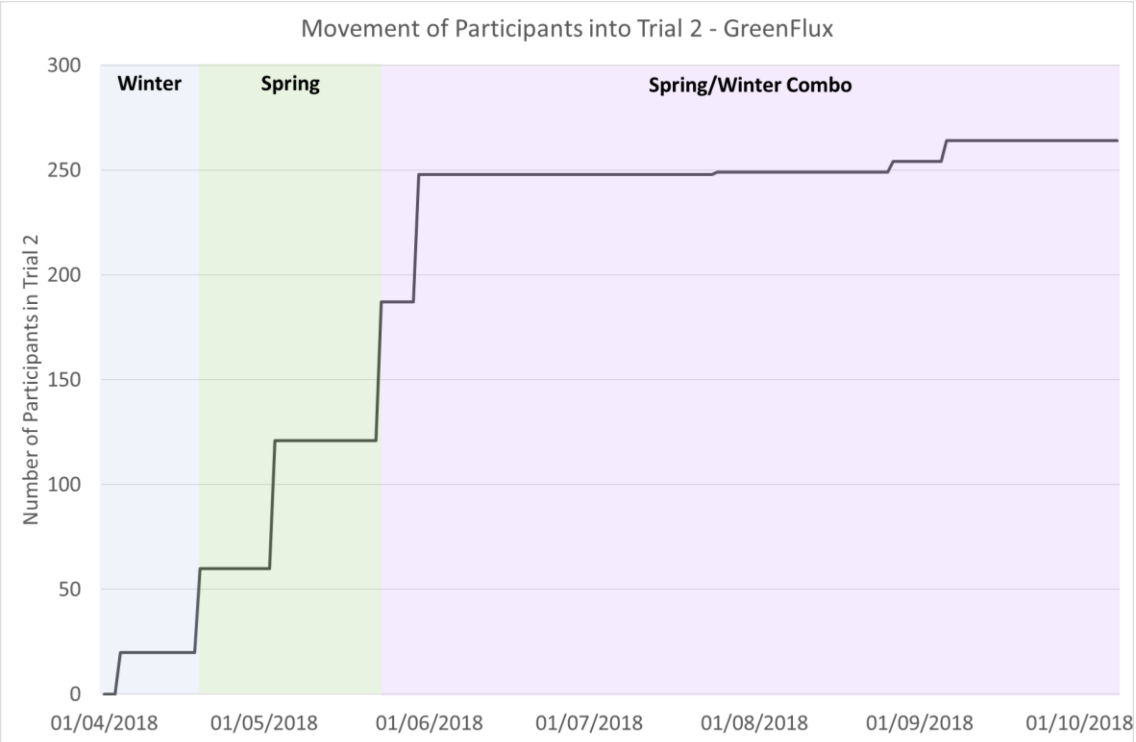


Figure 4-19: Number of Participants in GreenFlux Trial 2

The 'Spring/Winter Combo' profile of available capacity was used for the majority of Trial 2. A spring profile was implemented for around six weeks, however the additional capacity available (compared to winter) resulted in no management taking place. The combined profile was developed in order to ensure that management continued – which would be representative of some networks, or where PEV penetration is higher than the 30% used in developing the original seasonal profiles (see Appendix 1).

Management was active regularly (just over 50% of weekdays) during the evening peak, once the 'Spring/Winter' combo profiles were enacted. Details of the amount of management which occurred at a group level, and which participants were affected by this is contained in Section 11.2 of this report. The degree of interaction between participants and the app is explored in Section 11.2.5.

A trial survey was issued to these participants between July and November 2018, in order to assess their satisfaction with their charging arrangements at this stage in the trial, and collect feedback on the app, and the degree to which they had used it. Many of the questions used were identical to those in the baseline and Trial 1, so that changes in satisfaction could be reviewed. Analysis of these survey results can be found in Section 11.2.6.

4.10 Trial 3

Trial 3 aimed to investigate the use of time of use (ToU) pricing alongside smart charging, in order to understand how charging behaviour may be impacted by a financial incentive, and the impact this would have on the need for demand management. Further details of the motivations behind this part of the trial are given in Section 12.

The way in which ToU pricing was implemented differed between the two demand management providers and these differences are described in more detail in the following sections. A common tariff structure was implemented by both providers, shown below. This pricing was based on the Octopus Agile pricing data for the previous year. It applied only to the energy used by the participant's smart charger and was simulated via a reward system – no changes were made to the energy suppliers that participants were contracted with.

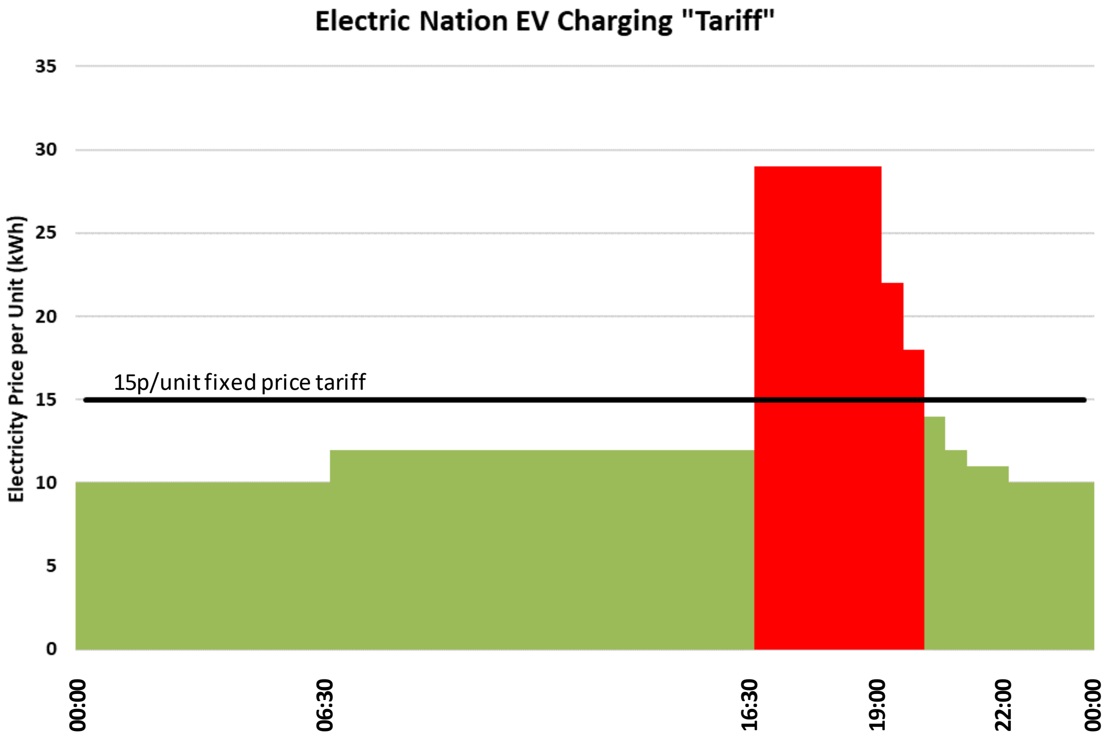


Figure 4-20: Electric Nation ToU Tariff Structure

All Trial 3 participants began the trial with a £10 reward (in the form of an online shopping voucher). Each charging session was analysed to calculate a 'cost' associated with the energy. Each unit of energy consumed during times when the price was more than 15p/kWh (the horizontal line above) decreased the reward value (i.e. charging during the red zone). Each unit consumed when the price was less than the flat rate increased the reward value.

4.10.1 CrowdCharge

The third iteration of the CrowdCharge system continued to use the same web-based journey planner 'app'. The main change in Trial 3 was to the algorithm for scheduling charging, which now aimed to move charging away from peak price periods.

Algorithm Description and Testing Example

In Trial 3 the CrowdCharge system incorporated the ToU tariff described above and aimed to optimise charging based on a combination of driver requirements (using app entries as per trial 2), capacity management, and delivering the required energy at the lowest overall cost. Example scenarios are described below:

- A participant connects their vehicle when they arrive home in the evening peak. They enter a journey plan with a time of departure of 7:30 the next morning. The system will therefore increase the charging which is done overnight, as the energy is not required until the following morning;
- A participant connects their vehicle when they arrive home in the evening, but no journey plans have been entered. The CrowdCharge system assumes the vehicle is required a few hours later, so peak time energy is used; and
- A participant connects their vehicle when they arrive home in the evening peak. They enter a journey plan with a departure time of later that evening. In this case the CrowdCharge system would use peak time energy to ensure that the energy requirement is met. By entering a journey plan the system will prioritise charging this vehicle if demand management is required.

Testing of the updated system was completed during the autumn of 2018, prior to the updates being rolled out to participants. This testing aimed to prove that:

- The algorithm would prioritise cars correctly based on journey requirements (including charging where no journey plans had been entered);
- Demand management would still occur if necessary (i.e. where it was not possible to give the maximum allocation to all vehicles); and
- Reward balances were calculated correctly.

An example of these test results is shown below. This particular test aimed to show:

- The use of peak/off-peak energy is determined by the journey plans entered; and
- Reward balances are calculated correctly.

This test did not require any demand management (this was included in other tests of Algorithm 3). The tariff used was a 'testing' version, where peak and off-peak periods occurred during the working day.

- Car 1 (16A rating): this car was plugged in at around 9:15, with the departure time set for 15:30. This energy requirement for the planned journey could be met using the off-peak energy available from lunchtime onwards.

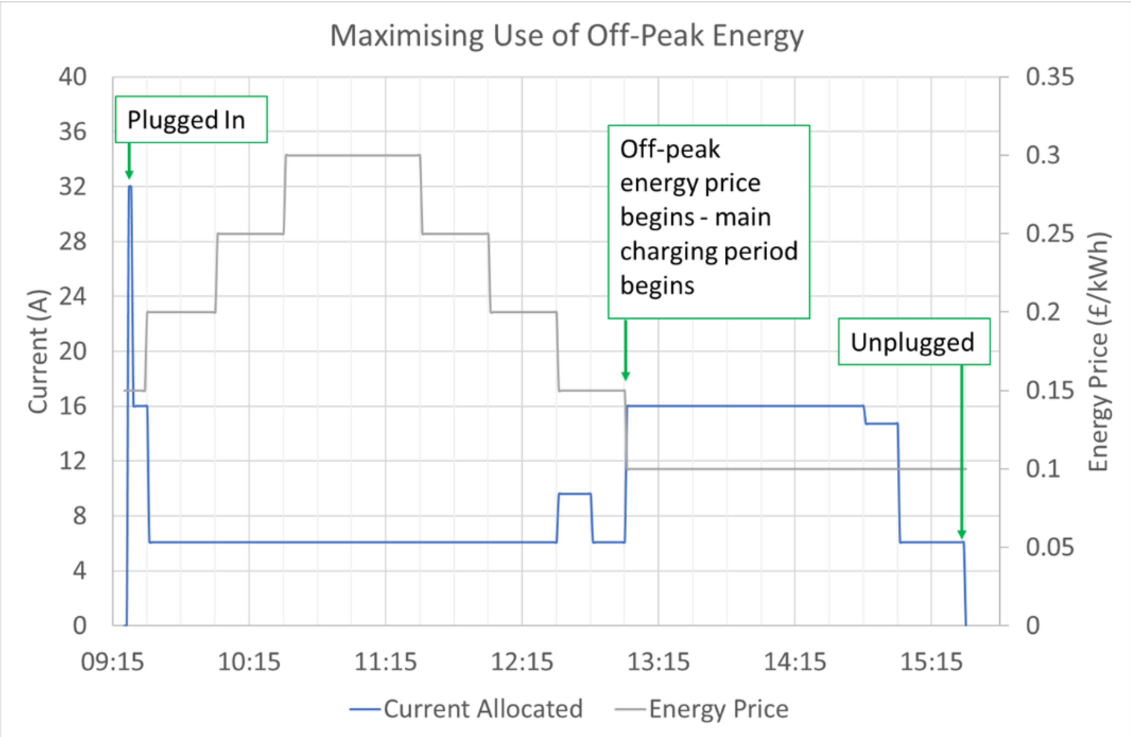


Figure 4-21: CrowdCharge Trial 3 Testing Example - Car 1

As shown above, the current allocation was low (6A, the minimum) while the price was high during the morning. When the price decreased to the off-peak rate (13:00) the current allocation increased to its maximum value. The reward balance increased, as expected.

- Car 2 (32A rating): this car was plugged in at around 9:15, with the departure time set for 12:30. The energy required for the planned journey meant that the vehicle needed to charge, despite the peak price.

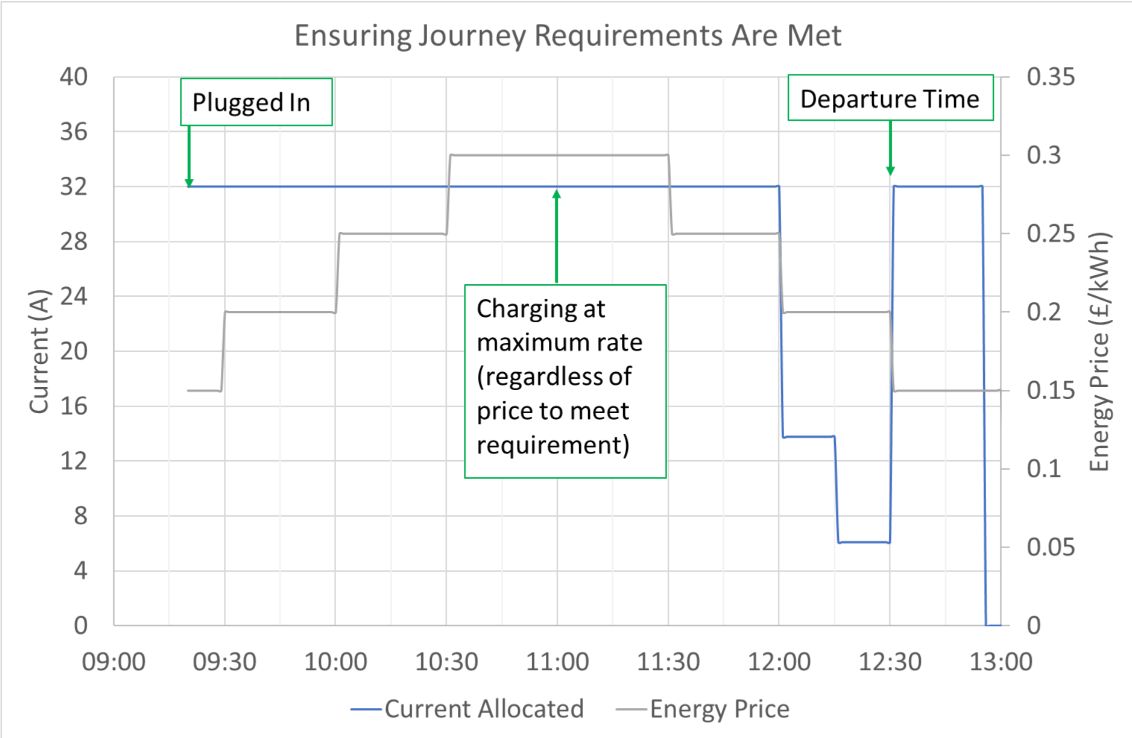


Figure 4-22: CrowdCharge Trial 3 Testing Example - Car 2

The car was allocated the maximum possible in order to provide the energy required, regardless of the price. The reward balance decreased, as expected.

The only changes to the CrowdCharge web-app for Trial 3 involved adding a display of the current reward balance, as shown in the screenshot below:

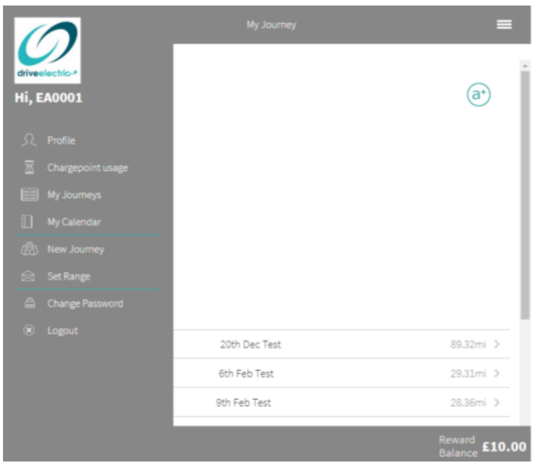


Figure 4-23: Updates to CrowdCharge Web-Based App for Trial 3

Customer Trial

All the participants in Trial 2 were transferred into Trial 3 during November 2018, in two batches. A small ‘pilot’ group was created and ran for one week, consisting of twenty participants to allow some initial user feedback on the new algorithm to be collected. The remaining participants were moved into Trial 3 the following week and operated under a ‘winter’ profile for the duration of the trial – until the end of demand management on 17th December.

Participants could only earn a reward (based on the time of day they charged) if they had an app account. Therefore, those participants who had not registered for an account when invited to do so in Trial 3 were asked again. This resulted in a further 17 participants registering.

Management was still required on around 70% of weekdays during the evening peak, despite the tariff system and algorithm updates. Details of the amount of management which occurred at a group level, is contained in Section 12.1.3 of this report. The degree of interaction between participants and the app is explored in Section 12.1.4.

A trial survey was issued to these participants in between December 2018 and January 2019, in order to assess their satisfaction with their charging arrangements at this stage in the trial, and collect feedback on the app, and the degree to which they had used it. Many of the questions used were identical to those in the previous surveys, so that changes in satisfaction could be reviewed. Analysis of these survey results can be found in Section 12.1.6.

4.10.2 GreenFlux

GreenFlux used the ToU tariff to calculate the ‘cost’ of charging sessions (compared to a flat rate tariff), and the difference between the two either increased or decreased the users reward balance. GreenFlux developed their app further in order to support participants with choosing off-peak charging.

Algorithm Description and Testing Example

The app was updated so that users could set a charging preference, which dictated what time of day their charger would allow charging. This preference would be used for all charging events until the user changed it (as opposed to a high priority request which only applied for a given charging session). The three preferences available were:

- “Minimise cost”: the system paused charging during peak and taper tariff period (only charging between 22:00 and 16:30);
- “Optimise time and cost”: the system only paused during the peak tariff period but would bring a charger on to charge during taper tariff (charging from 19:00 to 16:30); and

- "Optimise time": this was the default option and allowed charging at any time, regardless of cost, and chargers would only be curtailed if demand management was necessary.

The updated app also showed users their reward balance, past charging sessions and the impact these had on the reward balance, and information on the current charging session. The high priority feature was retained from Trial 2.

The app was tested to confirm:

- The app interpreted customers preferences correctly and this was reflected in the current available from the charger;
- Reward values were calculated correctly, including where the customer did not use the app (i.e. they change their plug-in time, or use a timer);
- Capacity limits continued to be enforced (i.e. if there was insufficient capacity for all participants who have selected 'optimise time' to charge at once then they were still managed) and demand management was still shared fairly amongst all active chargers;
- High priority requests still functioned correctly; and
- How charge events during offline periods were handled (what time would they start charging, what would happen to the reward value etc.).

An example of this testing is shown below. A 'testing' version of the tariff was set, as shown below. This ensured that behaviour during peak, taper and off-peak periods could be tested during the working day.

Table 4-5: Testing Version of Tariff Structure (used for GreenFlux Trial 3 Testing)

Tariff Start	Tariff End	Tariff	Tariff Category
00:00	10:00	0.12	0
10:00	12:00	0.3	2
12:00	12:15	0.22	1
12:15	12:30	0.18	1
12:30	12:45	0.14	1
12:45	13:00	0.12	1
13:00	16:00	0.1	0
16:00	00:00	0.12	0

(Tariff Category: 0 = Off-Peak, 2 = Peak Rate, 1 = Taper)

In this test, cars were connected on the following settings:

- Mk2 32A Leaf – minimise cost (plugged in 9:30) (GFX2, orange area);
- 32A Leaf – optimise time, with timer due to expire at 13:00 (plugged in at 9:30) (GFX5, grey area); and
- 16A Leaf – optimise time (plugged in at 9:50) (GFX1, blue area)

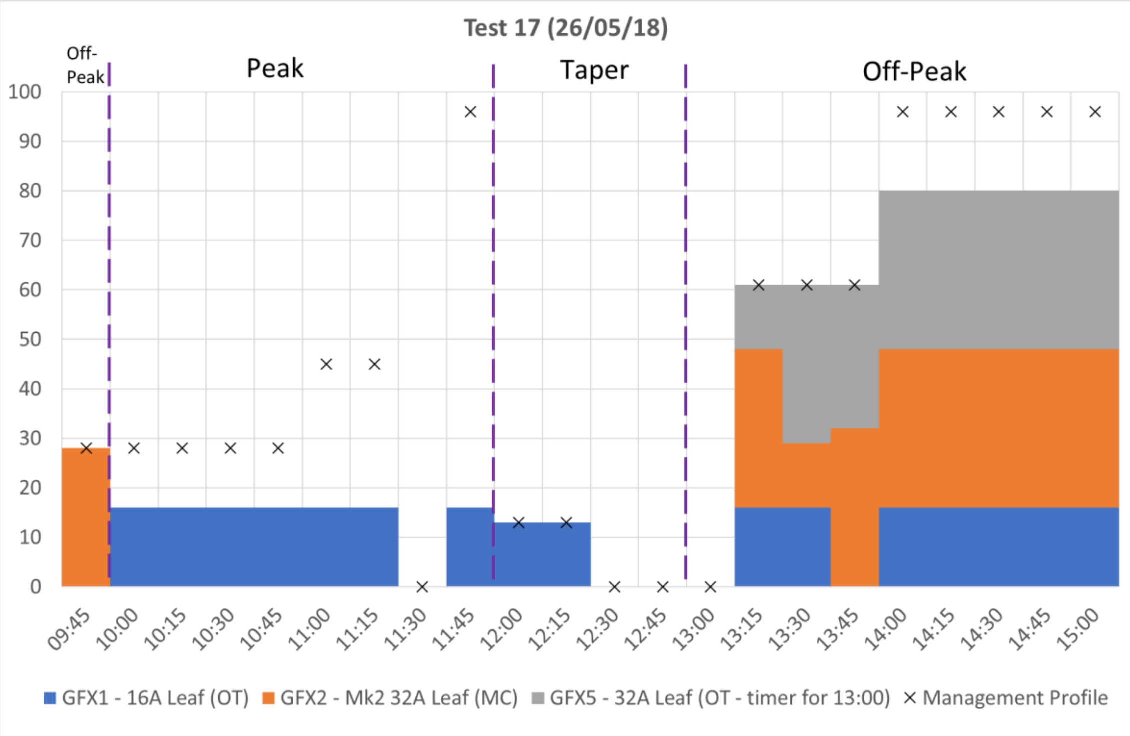
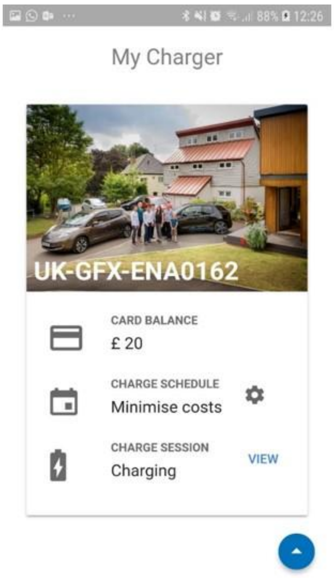


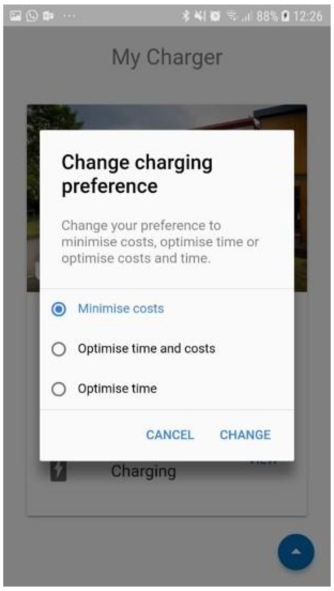
Figure 4-24: GreenFlux Trial 3 Testing Example

- The 16A Leaf (GFX1, blue area) used the 'optimise time' preference and so charged throughout the peak period. It was managed when necessary, as shown by the zero allocated at 11:30, and the reduced allocation at 12:00 – 13:00 (following the management profile);
- The 32A Leaf (GFX2, orange area) used the 'minimise cost' preference and therefore should only have charged during the off-peak periods. This can be seen in the graph above, as it charges before 10:00 (off-peak) and is then paused until off-peak begins again in the afternoon, and current was available. It was managed where necessary; and
- The second 32A Leaf (GFX5, grey area) used the 'optimise time' preference, but a timer was set on the vehicle, preventing charging from beginning until 13:00. This operated successfully and current was allocated to the vehicle the timer expired.

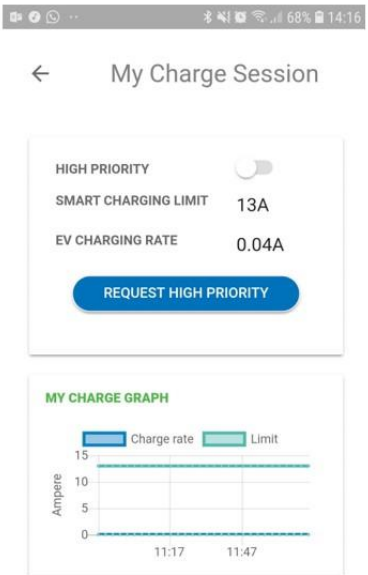
Screenshots of the updated app are shown below.



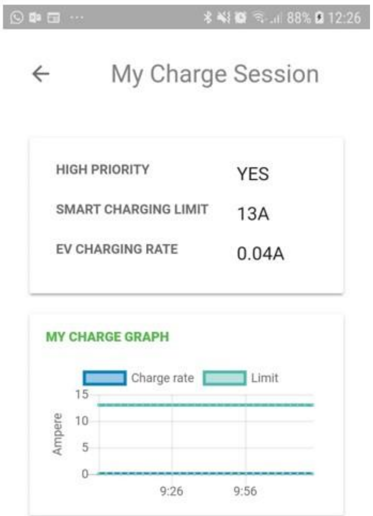
App homepage



Dialogue box to select a charging preference



View of current charging session, before high priority has been requested



View of current charging session, after a high priority request

Figure 4-25: GreenFlux Trial 3 App Screenshots

Customer Trial

A staged approach was used to launch Trial 3 to participants:

- w/c 8th October: all Trial 3 participants were sent details of the tariff/reward structure, and how the new app could be used. The number of installations of the app which would automatically update was limited. Participants could choose to manually update the app. However, GreenFlux could not know which participant had access to the updated app. Reward balances began to be calculated for all the Trial 3 participants, regardless of whether they had access to the update; and

- w/c 15th October: the limits on the number of installations which would update were removed, allowing all participants to access the updated app. All participants whose reward balance had decreased were reset to £10 (as they may not have had access to the app). Reward balances which had increased were not reset.

This allowed the volume of support calls relating to the new app/reward structure to be managed. Trial 3 remained operational until Monday 17th December. By the end of Trial 3, the app had been installed a total of 229 times, compared to 280 invitations (across Trial 2 and 3) (82% of participants).

The spring/winter combo profile was used until 15th November and was then replaced with a winter profile. A total of 274 participants were included in the GreenFlux Trial 3 group, and at least one charging event was available for 246 of these participants during Trial 3. Of these 246 participants, 149 had used one of the ‘non-default’ charging preferences (minimise cost, or optimise time and cost), and therefore must have used the app.

Management was only required during the first week of Trial 3 (where not all participants had access to the updated app) – a significant change compared to the previous (non-ToU reward) trials. Further details of this change are explored in Section 12.2.2.

A trial survey was issued to these participants in December 2018, in order to assess their satisfaction with their charging arrangements at this stage in the trial, and collect feedback on the app, and the degree to which they had used it. Many of the questions used were identical to those in the previous surveys, so that changes in satisfaction could be reviewed. Analysis of these survey results can be found in Section 12.2.5.

4.11 Project Learning Dissemination

Project learning has been disseminated to a wide audience via various mediums. The table below summarises some of the key project learning materials.

Table 4-6: Project dissemination material

Material	Description	
Project Website	The project website was used to host electronic versions of dissemination material and provide links to videos. News articles were hosted on the site publicising project milestones and interim findings.	www.electricnation.org.uk/ 
Smart Charging Guide	This 4-page leaflet, which was available in either printed or pdf version via the project website, provided simple information on what smart charging is, and why it may be beneficial to move PEV charging away from times of peak electricity demand.	https://www.westernpower.co.uk/innovation/projects/electric-nation
Latest Findings Leaflet	This 8-page leaflet, which was available in either printed or pdf version via the project website was produced in September 2018 to provide an overview of project findings up to the point of publication.	https://www.westernpower.co.uk/innovation/projects/electric-nation
Electric Nation model	An interactive table-top model that was taken to conferences to assist explanations of the impact of PEV charging on the LV network, and how smart charging could help mitigate potential issues.	
Video demonstrating project model	This video, filmed at LCNI 2017, showed Mark Dale of WPD using the Electric Nation to demonstrate the impact of PEV charging on the LV network, and how smart charging could help mitigate potential issues. This was hosted on the project website.	https://youtu.be/LICIPq6pPZ8
Twitter	The project Twitter account was used to promote dissemination events, circulate links to publications and videos and to publish interesting factoids from project learning and analysis.	@ElectricNation_ https://twitter.com/ElectricNation_

Material	Description	
Stakeholder newsletters	Newsletters were produced and circulated on a regular basis providing information on project progress, findings and activities. These were mainly in electronic format although a printed version was created for LCNI2018.	

A key means of disseminating interim project learning was via attendance, and more especially, presenting at conferences and workshops. The table below summarises the conferences and workshops that members of the project team presented at, or were present at, to represent the project.

Table 4-7: Presentations Given by the Electric Nation Team

Event	Presentation Title and Presenter	Date
Vehicle to Grid (V2G) Workshop – from Concept to Commercialisation	Installation lessons learned (Nick Storer – EA Technology)	6th February 2019
IET Manchester – evening lecture on 'Electric Vehicle Charging and their Impacts on the Electricity Distribution Network'.	Electric Nation (Esther Dudek – EA Technology)	13th December 2018
WPD Balancing Act, Bristol	Latest project Findings (Nick Storer – EA Technology)	21st November 2018
Low Carbon Network Innovation Conference 2018, Telford	Latest project Findings (Nick Storer – EA Technology)	16th and 17th October 2018
MR Utilities Conference	Managing EV demand on network capacity: testing consumer acceptance (Nicole McNab – Impact and Nick Storer – EA Technology)	4th October 2019
CENEX LCV 2018	Latest project Findings (Nick Storer – EA Technology)	12th and 13th September 2018
Smart Energy Marketplace Show	The impact of EVs (DriveElectric)	19th June 2018
Utilities Week Live	Electric Nation project (Mike Potter – DriveElectric)	22nd May 2018
Utility Week Future Networks Conference	Latest project findings (Mark Dale – WPD)	18th April 2018
Electric Vehicle Charging Infrastructure Event	Electric Nation (Roger Hey – WPD)	7th March 2018

Event	Presentation Title and Presenter	Date
EcoBuild	Latest project findings (Mark Dale – WPD)	7th March 2018
Storage Summit	Electric Nation (Roger Hey – WPD)	27th February 2018
New Energy Forum	Electric Nation and domestic smart charging (Roger Hey – WPD and Nick Storer – EA Technology)	9th January 2018
Low Carbon Network Innovation Conference 2017, Telford	Project Update Presentation (Gill Nowell – EA Technology)	6th -7th December 2017
2017 UN Climate Change Conference (COP23), Bonn	Electric Nation (Mark Dale – WPD and Esther Dudek– EA Technology)	6th – 10th November 2017
Balancing Act Conference, London	Electric Nation (Mark Dale – WPD and Nick Storer and Dan Hollingworth – EA Technology)	5th October 2017
LowCVP Seminar	The Electric Vehicle Revolution: Managing Impacts on the Powergrid (Dave Roberts – EA Technology and Mike Potter – DriveElectric)	11th October 2017
CENEX LCV 2017	Electric Nation: Smart Charging Trial (Mark Dale – WPD and Esther Dudek– EA Technology)	6th -7th September 2017
V2G 2017, Amsterdam	Nick Storer – EA Technology	11th -12th May 2017
All Energy, Glasgow	Electric Nation (Esther Dudek– EA Technology)	10th - 11th May 2017
CENEX V2G seminar	Electric Nation (Gill Nowell – EA Technology)	14th December 2016
Low Carbon Network Innovation Conference 2016, Manchester		11th -13th October 2016
CENEX LCV 2016	Electric Nation (Ben Godfrey – WPD and Gill Nowell – EA Technology)	6th – 7th September 2016

A dissemination event was hosted on 16th July 2019 at the British Motor Museum to share the findings from the customer trial. The event was attended by approximately 190 stakeholders from across the energy, charging infrastructure and automotive sectors, alongside representatives from academia.

Presentations from the event are available to download via the Electric Nation website[12].

Figure 4-26: Audience at the Electric Nation Dissemination Event 16th July 2019

[12] http://www.electricnation.org.uk/2019/07/17/electric-nation-smart-charged-conference-review/ Accessed August 2019

5 Hardware and Communications Performance

Communications were an integral part of the trial. Reliable communications were needed between the chargers and the back-office systems (CrowdCharge and GreenFlux). Firstly, to provide data for the project, and secondly to allow the chargers to be controlled for the purposes of smart charging.

This section describes the communications solutions which were installed, their performance, the issues encountered and how these were resolved.

5.1 Introduction and Systems Description

The hardware and communication solutions used in the project differed between the two demand management providers. In both cases, home broadband was the preferred primary communications method between the equipment in the participant's home and the demand management provider's back office (CrowdCharge or GreenFlux). This section describes the communications systems used.

In all cases the electrical installation complied with the relevant Wiring Regulations and IET Code of Practice for Electric Vehicle Charging Equipment.

The schematics below show the two systems used.

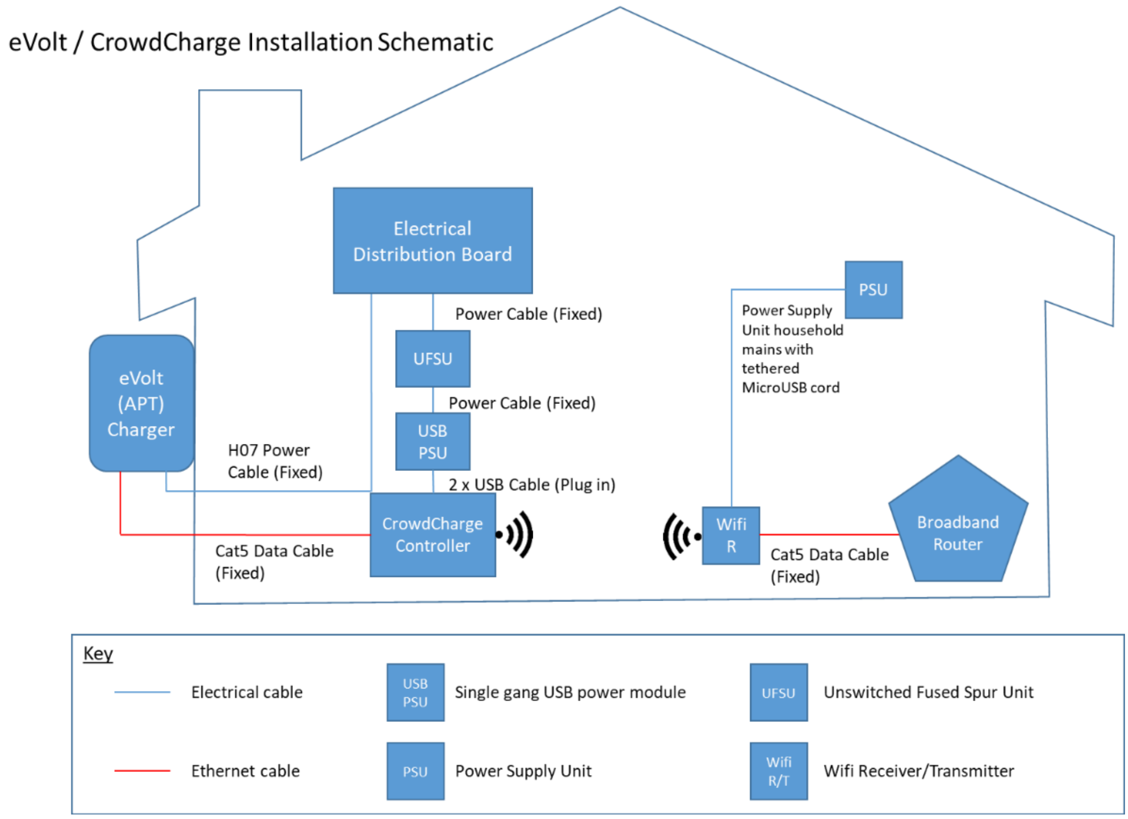


Figure 5-1: Installation Schematic (CrowdCharge)

The CrowdCharge system utilised a controller between the charger and the internet connection. Home broadband was the only communications method available for these chargers. Details of the performance of this system, and the issues experienced during the project can be found in Sections 5.2.1 and 5.3.2.

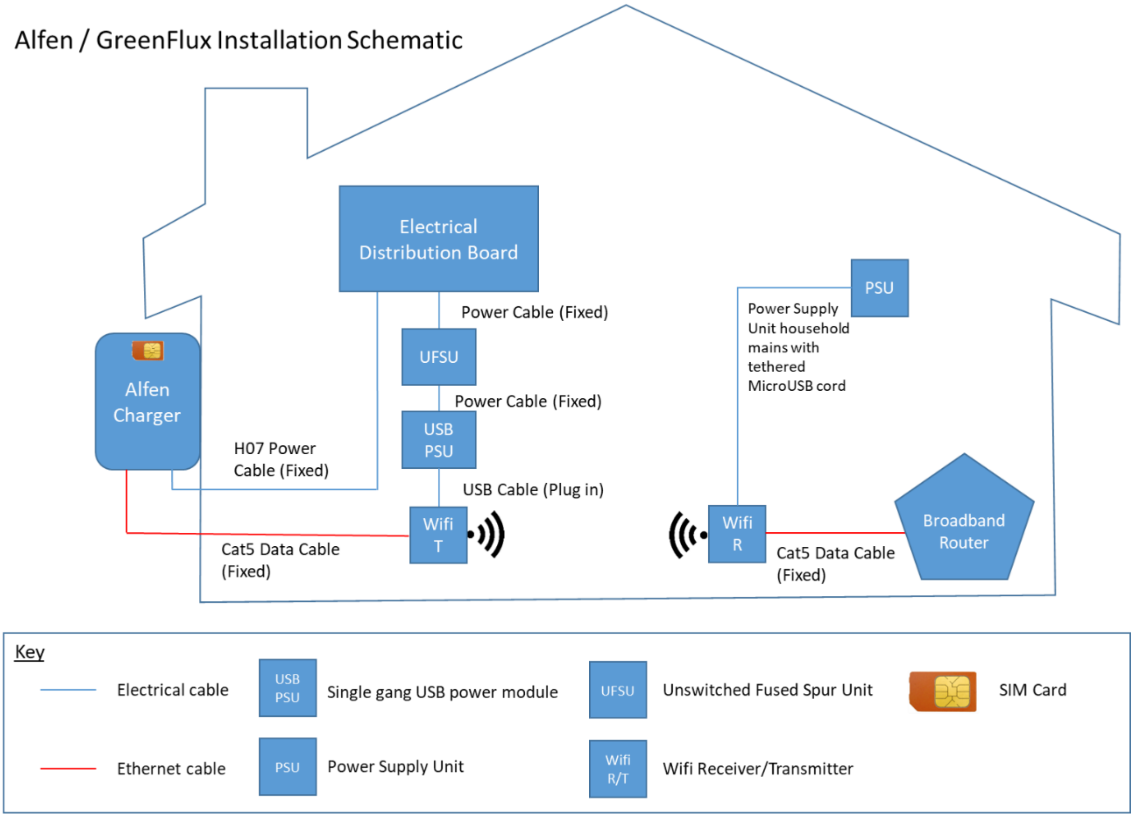


Figure 5-2: Installation Schematic (GreenFlux)

The GreenFlux installations did not use a controller; GreenFlux interfaced directly with the Alfen chargers. A multi-network SIM card was installed in each charger to provide a secondary, back-up, communications option, designed to be used if the broadband connection failed. Details of the performance of this system, and the issues encountered are given in Sections 5.2.2 and 5.3.3.

Both these schematics indicate the use of a Wi-Fi bridge (transmitter and receiver units) between either the charger, or CrowdCharge controller (which had a built in Wi-Fi bridge transmitter) and the broadband router. The Wi-Fi bridge consisted of two small units: a securely paired transmitter/receiver set, that utilise a non-standard (compared with broadband routers) low frequency channel. The low frequency used has better connectivity range and better building fabric penetration capabilities, but lower data transmission rate capabilities compared to standard Wi-Fi signals. This was acceptable, as the data packages to and from chargers were relatively small. This solution was used for the majority of installations and avoided installing ethernet cable through the participant's home. In some cases, the location of the charger and router meant that a hardwired connection was possible. In this case the Wi-Fi bridge was replaced with an ethernet data cable between the charger and router, or CrowdCharge controller and router. A small number of installations used power line carrier communications (referred to by the brand used, TP Link, below) to act as a bridge between charger and router. The charts below show the prevalence of each communications method in the trial, for both CrowdCharge and GreenFlux.

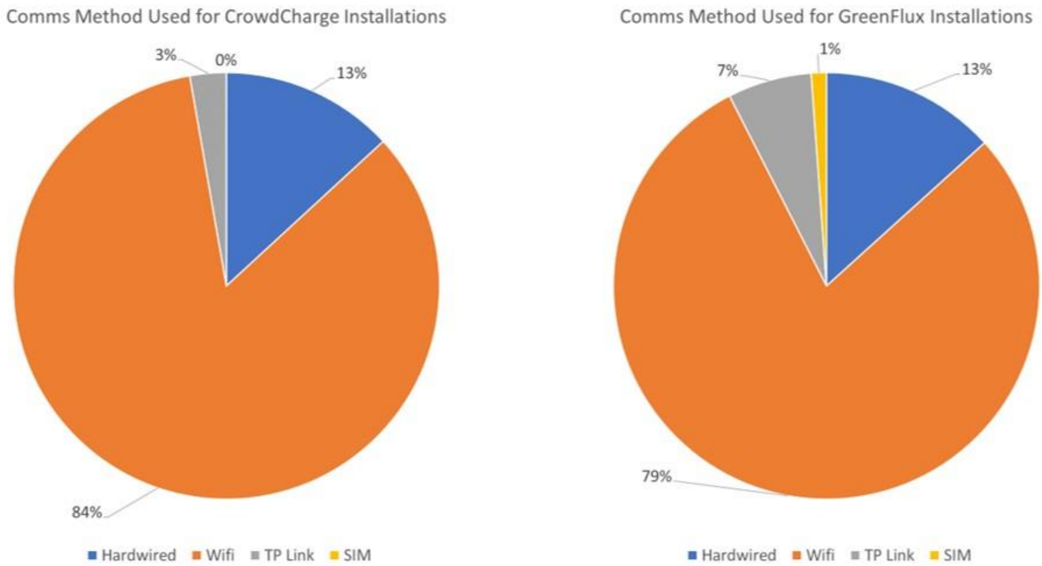


Figure 5-3: Comms Method Used

Wi-Fi was used for the vast majority of installations in both parts of the trial. This was the default method used as part of the installation procedures and may reflect participants' desire to avoid installing a cable connection through their home between the router and charger. A small number of GreenFlux installations could not establish a connection between home broadband the charger location so relied solely on the SIM card – this option was not available to CrowdCharge. The relative reliability of these options is shown below.

5.2 Overall Communications Performance

The reliability of communications between the back-office systems and installed chargers was tracked through the majority of the project. This was reported as part of the monthly project management reports and kept under review with both demand management providers. The reliability of the two systems is shown in more detail for the two systems in the sub-sections below.

5.2.1 CrowdCharge

The CrowdCharge back office consisted of two parts, referred to below as 'Hubeleon' and 'CrowdCharge'. For a charger to be managed and send full data to the project it required reliable communications with both systems. The online reporting tool used to calculate the figures below showed communications to 'Hubeleon' only. The extent to which chargers were only communicating with 'Hubeleon' was audited at several points during the project, and the impact this had on moving chargers into management is explored in Section 9.2.1.

The reporting system provided a communications reliability (%) for each charger, for each day – where 100% indicated that communications (to 'Hubeleon') were operational for the entire day. This was converted a weekly figure for each charger, by taking the average of all the days within the week. For each week the reliability of the installed fleet of chargers was calculated as follows:

$$\text{Total Comms Uptime (Fleet in Week x)} = \sum_{i=1}^{n} \text{Weekly Uptime } (\%)_i \times \text{Length of Week}$$

$$\text{Comms Reliability of Fleet (in Week x)} = \frac{\text{Total Comms Uptime (Fleet in Week x)}}{n \times \text{Length of Week}}$$

Where

$n =$ Number of chargers Installed in Week x; and
$i =$ Charger number

This data was made available by CrowdCharge from Week 30 2017 (w/c 24th July 2017, when 121 chargers had been installed) until the end of the trial.

The overall reliability (based on communications with 'Hubeleon' only) is shown in the graph below.

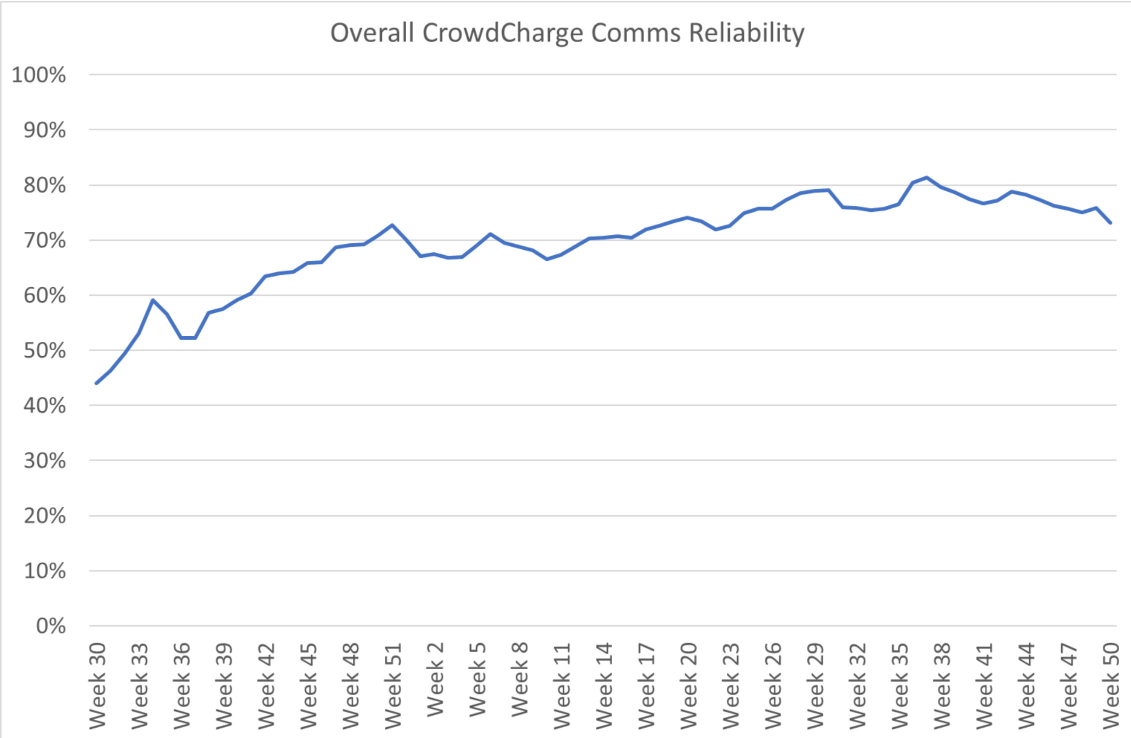


Figure 5-4: Overall CrowdCharge Comms Reliability

During 2017 communications reliability improved substantially, from a low base. Improvement during 2018 was slower and declined slightly towards the end of the trial. Further details of the issues which caused the performance shown above, and the measures put in place to address them are given in Section 5.3.2 below.

This data has been converted to a monthly average, and separated by the communications method used, as shown below.

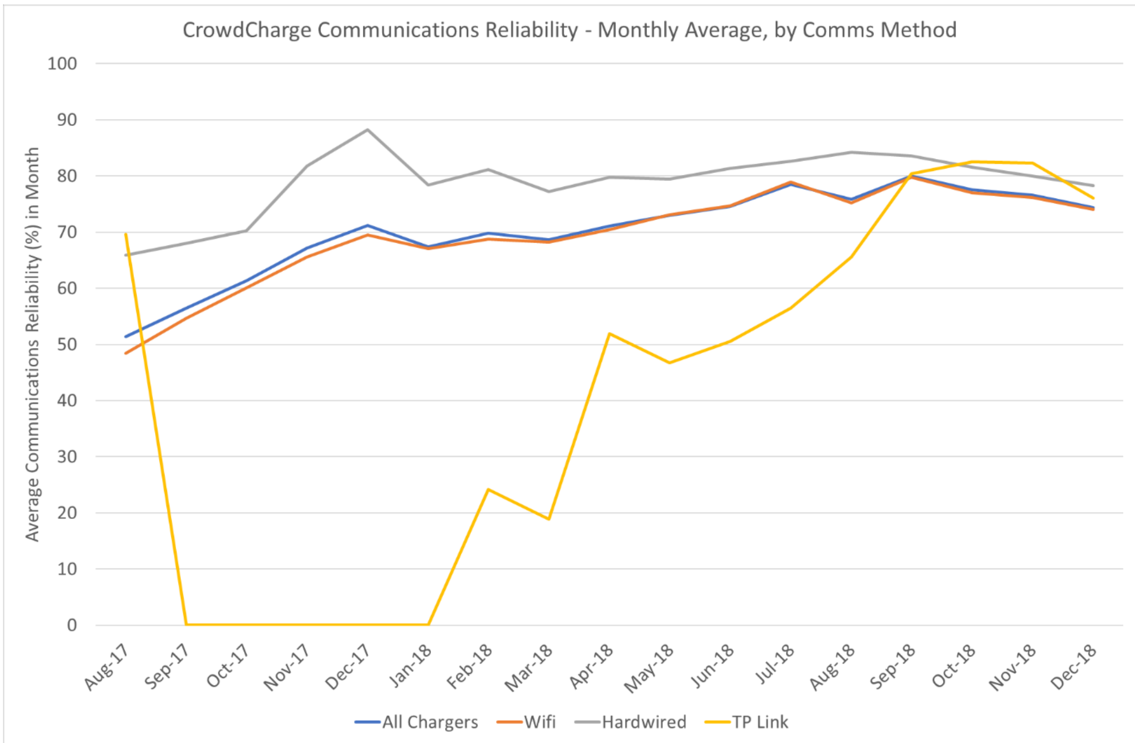


Figure 5-5: CrowdCharge Comms Reliability - by method used

The table below summarises the reliability of each communications method for the CrowdCharge group:

Table 5-1: Reliability of different comms methods (CrowdCharge)

Communications Method	Number of Installations	Average Reliability (Trial Duration)	Proportion of Weeks More Reliable than Population Average	Proportion of Weeks Less Reliable than Population Average
All	328	70%		
Hardwired	43	78%	100%	0%
Wi-Fi	275	69%	14%	86%
Power line carrier (TP Link)	9	41%	21%	79%

N.B. the comms method was unknown for 1 installation.

This shows that throughout the trial:

- Hardwired units outperformed the other available communications methods;
- The 'all chargers' reliability is very closely aligned to the Wi-Fi group, as this method dominates (84%, as shown above); and
- The power line carrier group only contained nine chargers by the end of the trial.

The 2017 TP Link data shown above consists of one charger from August – October, two chargers in November, and three in December. However, these appear to have a lower reliability than the Wi-Fi solution until the last four months of the trial.

5.2.2 GreenFlux

GreenFlux provided a weekly 'offline' report, which contained a record for each offline event, for each charger.

The chargers in the GreenFlux part of the trial transmitted a 'heartbeat' signal every 30 minutes, and when these had not been received this generated an offline event. If a charger was offline at the end of a week (i.e. offline event hadn't finished) then no information was provided for the end of the event.

This data was used to calculate the total offline time for each charger, for each week, which was then combined to give the total uptime of the installed fleet.

This data was made by available by GreenFlux from Week 20 2017 (w/c May 15th 2017, when 76 chargers had been installed).

The graph below shows the overall reliability of the installed fleet from Week 20 2017 until the end of the trial. Week 8 2018 is excluded as the way in which heartbeats were processed was altered during this week, which prevented meaningful data from being provided.

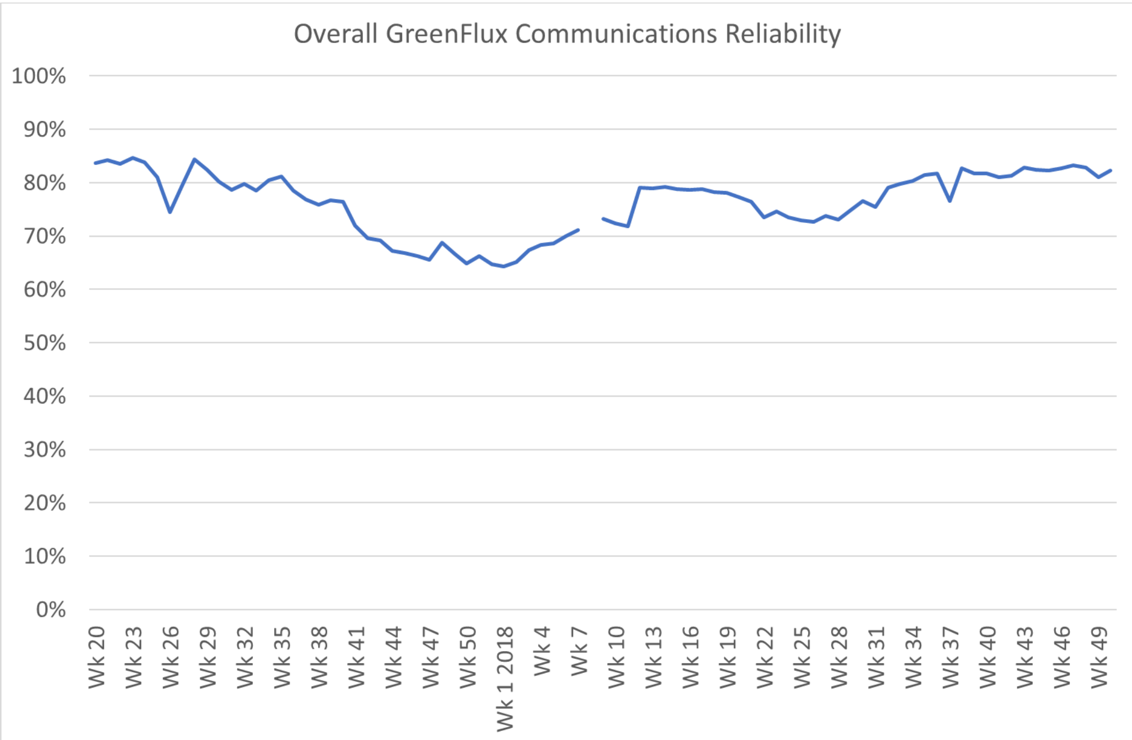


Figure 5-6: Overall GreenFlux Comms Reliability

This shows an initial high reliability, followed by a decline in the final part of 2017. Reliability generally improved in the first part of 2018 and stabilised at around 80%. Further details of the issues which caused the performance shown above, and the measures put in place to address them are given in Section 5.3.3.

This data has been separated by the communications method used and is shown below.

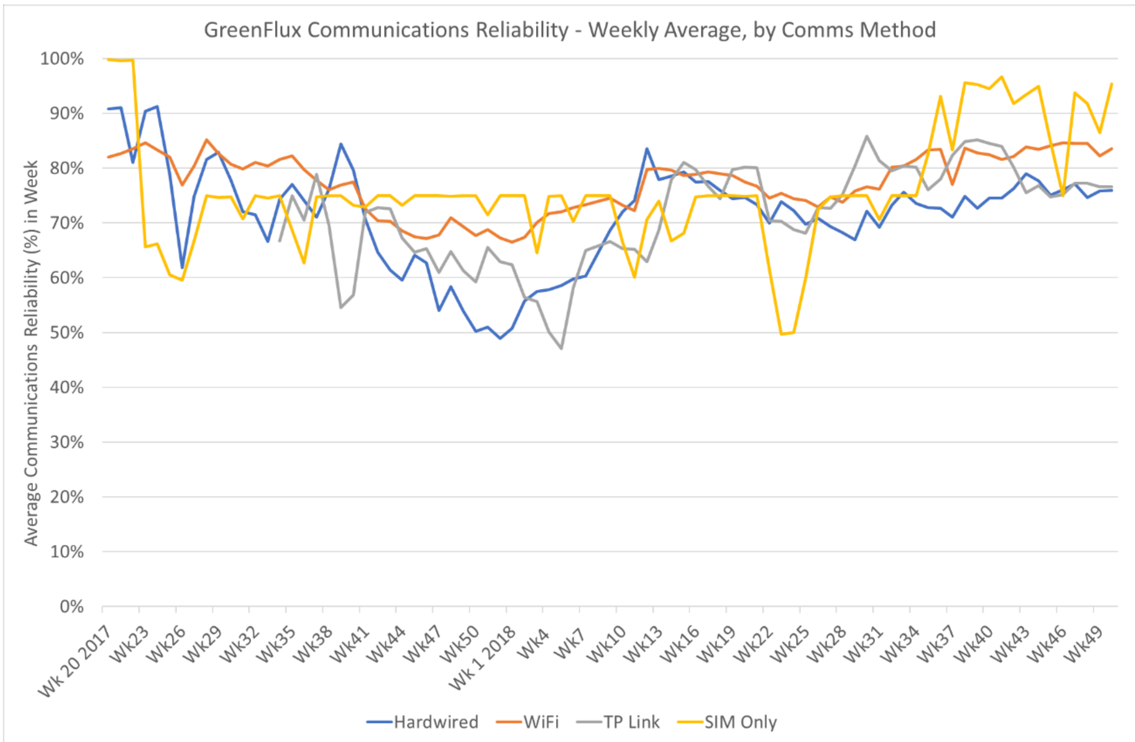


Figure 5-7: GreenFlux Comms Reliability - by method used

This shows a more mixed performance between the four different communications methods compared to the CrowdCharge data in Figure 5-5. The most reliable technology changed at different stages in the project. This can partly be explained by some of the issues described below (e.g. the incorrect configuration of chargers 216 – 317, see Table 5-5).

In each week, the reliability of each communications method has been compared to the population average, with the results summarised in the table below.

Table 5-2: Reliability of different comms methods (GreenFlux)

Communications Method	Number of Installations	Average Reliability (Trial Duration)	Proportion of Weeks More Reliable than Population Average	Proportion of Weeks Less Reliable than Population Average
All	346	74		
Hardwired with SIM backup	46	69	20%	80%
Wi-Fi with SIM backup	274	75	88%	12%
Power line carrier (TP Link) with SIM back-up	22	64	15%	85%
SIM only	4	74	53%	47%

This shows that over the course of the trial, the Wi-Fi (with SIM back-up) method was more reliable than the other methods, although there was still considerable variation within the Wi-Fi group across the trial, with weekly reliability varying between 67 and 85%.

The TP Link data appears to show a similar picture to the CrowdCharge data – i.e. that TP Link connections were less reliable than other technologies.

5.3 Communications Issues Experienced

This section summarises the various issues which affected the reliability of communications between the Electric Nation chargers and the two back offices. Issues are separated into those which impacted both systems, and those specific to CrowdCharge and GreenFlux.

5.3.1 Both Systems

The table below describes the issues which were common to both demand management providers (CrowdCharge and GreenFlux). It summarises the issues, the time period over which they applied, and solutions employed.

Table 5-3: Communications Issues Affecting Both CrowdCharge and GreenFlux

Description of Issue	Time Period Applicable	Solution Employed
Distance between Wi-Fi bridge transmitter and receiver was too large in some cases or radio-impermeable surfaces were in the line of flight between charger and router (such as metal garage doors), meaning chargers could not connect via Wi-Fi.	Throughout installation period, although most relevant for early installations	Installers were instructed to take more care over Wi-Fi bridge location during installation Procedures stipulated that the connection of the charger to the back office should have been confirmed before installer left site. However, it is believed the procedure was not followed in many cases by installers. From September 2017 onwards a relay unit was made available by The Tech Factory to allow the range to be extended. Installers could also use a TP Link unit instead of a Wi-Fi bridge.
Configuration of Wi-Fi units leading to units losing connection after power has been lost.	August 2017 – Dec 2017	Sites believed to have this fault were identified using the online data (typically they were online reliably for a period, then lost their connection entirely). Participants at these sites were sent a new pair of Wi-Fi units and instructions for how to fit them. This applied to approximately 200 installations. Where this was not successful in getting the charger back online a visit was arranged from The Tech Factory (see details of visits in Section 5.5).
Participants switching off their charger when not in use leading to apparent communications downtime.	Throughout the trial	Installers asked the participant to leave all the equipment switched on and reminders were included in participant newsletters during the project.

5.3.2 CrowdCharge

If the communications reliability of a CrowdCharge installation was poor, or it wasn't communicating with both parts of the back office ('Hubeleon' and 'CrowdCharge') then the charger couldn't be moved into the demand management trial.

If a charger lost its connection after it had been moved into a management group then data could be lost, and the charger would not be controllable. There was no negative customer impact associating with the charger losing its connection – offline chargers allowed trial participants to charge at full power.

A small number of units (less than 10) experienced a hardware issue related to unreliable communications, whereby the charger's memory became full after prolonged time without a connection, and participant could no longer use the charger – the charger ceased to function. In these cases, the Charger required a visit from APT eVolt to reset the firmware.

Table 5-4: Communications Issues Affecting CrowdCharge Installations

Description of Issue	Time Period Applicable	Solution Employed
One of the pilot installations revealed an issue whereby the original version of the CrowdCharge VPN configuration did not work with older BT HomeHub routers.	December 2016/January 2017 Resolved February 2017	The Tech Factory produced an improved version of the CrowdCharge VPN configuration. This VPN was tested on EA Technology staff home routers and installed on the CrowdCharge controllers on the test system at Capenhurst, to test functionality. The new version VPN was proved to work with legacy HomeHub 3 and a brand new HomeHub. This version of the VPN configuration was used in the all subsequent and existing trial installations (i.e. excluding the pilot installations).
Chargers offline due to software issue with communications board	Identified June 2017. Resolved via remote updates and site visits during the rest of 2017.	A software bug was identified by the manufacturer of the CrowdCharge communications board. This bug meant that the board could lose its configuration after repeated power cycles. This was addressed in a variety of ways: • Updated software was tested on pilot installations and the EA Technology test system • New units dispatched by The Tech Factory after August 2017 used the new software version • Units which were online, and running the old version, were updated remotely (where possible) Site visits were arranged to update the remainder
CrowdCharge controllers (containing the Wi-Fi transmitter) and Wi-Fi receivers had to be in the same batch for the Wi-Fi link to work. A batch of approximately 20 units were dispatched by The Tech Factory where the controller and Wi-Fi receiver were not in the same batch.	August 2017 Resolved September 2017	Remedied by posting correct receivers to the effected participants and following up with a phone call to ensure these were connected. Quality control changes were made at The Tech Factory to prevent this issue re-occurring. A Business as Usual deployment would require a solution where this issue (mis-matched batches of receivers and transmitters) could not occur.

Description of Issue	Time Period Applicable	Solution Employed
System wide offline events – cause not specified	Appeared and resolved during November 2017 (Week 43 and 44)	VPN server issues affecting the CrowdCharge back-office. Resolved by the Tech Factory.
CrowdCharge controller & charger configuration errors resulting in controllers which could not communicate with both 'Hubeleon' and 'CrowdCharge', and therefore did not provide data and could not be controlled.	Throughout the project	• Process changes were implemented at The Tech Factory to ensure units were correctly configured, including pre-installation testing. • Installers were reminded that pairs of chargers and controllers should be kept together, as supplied by the Tech Factory. • Installers were required (from August 2017 onwards) to call DriveElectric when they completed each installation, before leaving site. This enabled an initial communications check to be undertaken and the link between charger ID and participant ID to be confirmed. • CrowdCharge were able to remotely reconfigure some controllers to correct the error after installation. • Audits were completed by both CrowdCharge and EA Technology to identify units which were not communicating with both systems so the issue could be addressed.
Chargers went offline randomly throughout the project. It appeared that some controllers did not reinitiate communications automatically after broadband internet outages.	Throughout the project	Initially CrowdCharge were contacting participants after their charger had gone offline to request that they reset the equipment (forcing the controller board to re-initiate the connection). CrowdCharge and The Tech Factory developed an update to the controller board which would allow the board to reconnect automatically after a broadband outage. This update was rolled out to a batch of particularly problematic chargers during June 2018. This was unsuccessful - a large proportion of the updated units did not come back online after the update and subsequent internet outages. CrowdCharge and The Tech Factory continued to use phone calls to request customer equipment resets in the first instance and site visits where necessary to address this issue.

5.3.3 GreenFlux

If the communications reliability of a GreenFlux installation was poor, then the charger couldn't be moved into the demand management trial.

If a charger lost its connection after it had been moved into a management group, then meter value data would be lost (meaning that the time of charging could not be detected). However, charging transaction data was recorded by the charger and transmitted when communications were re-established (transaction data is useful and consists of a record of plug-in time, energy consumed during transaction and plug-out time).

In addition, offline GreenFlux chargers hold a charge allocation profile for the next hour of charging. If a charger lost its connection, then it would follow this profile for an hour, before reverting to a 'safe' value of 13A. This limits the potential impact of many uncontrolled chargers operating at 32A and therefore exceeding the network capacity, but leads to a negative customer experience, particularly for drivers of vehicles rated at 32A with large batteries.

Table 5-5: Communications Issues Affecting GreenFlux Installations

Description of Issue	Time Period Applicable	Solution Employed
Weak mobile phone signal at some installations meant that the SIM card would not connect so the charger did not have a back-up communications method.	Throughout trial	The use of external antennas was investigated but was not a practicable solution; omni-directional antennae have a limited ability to boost service and directional antennae require skilled set up and are expensive to install. Sites with poor mobile phone signal were reliant on the broadband connection. If sites had consistently poor communications reliability, they were not moved into demand management, in order to avoid the 13A default charge rate issue described in the introduction to this sub-section.
Failed ethernet port on the charger's communication board preventing a small number of units from connecting via ethernet (relying on SIM only, unless in the 216 – 317 group, see below).	Throughout the trial	These units were generally identified by The Tech Factory during their (small number) of visits to GreenFlux installations. In these cases, The Tech Factory engineer established that all the other elements of the communications system (wi-fi transmitter and receiver, ethernet cables etc.) were functioning correctly. This isolated the cause to a failure of the ethernet port on the communications board. The installer (or Siemens) then visited the site to replace the faulty board.
Some units communicated exclusively via the SIM connection (i.e. broadband connection was not working)	Reported in March 2017	Installation procedures were amended so that each communications method was tested in isolation. The aim was to ensure that both methods (SIM and broadband) were operating correctly before installers left site. The extent to which these procedures were followed is unclear – see the 'auto-detect' issue affecting chargers 216 – 317. If the updated procedures had been consistently followed, then this issue would have come to light much earlier.

Description of Issue	Time Period Applicable	Solution Employed
Incorrect configuration of chargers in the Alfen factory led to 101 units being dispatched configured to communicate via the wired connection only (rather than 'auto-detect' where the SIM connection would be used as a back-up). The impact of this is clear from the declining performance from Week 36 in Figure 5-6.	Charger IDs 216 – 317, installed between September 2017 and February 2018. Issue reported in November 2017.	This was resolved via a firmware update being applied to the affected chargers to change the relevant setting from 'wired' (ethernet only) to 'auto detect' (ethernet with SIM as back-up). Firmware updates were applied as follows: • Chargers which had not been installed before the issue was identified: installers phoned the Alfen service desk when they were installing the unit and the firmware update was applied. • Chargers which were installed and online: firmware update applied remotely, without intervention from the participant. • Chargers which were installed and offline: attempts were made to support the customer to get the charger online (e.g. reconnecting network cables, replacing the Wi-Fi transmitter and receiver units). If this was not possible then a small number of Tech Factory visits took place. This group of chargers were also part of the group visited by Siemens during the summer of 2018 (see Section 5.5)
Chargers which were offline (i.e. not sending data, and with the poor comms performance either preventing the charger from being moved into demand management, or in demand management and charging at 13A), but SIM cards using data.	Late 2017 – early 2018.	Two firmware updates were developed to resolve this issue. The first was not compatible with smart charging but provided greater diagnostic information to assist Alfen in developing a solution. A final version (3.3.6) was developed and applied to all chargers in the trial. The firmware update was applied remotely to all the online chargers, and Alfen commissioned Siemens to visit a further 59 units which were offline to update the firmware during July and August 2018. The effect of these visits can be seen by the increasing overall communications reliability during Weeks 27 to 35 2018 in Figure 5-6.
Offline event caused by an update made by Tele2 (SIM card provider) which prevented chargers from connecting to the Microsoft cloud VPN (part of the back-office system) via SIM. This led to 100 chargers losing their connection during 11th March 2018.	Week 10 and 11 2018 (early March).	This issue was highlighted by GreenFlux within hours of it occurring. It was resolved by Tele2 and GreenFlux on Tuesday 13th March. GreenFlux ensured that DriveElectric and EA Technology were updated throughout.

<table>
<tr><th>Description of Issue</th><th>Time Period Applicable</th><th>Solution Employed</th></tr>
<tr><td>Chargers were not able to send or receive messages via the broadband connection (primary method of communication).

When the charger had a message to send to the GreenFlux back office (e.g. a heartbeat, meter value or details of a transaction) it would briefly switch to SIM and send the data, before reverting to ethernet. The chargers therefore had a high online percentage. However, when GreenFlux sent messages to the charger (profiles of available current) these could not be received, so the charger switched to the safe value of 13A.</td><td>May – September 2018</td><td>The problem was initially identified via calls to the support line by customers who were experiencing slow charging (due to the 13A safe value). However, further investigations by GreenFlux showed the issue was much more prevalent than the support calls indicated.

In July 2018 the performance of chargers was reviewed, using the ‘delay value’ between the sending and receiving of messages by the charger:
No data was available for 27% of the installed chargers – either because they were offline (63%) or had not been used (37%)
55% had an acceptable delay value, suggesting they were not experiencing the issue.
15% had an unacceptably high delay.
The remaining 3% of chargers had a borderline delay value.
Chargers which were exhibiting this problem were able to send data out via their SIM card, suggesting that it was possible to establish a good SIM connection. Four solutions were employed:
If participants were being inconvenienced by slow charging (13A issue) and they could not be switched to SIM only they were removed from smart charging.
Where the SIM signal strength was good the chargers were reconfigured to SIM only, so all messages were sent and received via SIM (i.e. preventing the charger from switching back to broadband).
GreenFlux continued to monitor which chargers were sending delayed meter values and updated the configuration where necessary.
The presence of delayed meter values was added to the criteria which were reviewed by EA Technology before placing a charger into demand management. If delayed meter values were present, and the unit could not be switched to SIM only then it was not moved to demand management, thus avoiding the 13A safe value.
The root cause which prevented messages being sent or received via home broadband routers could not be identified. The issue was widespread and therefore unlikely to relate to a single Internet Service Provider or router type and may well sit with configuration of the charger communication system.</td></tr>
</table>

Description of Issue	Time Period Applicable	Solution Employed
Issue between GreenFlux back office and their SIM card provider (Tele2) causing significant offline periods for chargers on SIM only	Week 37 2018 (trial week 89) (September 2018)	This issue occurred after a considerable percentage of the installed units had been switched to SIM only (see row above). GreenFlux liaised with their SIM card provider to ensure this issue was resolved as quickly as possible. The issue (and its resolution) is clear from Figure 5-6.

5.4 Hardware Issues Experienced

The majority of issues experienced with the smart charging systems during the project related to the communications elements of the technology. A smaller number of hardware/configuration issues occurred, and these are summarised below:

- Some participants who owned BMW i3s and had their charger installed early in the project experienced nuisance tripping of the miniature circuit breaker (MCB). BMW i3s are rated at 32A and charge at 32A throughout their cycle (e.g. as opposed to 32A rated Nissan Leafs, which generally draw 28A). When the BMW i3s (and other similar vehicles) were drawing 32A for multiple hours this was causing heating of the MCB and resulting in occasional tripping. The specification of all future installations (regardless of vehicle) was upgraded to a 40A MCB and 63A Residual Current Device (RCD). Any participants whose charger was installed early in the project who experienced nuisance tripping had their equipment upgraded to the new specification.

  However, other PEVs that charge at this rate (such as all Tesla models), or even slightly above 32A (such as the Renault Zoe) did not appear to suffer this problem. Ultimately the cause of this problem remains a mystery.

- Early in the project a number of chargers supplied by Alfen did not match the specification agreed following testing and could not be used for smart charging until their configuration was updated. The wrong firmware version had also been applied. The following actions were taken:

  - A brief pause in dispatching equipment from Alfen until the issue had been resolved;
  - Structural changes within Alfen’s production process and quality assurance procedures to ensure that correct settings had been applied;
  - EA Technology reviewed all installed chargers to highlight those with configuration errors;
  - GreenFlux remotely updated the configuration of units which had been installed. Only one charger required a visit from the installer to address the issues (the others were updated remotely); and

  - For units which had been dispatched but not yet installed, installers were provided with details of the remote support process so that updates could be applied during the installation

- The following hardware faults were recorded against eVolt chargers (controlled by CrowdCharge):
  - Loose energy meter within charger = 6 units;
  - Error with Mode 3 controller = 3 units;
  - Socket failure = 3 units;
  - Charger broken upon delivery to The Tech Factory = 2 units;
  - Faulty contactor = 1 unit; and
  - Replaced RCD = 1 unit.

Overall, charger equipment manufacturing faults and early life (i.e. during the trial lifetime of a maximum of two years) failure rates were found to be disappointing for what is, and will become increasingly, viewed as a domestic appliance. Charger assembly and shipping faults, component faults and related in-service failures appear to have run at approximately 5% of the total supplied for both Alfen ICU and APT eVolt. These faults had direct impact on trial participants in that they either delayed the participant being able to charge at home or at some point prevented them from charging at home while the fault was diagnosed and repaired.

In addition, although this did not directly impact the trial participants as they were able to charge their PEV, Alfen ICU's quality assurance failure that resulted in 101 chargers being supplied with the wrong firmware configuration was disruptive to the trial and created a great deal of unplanned work for project delivery partners and suppliers and eventually cost Alfen ICU to rectify the problem via Siemens technical support. This resulted in nearly 30% of the total number of chargers supplied by Alfen ICU being out of specification for data collection and demand management purposes.

5.5 Site Visits to Rectify Communications Errors

As described in Section 4.3, EA Technology commissioned The Tech Factory to act as systems integration (communications) experts for the project. Their role included configuration of the CrowdCharge controllers and dispatch of hardware to the installers. In addition, they also completed site visits to units which were offline in order to identify the root cause and implement a solution. The Tech Factory took on this role, rather than installers, as a detailed knowledge of communications systems was required. In total The Tech Factory completed 346 visits during the project (including to decommission chargers). Siemens were also commissioned by Alfen to update the firmware of 59 of their units during the summer of 2018. This sub-section provides details of the visits undertaken.

5.5.1 Chargers Visited

In total 286 of the 673 chargers (42%) installed as part of Electric Nation were visited post-installation at least once, by either The Tech Factory or Siemens. 199 of the 328 CrowdCharge installations were visited at least once (61%) compared to 87 of 345 (25%) of the GreenFlux installations.

Details are given above (Table 5-5) for a considerable number of communications problems in relation to the GreenFlux system. However, the majority of these could be resolved remotely, or by working with the participant. This meant the number of site visits required was much lower – reducing the costs associated with ensuring chargers were online and reducing inconvenience to the participant.

Issues on the CrowdCharge system were much more likely to require a site visit to diagnose and resolve.

A number of chargers were visited multiple times (by either The Tech Factory or Siemens). The pie charts below show the proportion of the installed fleet with different numbers of site visits.

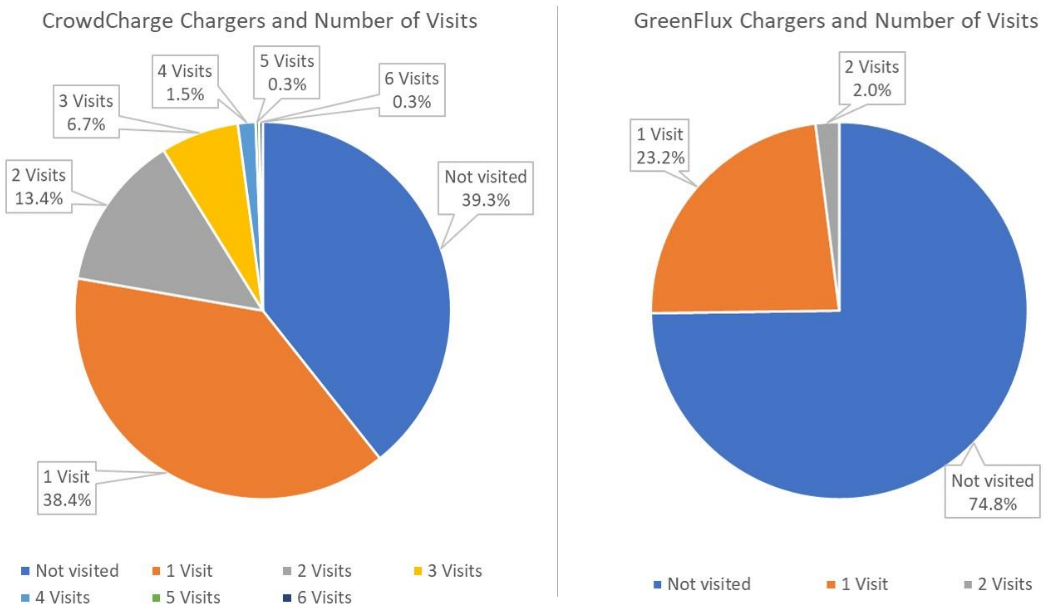


Figure 5-8: Number of Post-Installation Visits to Electric Nation Chargers

The number of visits each charger required over the course of the project (including decommissioning) may have varied depending on when the charger was installed. For example, the performance of chargers installed later would be better than early installations if changes to procedures improved communications. The graphs below explore this for CrowdCharge and GreenFlux.

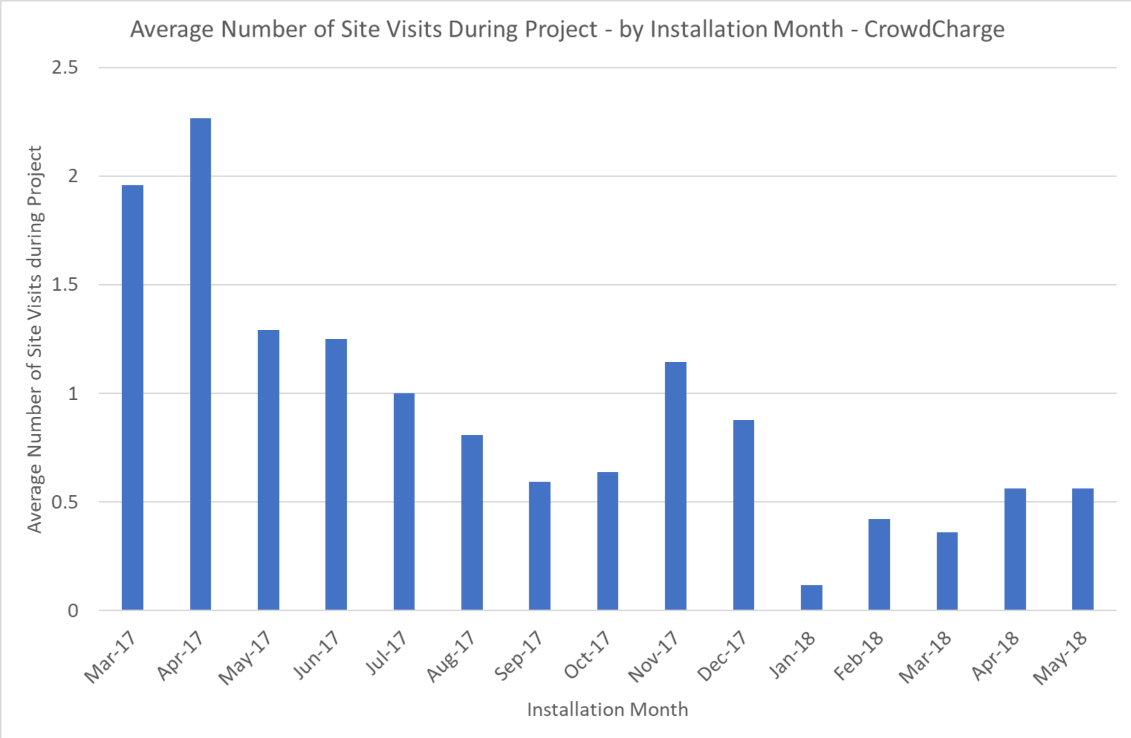


Figure 5-9: Number of Post-Installation Visits Required, by Installation Month (CrowdCharge)

Figure 5-9 shows the average number of site visits required for chargers installed in each month from March 2017 to May 2018. This shows that chargers installed earlier in the project were likely to require a greater number of site visits, possibly due to recurring issues which were not permanently resolved on the first visit, or new problems developing later in the project. However, the improvement did not continue for the duration of the project, as the average number of visits required was larger for units installed in February, March, April and May 2018, compared to January 2018.

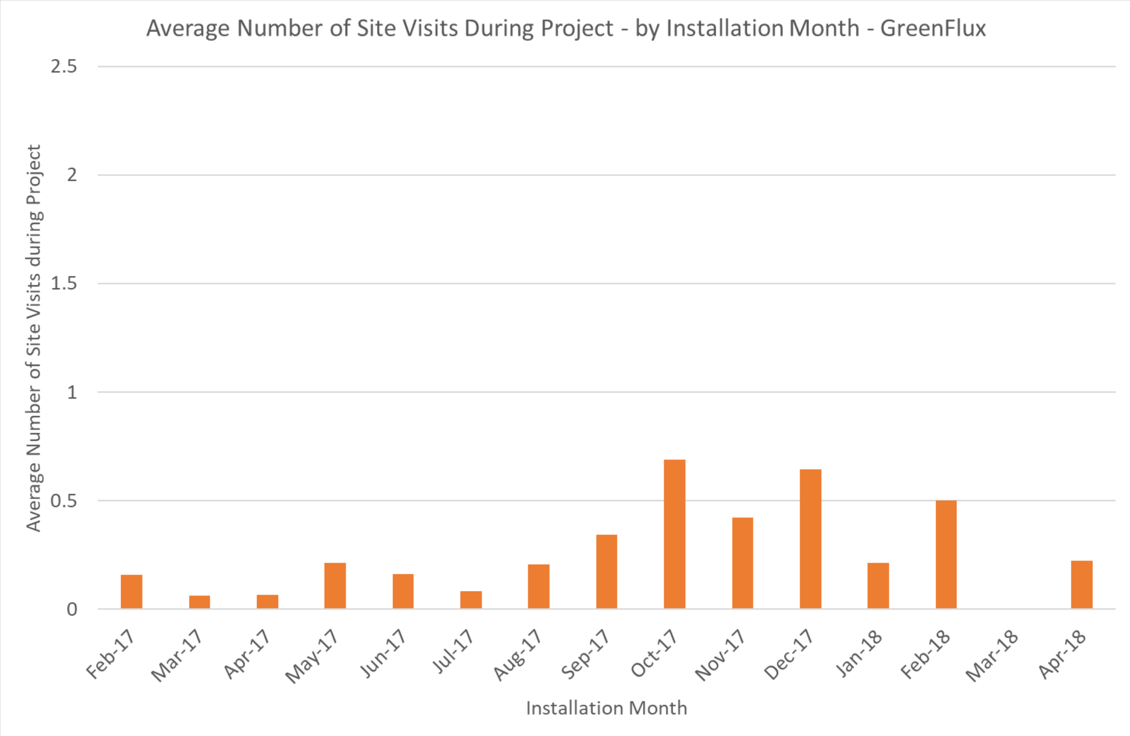


Figure 5-10: Number of Post-Installation Visits Required, by Installation Month (GreenFlux)

This graph clearly shows that the rate of site visits for GreenFlux installations was much lower than the CrowdCharge units. Installations in late 2017 and early 2018 required more site visits than other months – this was the period when units 216 – 317 were installed.

5.5.2 Visits over Time

Visits began in May 2017 to CrowdCharge units and they continued throughout the duration of the project. 54 of the 346 Tech Factory visits took place early in 2019 to decommission chargers where this could not be completed remotely (42 CrowdCharge, 12 GreenFlux) and these are not shown in the graphs below.

The timing of these visits is shown below, alongside the communications reliability of the fleet for each demand management provider (once this was available).

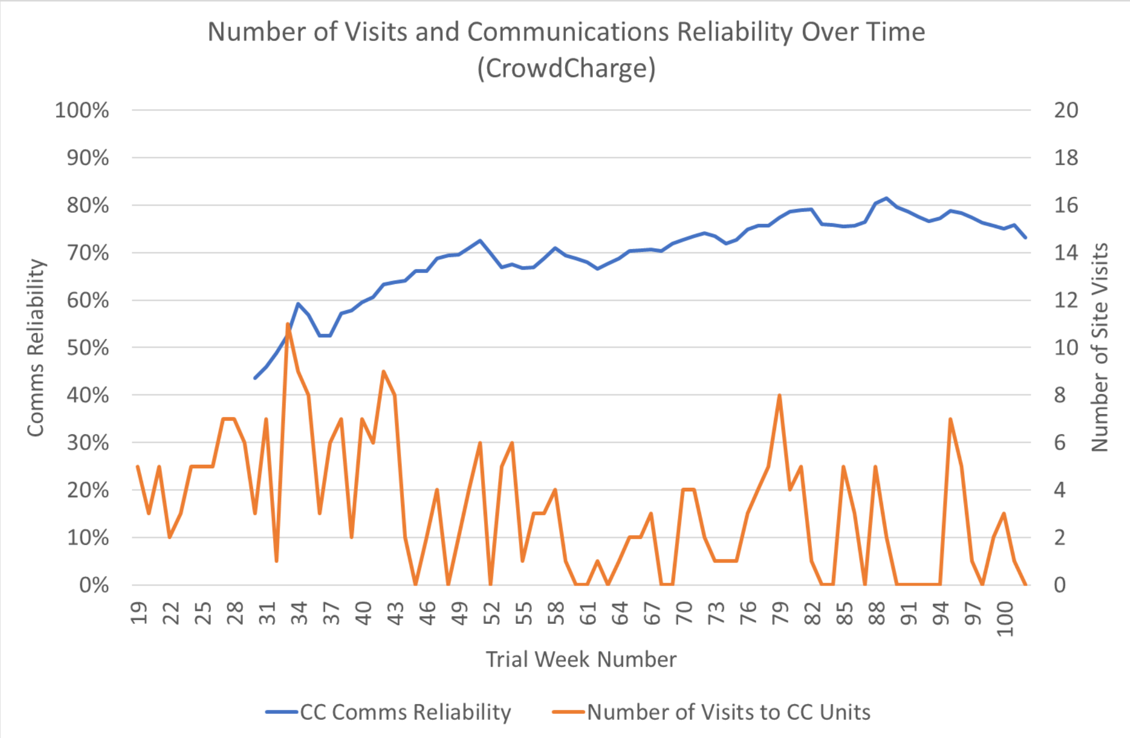


Figure 5-11: Number of Visits by the Tech Factory and Comms Reliability (CrowdCharge)

Visits to CrowdCharge units were more frequent in 2017 (Weeks 19 – 52), with 160 visits taking place in 2017, compared to 109 throughout the entire of 2018. This correlates with a steady increase in communications reliability through 2017. This increasing reliability is due to both the site visits and changes in installation and commissioning procedures.

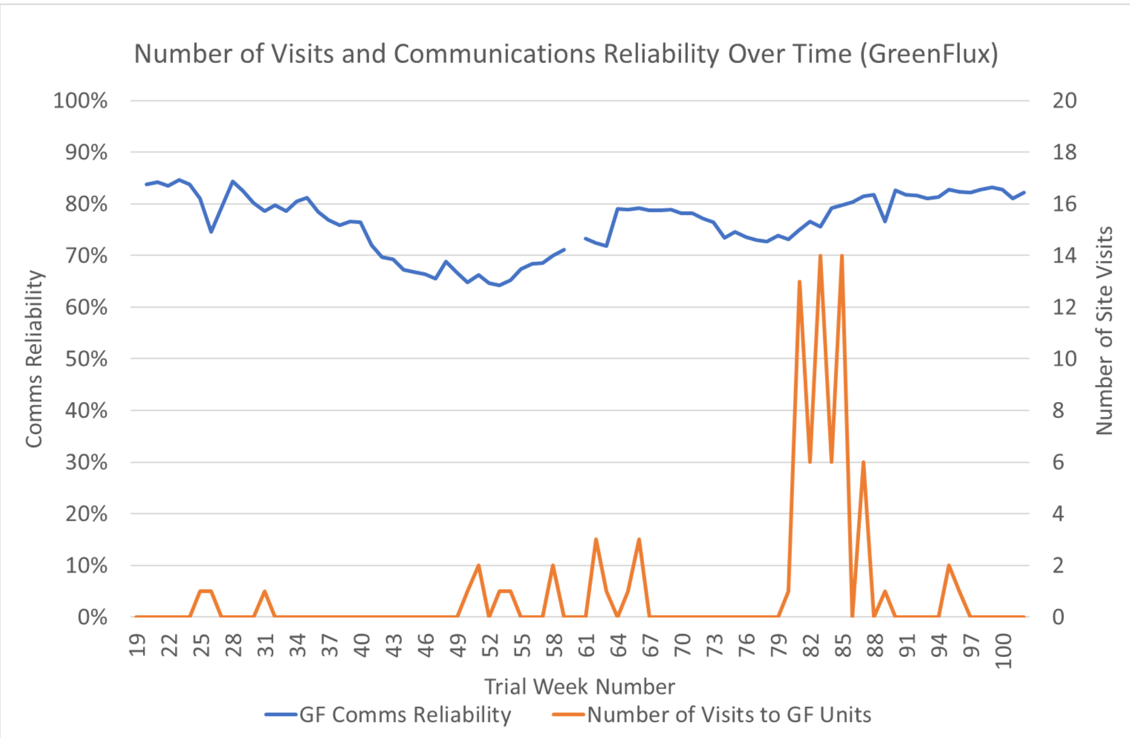


Figure 5-12: Number of Visits by the Tech Factory and Siemens and Comms Reliability (GreenFlux)

This shows slight increases in reliability associated with a small number of visits which took place in late 2017 and early 2018. These visits were mainly related to the '217 – 316' group (see Table 5-5 above). Remote updates were also taking place during this period. The large number of visits which took place in weeks 79 – 88 were completed by Siemens in order to update the firmware of 59 units, and this also improved the reliability of the fleet.

5.6 Summary

Reliable communications were established with the majority of the chargers installed as part of the Electric Nation trial. By the second half of 2018 the performance of both systems stabilised at around 80%. This reliability allowed 80% and 86% of CrowdCharge and GreenFlux participants respectively to move into the demand management trial (see Section 9.2) and generated substantial amounts of data which is analysed elsewhere in this report.

A wide range of communications issues occurred with different aspects of both systems. This required substantial effort by project partners and suppliers to address these issues, as shown by the number of site visits which occurred. A 'Business as Usual' deployment of smart charging would require a more stable communications solution, which required a much lower degree of effort to maintain. This is an area of potential innovation for charger manufacturers and communication equipment and service providers, and an area which requires additional training for installers of EV charging equipment.

This latter point is worth dwelling on; charger installers must be qualified electricians, however, (generally speaking) most electricians do not have training and skills in communication equipment installation. For example, a practical skill that the project tried to impart to the project's installers, making up ethernet cable plugs (RJ45 plugs) properly seemed to defy some installers (The Tech Factory found several poorly made plugs on site visits). In addition, the ability to follow installation and commissioning procedures to check communications had been properly established was a widespread problem and use of computers/software to diagnose communication and other faults seemed to be anathema to installers. This was probably exacerbated by cost/time pressures: the time taken to install and commission a smart charger has to be longer than, to date, ordinary "dumb" chargers. Costing of smart charger installations (i.e. ones that not only charge a PEV but also communicate to a back-office) must be realistic to give installers the time to do the job properly. Charger manufacturers also have a part to play in improving installer skills, practical and communications wise and making their products easier to install/commission.

5.7 Lessons Learned

Despite rigorous test system testing of the chargers and communications and the ten pilot installations, it was only when trial participant installations were in full swing and participants started to use their chargers that issues with the charger systems and communications became apparent.

The issues arising, can be roughly categorised as:

- Equipment firmware issues – high proportion
    - Requiring updates, sometimes repeatedly (e.g. Wi-Fi bridge, CrowdCharge Controller, Alfen Chargers)
    - Wrongly configured during manufacturing owing to poor quality assurance (e.g. Alfen and their despatch of 100 chargers with wrong configuration and The Tech Factory's despatch of wrongly configured CrowdCharge controllers and mis-matched controller-charger sets)
- Broadband Internet and mobile phone signal issues – common
- Installer error and inability to commission and complete on-site testing – common
- User behaviour, such as switching off charger between uses, switching off router at night – a small number
- Physical faults with equipment on delivery – very few

Recognising that charger technology and the charger manufacturing through to installation supply chain will have evolved somewhat since the inception and start of the project; some of these lessons may have been addressed by suppliers, at least in part. However, in light of the UK Government mandating smart charging for home EV chargers, some of these lessons are worth stating:

For Charger Manufacturers:

- Manufacturers must address the fact that homeowners will regard their EV charger like any other appliance. They will expect them to be simple to use and reliable – after all "it's just a socket to plug my car into";
- With this in mind, charger manufacturers should design their products:
    - To be reliable and physically robust (for shipping, installation and use);
    - To have stable, tested and proven firmware, not using their customer base as a testing environment;
    - To be capable of automatic firmware updates without homeowner support;
    - To have reliable and robust (secure) communication systems, not requiring the installer or owner to have to intervene to maintain reliable communications;
    - To have dual communication systems (broadband internet and mobile data), to improve communication performance and ensure the cellular installation has sufficient coverage to achieve reliable communications;

  - To be capable of reliable automatic reboot and communication establishment when power is lost;
  - To be capable of (secure) wireless connection to home broadband internet, or similar, as well as fixed ethernet connection; and
  - To have an On/Off switch that allows controlled shutdown and restart of chargers (there were a number of trial participants who habitually only powered up their charger when they wanted to charge, using the circuit breaker as a power switch);
- Charger manufacturers need to address installer support:
  - Ensuring chargers are easy to install and commission;
  - Provide training to enable installers to commission and troubleshoot firmware and communications issues;
  - Provide remote support to installers for commissioning and troubleshooting purposes; and
  - Provide installers with spare components for efficient rectification of physical damage and component failure (not charge installers for them).

For Installers:

- Installers need to improve their skills, being a qualified electrician is not enough, some communications and IT skills (and equipment) are required for a world where smart chargers become the norm.

System Integrators and Back Office Systems:

- Ensuring thorough testing of communication equipment devices and system wide communications (from charger to back-office and vice versa);
- Recognise that neither broadband internet, nor mobile data are perfectly reliable and ensure dual method communications are available; and
- Ensuring that if system issues occur that the resulting action is both network and/or energy supplier (as customers of smart charging services) sympathetic but also sympathetic to the PEV owner. For example, having a default charge profile installed in the charger that allows full rate charging at certain times of day, but reduces or prevents charging at times of peak demand or peak pricing (depending on smart charging service customers' requirements).

6 Trial Data

This section provides an overview of the type of data gathered during the trial, details of the groups and profiles involved, and a high-level overview of the data generated.

6.1 Installations

DriveElectric co-ordinated the installation of chargers for the Electric Nation trial. Chargers were installed throughout WPD's four licence areas, by Actemium (7% of all installations), DRSFM (5%), EV Charging Solutions (41%), Stratford Energy Solutions (31%) and The Phoenix Works (16%). During the recruitment phase each potential installation was assigned to either CrowdCharge or GreenFlux, and a suitable installer (based on factors including their location). The location of the chargers is shown on the map below.

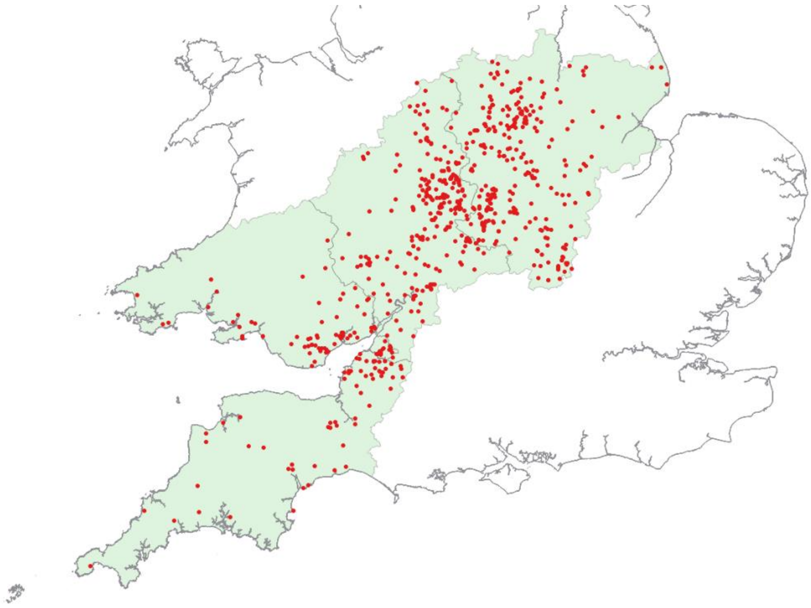


Figure 6-1: Location of Electric Nation Charger Installations

Installations took place between February 2017 and July 2018. The total number of installed chargers is shown in the graph below, per week, based on the dates provided by DriveElectric.

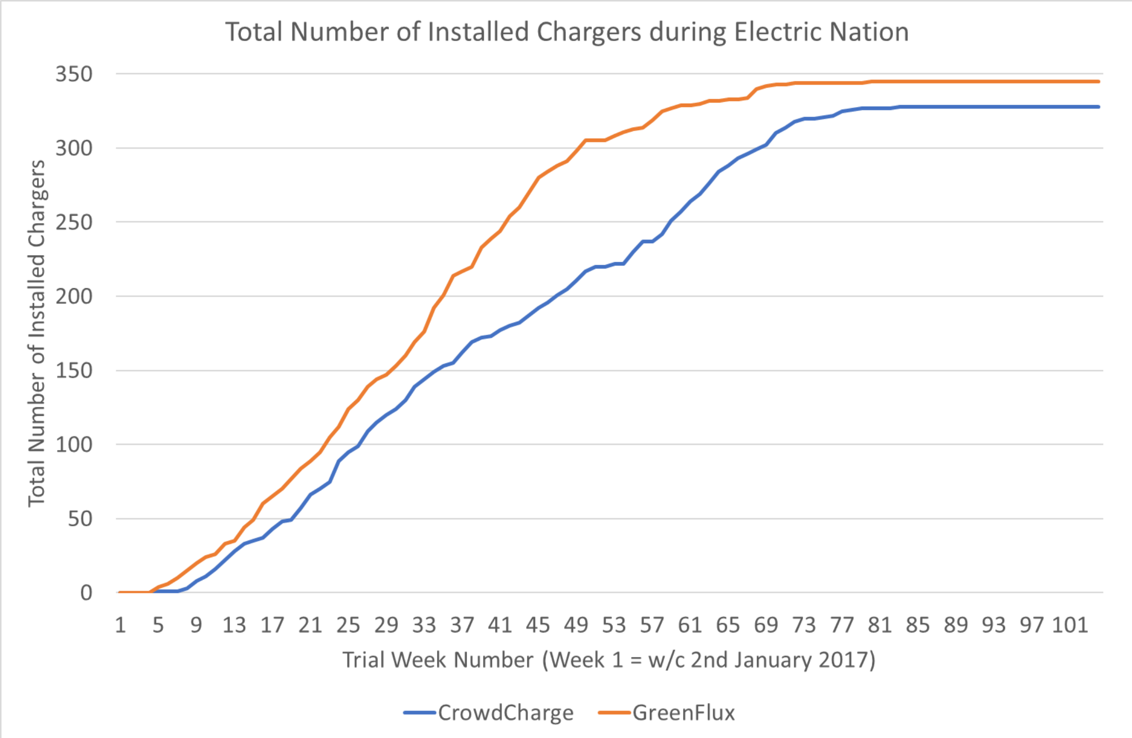


Figure 6-2: Number of Installed Chargers by Trial Week Number

By the end of 2017, 88% and 67% of GreenFlux and CrowdCharge installations respectively had been completed. Delays were experienced in completing the last installations due to installation difficulties (e.g. looped supplies), and longer delays between participants ordering their PEV and the delivery date. During the project 37 chargers were marked as 'Installed Inactive' by DriveElectric, indicating that a participant had dropped out of the trial. Reasons for this included moving home (and not re-locating the charger) and changing jobs and so no longer having a PEV as their company car.

6.2 Customer/PEV Data

Each charger was associated with a participant, and DriveElectric provided the following information for each participant and their vehicle:

- Participant ID number (used in customer research, as detailed in Section 6.8)
- Charger installation date
- Demand Management Provider (CrowdCharge or GreenFlux)
- Installer
- An estimate of when their vehicle would be delivered
- Car Make
- Car Model
- PEV Type (battery only, plug-in hybrid, range extender)
- Nominal rating of their vehicle (3.5 or 7kW)
- Battery capacity of their vehicle (kWh)

This information primarily relates to the vehicle registered as part of the trial. Further information about the participant (e.g. demographic information, number of people in household etc.) is available from the customer surveys, and details of these is given in Section 7 of this report.

The variety in the PEV types and battery capacity within the trial allows comparisons to be made of charging behaviour and response to smart charging/demand management based on these factors.

The composition of the trial cohorts is shown in the graphs below (for plug-in vehicle type and battery capacity), based on the last set of information provided by DriveElectric.

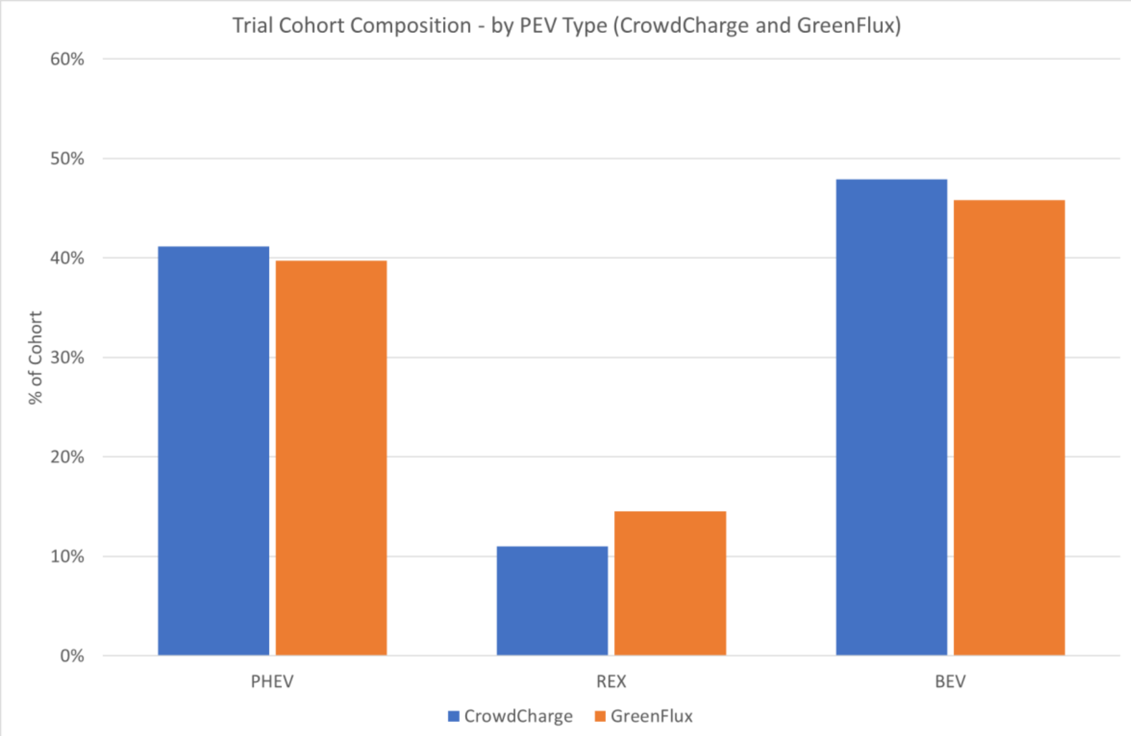


Figure 6-3: Trial Cohort Composition - by PEV Type

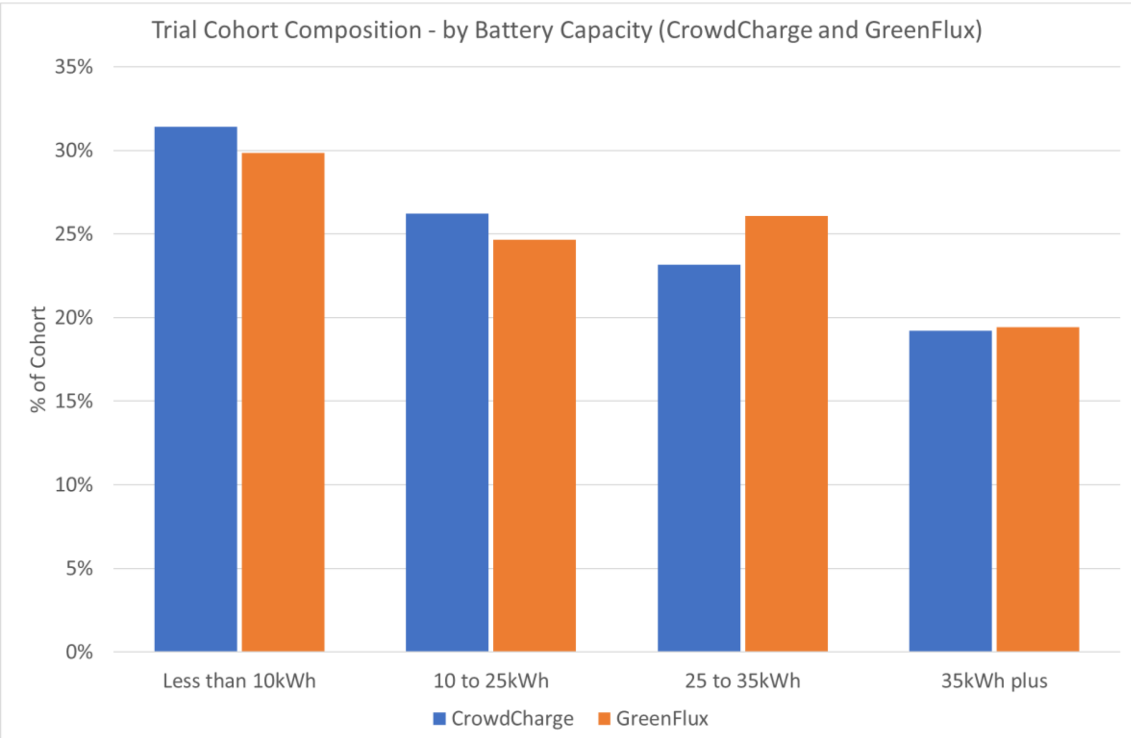


Figure 6-4: Trial Cohort Composition - by Battery Capacity

This can be compared to the recent UK sales, to show how closely the trial composition mirrors that of the wider current PEV population. Details of how these figures were derived are given in the October 2018 Customer Research and Trial Update Report[13]. Firstly, the table below shows the composition based on PEV type[14] (Plug in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs)):

Table 6-1: 2016 - 2018 UK PEV Registrations, by PEV Type

Year	PHEV Registrations		BEV Registrations		Totals
2016	74%	*(28,798)*	26%	*(10,246)*	39,044
2017	72%	*(34,660)*	28%	*(13,678)*	48,338
2018 (to end August)	76%	*(29,088)*	24%	*(9,038)*	38,126
Total	**74%**	***(92,546)***	**26%**	***(32,962)***	**125,508**

This does not contain a separate category for range extended (REX) 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 was 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 was used to compare the composition of battery sizes in Electric Nation to recent UK sales, with various assumptions made to estimate this based on the sales of popular models, and the battery capacities of these models[15].

Table 6-2: Composition of Electric Nation Cohort (by battery capacity) compared to UK PEV Sales

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%

This shows that the Electric Nation cohort was 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 future scenarios as the cost of larger batteries decreases.

[13] Available from: https://www.westernpower.co.uk/innovation/projects/electric-nation Derivation is in Section 4.2 of the report.
[14] Data from: http://www.eafo.eu/content/united-kingdom Accessed 09/10/2018
[15] Assumptions made are detailed in the July 2018 Customer Research and Trial Update Report. Available from: https://www.westernpower.co.uk/downloads/13523 See Section 7.2

The trial cohort included 45 different make/model combinations from 18 different manufacturers, spanning battery capacities from 4.4kWh (Toyota Prius Plug-In) to 100kWh (Tesla Model S or X). The manufacturers represented in the trial (CrowdCharge and GreenFlux shown together) are shown by the chart below.

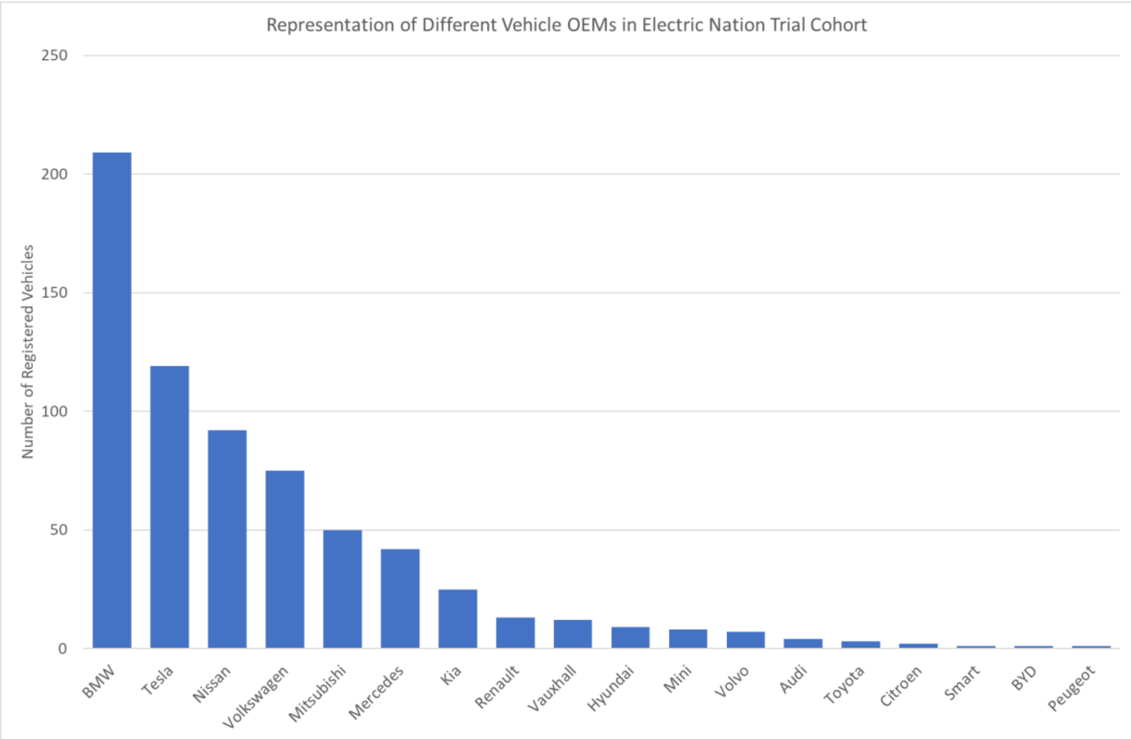


Figure 6-5: Number of Vehicles in the Electric Nation Trial, by Vehicle Manufacturer

BMW made up 31% of the trial cohort and included multiple vehicle types from the BMW i8 PHEV with a battery capacity of 7.1kWh (five participants) to the 33kWh i3 (battery only and range extender, a total of 99 participants).

The diversity of vehicle types included in the trial, with relatively large populations in each group (battery capacity group and PEV type shown above) allows conclusions to be drawn about the behaviour of different groups. This may be beneficial in predicting future behaviour as the mix of vehicles in the general UK fleet changes (e.g. higher proportion of battery only vehicles with larger batteries).

6.3 Groups

Once participants moved into the demand management phase of the project (Trials 1 to 3, as described above) they became part of a group. Separate groups were established for GreenFlux and CrowdCharge, with the group sizes increasing as more chargers were moved into demand management (further details of this process are given in Section 9). Groups were analogous to a scenario where a group of chargers were supplied from a particular substation or feeder. CrowdCharge and GreenFlux used their systems to ensure the total current drawn by groups of chargers did not exceed the capacity limits (see Section 6.4).

Groups were specified in 'GroupDefinition' files, which listed all the chargerIDs which formed part of the group, the Group Name (e.g. CC0001 or GF0001) and the start and end date for the group. These were issued by EA Technology to CrowdCharge and GreenFlux and enacted alongside a capacity profile (see Section 6.4).

The name of the group was also used to signify which trial the group was taking part in. The graphics and tables below summarise the groups. The graphics represent the length of each part of the 'demand management' part of the trial (to scale, based on duration).

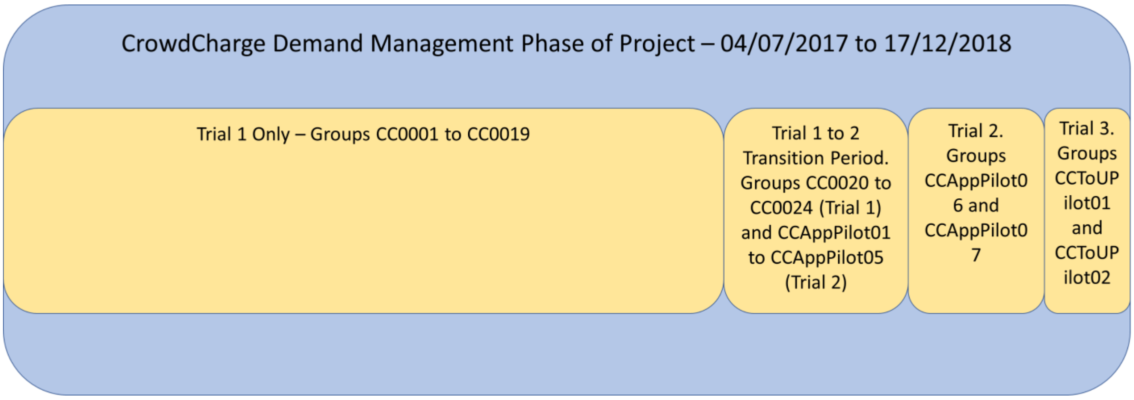


Figure 6-6: CrowdCharge Trials Timeline Overview

The size of the groups (number of chargers per group) is given in the table below.

Table 6-3: CrowdCharge Groups

Phase	Trial 1 Groups		Trial 2 Groups		Trial 3 Groups	
	Group ID	No. of Participants	Group ID	No. of Participants	Group ID	No. of Participants
Trial 1 Only (4th July 2017 to 13th June 2018)	CC0001	10				
	CC0002	21				
	CC0003	33				
	CC0004	45				
	CC0005	57				
	CC0006	76				

Phase	Trial 1 Groups		Trial 2 Groups		Trial 3 Groups	
	Group ID	No. of Participants	Group ID	No. of Participants	Group ID	No. of Participants
	CC0007	86				
	CC0008	102				
	CC0009	112				
	CC0010	124				
	CC0010	124				
	CC0011	149				
	CC0012	155				
	CC0013	167				
	CC0014	173				
	CC0015	187				
	CC0016	199				
	CC0017	206				
	CC0018	223				
	CC0019	235				
Trial 1 to Trial 2 Transition (13th June to 9th September 2018)	CC0020	215	CCAppPilot01	20		
	CC0021	204	CCAppPilot02	40		
	CC0022	174	CCAppPilot03	70		
	CC0023	151	CCAppPilot04	100		
	CC0024	35	CCAppPilot05	216		
Trial 2 (9th September to 6th November 2018)			CCAppPilot06	245		
Trial 3 Pilot (6th to 13th November 2018)			CCAppPilot07	225	CCToUPilot01	20
Trial 3 (13th November to 17th December 2018)					CCToUPilot01	245

In addition to the groups shown above 'CC0025' was operational throughout Trials 2 and 3. In order for a charger to take part in Trial 2 or 3 a software upgrade to the controller was necessary. This was not possible for eighteen chargers and so these remained in group CC0025 until the end of the trial.

An extended trial period was necessary in Trial 1 in order to slowly move participants into management after their charger had been installed and reliable communications had been established. This took a substantial of period of time due to the timescales for installations shown in Figure 6-2 and the reliability of communications during 2017, shown in Figure 5-4.

The length of the transition period between Trial 1 and 2 was dictated by the time necessary to set up app accounts for all the participants. Delays in the development of the Trial 2 and 3 algorithms and app interfaces, and their availability for testing reduced the time for which it was possible to test these systems with participants before the agreed end of the demand management trials.

A similar diagram and table are shown below, for the three GreenFlux trials.

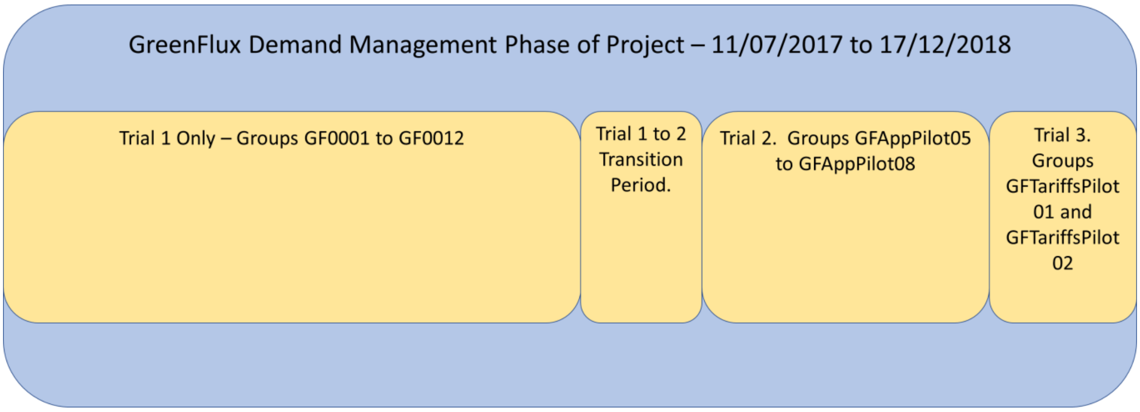


Figure 6-7: GreenFlux Trials Timeline Overview

The size of the groups (number of chargers per group) is given in the table below.

Table 6-4: GreenFlux Groups

Phase	Trial 1 Groups		Trial 2 Groups		Trial 3 Groups	
	Group ID	No. of Participants	Group ID	No. of Participants	Group ID	No. of Participants
Trial 1 Only (11th July 2017 to 4th April 2018)	GF0001	16				
	GF0002	31				
	GF0003	44				
	GF0004	64				
	GF0005	93				
	GF0006	132				
	GF0007	143				
	GF0007	143				
	GF0008	148				

Phase	Trial 1 Groups		Trial 2 Groups		Trial 3 Groups	
	Group ID	No. of Participants	Group ID	No. of Participants	Group ID	No. of Participants
	GF0009	168				
	GF0010	179				
	GF0011	188				
	GF0012	209				
Trial 1 to Trial 2 Transition (4th April to 30th May 2018)	GF0013	189	GFAppPilot01	20		
	GF0014	209				
	GF0015	169	GFAppPilot02	60		
	GF0016	119	GFAppPilot03	121		
	GF0017	59	GFAppPilot04	187		
Trial 2 (30th May to 10th October 2018)			GFAppPilot05	248		
			GFAppPilot06	249		
			GFAppPilot07	254		
			GFAppPilot08	264		
Trial 3 (10th October to 17th December 2018)					GFTariffsPilot01	274
					GFTariffsPilot02	274

The apps and algorithm updates for GreenFlux Trials 2 and 3 were available for testing earlier in 2018 compared to CrowdCharge, allowing for a longer deployment in the trial.

6.4 Capacity Profiles

Capacity profiles were established for each group. These profiles set out the available capacity (in Amps) which could be used by groups of EV chargers, referred to elsewhere in this report as 'capacity limits' or 'capacity profiles'. Separate weekday and weekend profiles were defined, with each day made up of 48 half hourly periods.

The way in which these profiles were derived is set out in Appendix 1. The available capacity was based on the difference between existing demand on an HV feeder, and its rating – therefore showing the 'spare' capacity which was available to charge PEVs. Within Electric Nation a static profile was applied – i.e. for a given half hour period, every weekday when a given profile was active, the available current was the same.

A more complex, dynamic, solution could be deployed under a business as usual scenario if real-time monitoring data was available to signal the actual loading on the feeder, and so the available capacity for EV charging. This type of solution would offer two main advantages:

- It could allow greater EV charging to occur before curtailment began (if the static estimates of available capacity were too conservative); and
- It would better protect the network by ensuring that curtailment was activated sooner (if the static estimates were too generous).

Different seasonal profiles were developed, which took account of changes in background loading through the year. An adjustment was also made based on the communications reliability of the managed group. The profiles were set based on the number of chargers in the group. However, if a proportion of these chargers were not communicating (i.e. the back office was not aware they were in use) then the likelihood of management decreased. Therefore, the profile was adjusted – for example, for a group containing 100 chargers, with communications reliability of 90%, the available current would be set based on a group of 90 chargers (90% of 100). The communications reliability of the managed group consistently outperformed the population averages shown in Figure 5-4 and Figure 5-6, as chargers with very poor communications reliability were not transferred into the managed groups (see Section 9).

The diagrams below show the time periods when different seasonal profiles were in operation throughout the trial, with each colour signifying a different season, as shown in the key.

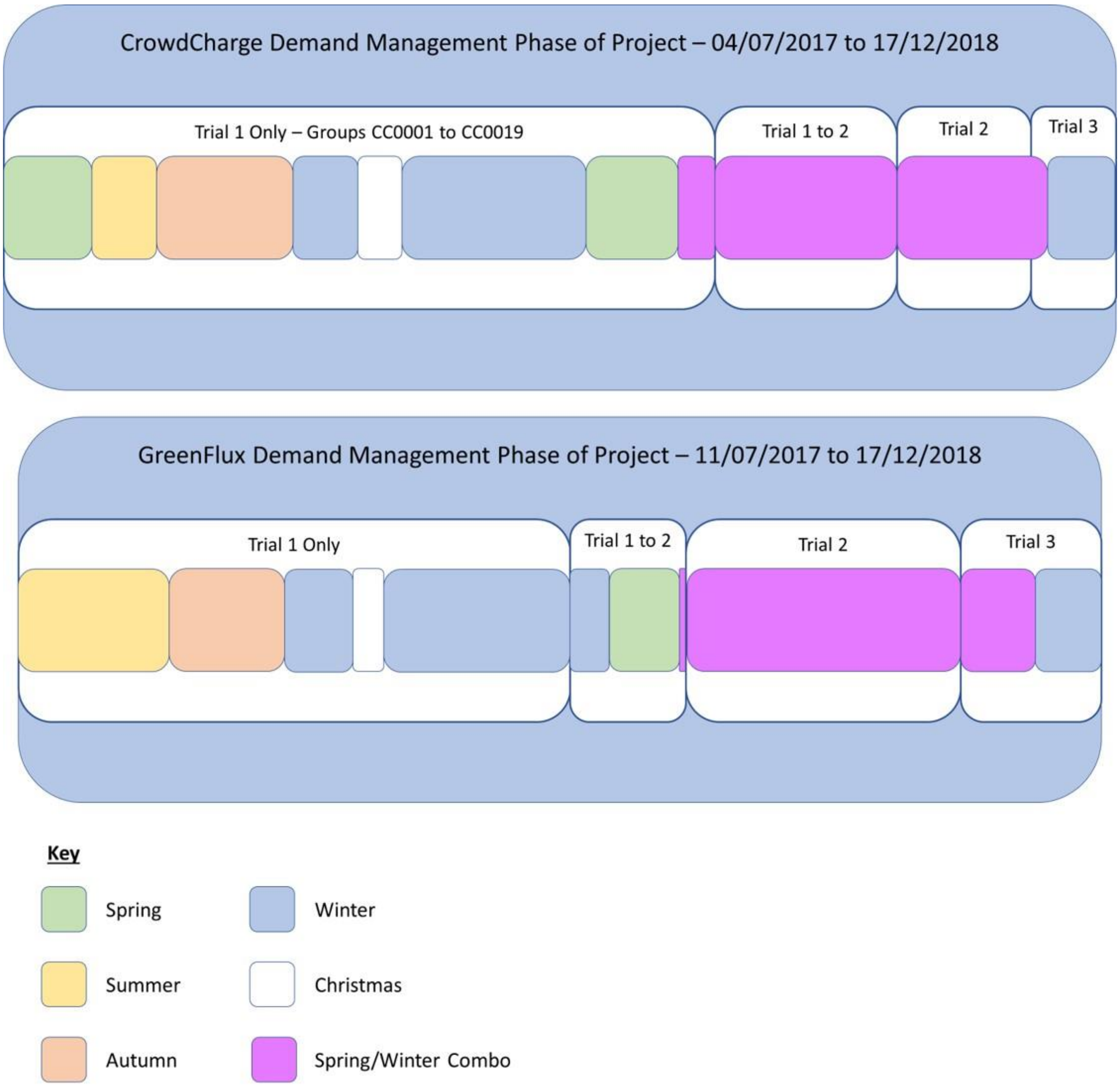


Figure 6-8: Seasonal Profiles Used in Electric Nation

Figure 6-8 above show the profiles roughly followed the seasons until late December 2017. 'Christmas' profiles were enacted over the festive break. These profiles removed the possibility of management occurring (i.e. profiles had 32A x the number of chargers in the group, all day, every day). The customer support availability from DriveElectric and CrowdCharge/GreenFlux was lower during the holiday period, and so to avoid any potential issues for trial participants management was suspended over the break. Data continued to be collected from chargers to show how demand differed during this period.

Spring profiles were applied to both parts of the trial in mid-April 2018. These ran for several weeks but the amount of capacity available throughout the day (including in the evening peak) meant that no demand management was necessary. These profiles were based on real network loading data for an HV feeder in the East Midlands, and the profiles were set to be equivalent to the level of curtailment that would be required when 30% of passenger cars are PEVs. 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 PEVs (i.e. those with less spare capacity than the specific East Midlands example chosen), or on the specific network used but with higher PEV ownership levels.

This also ensured that the project could continue to test the acceptability of smart charging solutions. The 'spring-winter combined' profile matched the spring profile outside of the evening peak period but reverted to a modified winter profile in the peak. The modification increased the available capacity slightly compared to winter, therefore reducing the levels of management slightly. The 'spring-winter combined' profile had less capacity available than either the summer or autumn profiles, so they remained in place until winter profiles were re-applied in mid-November 2018.

An example of each profile is shown below (separate figures for weekday and weekend), based on a group size of 250 participants (100% comms reliability), to allow comparison. The 'Christmas' profile has been excluded and would be a horizontal line at 8000A (i.e. 250 x 32A).

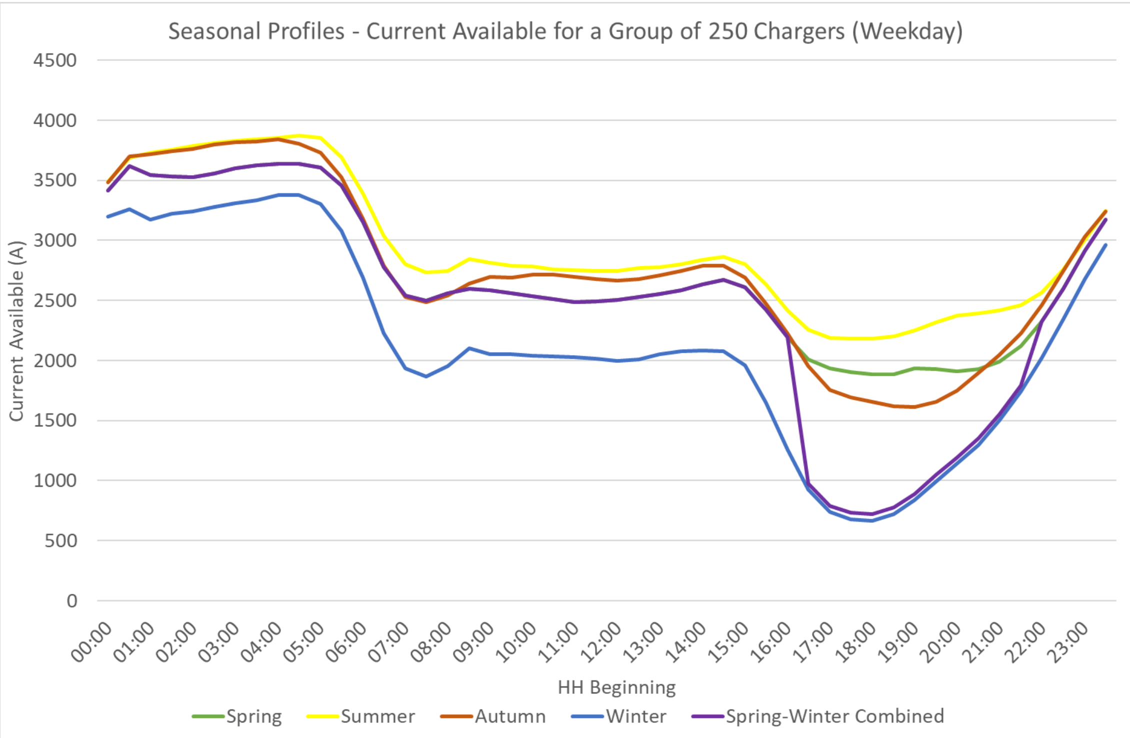


Figure 6-9: Example Seasonal Profiles (Weekday)

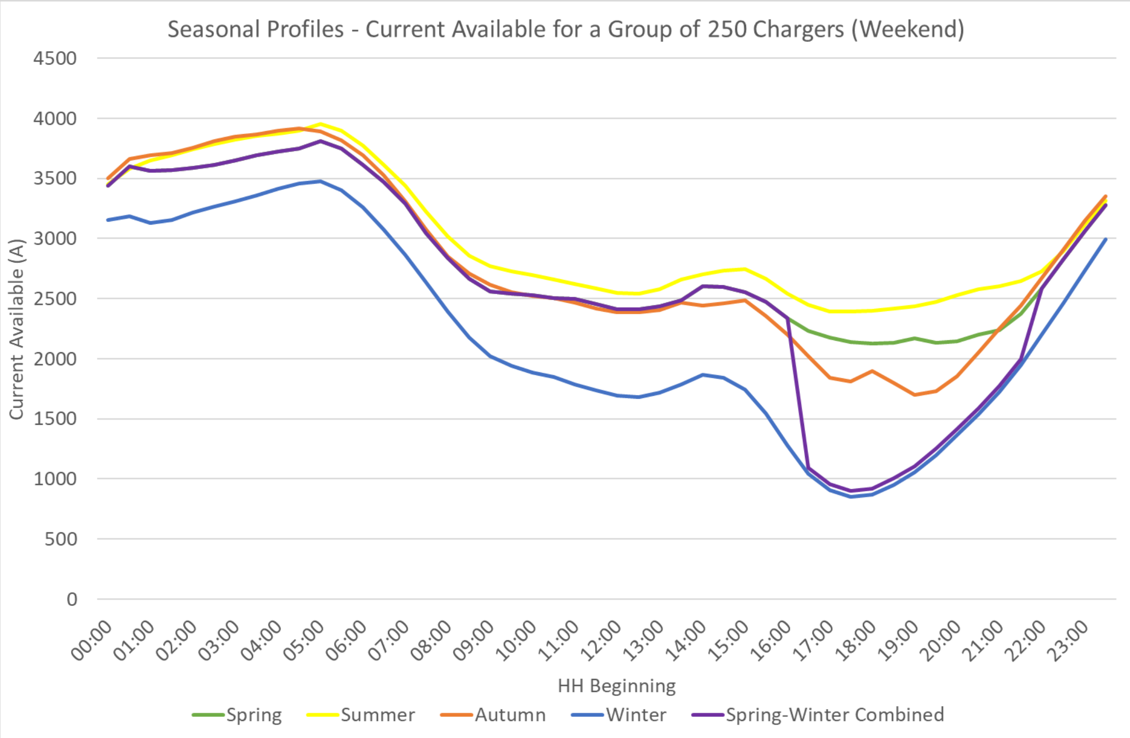


Figure 6-10: Example Seasonal Profiles (Weekend)

As described above the profiles set out the available current in each half hour period, labelled half hour (HH) 1 – HH48. The way each demand management provider interpreted this against local time differed, as described below:

- CrowdCharge: half hours were applied based on UTC (Co-ordinated Universal Time). Therefore, during wintertime (GMT – Greenwich Mean Time) HH1 referred to the half hour beginning 00:00. However, in British Summer Time (BST – late March to later October), HH1 continued to be applied at 00:00 UTC, now 01:00 local time; and
- GreenFlux: the profiles were adjusted so that HH1 was the half hour beginning 00:00 in both winter and summer time.

This difference has been taken account of in the calculation of periods when management was active set out in Sections 10, 11 and 12.

6.5 Data from Smart Chargers

The smart chargers installed as part of the project sent two different types of information to CrowdCharge and GreenFlux, which was then shared with EA Technology for analysis purposes:

- Transaction records: one row of data per charging event, showing the charger ID, the times at which the vehicle was plugged and unplugged, and the amount of energy transferred in the charge session; and
- Current meter values: time series data, with a record of the amount of current (amps) made available from the charge point and drawn by the vehicle, either for each minute (CrowdCharge), or every three minutes (GreenFlux). This allowed 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?).

In all cases, timestamp values were supplied in UTC. Within the analysis described in later sections of this report these have been adjusted to local time.

These data types are explored in more detail in the sub-sections below.

6.5.1 Transaction Data

A transaction record was generated each time a vehicle was plugged into an Electric Nation charger. The following fields were provided by both CrowdCharge and GreenFlux:

- ChargerID – the identification number of the charger which the record related to. This could be linked to a participant and their registered vehicle, using the information provided by DriveElectric;
- GroupID – field should show the group which the charger was in at the time of the charge event. Neither CrowdCharge or GreenFlux could retrospectively apply this to information provided once the group had changed (e.g. a download of transaction data taken for CrowdCharge at the end of the project would only contain GroupIDs of 'NULL' (chargers not being managed), CC0025 and CCToUPilot02, regardless of which group was active at the time of the transaction). This raw data was therefore replaced in the analysis database with the correct GroupID, using the ChargerID, StartTime of the transaction (see below), and the Group definitions;
- StartTime – the time at which the vehicle was plugged in;
- StopTime – the time at which the vehicle was unplugged; and
- Consumed Energy – the amount of energy transferred during the charge event, in kWh.

A wide range of other quantities have been calculated for each transaction within the Electric Nation analysis database, using the meter values which relate to each transaction. Examples of these fields include the time charging began, the maximum current drawn and the time charging ended.

The handling of transaction records for charge sessions which occurred when the charger was offline varied between the CrowdCharge and GreenFlux, and at different points in the trial:

- CrowdCharge: prior to the controller update applied at the start of Trial 2 charging records from chargers which were offline were often lost. After the controller software update these records were held locally and supplied when the charger reconnected to the back office; and
- GreenFlux: transaction records for sessions which occurred when the charger was offline were held locally (at the charger). Once communications were restored these records were sent to GreenFlux and provided to EA Technology. This applied for the full duration of the trial.

A transaction record was generated each time a vehicle was plugged in (and subsequently unplugged), even if the vehicle was unplugged again very soon afterwards, or very little energy was transferred. Including these records within the analysis would give a false impression of certain aspects of charging behaviour, such as the frequency of charging (artificially inflating the value) or the average length of a plug-in event (lowering the value). Some inaccuracies in the data also mean that a small number of records were received with implausibly high energy consumption figures (greater than 100kWh, the largest battery capacity in the project). This issue was not widespread – comparing the energy drawn to the battery capacity registered to each charger shows that the majority were within expected value. The data presented elsewhere in this report therefore only includes charge sessions where the consumed energy was between 0.5 and 100kWh. The table below summarises the number of transaction records meeting these criteria for each stage of the trial.

Table 6-5: Number of Transaction Records Collected

	Number of Transaction Records (Consumed Energy 0.5 to 100 kWh)				
	Outside of Management	Trial 1	Trial 2	Trial 3	Total
CrowdCharge	23,447	27,598	12,756	5,991	**69,792**
GreenFlux	27,690	22,974	19,732	9,917	**80,313**

The number of records is to be expected based on the length of time for which the trials were operational. The ‘outside of management’ transactions are made up of all the transactions from chargers which never went into demand management, through the length of the project, plus the early charge events of those that later went into demand management. Management will not have affected all the transactions which were part of the 'Trial' groups (e.g. 22,974 transactions in Trial 1 for GreenFlux), as management may not have been required at the time the transaction took place. Further details of the management of individual transactions can be found in Sections 10, 11 and 12.

6.5.2 Current Meter Values

Meter values were the most granular type of data supplied to the project. The fields supplied are described below:

- CrowdCharge: the fields below were sent every minute for the full duration of the charging session (from plug-in to plug-out) prior to the controller update described above. After this update values were sent every minute when the 'Status' was 2 (see below) and every half hour when the 'Status' was 1;
    - ChargerID;
    - Timestamp;
    - MaxAmpsUsed - the current drawn by the car, in Amps;
    - AmpsAllocated_Charger - the current limit interpreted by the charger (i.e. what was available);
    - CC_Amps_Allocated – the current limit set by the CrowdCharge back office. In some instances, this may have differed slightly from the limit as interpreted by the charger[16]; and
    - Status (1 or 2) – 1 indicated a car which was connected and not charging (either because a timer was set and not elapsed, or the vehicle has finished charging), or 2 (actively charging).
- GreenFlux: the fields below were sent every three minutes for the full duration of the charging session (from plug-in to plug-out) throughout the trial;
    - ChargerID;
    - Timestamp;
    - MaxAmpsUsed – the current drawn by the car, in Amps; and
    - AmpsAllocated – the current available, as reported by the charger. Within the analysis an alternative 15-minute value has been used, as supplied by GreenFlux (see Section 6.6.2) as this is more accurate.

Meter values have been associated with a transaction. For example, if a transaction record for charger ID 'A', with plug-in and plug-out times of 2nd March 2017 10:00 to 2nd March 2017 17:00 respectively, has been assigned a transaction ID of '1234' then all the meter values from charger ID 'A' with timestamps between 2nd March 2017 10:00 and 2nd March 2017 17:00 will also have transaction ID '1234' assigned to them. This allows quantities such as the average current drawn in a transaction to be calculated.

As described above, meter values were not available for all transactions (for example GreenFlux transactions which occurred whilst a charger was offline). In these cases, it was

[16] This could occur due to the charger software rounding up or down of the value received from the CrowdCharge back office, or the charger software converting from current values to percentages.

not possible to calculate certain properties for those transactions such as the time when charging began.

Meter values were the largest dataset in the project. CrowdCharge chargers sent over 29 million values, and GreenFlux over 15 million. The difference is understandable because GreenFlux generated a meter value every three minutes and CrowdCharge once a minute.

6.6 Additional Data from CrowdCharge and GreenFlux

CrowdCharge and GreenFlux both sent further information generated by their back-office systems, and this is described in the two sections below.

6.6.1 CrowdCharge – Charge Control Log

As described in Section 10.1 during Trial 1, management was applied at a group level, with all chargers in the group receiving the same allocation in a given minute (e.g. if the demand/capacity limit was 300A and ten chargers were active then each was allocated 30A). The CrowdCharge system included a 'charge control log' which generated a message for each charger, for each minute when management was active, for example:

> "[1] Group demand control active for Charger_id 262. New charger current limit is 30.0 Amps. Charger_id is in Group 8, which has a Group current limit of 120.0 Amps, and a total of 4.0 active chargers, resulting in an allocation of 30.0 Amps per charger."

These messages have been processed to create a charge control log table within the analysis database. This table contains a record for each minute when management was active (rather than for each charger, for each minute), with the following fields:

- DateTime – when management was active (in UTC);
- GroupID – ID of the group which was operational and being managed (e.g. CC0001 etc.);
- ProfileID – ID of the capacity profile which applied to the group (see Section 6.4);
- ChargerCurrentLimit – the current available to each charger (30A in the text example above);
- GroupProfileLimit – the capacity profile limit for that particular profile and time (120A in the text example above); and
- NoActiveChargers – the number of chargers in the group with a Status of 2 in the given date time (4 in the example above).

This table has been used to show the frequency of management during Trial 1 (see Section 10.1.3) and used in determining whether individual Trial 1 transactions were constrained (see Section 10.1.4).

6.6.2 GreenFlux – Allocation Data

Allocation data was provided by GreenFlux for the duration of the smart charging part of the trial. This showed the current allocated to each charger by the GreenFlux algorithm, for each 15-minute block. This data was used to show when management was active at a group level (e.g. see Section 10.2.3 for Trial 1) and in determining whether individual transactions had been managed (see Section 10.2.4 for Trial 1). The fields provided were:

- ChargerID;
- Start Time – the start of the 15-minute block;
- EndTime – the end of the 15-minute block; and
- Allocated – the current (A) allocated to that charger in the 15-minute block.

Meter values (MaxAmpsUsed) were averaged across 15-minute blocks to allow comparison of the current drawn to the current allocated.

6.7 App Usage Data

The data available on app usage/interaction varied between the two systems developed by CrowdCharge and GreenFlux.

6.7.1 CrowdCharge

As described in Section 11.1.1 participants were invited to register for a CrowdCharge account, and then could enter three different types of information (regular journey plans, one-off journeys or state of charge). The following pieces of information were provided by CrowdCharge:

- The date each participant was invited to register for an account;
- The date their account was set-up and operational (blank for those who didn't respond); and
- Details of the number of state of charge entries, regular journeys and one-off journeys entered by each user from their registration to 11th October 2018, then 11th October 2018 to 7th January 2019.

6.7.2 GreenFlux

GreenFlux participants in Trial 2 and 3 were invited to download an app from the Google Play (Android) or App Store (iOS). The two updates had various ways by which participants could interact with the smart charging system:

- Trial 2 app version: users could request high priority for the active charging session; and
- Trial 3 app version: as Trial 2, plus users could select a charging preference (minimise cost, optimise time or optimise time and cost). The preference they selected would remain active and be applied to all charging sessions until they changed it again.

'Optimise time' was the default option. Further details of this are given in Sections 4.10.2 and 0.

GreenFlux provided three different types of information relating to the app:

- Number of downloads from both App Stores (per day). It was not possible to identify which participants had downloaded the app from this information. However, it allows a comparison to be made of when the app was downloaded (and how many times) compared to the number of people who had been sent a link;
- Time of high priority requests against each transaction (blank if no high priority request was made); and
- Charging preference (minimise cost, optimise time etc.) associated with each transaction during Trial 3.

From this information the extent to which participants interacted with the GreenFlux smart charging system can be analysed. The results of this analysis can be found in Sections 11.2.5 and 12.2.4. Participants also self-reported their use of the apps and gave additional qualitative information around issues such as why they used the app in the Trial 2 and 3 surveys (see Sections 11.2.5 and 12.2.5).

6.8 Customer Survey Data

6.8.1 Introduction to Surveys

Customer research was one of the many data sources gathered by the Electric Nation trial. This research was undertaken by Impact[17]. The customer research data forms a key part of answering the overall customer objective of the trial, as part of this report:

> "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 trial[18] required participants to complete a number of surveys during the course of the Project. This enabled the Project to understand participants' attitudes toward charging their PEVs and their level of acceptance of varying degrees of demand management/smart charging. By repeating the surveys at each part of the trial (Trials 1, 2 and 3) the effect of changing the demand management/smart charging systems can be studied. For example, whether the introduction of apps (Trial 2) or ToU rewards (Trial 3) changed participants' attitudes towards charging their vehicles and

[17] https://www.impactmr.com/ Accessed August 2019
[18] This condition was highlighted in project publicity literature, such as the Project website and brochure – accessible via the Project website http://www.electricnation.org.uk

managed charging. Details of the results of the customer research conducted for each Trial are given in the relevant sections of this report.

Participants' contact details were collected by DriveElectric, the project partner responsible for participant recruitment and associated data protection[19], as part of the enrolment process. DriveElectric clearly explained to trial participants before they enrolled in the trial that they were obliged to complete customer research surveys. The graphic below demonstrates the exchange of participant data between DriveElectric and Impact.

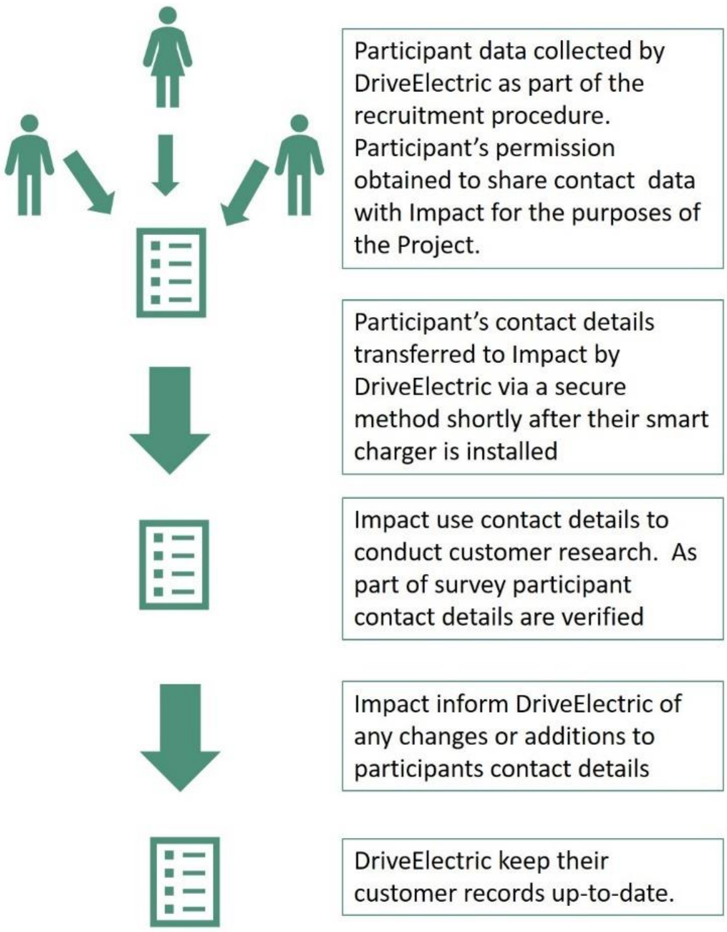


Figure 6-11: Exchange of participant data between DriveElectric and Impact

Shortly after the installation of a participant's smart charger they were asked to complete the Recruitment survey (see Appendix 4). The information collected in this survey was focused on:

- Demographic and socio-economic data;
- Information about the participants, their household and their PEV; and

[19] 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.

- Their level of satisfaction with their smart charger installation experience.

Until May 2018 participants were then asked to complete a Baseline survey (see Appendix 5). This survey was issued between 4 and 6 weeks after having their charger installed or after receiving their PEV, whichever was later. It obtained data on the participant's charging behaviour, their satisfaction with this and their attitude towards having their charging managed. After June 2018 a large enough sample size to be statistically comparable (i.e. more than 100 in each of the two cohorts) of the Baseline survey had been collected. After this point participants were moved into demand management as soon as stable communications had been proven with their charge point.

Further surveys were issued to participants towards the end of each of the trials (Trial 1, 2 and 3). A final survey was also conducted after all three trials were complete. These surveys (see Appendices to this document for full surveys) were similar to the Baseline survey so that the results could be compared (e.g. looking at satisfaction with charging arrangements). However, as the trial progressed, they also contained questions specific to each trial (e.g. to collect information about use of apps during Trial 2 and 3). Table 6-6 below shows the timing of the surveys.

Table 6-6: Trial Survey Timings

Survey	Issued Between	Timing
Recruitment	14th December 2016 to 13th July 2018[20]	Issued within two weeks of the participant having their smart charger installed.
Baseline	11th April 2017 to 24th June 2018	Issued to participants between 4 and 6 weeks after having their charger installed or after receiving their PEV (whichever was later).
Trial 1 (CrowdCharge and GreenFlux)	15th January to 28th April 2018	Issued to participants after they had experienced management for at least 4 weeks.
Trial 2 - GreenFlux	23rd July to 8th November 2018	Issued to participants 4 weeks after they received access to the app.
Trial 2 - CrowdCharge	1st August to 19th November 2018	Issued to participants 6 weeks after they received access to the app. CrowdCharge participants were given longer (compared to GreenFlux) because the set-up period between a participant indicating that they would like an account, and them having access to the app, was longer.
Trial 3 - GreenFlux	5th December 2018 to 8th January 2019	Issued to participants 4 weeks after they received access to the updated app.

[20] The Recruitment survey was re-opened to allow participants who had not completed it at the start of the trial another opportunity to do so whilst the Final Survey was in progress (i.e. 15th January to 9th February 2019)

Survey	Issued Between	Timing
Trial 3 - CrowdCharge	14th December 2018 to 11th January 2019	Issued to participants 4 weeks after they received access to the updated app.
Final Survey	10th January to 14th February 2019	Survey issued to all participants (CrowdCharge and GreenFlux) simultaneously, after smart charging had been disabled.

In addition to the surveys above two focus groups were held (one each for CrowdCharge and GreenFlux). This supplemented the data from the survey with additional qualitative data ensuring that learning from the project was as extensive as possible.

Participants were asked to volunteer for the focus groups in a newsletter circulated towards the end of the project. Invitations to the focus groups were sent to participants with priority being given to those who had taken part in all three trials. The focus groups were attended by seven and five participants each, for GreenFlux and CrowdCharge respectively. An in-depth telephone interview was carried out with an additional participant to supplement the responses from the CrowdCharge group.

6.8.2 Data Collection

The table below shows the completion rate for each of the surveys.

Table 6-7: Survey Response Rates

Survey	Number Issued	Number Completed	Completion Rate
Recruitment	672	615	92%
Baseline	531	508	96%
Trial 1 - CrowdCharge	143	134	94%
Trial 1 - GreenFlux	167	144	86%
Trial 2 - CrowdCharge	236	168	71%
Trial 2 - GreenFlux	265	230	87%
Trial 3 - CrowdCharge	245	194	79%
Trial 3 - GreenFlux	273	207	76%
Final Survey	661	513	78%

The survey response rate across the trial was high. The high response rate can be attributed to a number of factors and processes put in place by the project team:

- Newsletters was 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) who would be sending the surveys;
  - The incentive they would receive for completing some surveys; and
  - Asking them to expect a survey soon in newsletters which were issued around the time that a new survey would be opened.
- Tweets sent from the project Twitter account to remind participants to complete the surveys;
- DriveElectric reminded participants during the enrolment process that under the terms of the trial, in return for the installation of a free "smart" EV charger at their home, they would be asked to participate in customer research surveys (trial participants could, of course, withdraw from the trial at any time or just not participate in a survey);
- DriveElectric ensured that participants were expecting communication from Impact as part of the trial;
- DriveElectric collected personal email addresses from participants rather than work addresses, as work addresses were more likely to reject emails from Impact as spam. They also encouraged participants to add Impact's email address to their contacts list, again to reduce the chance that emails would be filtered as spam or blocked by servers which are likely to be more sensitive in their place of work;
- Participants were given the flexibility to complete the survey over the phone or online and with/without the assistance of a professional interviewer;
- Impact made multiple attempts to contact participants who had not completed their surveys. This procedure is outlined in Figure 6-12 below. If this was unsuccessful, then Impact and/or DriveElectric sent a personalised email to ensure communication has been received and check that the participant had been given ample opportunity to participate in the research;
- The high response rates achieved and active communication from participants demonstrates that participants were enthusiastic about taking part in the trial and completing the surveys;
- Surveys were kept succinct and not unduly onerous for participants to complete. This helped to prevent survey fatigue and encouraged future participation (surveys should have taken roughly 10 minutes or less to complete). Response rates tended 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 could be disrupted by holiday seasons; and
- It should be noted that surveys did not highlight details of the charging algorithm, or provide too much information about being managed, in order to avoid biasing the results.

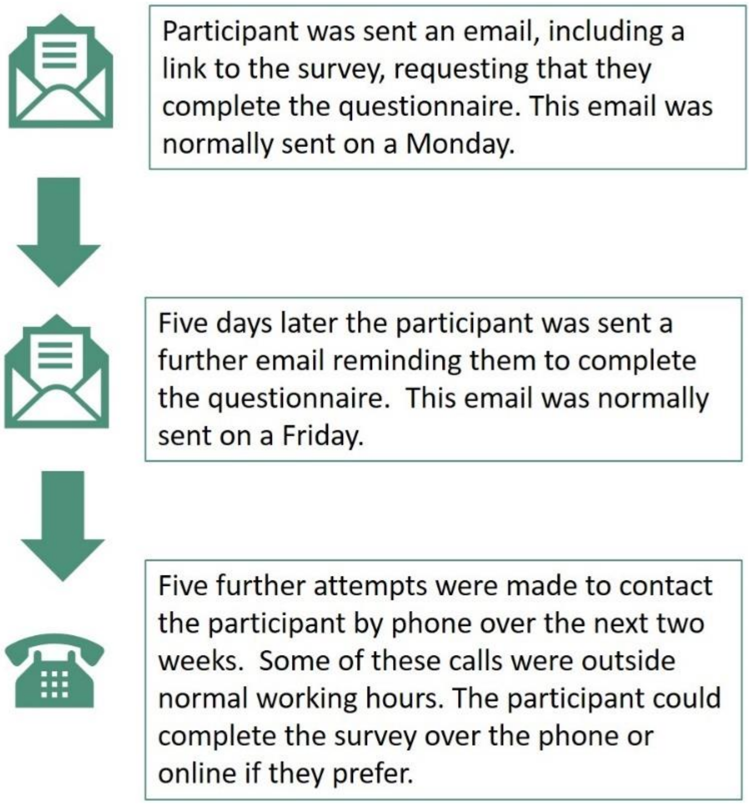


Figure 6-12: Procedure used to encourage participants to complete questionnaires

For all trial surveys, the participant was sent a link to the questionnaire by email. If they failed to complete the survey within an allotted period, then the link was re-sent with a further email reminding them to complete the questionnaire. If the participant still did not complete the survey, then Impact attempted to contact them by telephone. The participant was telephoned several times over the following weeks.

Participants received a £10 Amazon voucher for completing each of the trial surveys and a £25 Amazon voucher for completion of the final survey. Completion of the Recruitment and Baseline surveys were an obligatory condition of trial participation and therefore not rewarded. Participants were not eligible for the vouchers above if they did not complete the Recruitment and Baseline surveys. Participants who took part in the online focus groups in February 2019 received a £40 Amazon voucher.

6.8.3 Data Flow

Information from the surveys was used alongside data from the smart chargers to judge the acceptability of smart charging amongst participants. The flow of this information is shown below:

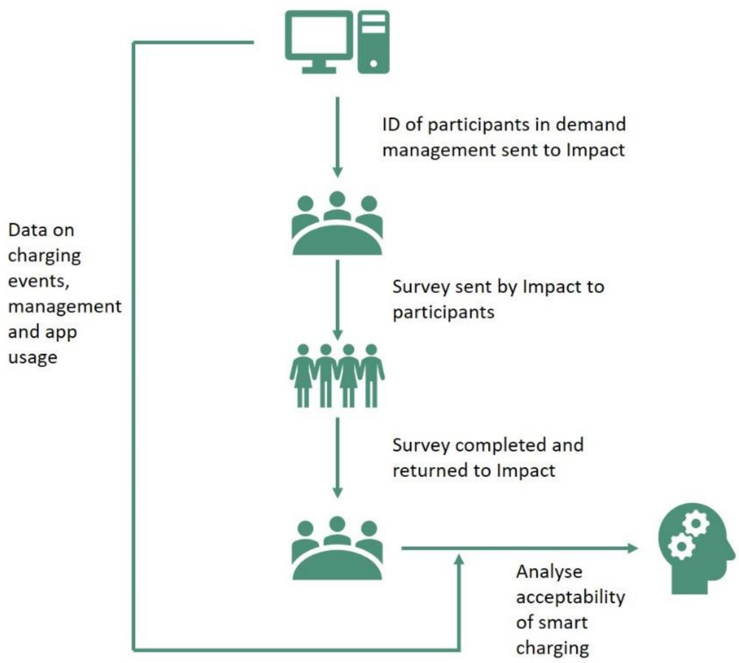


Figure 6-13: Data flow for trial surveys

Impact were informed by EA Technology of the ID of participants who had been moved into a demand management group (for Trial 1, Trial 2 and Trial 3) in order for them to be issued a trial survey. Impact then issued survey links to the relevant participants and encouraged them to complete the survey, either online or by telephone according to the participant's choice. Impact then shared the survey results with EA Technology, who combined the survey data with other data sources (such as the amount of management each participant experienced, or their usage of the apps in Trial 2 and 3) in order to assess the acceptability of smart charging to participants. The conclusions of this work are reported later in this report (Sections 10, 11 and 12).

7 Description of Electric Nation Participants

Approximately a fortnight after trial participants had their smart charger installed, they were sent an invitation to complete the Recruitment survey. This gathered demographic and socio-economic information about the trial participants. It provided the Project with a description of the trial population and frame of reference against which all future survey measurements could be compared.

The data provided in this section describe the trial population who responded to the Recruitment survey. As noted in Section 6.8.2, 92% of participants completed this survey. A small number of supplementary data points have been included from the Final survey, carried out at the end of the project and several from the Baseline survey (this is stated in the details below). This results in slightly different samples across some of the questions below. However, in all cases the responses gained provide an overview of the people who took part in Electric Nation. The full text of the Recruitment survey can be found in Appendix 4.

7.1 Gender

There was a pronounced gender split amongst participants. Of the 616 participants who completed the Recruitment survey 89% were male, compared with 11% female (Figure 7-1).

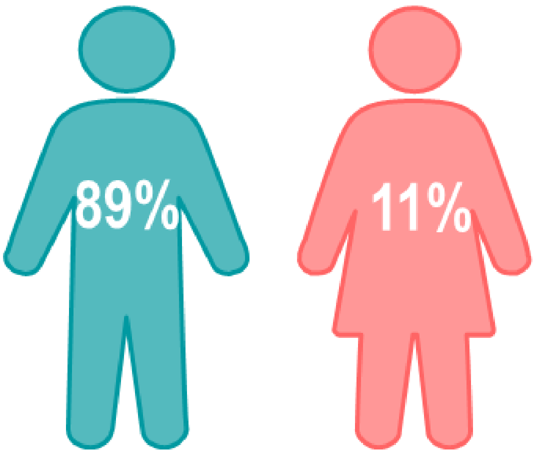


Figure 7-1: Gender split of participants (based on 616 surveys)

DriveElectric shared contact details for each Electric Nation participant with Impact (for the purposes of carrying out the surveys). The gender split shown above therefore represents the gender of those who signed up to the trial (not the registered keeper of the PEV). The recruitment (and all other surveys) requested that they were completed by a ‘regular’ driver of the vehicle.

Directly comparable data (i.e. showing the gender of 'regular' drivers of vehicles) is not available. However, for comparison purposes Figure 7-2 below shows the gender breakdown of registered keepers of privately-owned cars in the UK (2018[21]).

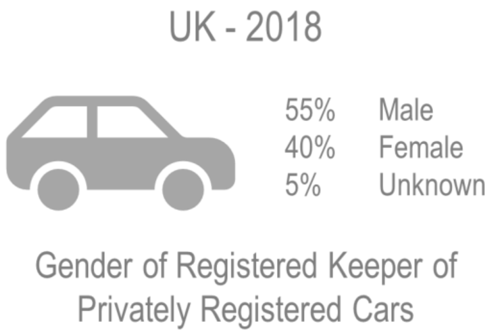


Figure 7-2: Gender of Registered Keeper of Privately Registered Cars (2018)

This shows that the Electric Nation trial population was not representative of the UK population, as it was heavily biased towards males (89%). This may reflect a greater tendency for men to buy/lease PEVs (the statistics in Figure 7-2 are for all fuel types) and/or a greater interest in signing up to take part in a trial.

7.2 Age

The chart below (Figure 7-3) illustrates the age range of participants. The majority of participants (63%) were aged between 36 and 55, however the trial included participants from all age groups eligible to drive a vehicle. Only a very small proportion (1%) were in the lowest age group (18 – 25). This is likely to be due to the financial commitment involved in buying/leasing a PEV, meaning that very few of the youngest drivers were in a position to do so, and therefore they were not represented within the Electric Nation participant group.

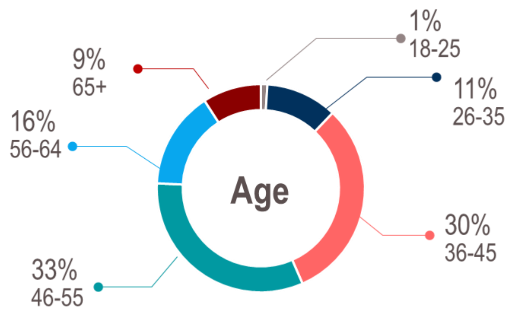


Figure 7-3: Age split of participants (based on 616 surveys)

[21] Department of Transport Statistics. Table VEH02. Licensed cars by keepership (private and company): Great Britain and United Kingdom. Available from: https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars#licensed-vehicles Accessed August 2019

The average age of participants was 48. The youngest participant was 21 and the oldest was over 80.

Figure 7-4, below, shows that the GreenFlux and CrowdCharge cohorts had a similar age profile.

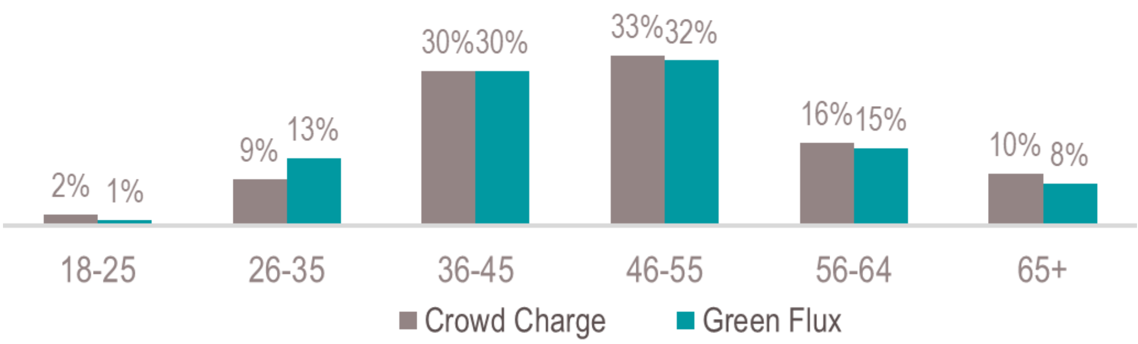


Figure 7-4: Comparison of the age profiles of the GreenFlux (320) and CrowdCharge (296)

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

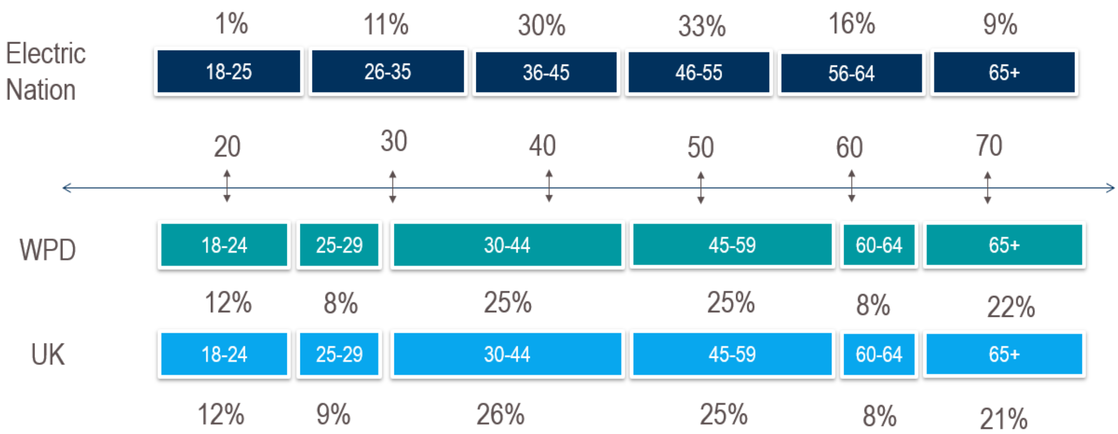


Figure 7-5: Comparison of participant age breakdown to national and WPD licence areas (based on 616 participants , 2011 UK Census data used for UK and WPD comparison)

7.3 Household Size

Electric Nation participants represented a range of different household sizes (including adults and children). This is demonstrated in Figure 7-6, below:

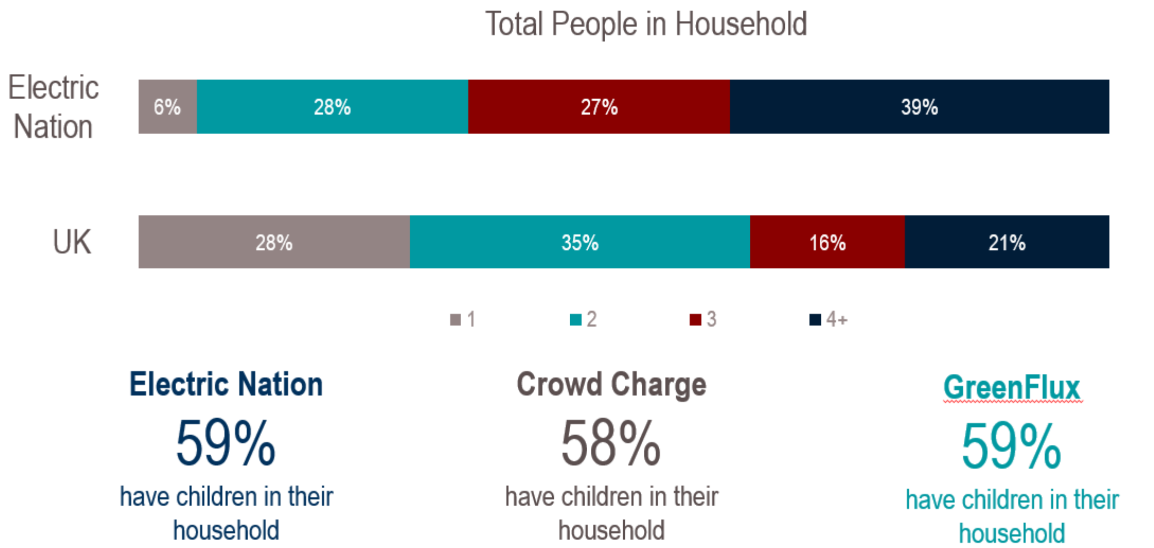


Figure 7-6: Participant household size (Total people in household and, number of children in household based on 616 respondents, compared with 2011 Census data)

Electric Nation trial participants were more likely to be from households with multiple occupants than the UK norm, particularly households with 3 or more occupants (66% of the Electric Nation population, compared to 37% of the UK).

The number of children in participant households is illustrated in Figure 7-7, below:

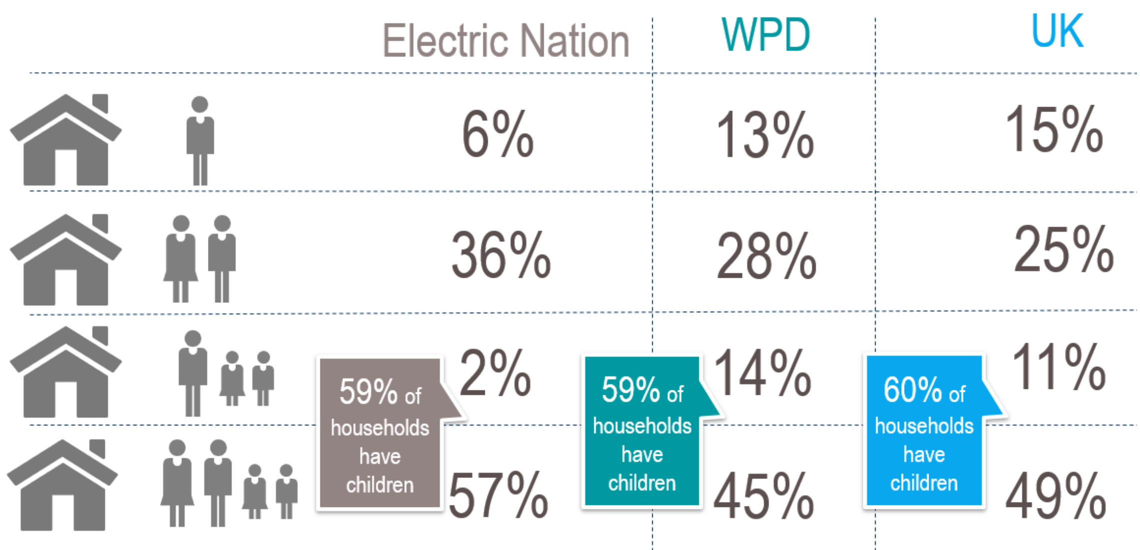


Figure 7-7: Number of children in participant households (based on 616 surveys)

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

7.4 Socio-economic and Employment Data

Figure 7-8, below, shows the socioeconomic characteristics of trial participants and compares this to the groupings for WPDs licence area and national figures.

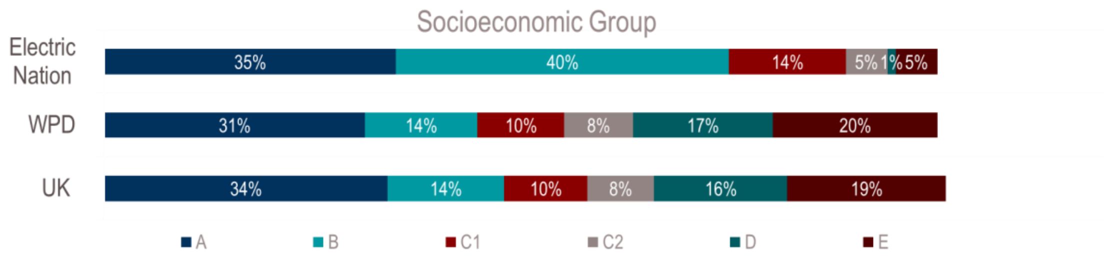


Figure 7-8: Socio- economic category of participants (based on 616 surveys, UK and WPD comparison data from 2011 Census data)

Table 7-1 below, provides a breakdown of the socio-economic segmentations of these categories.

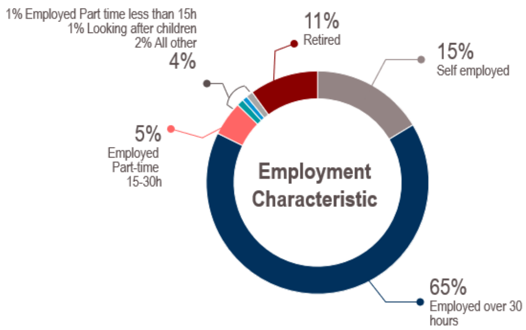
Table 7-1: Definitions of socio-economic categories

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

Trial participants were more likely to be from higher socio-economic categories than both the UK and WPD population. Most trial participants were engaged in Higher or Intermediate professions however trial participants were recruited from all socio-economic categories. Only 20% of respondents had a household income between £6,499 and £39,999. 22% of households had an income of between £40,000 and £59,000, while 29% had an income between £60,000 and £89,000. 28% of trial participants had a household income over £90,000 per annum.

During the project (and at the time of writing) PEVs were more expensive to buy or lease than petrol or diesel vehicles, even though the running costs are lower. There were only a small number of PEVs available on the second-hand market. The financial outlay involved in buying/leasing a PEV means they are more likely to be owned by those who are more affluent (who also tend to be more highly educated). This is visible in the data above, and in Figure 7-12.

Figure 7-9, below, illustrates the employment characteristics of participants. Most participants worked full time. However, the trial had a proportion (11%) of participants who were retired. The number of self-employed participants was similar to the national rate[22] using 2016 data. Figure 7-9 compares the Electric Nation participants to the WPD licence area, using 2011 census data, as this data source allows the self-employment rate to be quantified for this area – rates of self-employment have increased nationally since the 2011 census[22].



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%

Figure 7-9: Participant employment characteristics (based on 616 participants, WPD and UK source Census data 2011)

[22] 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 7-10 below, illustrates the working pattern of those participants who were in employment.

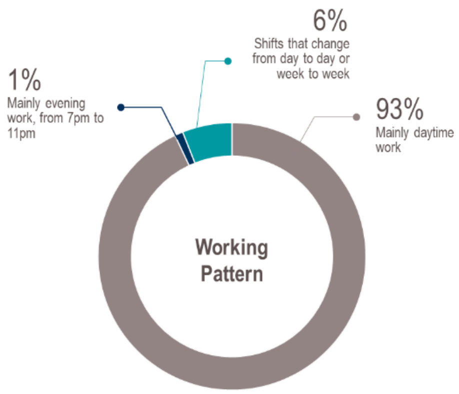


Figure 7-10: Working time characteristics of participants in employment (535 participants)

This demonstrates that 9 out of 10 participants work during the daytime. It could suggest that these participants may have less flexibility about when they charge their vehicles, compared to other trial participants who are at home during the day (e.g. retired participants, stay-at-home parents, or those who work from home). They may be more likely to charge their vehicle during the evening, or overnight. Flexibility (defined within this project as the difference between the time plugged in compared to the time charging) is explored in more detail in Section 8.9. Insights into where trial participants charge their cars (based on the Baseline Survey responses) are shown in Section 9.1.1.

7.5 Attitudes to Technology Adoption

Participants in Electric Nation had all either bought or leased a PEV. The factors which motivated them to do so are shown in Figure 7-18. Adoption of PEVs remains relatively low amongst the UK population. In 2018, a total of 2,341,500 cars were registered for the first time, of these 59,500 (2.5%) were PEVs[23].

PEVs represent a new technology and drivers will adopt them at different stages, depending partly on their attitudes to new technology. As new technologies/offerings (such as PEVs) are introduced to the market they are taken up gradually, by different types of consumers at different times. 'Diffusion of Innovations' theory (popularised by Everett Rogers, 1962[24]) seeks to explain how these new initiatives spread through a population. Different types of

[23] Department for Transport Vehicle Licensing Statistics. Table VEH0253. 59,500 = total of 'Plug in Hybrid Electric', 'Battery Electric' and 'Range-Extended Electric' categories. Data table available from: https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars#registered-for-the-first-time Accessed August 2019

[24] Information from: http://en.wikipedia.org/wiki/Diffusion_of_innovations#Diffusion_of_New_Technology Accessed August 2019. Article based on: Diffusion of Innovations. Rogers, Everett M. (1962 and 1983 editions).

adopters will take up the innovation at different rates. These different types of adopters were defined by Rogers as:

- Innovators: the first individuals to adopt an innovation. They are generally willing to take risks, are often young, of a high social class, with great financial liquidity and are linked to other innovators. They have a relatively high tolerance to risk (i.e. have sufficient financial liquidity to accept the risks). In relation to Electric Nation these participants may be more willing to accept the risk associated with smart charging;
- Early Adopters: these are similar to innovators. These individuals have the highest degree of opinion leadership – they share their experiences with others. This is visible in the current online community of highly engaged PEV drivers who share their experiences with others, including those considering switching to PEVs;
- Early Majority: individuals in this category adopt an innovation after a varying amount of time, but this is significantly longer than for the previous two categories. They have above average social status and contact with early adopters;
- Late Majority: individuals in this category will adopt an innovation after the average member of society. They often have a high degree of scepticism, with below average social status, low ability to absorb financial risk and are likely to be in contact with others in the late majority and early majority categories; and
- Laggards: the last group to adopt an innovation. They typically have an aversion to change, be focussed on 'traditions', of a lower social status, often older and in contact with only family and close friends.

Rogers showed this diffusion graphically (see below), where the blue bell curve shows the proportion of the market within each of five categories, and the yellow s-curve showing the market share of the innovation increasing over time as each of the different groups adopt the innovation.

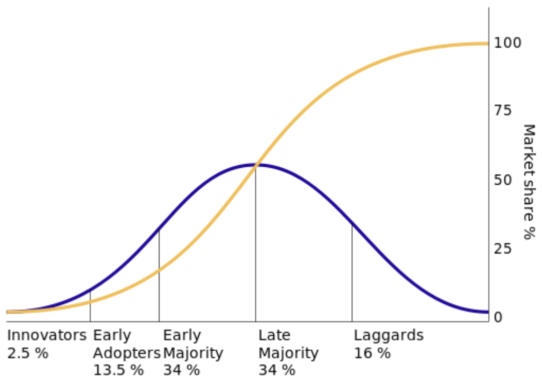


Figure 7-11: Technology Adoption Curve

As part of the Final Survey Impact included a question to determine participants' attitudes towards new technology and allow them to be categorised into the five groups described above. The results are shown in Figure 7-12. This is based on the 514 participants who completed the Final Survey (96% of the respondents also completed the Recruitment survey).

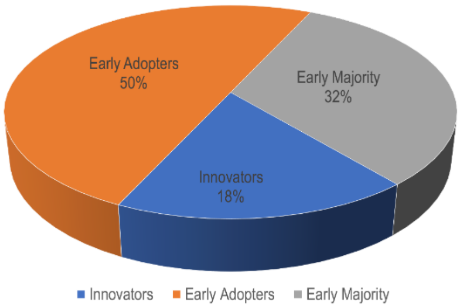


Figure 7-12: Attitudes to Technology Adoption - Electric Nation Participants (Base: 514)

As expected, the Electric Nation participant group (based on those who completed the Final Survey) is skewed towards innovators and early adopters (68%, compared to 16% on the technology adoption curve proposed by Rogers, shown in Figure 7-11). The presence of the 'early majority' group may as a result of those participants who bought/leased their PEV through a company scheme, who may have been much more motivated by favourable tax rates (compared to a petrol or diesel car), rather than an inherent interest in PEVs and their environmental benefits. The large number of innovators and early adopters also aligns with the fact that that the sample is skewed towards more affluent and older/middle age participants.

7.6 Car Type

Figure 7-13, below, Illustrates the participants declaration of the plug in vehicle type they owned and would use in the trial. Equivalent data based on the information provided by DriveElectric is shown in Figure 6-3.

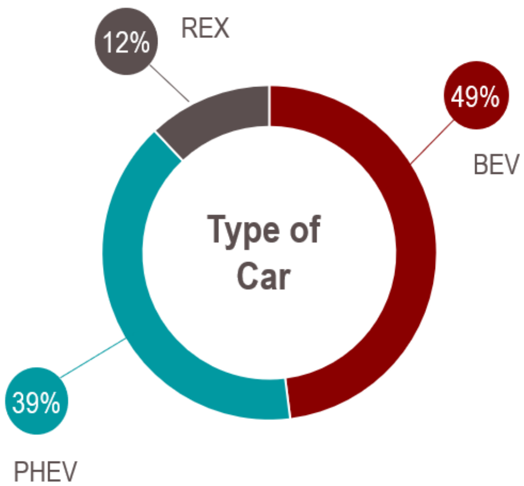


Figure 7-13: Vehicle type split amongst participants (based on 616 surveys)

Participants with a PHEV could drive their vehicle despite the battery being empty (discharged). These participants might therefore be less concerned about completing a charge and therefore having their charge managed.

Figure 7-14, below, illustrates the range of different battery sizes within the trial, as declared by the trial participants knowledge of their vehicles. Figure 6-4 shows the equivalent data as provided by DriveElectric, separated into the CrowdCharge and GreenFlux cohorts.

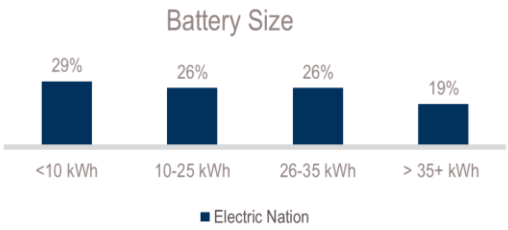


Figure 7-14: Spread of different (self-reported) battery sizes within the trial (based on 616 participants)

84% of trial participants declared they had access to one or more vehicle in their household. Those participants who had access to another vehicle were asked how the other vehicles(s) were powered – see Figure 7-15 - note that some households have access to multiple other vehicles, hence the figures stated add up to more than 100%.

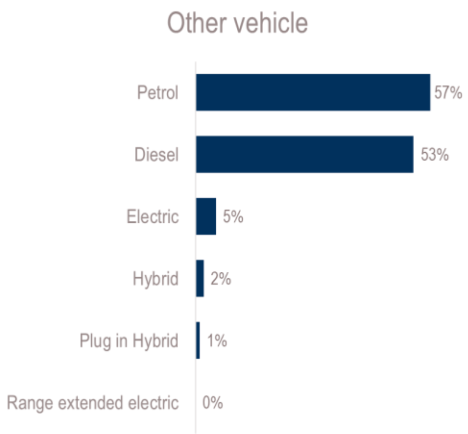


Figure 7-15: What type of alternative car does your household have access to (420 participants have access to another vehicle)

More than 20 project participant households had more than one plug-in vehicle. Within those households who had multiple vehicles (of any fuel type) 26% (of those with more than one vehicle in the household) had more than one additional vehicle as is demonstrated in Figure 7-16.

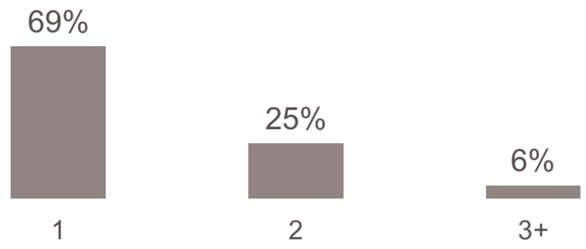


Figure 7-16: How many other vehicles in participant household (based on those with multiple vehicles: 421 responses)

Participants who had two cars in their household were less likely to live in a rural area (42% in comparison to 56%). Those who had 3 (21%) or 4+ (5%) cars in their household were more likely to live in a rural area (30% for 3 cars and 10 % for 4+ cars).

Figure 7-17 compares the number of cars in the household for the Electric Nation trial participants (who must have at least one car in the household in order to take part) to England and Wales as whole. 82% of Electric Nation participants (across all locations) had another car in the household. In England and Wales, 75% of households had access to at least one vehicle. Of these, 43% of households had two or more cars or vans[25] - showing that Electric Nation participants were more likely to have another vehicle.

	Urban					Rural				
	0	1	2	3	4+	0	1	2	3	4+
Electric Nation	0%	19%	62%	15%	4%	0%	19%	52%	23%	6%
England and Wales	29%	43%	22%	5%	2%	12%	40%	35%	9%	4%

Figure 7-17: Electric Nation total number of vehicles in the household - compared to England and Wales (based on 616 responses, Urban=241, Rural/Mixed=323) compared to census data 2011)

Participants were asked in the Final survey about their motivations for buying or leasing their first PEV – see Figure 7-18. Most trial participants (based on the 514 participants who completed the Final Survey) stated that they chose a PEV because of their low running costs and for environmental reasons.

25 Analysis based on Table KS404EW. 2011 Census. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/2011censuskeystatisticsforenglandandwales/2012-12-11#car-or-van-availability Accessed August 2019

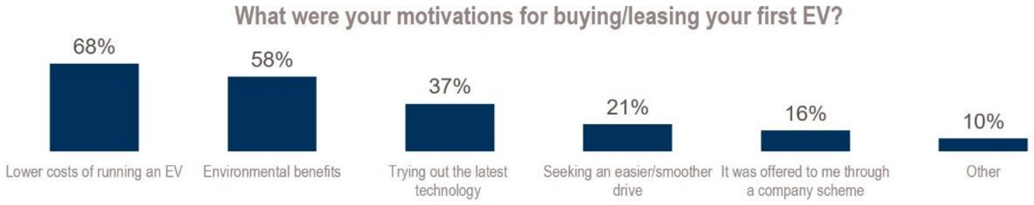


Figure 7-18: What was your motivation towards buying/leasing your first EV? Base All respondents to the Final Survey, 514

This was expanded on in the focus groups held at the end of the trial. The quotes shown below in Figure 7-19 illustrate typical participant reasoning (from those who took part in focus groups) for choosing a PEV.

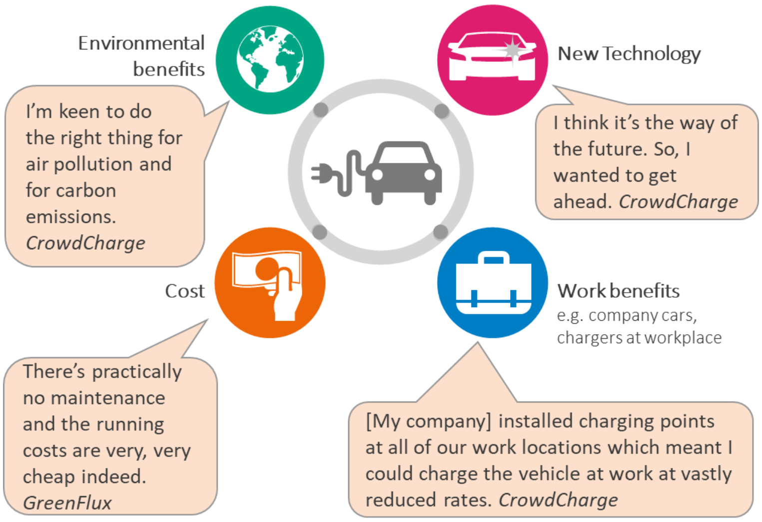


Figure 7-19: Example reasons why focus group participants chose a PEV

In the Final Survey participants were asked whether they had bought or leased their vehicle or if it was a company car – see Figure 7-20.

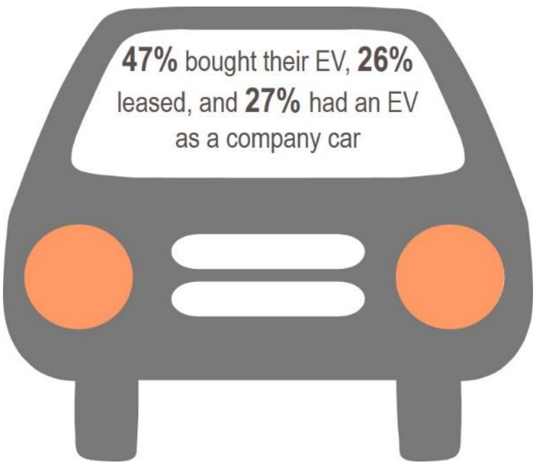


Figure 7-20: Which of the following best describes the vehicle that is registered as part of the Electric Nation project? (Base: All respondents to the Final Survey, 514)

These results have been disaggregated to show the differences between different PEV types and battery sizes, shown in Table 7-2.

Table 7-2: Which of the following best describes the vehicle that is registered as part of the Electric nation project? (Base: All respondents to the Final Survey, 514) – disaggregated by PEV Type and Battery Capacity

		Sample Size	Bought	Leased	Company Car
All		511*	47%	26%	27%
PEV Type	PHEV	203	33%	18%	49%
	REX	65	60%	29%	11%
	BEV	243	56%	30%	14%
Battery Capacity	Less than 10kWh	151	21%	19%	61%
	10 to 25kWh	130	79%	16%	5%
	25 to 35kWh	126	43%	47%	10%
	35kWh plus	104	52%	21%	27%

*: excludes those who replied ‘Prefer not to say’

Participants whose PEV was a company car were more likely to own a PHEV, and therefore a vehicle with a smaller battery capacity. 61% of ‘Less than 10kWh’ vehicles were company cars, compared to 27% of all those who responded to the survey. There are some statistically significant differences within this data, as follows:

- PHEVs were significantly more likely to be company cars than BEVs[26] (49% PHEVs were company cars, compared to 14% of BEVs);
- Smallest battery capacities (‘Less than 10kWh) significantly more likely to be company cars than all other battery capacity groups (linked to the PHEV finding above[27]); and
- 25 to 35kWh group were significantly more likely to be leased than other battery types[28].

7.7 Use of Vehicle

Participants were asked how they used their PEV (selecting all that applied from ‘Social’, ‘Commuting’ and ‘Business’). This question was asked as part of the Baseline Survey and the responses below are based on the 495 participants who completed that survey.

[26] Z test. Z = 8.04 (value of 1.96 would indicate 5% confidence level)
[27] Z test comparing proportion of vehicles which were company cars between; ‘Less than 10kWh’ and ’10 to 25kWh z = 9.81, ‘Less than 10kWh’ and ’25 to 35kWh’ = 8.72, ‘Less than 10kWh’ and ’35kWh plus’ z = 5.35
[28] Z test comparing proportion of vehicles which were leased between; ’25 to 35kWh’ and ‘Less than 10kWh’ z = 4.99, ’25 to 35kWh’ and ’10 to 25kWh’ z = 5.35, ’25 to 35kWh’ and ’35kWh plus’ z = 4.11

Figure 7-21: How do you use your PEV? (495 responses, from Baseline Survey)

Further details of vehicle uses are given below (Table 7-3).

Table 7-3: % of Participants Answering Each Combination of Vehicle Uses (Base: 495, Baseline Survey)

Description of Uses	% of Respondents
All three uses	33%
Social and commuting	24%
Social only	20%
Commuting only	9%
Social and business	8%
Business only	6%
Business and commuting	0%

The most common response given by participants was all three uses, followed by social and commuting and social only.

In the Final Survey participants were asked how many miles they drive in their PEV in a typical week. Their responses (i.e. based on the 514 participants who completed the Final Survey) are shown in Figure 7-22.

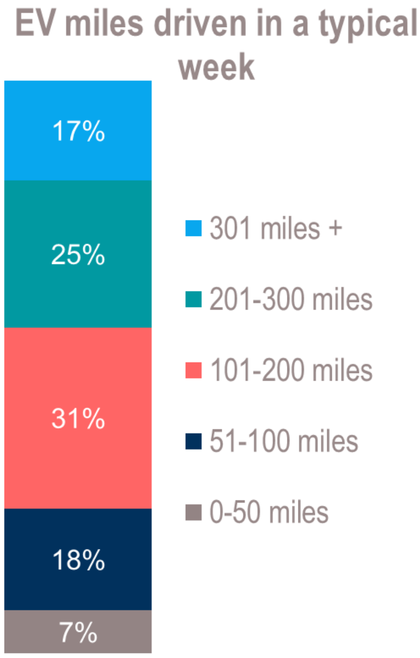


Figure 7-22: In a typical week, how many miles do you drive in your electric vehicle? (514 responses)

Over half of the trial participants reported driving between 100 and 300 miles. These figures are disaggregated by PEV type and vehicle battery capacity below.

Table 7-4: Typical Weekly Mileage, disaggregated by PEV Type and Battery Capacity (Base: 514 responses to Final Survey)

		Sample Size	0 to 50 miles	51 to 100 miles	101 to 200 miles	201 to 300 miles	301 miles plus
All		509*	7%	18%	32%	26%	17%
PEV Type	PHEV	203	7%	17%	30%	26%	21%
	REX	65	9%	14%	40%	18%	18%
	BEV	241	7%	20%	31%	28%	15%
Battery Capacity	Less than 10kWh	151	7%	15%	28%	25%	25%
	10 to 25kWh	130	9%	26%	34%	21%	10%
	25 to 35kWh	125	6%	20%	36%	22%	15%
	35kWh plus	103	6%	9%	29%	37%	19%

*excludes responses of ‘Don’t know’ and ‘Prefer not to say’

Analysis of this data shows that those who own vehicles with a battery capacity of 35kWh plus were significantly[29] less likely to be travelling shorter distances each week (51 to 100 miles per week) compared to PEVs with smaller battery capacities. In addition, they were statistically more likely to be travelling 200 to 300 miles per week.

Figure 7-23 shows participant responses when they were asked (in the Final Survey, completed by 514 participants) if anyone else drove the PEV registered with the trial.

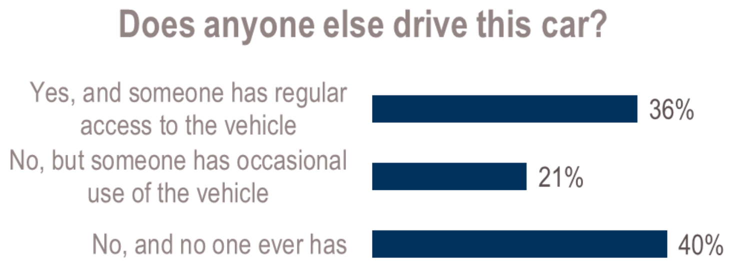


Figure 7-23: Does anyone else in your household drive the PEV registered as part of the Electric Nation trial? (514 responses)

Responses were mixed. 40% of the PEV's registered with the project are driven by one person only, however over one third are regularly driven by more than one driver.

7.8 Ownership of Solar Photovoltaic (PV) Panels

Over one fifth of participants had solar PV panels fitted to their properties. This is a much larger proportion than the general population[30] (approximately 3%). This suggests that Electric Nation participants were more environmentally minded than the general population, and also have the financial means to invest in solar PV panels or have seen them as a good investment opportunity.

7.9 Participant Location

Participant postcodes (of those who completed a Recruitment survey) were used to analyse where across the WPD licence area they live – Figure 7-24.

[29] 5% level using a z-test

[30] 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.

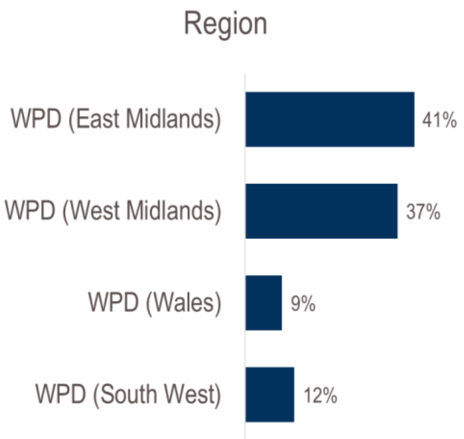


Figure 7-24: Breakdown of participant location based on WPD licence area (based on 616 participants)

Participants were mainly drawn from the more densely populated WPD licence areas in the Midlands – as illustrated in Figure 7-25.

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%

Figure 7-25: Breakdown of participant location by city (based on 616 participants)

The city that had the highest number of participants in the trial was Coventry, followed closely by Birmingham. DriveElectric collated data showing the way in which each 'lead' (someone interested in joining the project) was generated. 84 Leads were generated with a CV (Coventry) postcode. Of these, 21% came via Google, 17% from Stratford (one of the installation partners) and 14% via friends and 7% via work colleagues. Across the project Stratford generated the largest numbers of referrals, although the reasons why this would be particularly significant in Coventry is not clear.

Trial participants were asked to declare the locale of their home; whether they think they live in an urban, suburban or rural area – Figure 7-26.

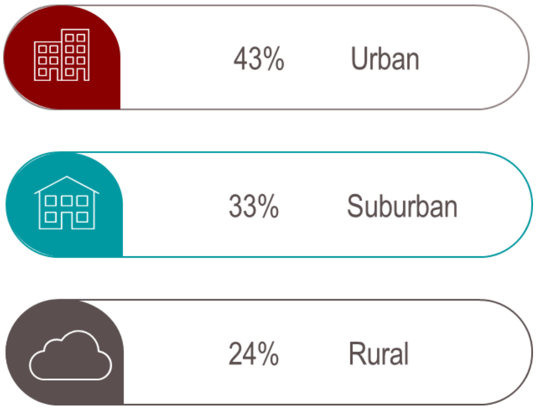


Figure 7-26: Do you live in an urban, suburban or rural area? (569 respondents from the Recruitment Survey)

Respondents were most likely to state that they live in an urban area, however, a quarter responded that they lived in a rural area. The licence areas covered by WPD have a higher rural population than the rest of England and Wales, and this is reflected in the participant population – Table 7-5.

Table 7-5: Urban and rural split in England and Wales, and the WPD licence area (Data source Census 2011)

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

Table 7-6, shows the spread of participants with different battery sizes and types of PEV across rural, suburban and urban regions, and the spread in GreenFlux and CrowdCharge cohorts.

Table 7-6: Characteristics by rural, urban and suburban setting (based on 614 participants)

Location	Battery Capacity				PEV Type		
	Less than 10kWh	10 to 25kWh	25 to 35kWh	35kWh plus	BEV	PHEV	REX
Urban	34%	27%	18%	22%	47%	42%	10%
Suburban	32%	24%	31%	13%	46%	41%	12%
Rural	23%	30%	26%	21%	50%	36%	13%

Urban participants were significantly[31] more likely to own a smaller battery sized vehicle than participants who live in rural areas.

Participants who lived in a suburban area were statistically more likely to have a 25-35kWh battery car than those who live in urban areas. Participants who lived in a suburban area were also less likely to have a vehicle with the largest battery capacities (35kWh plus).

Figure 7-27 below shows the proportion of participants in each location type who owned solar panels. Analysis of the data shows that participants in rural locations were statistically more likely to have solar panels compared those in suburban or urban areas.

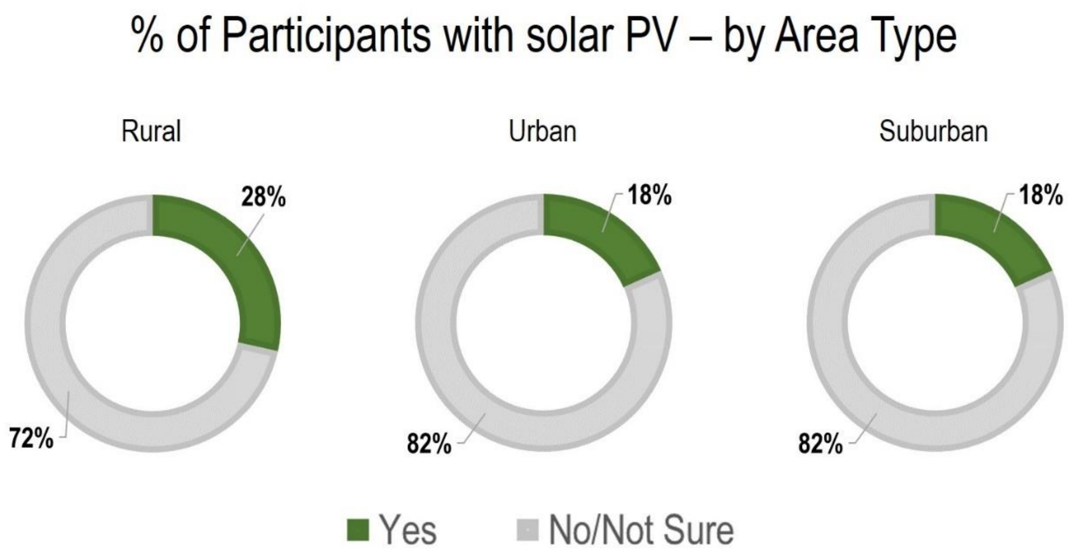


Figure 7-27: % of Participants with Solar PV by Area Type (Base: 564 participants who selected an area type in the Recruitment Survey)

7.10 Participant Expenditure on Gas and Electricity

Participants were asked about their average spend on gas and electricity per year (before they bought a PEV) – see Figure 7-28.

[31] 5% level using a z-test

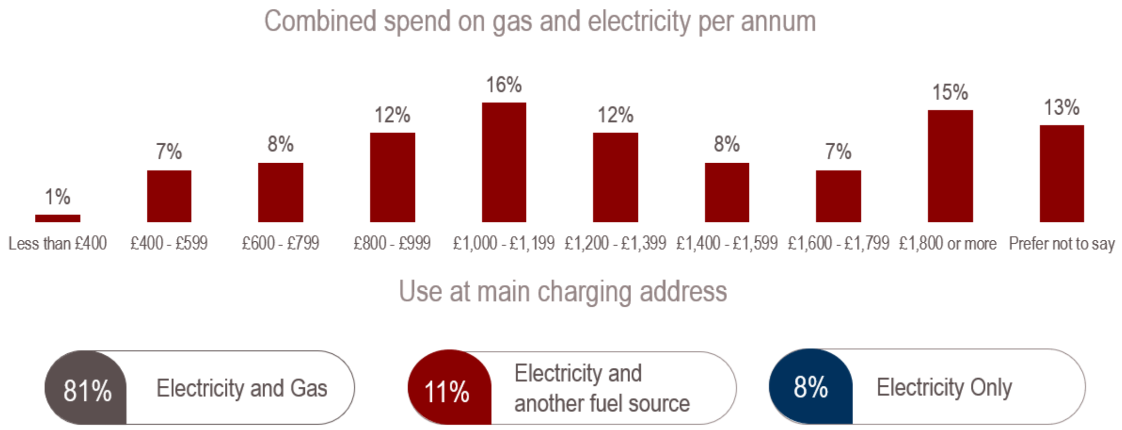


Figure 7-28: Trial participant combined spend on gas and electricity per annum and household energy source (Base: 616 respondents)

The average participant household spend was £1,065 per annum however there is a large variation between households. The UK average dual fuel annual cost in 2019 was £1,254 per annum (for a variable tariff)[32]. It has been estimated that across England and Wales 11% of households do not have access to mains gas[33].

7.11 Comparison of the CrowdCharge and GreenFlux Cohort Characteristics

Participants were randomly assigned to either the CrowdCharge or GreenFlux cohorts during the recruitment process (described in Section 4.7.6). The data in this sub-section compares the characteristics of the participants in each cohort.

In terms of gender, the CrowdCharge and GreenFlux cohorts were similar in participant characteristics to the overall Electric Nation trial (12% female and 88% male – see Figure 7-1).

Figure 7-29: What is your gender? (Base – CrowdCharge: 293, GreenFlux: 322)

[32] https://www.moneyadviceservice.org.uk/blog/what-is-the-average-cost-of-utility-bills-per-month Accessed August 2019

[33] 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

The distribution of ages in each of the two cohorts was also broadly similar, as shown in Figure 7-30.

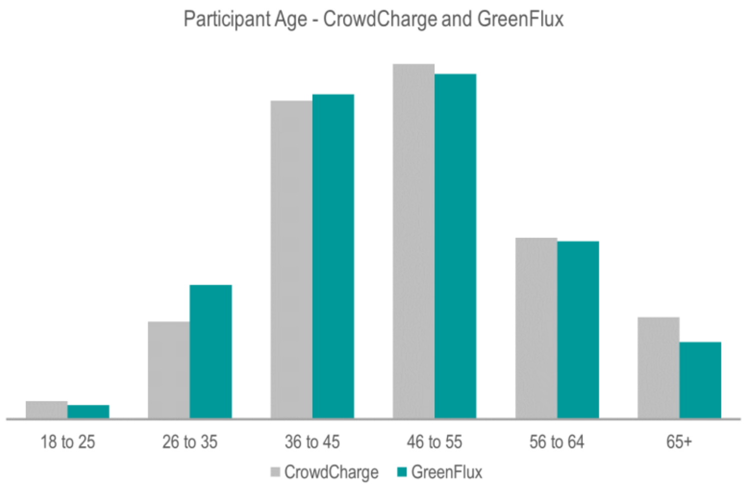


Figure 7-30: How old are you? (Base – CrowdCharge – 296, GreenFlux - 320)

The two cohorts were also broadly similar in terms of the areas where trial participants lived – as shown in the compositions below, based on trial participants self-reported classification.

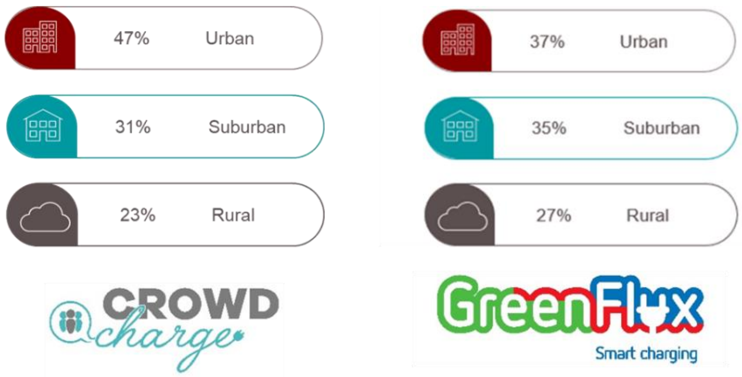


Figure 7-31: Do you live in an urban, suburban or rural area? (Base – CrowdCharge: 296, GreenFlux: 320)

7.12 Summary of Participants

The Electric Nation trial population can be summarised as follows:

- The trial population is skewed towards affluent males, aged 36-55, in higher or intermediate professions and is not representative of the WPD regional customer base;
- The survey population demographic is also not representative of the wider population of driving licence holders;
- Based on survey results 18% of the sample were classified as 'innovators', 50% were 'early adopters' and the rest were 'early majority' according to the Rogers' bell curve

for technology adoption. According to Rogers'[34] 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;

- 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; and
- The CrowdCharge and GreenFlux cohorts were broadly similar in terms of age, gender and rurality.

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

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

8 Charging Behaviour

The data generated by the Electric Nation project provides a substantial body of evidence in relation to home charging behaviour, based on a sample of approximately 670 participants, with a wide range of plug-in vehicle types. The volume and breadth of data exceeds that which has been generated by other innovation projects in the field to date.

Two of the objectives of Electric Nation are to:

- "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"; and
- "Build a better understanding of how vehicle usage affects charging behaviour"

This section uses the data gathered during the Electric Nation Smart Charging Trial to describe the participant's charging behaviour, including factors such as:

- Time of plug-in;
- Time when charging begins;
- Charging frequency;
- Energy consumed (both annual and when compared to battery capacity);
- Estimated state of charge when plugging in;
- Use of timers;
- 'Hot unplugging' (i.e. unplugging the vehicle before it was fully charged); and
- Flexibility.

Factors which may affect these different aspects of charging behaviour are also explored, such as:

- The PEV type (battery only, plug in hybrid etc.);
- Size of battery;
- Use of the vehicle; and
- Access to other charging infrastructure.

Charging behaviour across a population of drivers (e.g. a group supplied from a given LV or HV substation) results in additional demand on the substation. Data from Electric Nation has been used to develop model profiles of EV charging load to predict this additional demand. The statistical approach taken to this modelling work is in line with the profiles developed for modelling of demand on LV networks according to ACE 49[35]. Further details are given in Section 8.10. This is a key requirement of the Network Assessment Tool

[35] ENA 1981. "Report on Statistical Method for Calculating Demands and Voltage Regulations on LV Radial Distribution Systems". Energy Networks Association 1981.

developed as part of the Electric Nation project. This section also describes these profiles and how they were developed.

8.1 Plug-In Time

Each time a chargepoint was used during the project a 'transaction' record was generated (see Section 6.5.1 for more details). This recorded the time the vehicle was plugged in, when it was unplugged, and the amount of energy transferred during the charging event. The time when charging began may differ from the plug-in time and this is explored in Sections 8.2 and 8.7. All the transaction record times have been converted into local time (i.e. GMT or BST).

Figure 8-1 shows the percentage of all plug-in events (separated by weekday and weekends) which occurred in each hour over most of the duration of the trial. Data from Trial 3 is excluded as the Time of Use incentive may have led to a change in plug-in behaviour (this is examined in more detail in Section 12).

This data is based on 98,656 and 35,541 charging events on weekdays and weekends respectively. Data from CrowdCharge and GreenFlux has been combined as the choice of demand management provider has no impact on the participants' plug-in behaviour.

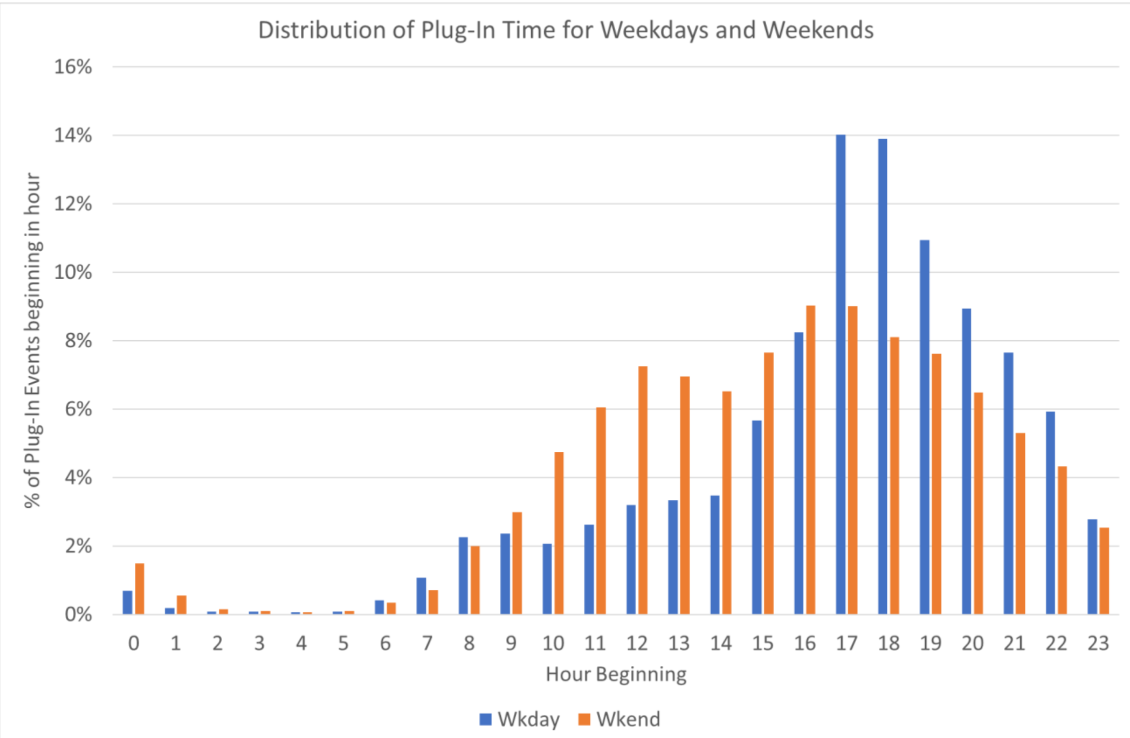


Figure 8-1: Distribution of Plug-In Time - Weekday and Weekend

This chart shows that weekday plug-in times are clustered around the evening peak, as drivers return home from work. Across the trial, approximately 28% of weekday charging events were plugged in between 17:00 and 18:59.

Plug-ins at the weekend are more evenly distributed throughout the day. This graph considers only the proportion of events plugged in each hour, and not the percentage of the population who plug in (i.e. it does not mean that 14% of the population plug-in between 17:00 and 17:59 on weekdays). Section 8.10.1 shows the variation in proportion of the population who are charging in each half hour period through the day.

8.2 Time When Charging Began

PEVs include an option within the vehicle's menu (or via an app) to configure the time at which the vehicle will begin charging, so this can be delayed to some point after the vehicle has been plugged in.

An example application of this would include a driver that returns from work at 18:00 and plugs their car in, but has a timer configured to delay the start of charging until 00:00, when an off-peak Economy 7 rate begins.

Within the trial data, the time when charging began can be detected for charging records where current meter readings are available (see Section 6.5.2), as this shows the time at which current began to be supplied to the vehicle. This data is not available for all transactions due to communications outages which caused the meter value readings to be lost and other data issues. A start of charging time is available for 108,501 charging events (58,416 GreenFlux, 50,085 CrowdCharge).

The analysis presented below in Figure 8-2 excludes Trial 3, as the Time of Use tariff had a large effect on the time when charging began. It is therefore based on 94,519 charging events (69,462 weekday, 25,057 weekend). Outside of Trial 3 the smart charging system will not have delayed the start of charging and therefore the effect shown in the graphs below is solely due to actions by participants (i.e. using timers on their vehicles).

The distribution below shows the proportion of the charging events which began in each hour, separated by weekday and weekend.

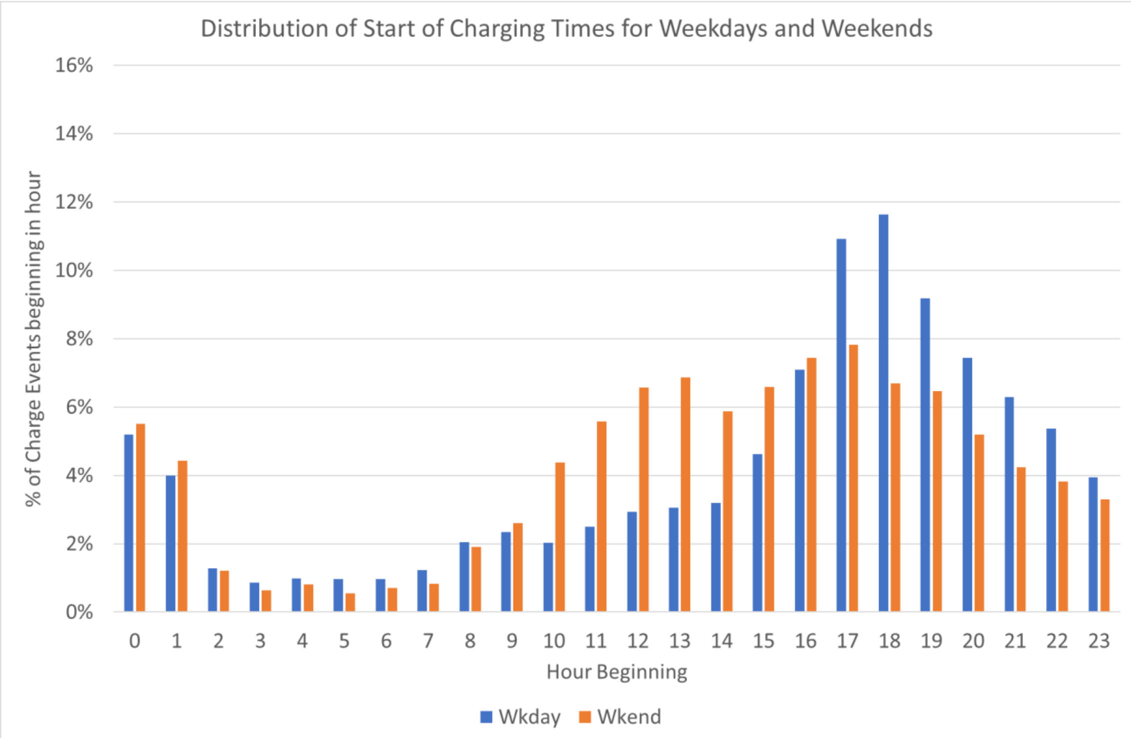


Figure 8-2: Distribution of Start Charge Time - Weekday and Weekend

This shows a similar overall pattern to the plug-in data in the previous section, but the use of timers has reduced the height of the evening peak, and increased the number of events which begin around midnight (e.g. 17:00 – 17:59 = 14% of plug-ins, but 11% of 'start of charging', 00:00 – 00:59 = 1% of plug-ins, but 5% of start of charging (weekdays)). This is shown more clearly in Figure 8-3 below.

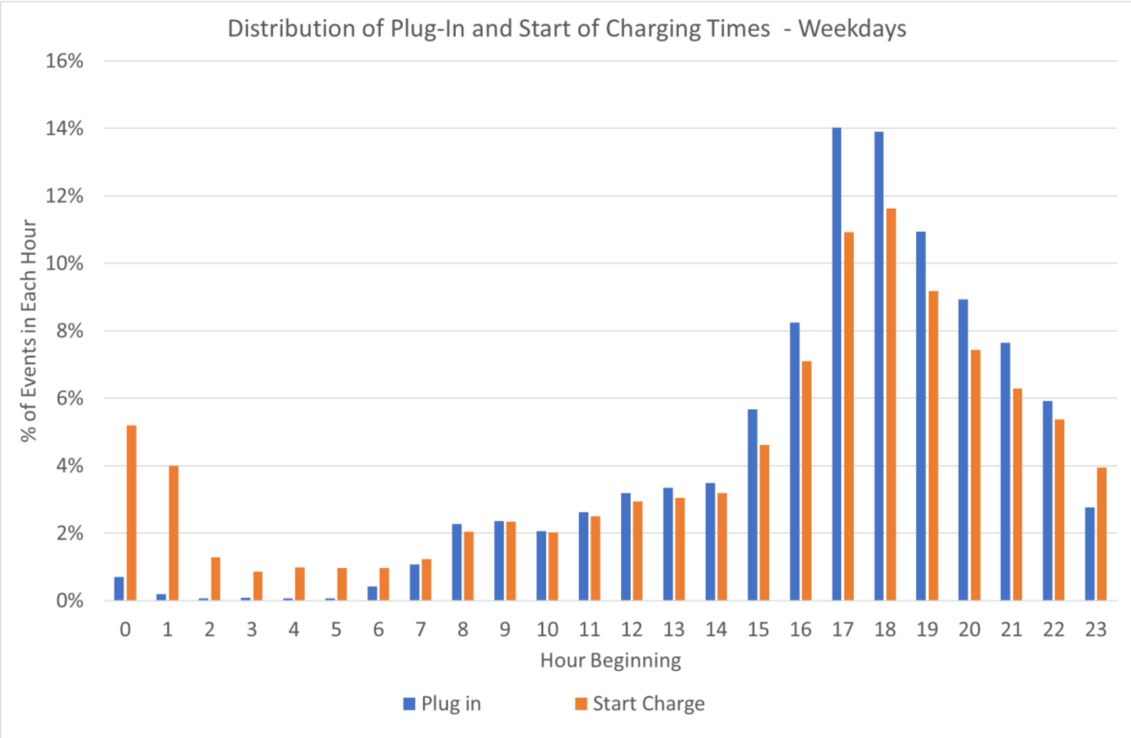


Figure 8-3: Comparing Plug-In and Start Charge (Weekdays)

This begins to show the flexibility which is available from PEV drivers, as their vehicle is plugged in for long enough to delay the start of charging. It also shows that participants were responding to some kind of signal (such as an existing time of use tariff) and moving their charging away from the peak times. The use of timers by different groups of participants is reviewed in more detail in Section 8.7.

The time of day when timers are used may vary depending on the flexibility which drivers have and the signals involved. For example, plug-ins in the middle of the day may relate to a top-up charge where the driver is using the vehicle again and it needs to charge for the entire time it is plugged in. Alternatively, a participant may have an off-peak rate which applies overnight, therefore for a top-up during the day they would not use a timer, as the off-peak price is not available during the period when they are charging.

The graphs below show the proportion of plug-in events for each hour where a timer was used, with separate graphs for weekdays (Figure 8-4) and weekends (Figure 8-5).

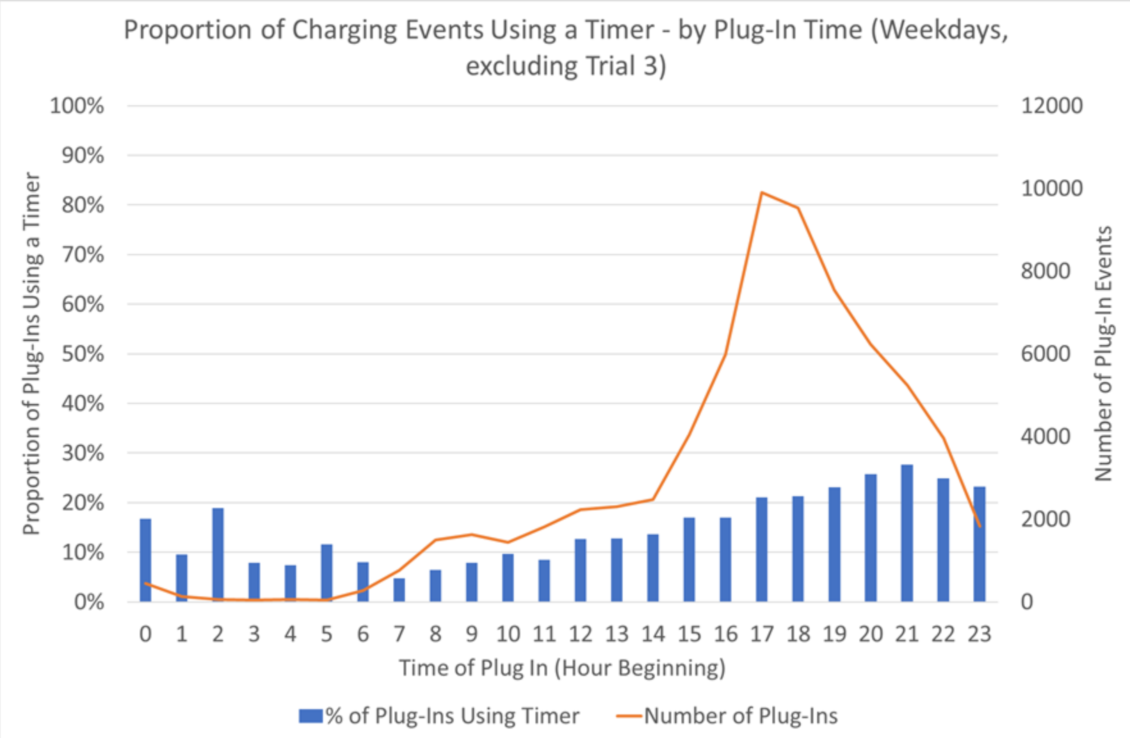


Figure 8-4: Proportion of Plug-In Events Using a Timer (Weekdays)

This shows that during weekdays timer use is slightly more frequent when vehicles are plugged in from late afternoon to the early hours of the morning (although the number of plug-in events in the early hours of the morning is small).

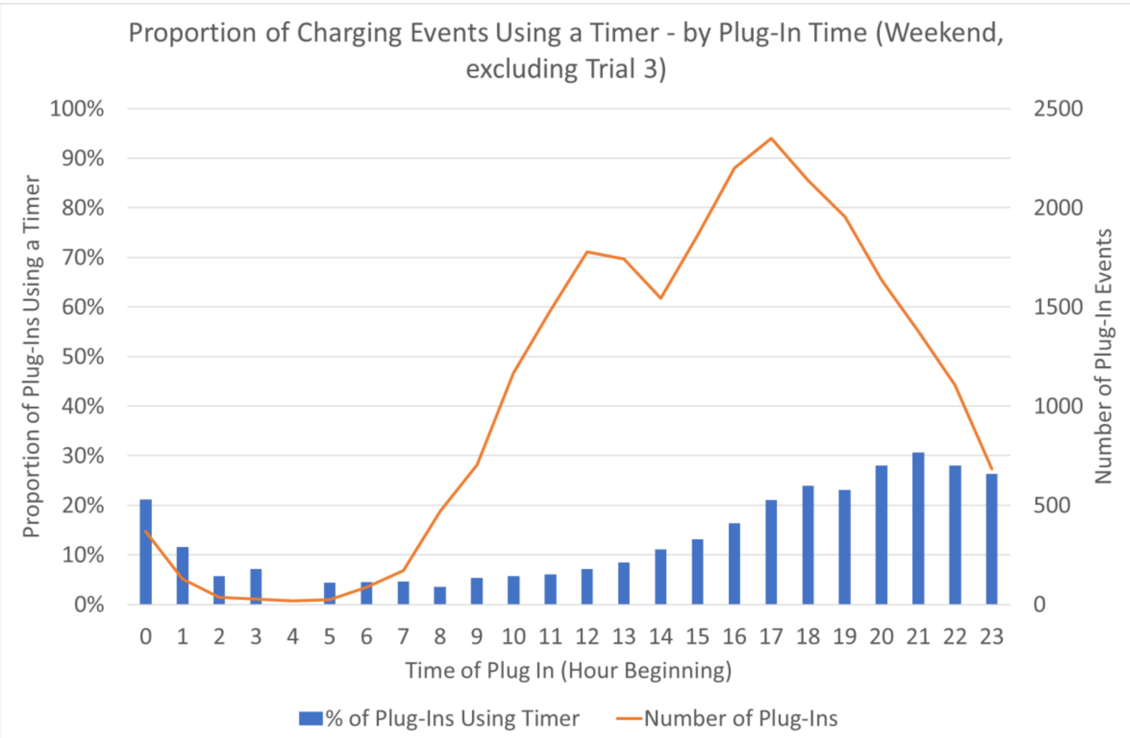


Figure 8-5: Proportion of Plug-In Events Using a Timer (Weekend)

The same pattern is observed at weekends, with timer use more common for plug-in events later in the day.

Overall, timers are used for 20% of charging events which began on weekdays, compared to 17% of those beginning at the weekend. This pattern of increasing timer use for plug-in events which begin later in the day is linked to the amount of flexibility available, and this is reviewed in more detail in Section 8.9.

8.3 Charging Frequency

How often PEV drivers plug-in and charge their vehicle is one of the contributing factors towards the diversity of the charging load. For example, given the distribution above, which shows that charging events are clustered around the evening peak, if all drivers plugged in once a day then the resulting additional peak time load would be much higher than if drivers plugged in less frequently.

This sub-section shows the frequency with which Electric Nation participants charged their vehicles at home during the trial, and some of the factors which affect this.

'Charging Frequency' (number of charge sessions per day) has been calculated for each participant for each month. A series of criteria have been applied to the data to ensure only valid frequencies are included, as follows:

- A frequency is calculated for full months after the charger was installed. This interval was chosen to enable any seasonal variations to be identified (see Figure 8-13), while minimising the impact of week by week variations. For example, charging frequency will be calculated from September 2017 onwards for a charger installed partway through August 2017 (subject to the other criteria below). December 2018 has been excluded for all chargers, as the trial ended on 17th December;
- If communications between the charger and back office were poor then records may have been lost, which would artificially lower the charging frequency. This has been accounted for as follows:
    - CrowdCharge chargers: must have had a reliability of greater than 70% between the charger and Hubeleon for the month in question. Sensitivity analysis showed that including chargers below this threshold caused the plug-in frequency to be underestimated.
    - GreenFlux chargers: must have been in contact with the back office after the end of the month in question, so that any transaction records from the given month would have been sent to the back office (i.e. no lost records for the given month).
- If there are no transaction records for the charger at any point before the month in question, then no frequency is calculated. Some chargers were online and not being used for a couple of months after the charger was installed, as the participant's vehicle had not been delivered. In this case the number of transactions would be

zero, and it would pass all the other criteria set out. However, the zero frequency is not valid. This criterion avoids this, as a charger effectively only becomes 'active' after it has been used for the first time; and

- Any charger which had been marked as 'Installed Inactive' by DriveElectric (indicating that the participant had left the project) is excluded from analysis after their last full month in the project.

Each participant's median charging frequency has been calculated, subject to having at least six months of valid data between December 2017 and November 2018. This data is based on 495 participants. The box and whisker diagrams[36] below show the distribution of these charging frequencies by PEV type (Figure 8-6) and battery capacity (Figure 8-7).

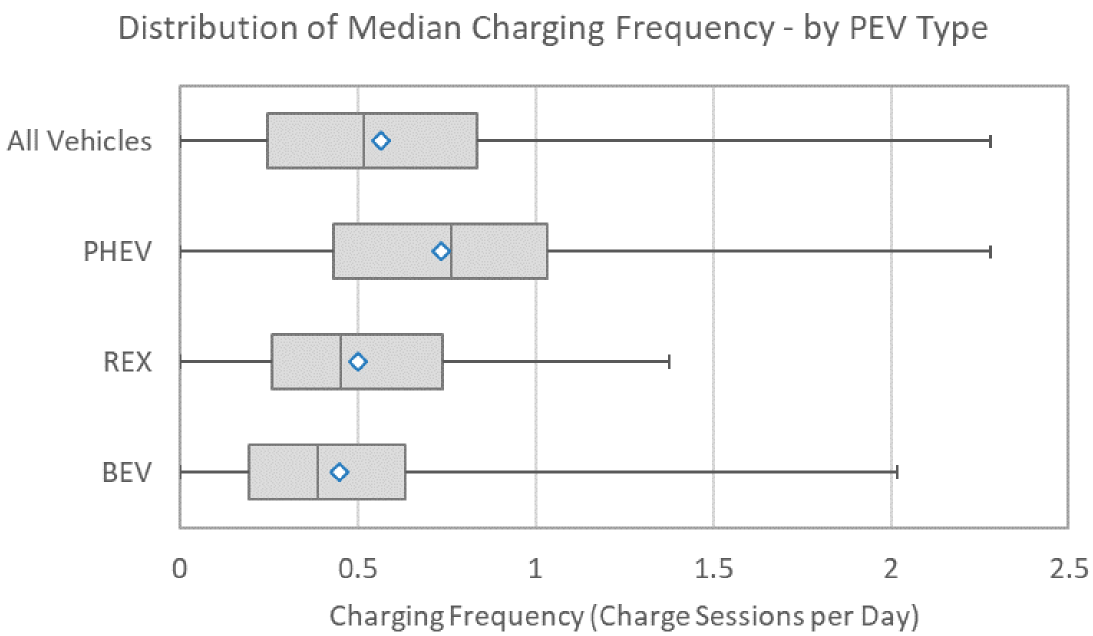


Figure 8-6: Distribution of Median Charging Frequency - by PEV Type

[36] Box and whisker diagrams show the distribution of data for a population. The diagrams show the quartiles of the data. The outer edge (end point of the 'whisker' on the left-hand side) shows the minimum value in the data- 0 in Figure 8-6. The first quartile is shown by the left-hand edge of the box, the median by the line in the middle of the box, and the third quartile by the right-hand edge of the box. The maximum value is shown by the value at the end of the 'whisker' on the right-hand side. The diamond indicates the average value for the population.

For example, for the 'All Participants' group in Figure 8-6. The minimum value was 0 charges per day, the 1st quartile (i.e. 25% of the population had a charging frequency of less than this) was 0.25 charges per day. The median value was 0.52 charges per day, and the upper quartile 0.83. The maximum value for any participant was 2.28 charging sessions per day. The average charging frequency for all participants was 0.56.

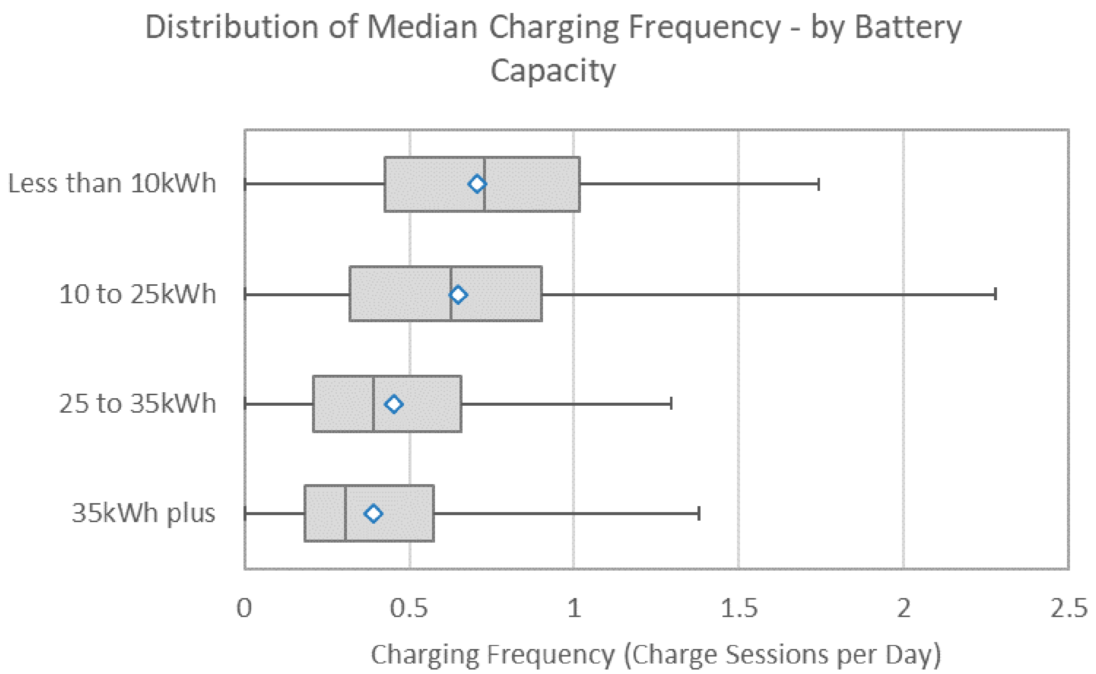


Figure 8-7: Distribution of Median Charging Frequency - by Battery Capacity

The median value for each category is summarised in Table 8-1 below, for ease of comparison.

Table 8-1: Median Charging Frequency by PEV Type and Battery Capacity

<table>
<tr><th colspan="2">Category</th><th>Median Charging Frequency (Charge Sessions per Day)</th></tr>
<tr><td colspan="2">All Participants</td><td>0.52</td></tr>
<tr><td rowspan="3">PEV Type</td><td>PHEV</td><td>0.76</td></tr>
<tr><td>REX</td><td>0.45</td></tr>
<tr><td>BEV</td><td>0.39</td></tr>
<tr><td rowspan="4">Battery Capacity</td><td>Less than 10kWh</td><td>0.73</td></tr>
<tr><td>10 to 25kWh</td><td>0.63</td></tr>
<tr><td>25 to 35kWh</td><td>0.39</td></tr>
<tr><td>35kWh plus</td><td>0.31</td></tr>
</table>

This shows that across the trial population, drivers charge around every other day (median value of 0.52 charging sessions a day).

72 of the 495 participants (15%) with at least six months valid data have a charging frequency of 1 or above (i.e. charging every day, or more frequently). This group is dominated by PHEV drivers (72% of the group). Of those who charge at least once a day,

28% drive a REX or BEV vehicle – 20 participants. Of these 20 participants, 9 have the smallest battery size available in the REX/BEV groups – 10 to 25kWh.

Charging frequency decreases as battery capacity increases, as the distance which the participant could drive before needing to re-charge increases. The table below illustrates this by showing the most common vehicle in each battery capacity group, its battery capacity and estimated vehicle range.

Table 8-2: Electric range for most common PEVs in each battery capacity category

Battery Capacity Group	Most Popular Vehicle Make/Model	Battery Capacity	Estimated Range (miles)[37]
Less than 10kWh	BMW 330e	7.6kWh	25 miles
10 to 25kWh	Nissan Leaf 2011 - 2015	24kWh	124 miles
25 to 35kWh	BMW i3 94Ah	33kWh	146 miles
35kWh plus	Tesla Model S 75	75kWh	304 miles

Other factors may also influence the frequency with which participants charge, for example their weekly mileage or whether they have access to alternative charging facilities. The analysis below explores this in more detail.

As described elsewhere in this report Electric Nation participants completed a series of questionnaires during the trial. In many cases participants have answered the same question several times (e.g. at the baseline survey, end of Trial 1, end of Trial 2 etc.). The answers may have changed during the length of the trial. For example, participants were asked what other charging infrastructure they had access to (e.g. at work, at shopping centres etc.) and how often they used them. Due to the length of the trial and the rapid development of charging infrastructure these answers may have varied. The analysis below has therefore focused on a single part of the project – Trial 2 (May to September 2018 for GreenFlux, July to October 2018 for CrowdCharge, inclusive). This period was chosen as it gave the best combination of trial duration and survey response rate.

An average charging frequency has been calculated for each participant for this period, where data is available for at least half of Trial 2. Data was available for 530 participants. This has been further reduced to include only those participants who provided all the information described below from the customer research surveys. This analysis is therefore based on 327 participants.

During this period, participant's average charging frequency varied as shown in the box plot below (Figure 8-8):

[37] NEDC Test Cycle has been used in all cases. Values taken from https://ev-database.uk/ Accessed August 2019

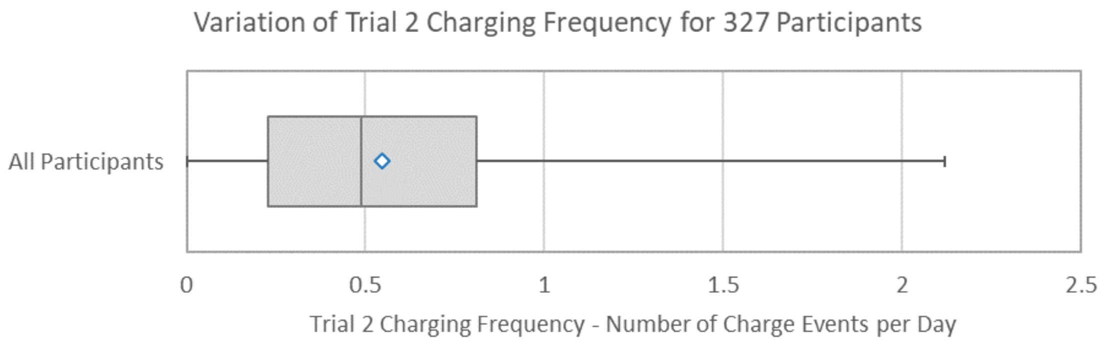


Figure 8-8: Distribution of Charging Frequency during Trial 2 (for 327 participants)

This is slightly lower than the yearly figures shown for 'All Vehicles' in Figure 8-6 above, as Trial 2 covered the summer period, where charging frequency tends to be slightly lower as the warmer weather increased the range of the PEVs in the trial.

Each participant was assigned to their respective quartile – for example, all participants with an average charging frequency between 0 and 0.23 sessions per day are in the '1st Quartile', meaning they are in the bottom 25% for charging frequency. The analysis below compares the composition of each quartile – for example, do participants who regularly charge at work have a lower charging frequency at home? Several characteristics have been chosen for this type of analysis from the survey answers. The survey questions used are:

- Most frequent charging location (multiple choice question, options reduced in this analysis to 'Home' (i.e. their Electric Nation charger) and 'Elsewhere' (all other options);
- Use of other charging locations, and frequency. Participants were given the option to select any of eight possible charging locations and indicate how frequently they used each, with the following options available:
    - More than once a day;
    - Once a day;
    - 5 – 6 times a week;
    - 3 – 4 times a week;
    - Once or twice a week;
    - Once a fortnight;
    - Less than once a fortnight; and
    - Not regular/don't know.

  These frequencies have been converted so that only responses with a frequency of more than once a fortnight (i.e. top five bullet points) have been included. The participants have then been assigned to one of three categories, using the hierarchy described below:

- Charging at Work: work has been selected, with a frequency of more than once a fortnight; if this is not the case then
- Charging elsewhere: another location (apart from home) has been selected, with a frequency of more than once a fortnight; if this is not the case then
- Home only.

This simple classification was done to enable the analysis to differentiate participants depending on whether records from their home charger accurately represent their total energy usage.

Access to other locations (e.g. shopping centres) is less likely to provide a similar charging experience to the home. Table 9-1 in Section 9.1.1 reports on the frequency with which trial participants report using each type of charging infrastructure, including away from home.

- Mileage in a typical week - reported in the final survey (included where the participant completed this survey).

The graphics below show this for the 327 participants where all the data described (survey responses and charging frequency during Trial 2) was available.

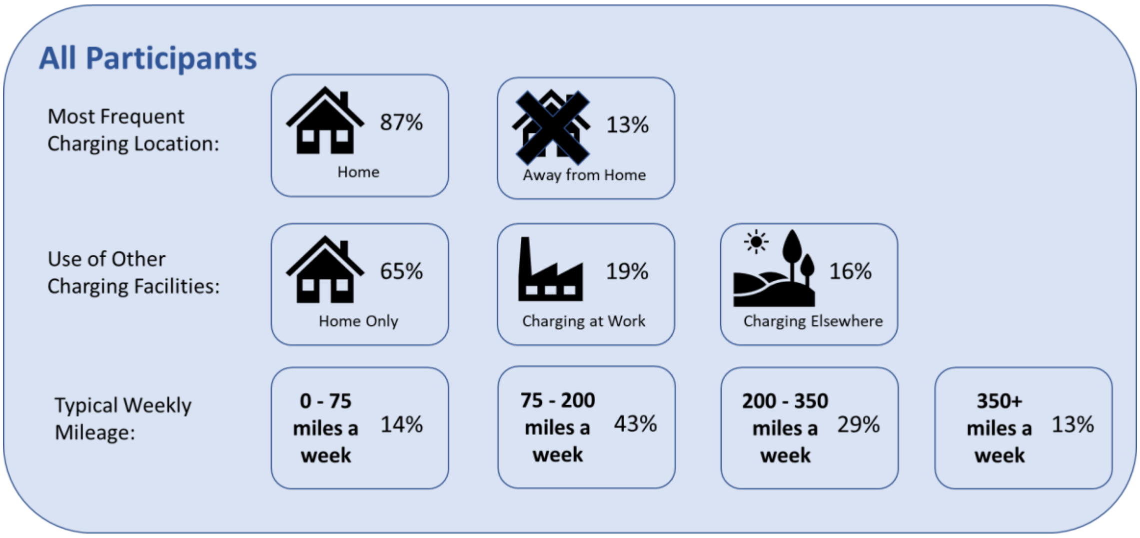


Figure 8-9: Charging Frequency Attribute Analysis Infographic - All Participants

The effect of each characteristic in turn is shown in the sub-sections below.

Most Frequent Charging Location:
285 participants (87%) stated that 'Home' was their most frequently used charging location. 42 (13%) participants selected another location.

Figure 8-10: Most Frequently Used Charging Location - Comparing % of Each Group in Each Charging Frequency Quartile (1st quartile = lowest frequency)

Statistical analysis of this data shows that:

- Participants whose most frequent charging location was away from home were significantly **more** likely to be in the first quartile for their charging frequency at home (i.e. charge between 0 and 1.6 times a week)[38]; and
- Participants whose most frequent charging location was at home were significantly **more** likely to be in both the third and fourth quartile for charging frequency (i.e. charging more than 5.7 times a week)[39].

Use of Other Charging Facilities:
When classified according to the hierarchy described above 214 participants (65%) only charged at home, 62 charged at work (19%) and 51 (16%) charged elsewhere.

---

[38] Z Test. Comparing % in 1st Quartile for 'Home' and 'Elsewhere' (17% vs. 79%) Z = 8.67 (a value of 1.96 would indicate confidence at the 5% level).
[39] Z Test. Comparing % in 3rd Quartile for 'Home' and 'Elsewhere' (28% vs. 0%) Z = 3.94. Comparing % in 4th Quartile for 'Home' and 'Elsewhere' (28% vs. 2%) Z = 3.65.

Figure 8-11: Use of Other Charging Facilities - Comparing % of Each Group in Each Charging Frequency Quartile (1st quartile = lowest frequency)

Statistical analysis of this data shows that:

- Participants who charged at work were **more** likely to be in the first quartile for charging frequency (i.e. charging fewer than 1.6 times a week) at home than those who only charged at home[40]; and
- Participants who charged in another location than home or work regularly (i.e. the 'charged elsewhere' group) were **more** likely to be in the second quartile for charging frequency (charging between 1.6 and 3.4 times a week) than those who charged at work[41].

Typical Weekly Mileage:
Participants typical weekly mileage was converted into four broad categories:

- 0 to 75 miles a week: 46 participants (14%);
- 75 to 200 miles a week: 141 participants (43%);
- 200 to 350 miles a week: 96 participants (29%); and
- 350 miles or more a week: 44 participants (14%).

[40] Z Test. Comparing % in 1st Quartile for 'Charging at Work' and 'Home only' (35% vs. 22%) Z = 2.08.
[41] Z Test. Comparing % in 2nd Quartile for 'Charging at Work' and 'Charging Elsewhere' (15% vs. 33%) Z = 2.26.

Figure 8-12: Typical Weekly Mileage - Comparing % of Each Group in Each Charging Frequency Quartile

Statistical analysis of this data shows that:

- Participants with a typical weekly mileage of between 0 and 75 miles were **more** likely to be in the first quartile than all others group, having a charging frequency of fewer than 1.6 times a week[42];
- Participants with a typical weekly mileage of between 75 and 200 miles were **more** likely to be in the first quartile than those who drove between 200 and 350 miles a week[43];
- Participants with a typical weekly mileage of between 0 and 75 miles were **less** likely to be in the third quartile (frequency between 3.4 and 5.7 times a week) than those who drove either 75 to 200 or 200 to 350 miles a week[44];

[42] Z Test. Comparing % in 1st Quartile for ‘0 to 75 miles’ and ’75 to 200 miles’ (52% vs. 26%) Z = 3.27. ‘0 to 75 miles’ and ’200 to 350miles’ (52% vs. 11%) Z = 5.33. ‘0 to 75 miles’ and ’350 miles plus’ (52% vs. 23%) Z = 2.84.
[43] Z Test. Comparing % in 1st Quartile for ’75 to 200 miles’ and ’200 to 350 miles’ (26% vs. 11%) Z = 2.84.
[44] Z Test. Comparing % in 3rd Quartile for ’0 to 75 miles’ and ’75 to 200 miles’ (9% vs. 28%) Z = 2.65. Comparing % in 3rd Quartile for ‘0 to 75 miles’ and ‘200 to 350 miles’ (9% vs. 27%) Z = 2.46.

- Participants who drove between 200 and 350 miles a week were **more** likely to be in the fourth quartile (charging more than 5.7 times a week) than those who drove either 0 to 75 or 75 to 200 miles a week[45]; and
- Participants who drove 350 miles a week or more were **more** likely to be in the third and fourth quartiles than those who drove up to 75 miles a week[46].

Frequency of charging, and energy consumed per charge event are likely to be interrelated – for example, some participants may charge their vehicle frequently, but starting from a high state of charge, whilst others may charge less frequently but start from a lower state of charge, even where the total energy delivered is the same. This is explored more in Section 8.6.

The analysis above focused on participant's charging frequency over multiple months, and what factors may influence this. There may also be a relationship between charging frequency and the time of year. The following analysis sets this out in more detail.

A charging frequency has been calculated for each participant, for each month where valid data is available (see the bullet points at the start of this sub-section). The average charging frequency for each month from December 2017 to November 2018 is shown in the graphs below, first by PEV type (Figure 8-13), and then by battery capacity (Figure 8-14).

[45] Z Test. Comparing % in 4th Quartile for '0 to 75 miles' and '200 to 350 miles' (9% vs. 36%) Z = 3.38. Comparing % in 4th Quartile for '75 to 200 miles' and '200 to 350 miles' (21% vs. 36%) Z = 2.55

[46] Z Test. Comparing % in 3rd Quartile for '0 to 75 miles' and '350 miles plus' (9% vs. 25%) Z = 2.03. Comparing % in 4th Quartile for '0 to 75 miles' and '350 miles plus' (9% vs. 32%) Z = 2.71

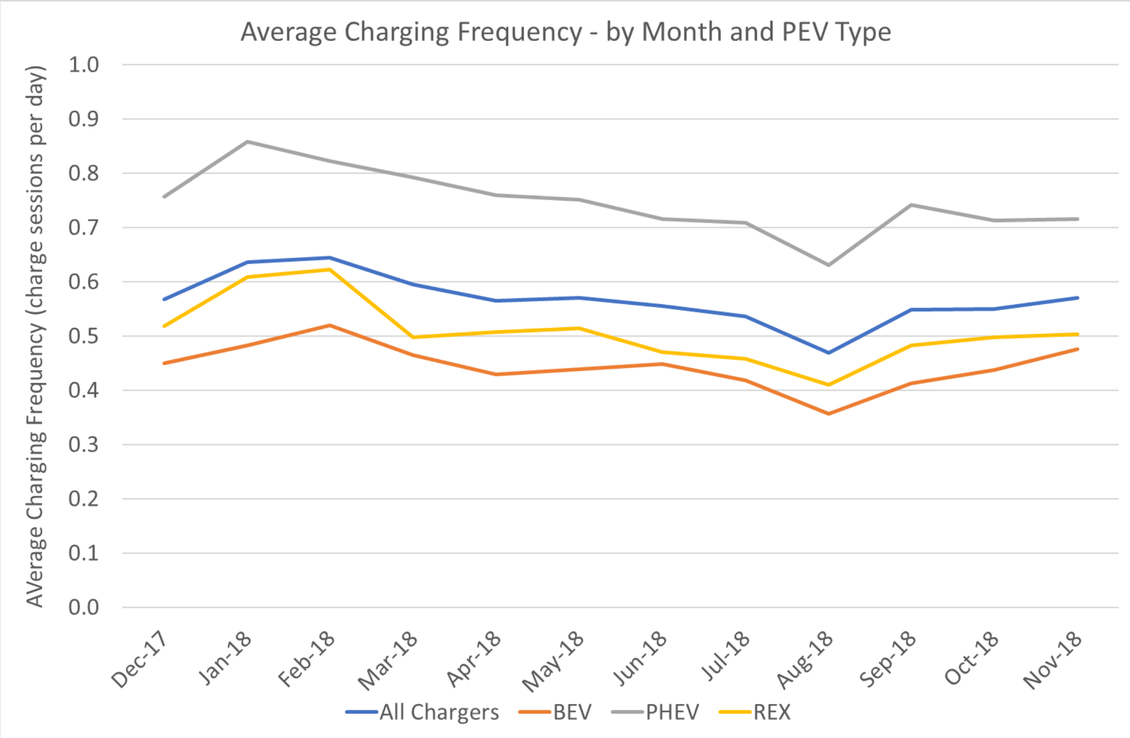


Figure 8-13: Seasonal Variation in Charging Frequency - by PEV Type

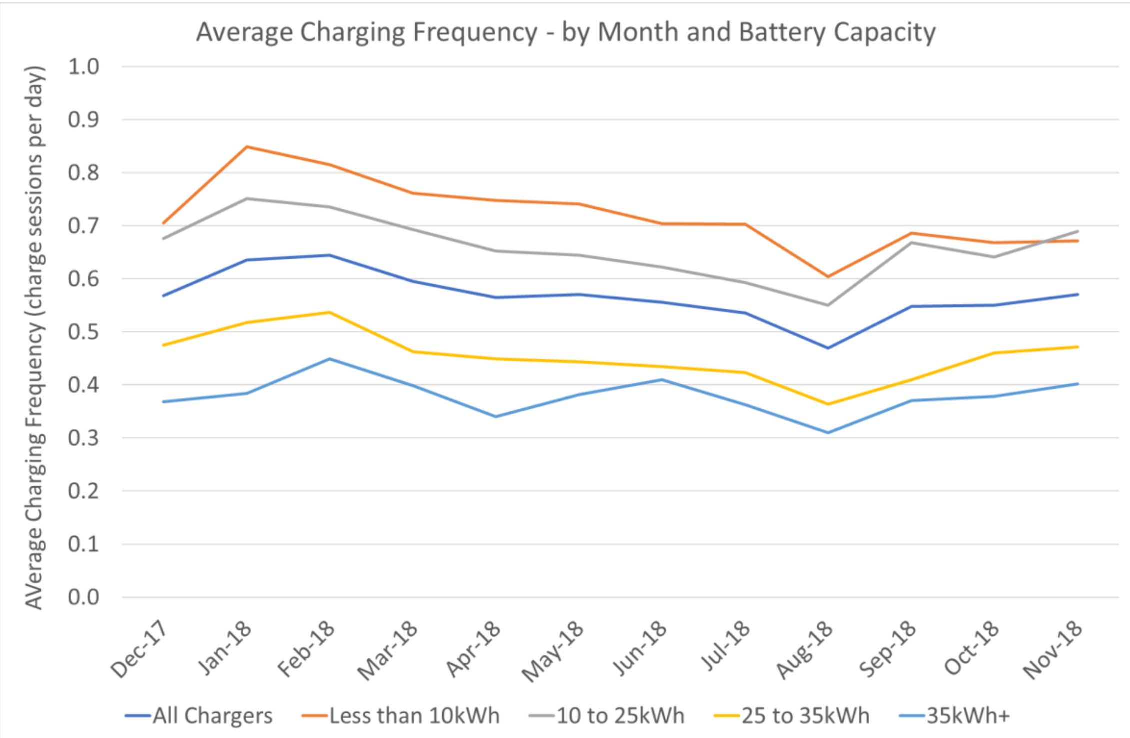


Figure 8-14: Seasonal Variation in Charging Frequency - by Battery Capacity

Both graphs show a similar trend across the year, for all PEV types and battery capacity groups: charging frequency is higher in the winter months, reaching a peak in February 2018. The lowest charging frequency occurred in August 2018. This is likely to be due to a combination of good weather, and the holiday season, when Electric Nation participants may have been away and therefore not using their home charger. The differences between PEV types and battery capacities are the same as shown in Figure 8-6, where PHEVs and vehicles with smaller batteries are charged more frequently than BEVs, or vehicles with larger batteries.

8.4 Energy Consumption

8.4.1 Annual Energy Consumption

Transaction records from chargers can be used to analyse the total electricity consumed by participants to charge their PEV using their Electric Nation charger. These records have been analysed on a month-by-month basis, to calculate the total energy consumed for each charger, for each month. Criteria have been applied to this data in a similar manner to those described in Section 8.3, as follows:

- Energy consumed is only calculated for full months after the charger was installed. For example, energy consumption will be calculated from September 2017 onwards for a charger installed partway through August 2017 (subject to the other criteria below). December 2018 has been excluded for all chargers, as the trial ended on 17th December;
- If communications between the charger and back office was poor then records may have been lost, which would artificially lower the energy consumed. This has been accounted for as follows:
    - CrowdCharge chargers: must have had a reliability of greater than 70% between the charger and Hubeleon for the month in question; and
    - GreenFlux chargers: must have been in contact with the back office after the end of the month in question, so that any transaction records from the given month would have been sent to the back office.
- If there are no transaction records for the charger at any point before the month in question, then the energy consumption is not calculated. Some chargers were online and not being used for a couple of months after the charger was installed, as the participant's vehicle hadn't been delivered. In this case the total energy consumed would be 0kWh, and it would pass all the other criteria set out. However, the zero value is not valid. This criterion avoids this, as a charger effectively only becomes 'active' after it has been used for the first time; and
- Any charger which had been marked as 'Installed Inactive' by DriveElectric (indicating that the participant had left the project) is excluded from analysis after their last full month in the project.

Total annual energy consumed has been estimated using data from December 2017 until November 2018. An annual total has been estimated for participants where at least six out of twelve months data is available, on a pro-rata basis. For example, if a participant consumed 380kWh in seven months then their annual total would be estimated as 652kWh (380 ÷ (7/12)). No adjustment was made for seasonal variation. If a greater degree of certainty is required to estimate an individual's annual energy consumption, then a suitable adjustment would need to be made. Using this method, annual energy consumption has been estimated for 495 of the 673 participants. The remaining 178 do not have at least six months of valid data available.

The box and whisker diagrams below (Figure 8-15) shows the range of annual energy consumption, split by battery capacity group.

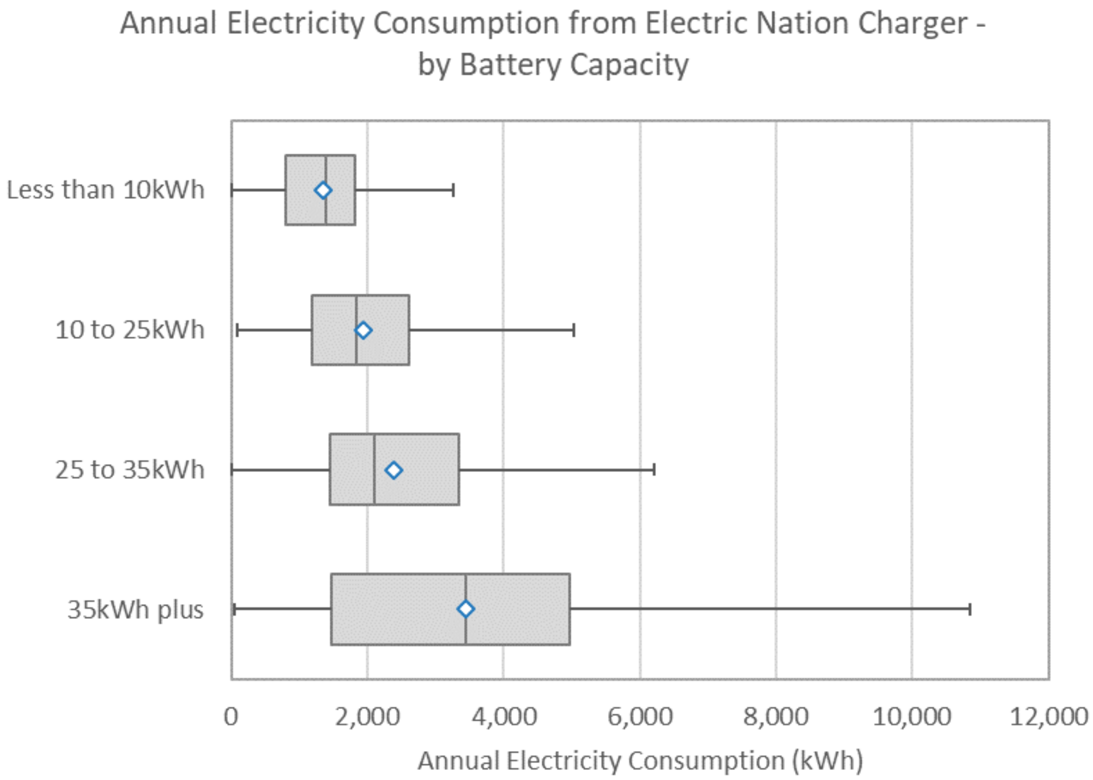


Figure 8-15: Annual Electricity Consumption - by Battery Capacity

This shows that energy consumption increases with increasing battery size. For comparison, typical domestic electricity consumption values range from 1,900 to 4,600kWh[47], so the majority of PEV vehicles approximately double the annual electricity consumption of a household. Figure 8-15 includes PHEV and REX vehicles that are likely to also use petrol or diesel. Figure 8-16, below, considers BEVs only (where electricity is the only fuel source available).

[47] Typical Domestic Consumption Values published by Ofgem (Low – High Profile Class 1 Estimates). Available from: https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values 2017 data

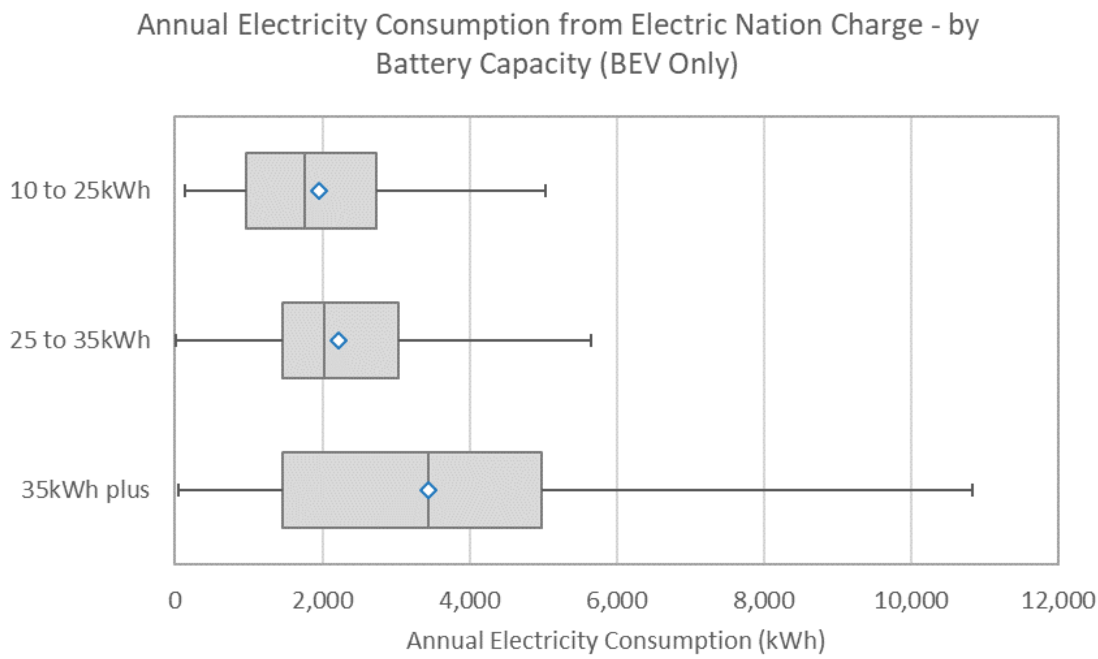


Figure 8-16: Annual Electricity Consumption (BEVs Only) – by Battery Capacity

This shows a very similar trend to Figure 8-15. Within Electric Nation the group of 'REX' vehicles consisted overwhelmingly of BMW i3 REX vehicles which use a small two-cylinder engine to extend the battery range. The BMW i3 REX vehicles in the trial had a battery capacity of either 22, 24 or 33kWh. Figure 8-17, below, compares the energy consumption of BMW i3 REX vehicles and the 'BEV' figures for the two battery capacity groups.

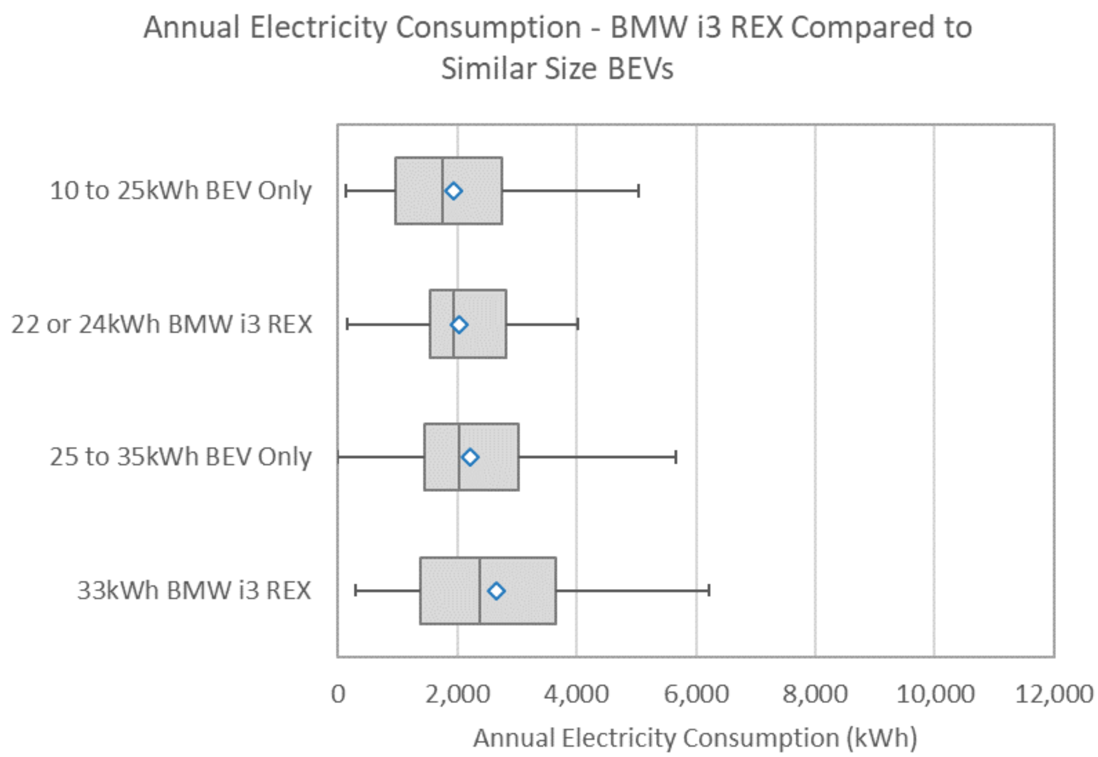


Figure 8-17: Annual Electricity Consumption - BMW i3 REX compared to similar size BEVs

This shows that the annual electricity consumption of BMW i3 REX vehicles is similar to BEV vehicles of a similar battery capacity.

8.4.2 Energy Consumption per Charge Session

The transaction data has also been analysed to show the energy consumption in each transaction, split by the four categories of battery capacity (Less than 10kWh etc.). The category assigned to each charger/participant is based on the information provided by DriveElectric. In a minority of cases the battery capacity appears to be incorrect (e.g. the participant may have changed their vehicle during the trial or gave incorrect details). Two filters have been applied to the data:

- Participants are excluded from the analysis where greater than 10% of transactions from their charger exceed the registered battery capacity by more than 2.5%. 31 participants (out of 600 with transaction records) are excluded by this filter.
- Individual records are excluded where the energy consumed for the charging session (i.e. for an individual charging event) was greater than 1.025 x Battery Capacity.

Further details of the rationale for these filters is given in Section 8.5. Applying these criteria leaves 137,886 records from 569 participants.

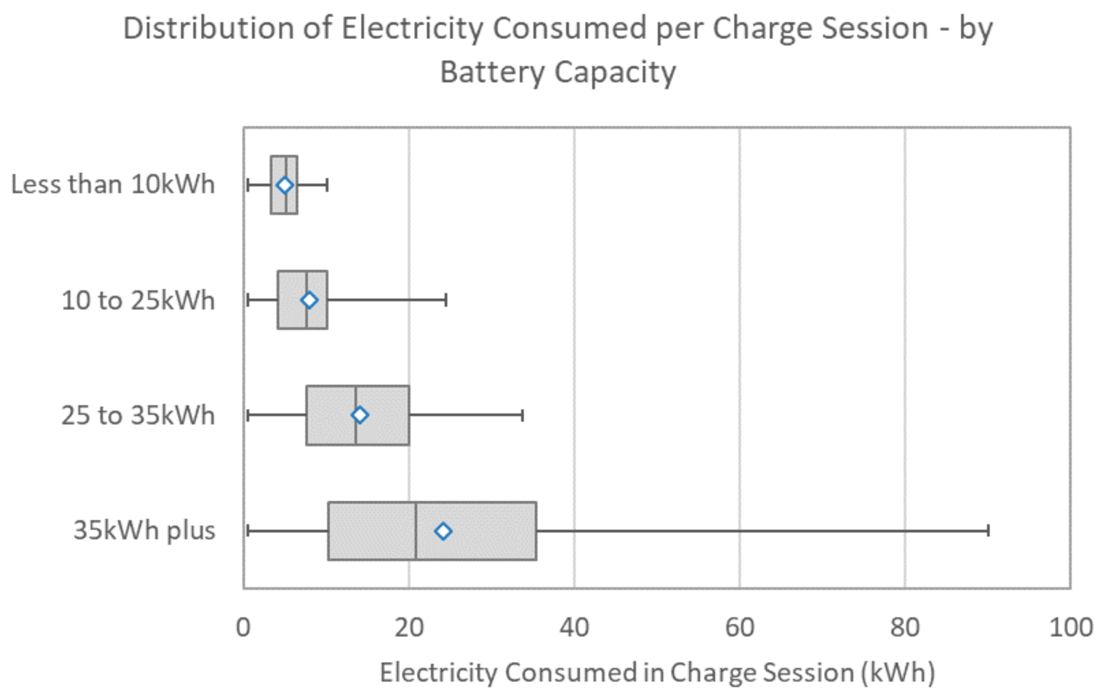


Figure 8-18: Electricity Consumed in Charge Session - by Battery Capacity

As expected, this shows a higher energy consumption per charging event as battery size increases. When compared to the likely battery capacity it appears to indicate that drivers re-fill a greater proportion of their battery capacity in each charging event for vehicles with lower battery capacities. This is summarised in Table 8-3 below. The comparison between battery capacity and likely state of charge at plug-in is explored in more detail in Section 8.5 below.

Table 8-3: Median Battery Capacity compared to Median Energy Consumption per Charging Event - by Battery Capacity

Battery Capacity Group	No. of Charging Events	Median Battery Capacity (kWh)	Median Energy Consumption per Charge Event (kWh)	Median Energy Consumption/Median Battery Capacity
Less than 10kWh	44,660	7.6	5.2	68%
10 to 25kWh	42,718	16	7.7	48%
25 to 35kWh	33,134	33	13.6	41%
35kWh plus	17,379	75	20.9	28%

8.5 Estimated State of Charge at Plug-In

Electric vehicle drivers may choose to plug their vehicle in to charge at any state of charge, and this (along with the vehicle/charger/cable rating and length of time plugged in) will determine how long the vehicle will charge for. For drivers with similar journey plans, smart charging was generally more likely to create an inconvenience for a driver whose vehicle battery was nearly empty, compared to another driver whose battery was nearly full.

This section therefore explores the energy consumed during charging sessions, and how this compares to the battery capacity of vehicles. In an ideal scenario the actual state of charge of the vehicle at plug-in would be analysed. However, existing communications protocols between PEVs and AC chargers such as those installed in Electric Nation do not allow for the exchange of this datapoint. The analysis below therefore only considers charging events which were not 'hot unplugged[48]' – i.e. the vehicle had reached 100% state of charge before being unplugged. Using this criterion, the energy consumed, and the registered battery capacity allows the state of charge at plug-in to be estimated for each transaction. For example, a vehicle had fully charged before it was unplugged, 20kWh of energy was transferred and the battery capacity is 30kWh: therefore, the battery state of charge at plug-in was approximately 33%.

As part of the recruitment process, each participant registered their plug-in vehicle with the trial, including its battery capacity (kWh). The energy consumed in each charging session is included as part of the transaction record and can be compared to the battery capacity associated with each participant's car.

For the purposes of this analysis:

$$\text{Estimated State of Charge at Plug-In} = 1 - \frac{\text{Energy Consumed During Transaction}}{\text{Nominal Vehicle Battery Capacity}}$$

(this analysis can only be completed where the vehicle was not hot-unplugged)

For most charge events the energy consumed data appears accurate, with the consumed energy less than 1.025 x Battery Capacity for 98% of the transactions (where the vehicle was not 'hot unplugged'). There are several potential causes for transactions where the energy consumed is greater than the battery capacity of the registered vehicle, including:

1. AC/DC conversion losses in the vehicle's onboard charging electronics, e.g. switching losses in the conversion electronics. This can be considerable when the charging rate is less than the maximum charging rate: losses of up to 30% have been stated at charging rates less than 30% of nominal rate;
2. Pre-conditioning of the passenger compartment, especially pre-heating and defrosting in winter before starting a journey, less so in summer where air

[48] The definition of 'hot unplug' is shown in Table 8-7 in Section 8.8

conditioning might be used to pre-cool a vehicle (as heat pumps are considerably more efficient than resistive heating);
3. Temperature control of the battery pack (used in some, but not all, PEVs);
4. Occasional use of the Electric Nation charger by another vehicle;
5. Inaccurate data (e.g. multiple transaction records merged into one); and
6. Registered vehicle is incorrect (either in both make and model, or battery capacity).

1, 2 and 3 are unavoidable parasitic energy consumption and are taken into account in the 2.5% excess energy allowance made above. 4 and 5 would lead to a very small proportion of an individual participant's records exceeding the registered capacity, whilst 6 would be likely to lead to more frequent issues.

For the purposes of this analysis the following filters have been applied:

- Participants are excluded from the analysis where greater than 10% of transactions from their charger exceed the registered battery capacity by more than 2.5% (based on only those transactions which were not unplugged). 35 participants (out of 579 with transaction records where hot unplugged = No) are excluded by this filter.
- Individual records are excluded where the energy consumed was greater than 1.025 x Battery Capacity.

From the original 87,822 transaction records from 579 participants, applying the criteria above leaves 82,491 records from 544 participants.

It is likely that the estimated state of charge at plug-in varies across the different battery capacities in the project. This is shown in the box and whisker diagram below (Figure 8-19), based on all transactions associated with each battery capacity group which were not hot unplugged (i.e. from 82,242 records, as those where consumed energy was greater than the battery capacity have been excluded).

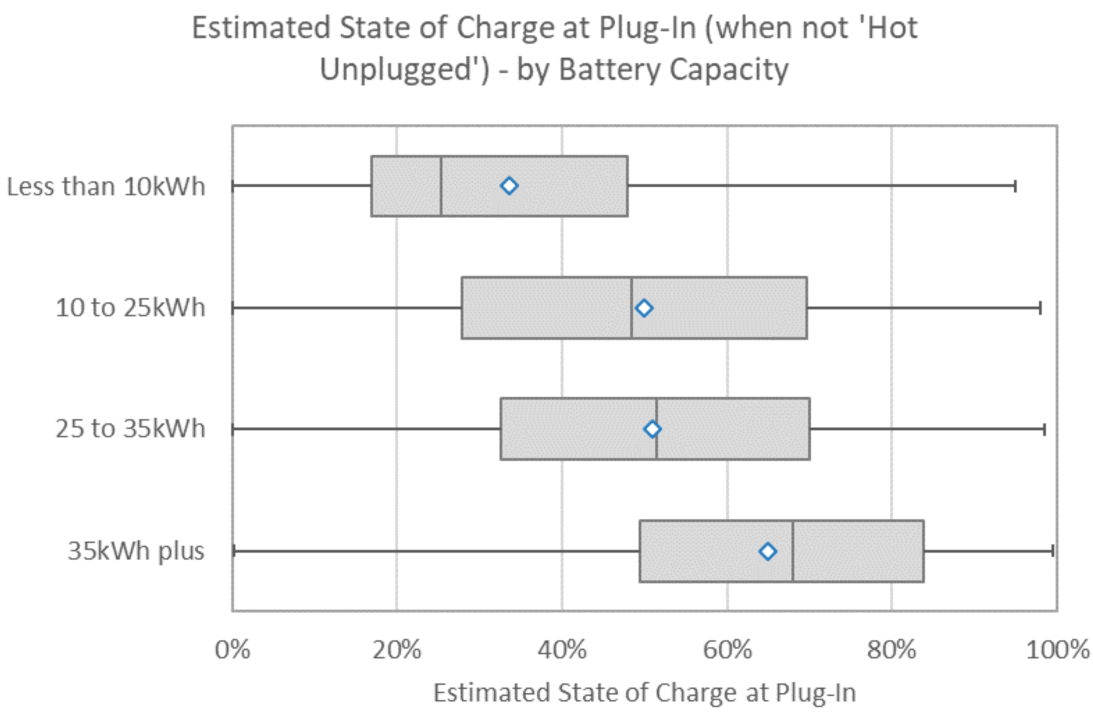


Figure 8-19: Estimated State of Charge at Plug-In - by Battery Capacity

This shows that vehicles with smaller batteries are generally at a lower state of charge when they connect, compared to those with larger batteries. For example, based on 26,209 charging records for vehicles with a battery capacity of less than 10kWh the average estimated state of charge at plug-in was 34%, compared to an average of 65% for transactions involving vehicles with battery capacities of greater than 35kWh. This also aligns with the findings in relation to energy consumed per charging session shown in Table 8-3 above.

There may be a relationship between the energy consumed in a charge session, and the frequency of charging. For example, two participants who drive a similar number of miles each week, and have the same vehicle, could adopt different recharging strategies; charging frequently, with the battery nearly full each time, or charging less frequently, but with the battery on a lower state of charge (nearly empty). This is explored in greater detail in the following section.

8.6 Relationship between Charging Frequency and State of Charge at Plug-In

The sections above gave details of the calculation of charging frequency and the estimated state of charge at plug-in (where the participant did not hot unplug) for each participant. These two data points can be combined to look at charging behaviour in terms of the combination of the two datapoints, and what influences this combination. Two data points have been calculated for each participant:

- Median charging frequency, where data for at least six of twelve months are available, and the median charging frequency is greater than 0; and
- Median Estimated State of Charge at plug-in (based on transactions where the battery was fully re-charged).

Both datapoints (frequency and estimated state of charge at plug-in) are available for 458 of the 673 participants. Each participant can be represented as a point on a graph, showing their median estimated SoC at plug-in (x axis) and median charging frequency (y axis). Four charts are shown below, for each group of battery capacity (Less than 10kWh etc.) using the matrix shown in Figure 8-20:

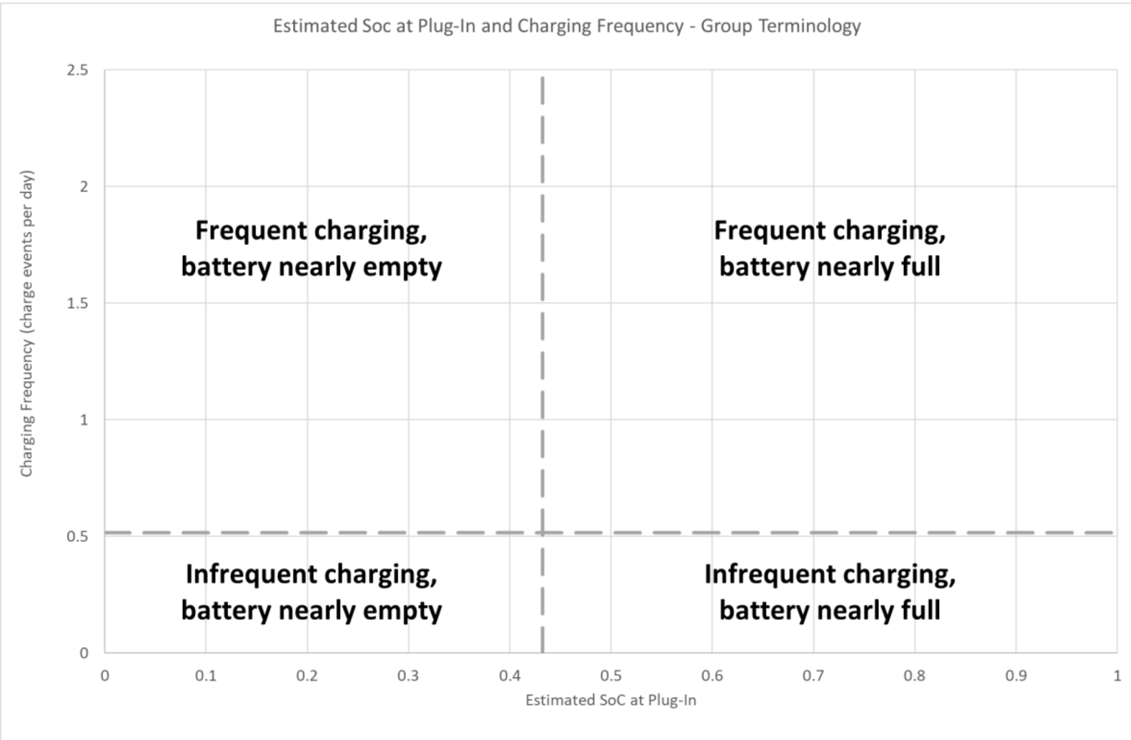


Figure 8-20: Matrix combining charging frequency and estimated state of charge at plug-in

The dotted horizontal and vertical lines show the median charging frequency and estimated SoC at plug-in respectively for the full population of 458 participants.

The percentage of the groups' population which falls into each quadrant is shown on the plots below (Figure 8-21).

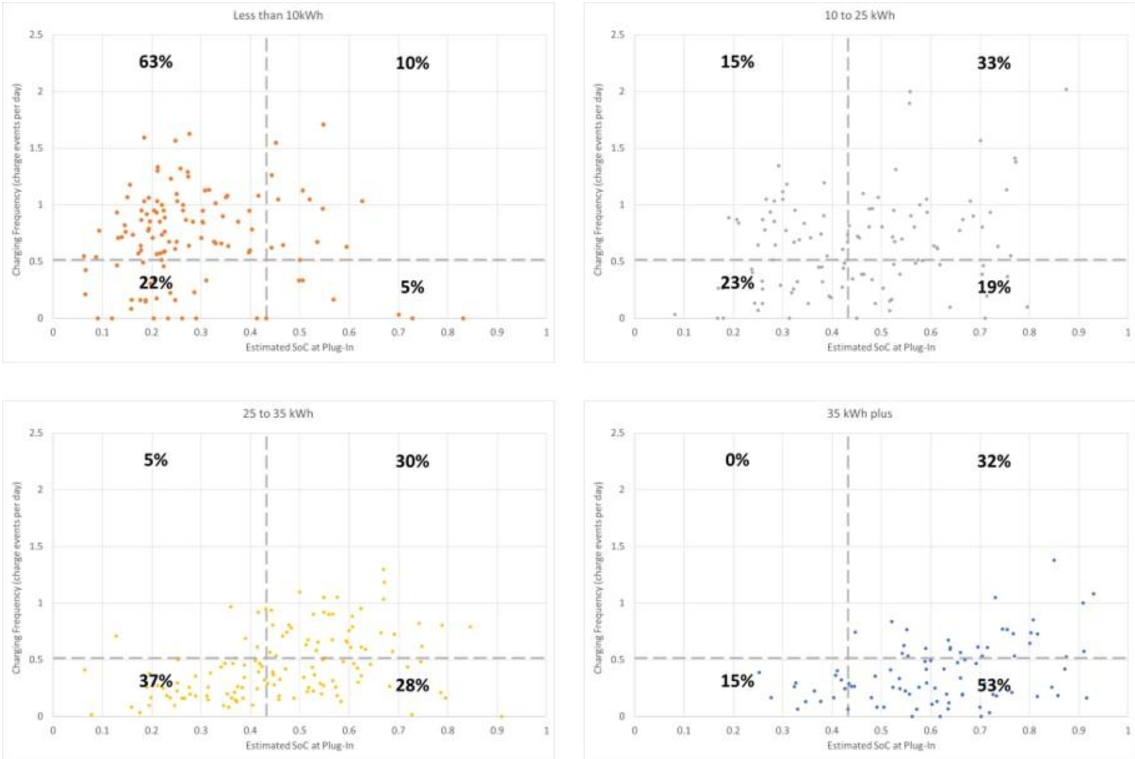


Figure 8-21: Combination of charging frequency and estimated state of charge at plug-in, by battery capacity

This shows that owners of vehicles with the smallest battery capacities are likely to be charging vehicles from a lower state of charge than other groups (85% below the population median – in the left-hand quadrants). Participants in the 'Less than 10kWh' group are statistically[49] more likely to be in the top-right quadrant (frequent charging, low state of charge) than all the other groups.

The '10 to 25kWh' group are more evenly distributed amongst the four quadrants, with a significantly greater tendency[50] to recharge their vehicles from a higher state of charge[51] than the 'Less than 10kWh' group (more dots on the right-hand side). They are significantly less likely to be charging their vehicle infrequently and from a high state of charge (bottom right quadrant) than owners of 35kWh plus vehicles[52]. This is understandable, as the electric range of vehicles in the '10 to 25kWh' group is substantially lower than those in the '35kWh plus' group (see comparison in Table 8-2).

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[49] Statistical analysis in this section completed with a z-test. 5% confidence interval. Z values compared % in top-left quadrant between battery capacity groups: Less than 10kWh and 10 to 25kWh Z = 5.86, Less than 10kWh and 25 to 35kWh Z = 9.7, Less than 10kWh and 35kWh plus Z = 9.32.

[50] Comparing % of participants on the right hand side between 'Less than 10kWh' and '10 to 25kWh' group, Z = 6.02

[51] By excluding charge events where the vehicle was hot unplugged the energy consumed in the charge session can be used alongside the registered battery capacity to estimate the state of charge at plug-in.

[52] Z value = 7.84.

The '35kWh plus' group tend to charge least frequently and from a higher starting state of charge than any other group[53]. However, these charging events may still last longer than charging events for smaller batteries because of the absolute amount of energy involved.

The categorisation above is based on attributes of the participant's vehicle (battery capacity). Other factors may also influence the tendency of a participant to fall into a particular group (quadrant on the graph above), for example whether they use other charging infrastructure (as well as their home charger) or weekly mileage. Information has been collected from participants via the use of customer surveys at multiple points during the trial. The following points have been included in this analysis:

- Use of other charging locations, and frequency. As described above (see Section 8.3) these frequencies have been assigned to one of three categories, using the hierarchy below:
    - Charging at Work: work has been selected, with a frequency of more than once a fortnight; if this is not the case then
    - Charging elsewhere: another location (apart from home) has been selected, with a frequency of more than once a fortnight; if this is not the case then
    - Home only.

  This simple classification was done to enable the analysis to differentiate participants depending on whether records from their home charger accurately represent their total energy usage. Survey responses from Trial 2 were used.
- Mileage in a typical week- reported in the final survey (included where the participant completed this survey); and
- Arrangements for obtaining a PEV (bought, leased or company car) – reported in the final survey

This data is based on the 297 participants who provided answers to all the survey questions above and had data for their median charging frequency and estimated state of charge at plug-in.

Each attribute is considered in turn below, comparing the proportion of participants with each attribute who fell into each of the four quadrants.

[53] Z values comparing % in bottom right hand quadrant. '35kWh plus' and 'Less than 10kWh' Z = 7.84, '35kWh plus' and '10 to 25kWh' Z = 5.09, '35kWh plus' and '25 to 35kWh' Z = 3.72.

Use of Other Charging Locations

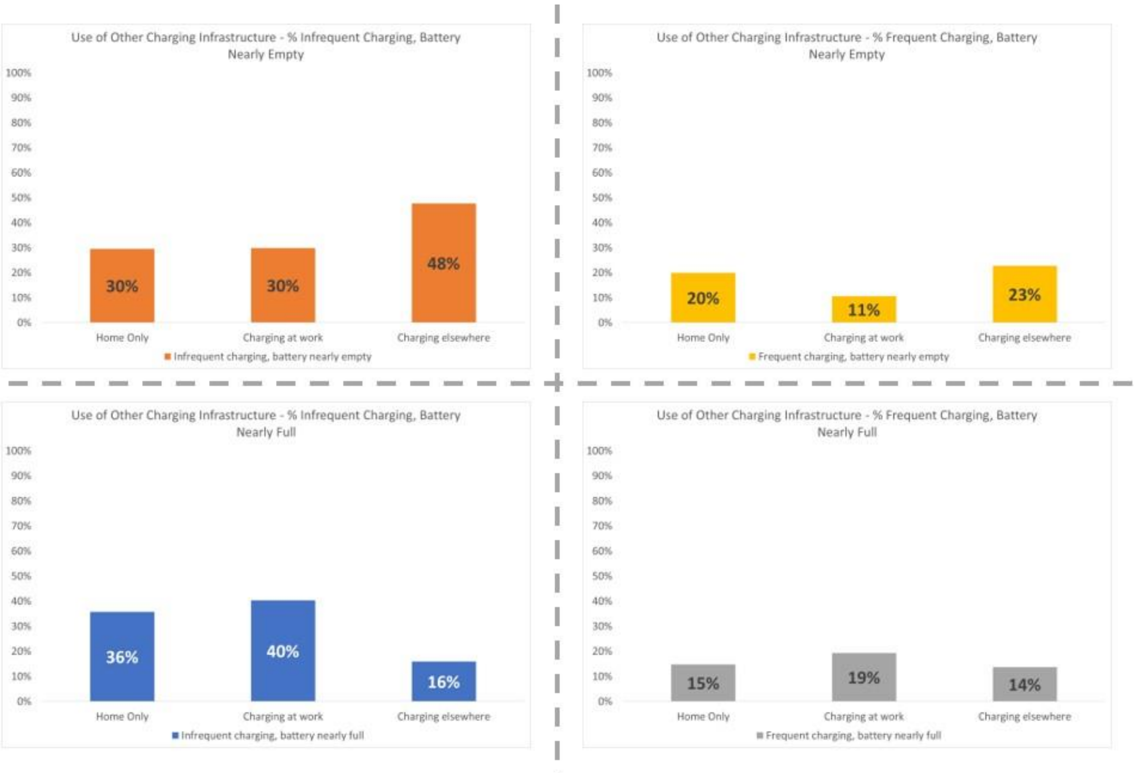

Figure 8-22: Use of Other Charging Infrastructure - link with charging frequency/state of charge at plug-in

Participants who charged their vehicle at home, or charged at work, were statistically **more** likely to charge infrequently with a battery that was nearly full (at home) (blue bars) than those who also charge elsewhere (according to the definitions set out above)[54].

Those who used charging infrastructure elsewhere were statistically **less** likely to charge infrequently, with a battery that was nearly empty (orange bars), than those who only charge at home[55]. This is understandable as by charging elsewhere their battery was either more likely to be at a higher state of charge when they connected at home, or they would have needed to charge at home less frequently.

[54] Z Test. Home vs. Charging Elsewhere (36% vs. 16%) Z = 2.56. Work vs. Charging Elsewhere (40% vs. 16%) Z = 2.62.

[55] Z Test. Home vs. Charging Elsewhere (30% vs. 48%) Z = 2.29

Typical Weekly Mileage

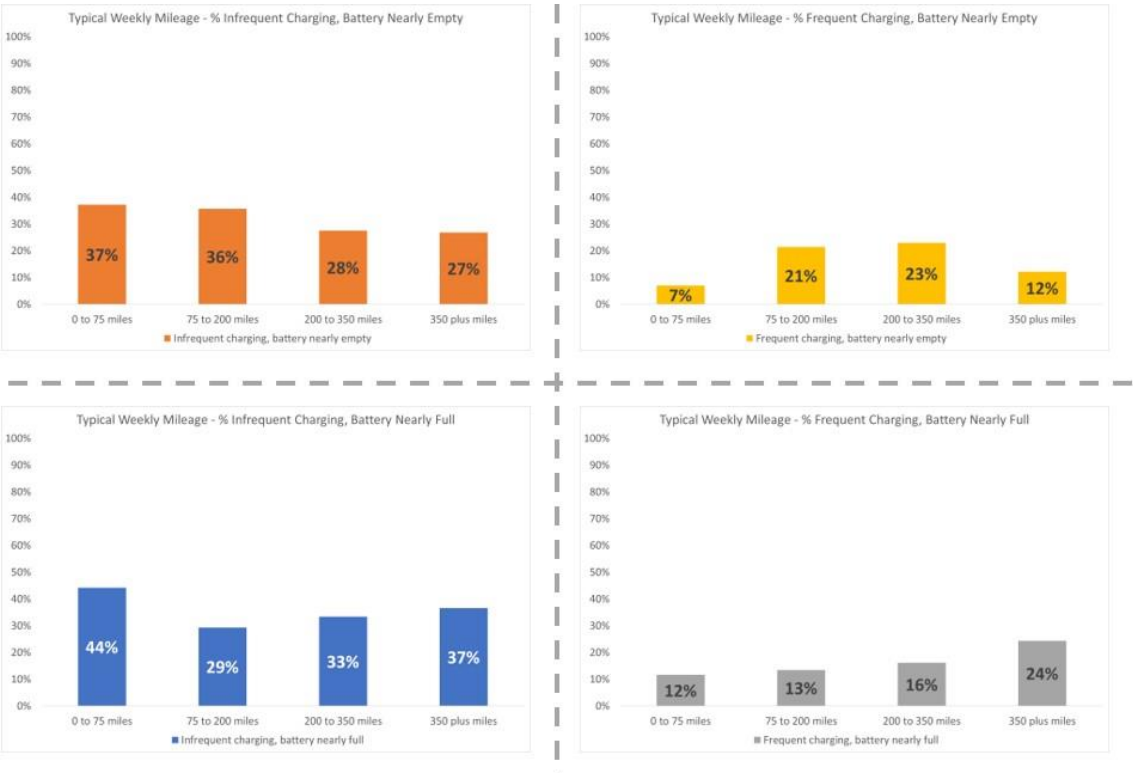

Figure 8-23: Typical Weekly Mileage - link with charging frequency/state of charge at plug-in

Participants who drove less than 75 miles in a typical week were statistically **less** likely to be charging frequently, with a battery that was nearly empty (yellow bars), than both those who drove 75 to 200 miles a week, or those who drove 200 to 350 miles a week[56].

[56] Z Test. % Charging Frequently Battery Nearly Full. 0 to 75 miles vs. 75 to 200 = 7% vs. 21% Z = 2.09. 0 to 75 miles vs. 200 to 350 miles = 7% vs. 23% Z = 2.25.

Arrangement for Obtaining PEV:

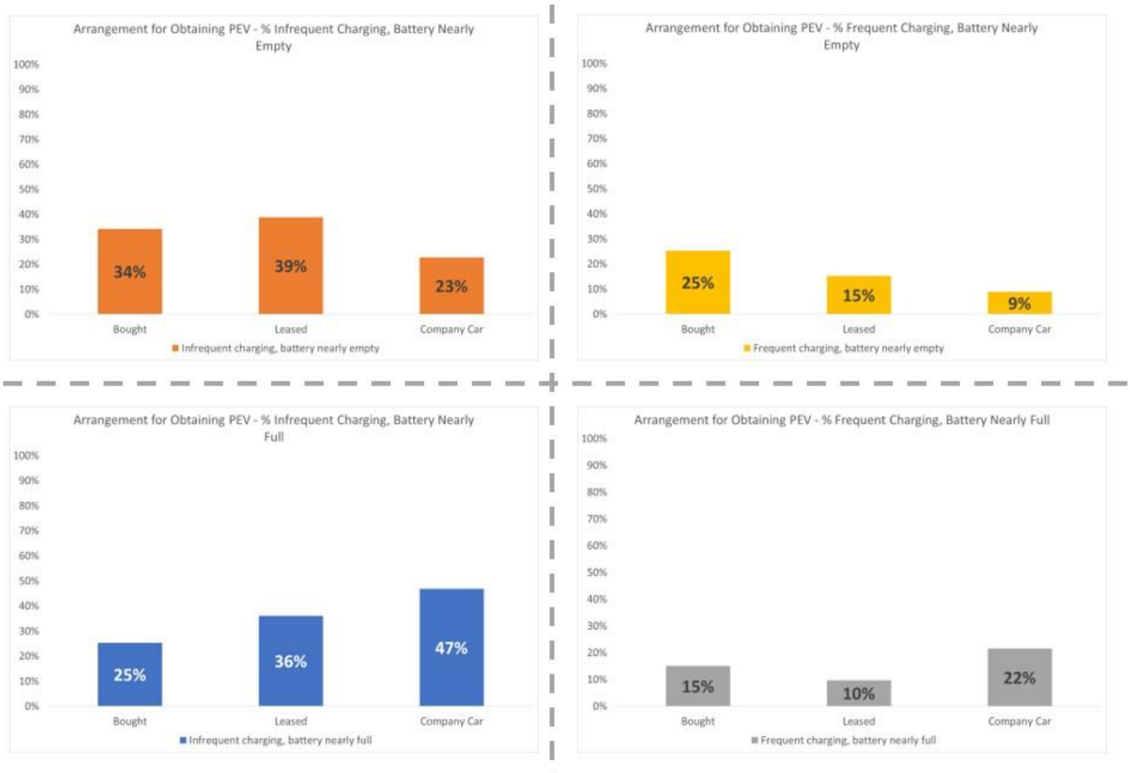

Figure 8-24: Arrangement for Obtaining PEV - link with charging frequency/state of charge at plug-in

There were two statistically significant differences between those whose vehicles was a company car compared to those who bought their PEV:

- They (company car group) were **more** likely to charge their car infrequently, with a battery that was nearly full (blue bars)[57]; and
- They were also **less** likely to charge frequently, with a battery that was nearly empty (yellow bars)[58].

In addition, those who leased their vehicle were **more** likely to charge infrequently, with the battery nearly empty (orange bars), than those whose vehicle was a company car[59].

This may be partly due to the differences in the vehicle type (battery capacity) of vehicles that were bought, leased or obtained as a company car. Table 8-4 below shows the breakdown for each of these groups, for the 297 participants which were used in this analysis.

[57] Z test. Comparing % Infrequent, Battery Nearly Full – Bought vs. Company Car = 25% vs. 47%. Z = 3.36
[58] Z test. Comparing % Frequent, Battery Nearly Empty – Bought vs. Company Car = 25% vs. 9%. Z = 2.90
[59] Z test. Comparing % Infrequent, Battery Nearly Empty – Leased vs. Company Car = 39% vs. 23%. Z = 2.13

Table 8-4: Relationship between Arrangement for Obtaining PEV and Vehicle Battery Capacity

Arrangement for Obtaining PEV	Less than 10kWh	10 to 25kWh	25 to 35kWh	35kWh plus
Bought	11%	45%	24%	21%
Leased	17%	11%	56%	17%
Company Car	62%	6%	13%	19%

8.7 Use of Timers

PEVs include the ability to use the car's menus, or an app, to set a timer which will control when the vehicle will charge. For example, a driver who is on an Economy 7 ToU tariff may plug their car in when they get home from work, but have a timer set so that it begins to charge at midnight.

This section looks at how widespread the use of timers was within the trial cohort and which participants were more likely to use them. Trial 3 introduced a ToU incentive to all participants that was designed to influence charging behaviour, including use of timers. Therefore, the analysis in this section is based on 94,519 charging events from Trial 1 and Trial 2.

PEV 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, because of their participation in the trial, owing to an awareness of network capacity issues and a desire to minimise this, even in the absence of tariff incentives.

A charging event has been defined as using a timer when there was a delay of at least thirty minutes between the vehicle being plugged in, and it starting to charge. 17,834 of the 94,519 charging events involved the use of a timer (i.e. 19% of all transactions).

Figure 8-25, below, shows the contribution of individual participants to the total number of transactions with timers. This indicates that approximately 20% of participants are responsible for 80% of transactions involving timers.

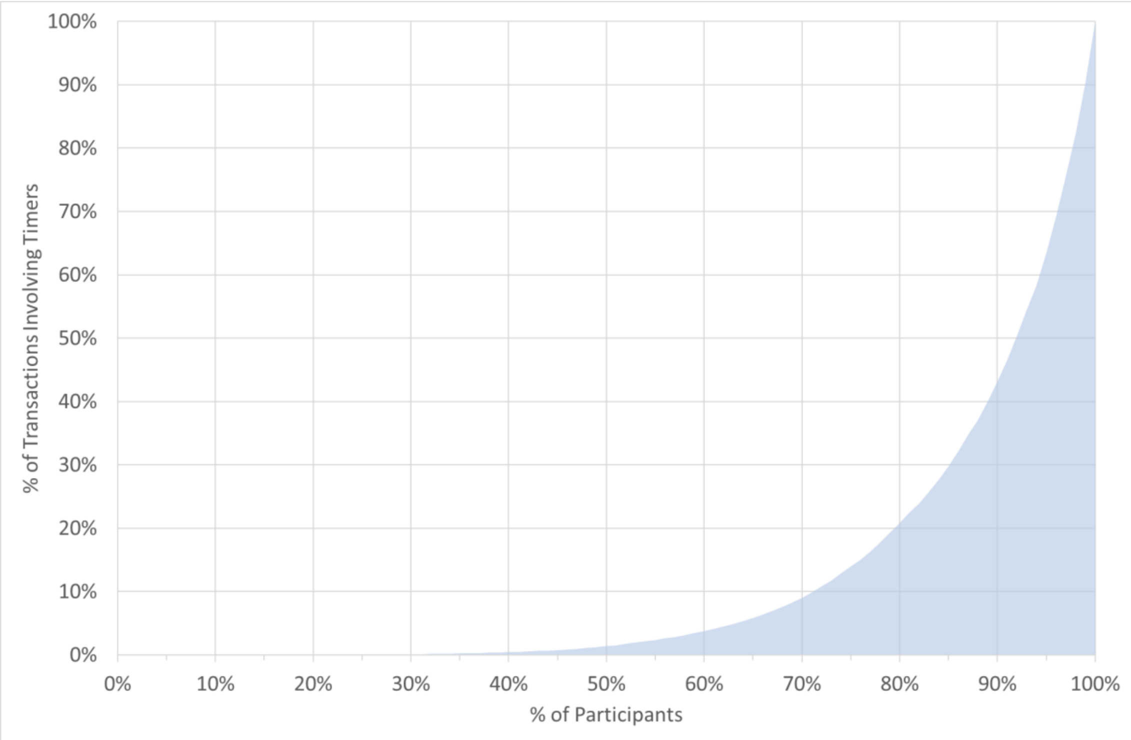

Figure 8-25: Use of Timers by Electric Nation Participants

The analysis below aims to explore the factors which may increase the likelihood that a participant regularly uses a timer. Participants have been included in this analysis where data is available for at least 10 charging events – 554 participants. The remaining participants may not have used their charger, or comms may have been poor meaning that the 'current meter value' records which allow timer use to be detected were not available.

For each participant, where at least ten charging events were available (with a start charge time), the percentage of their charge events where they used a timer was calculated. The box and whisker plot below (Figure 8-26) shows the distribution of these values, for all participants, and by PEV type.

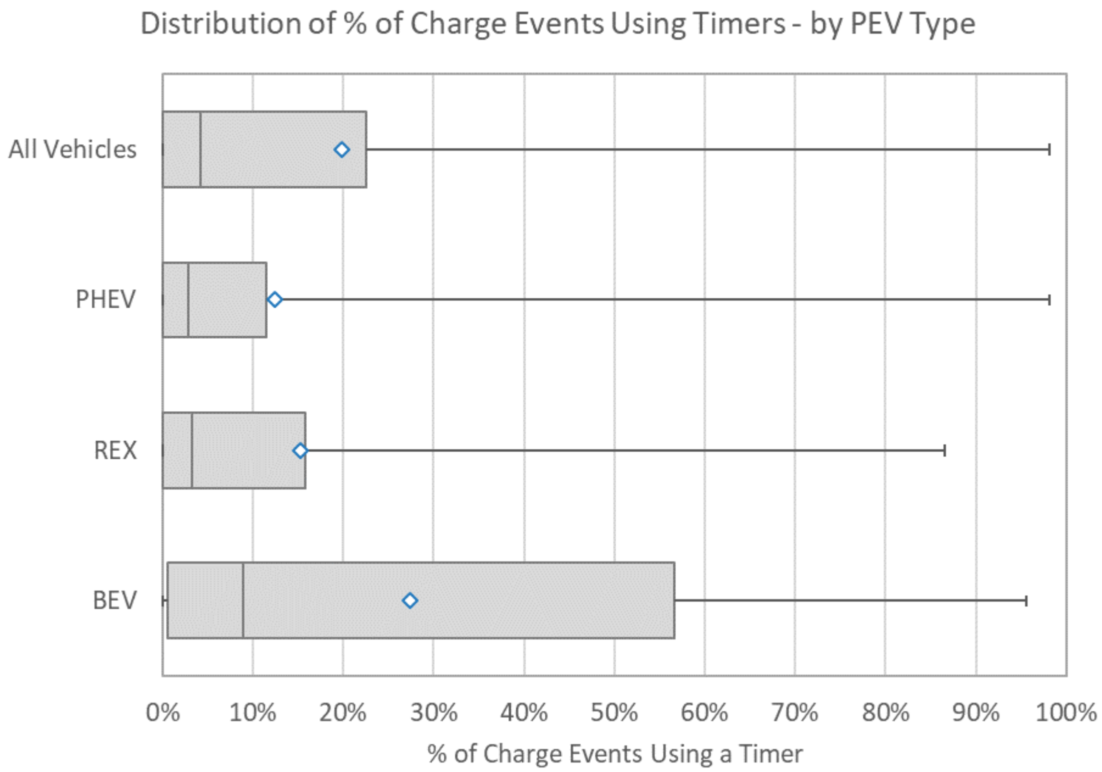

Figure 8-26: Use of Timers - by PEV Type

This shows considerable variation in the use of timers, particularly for full battery electric vehicles (large interquartile range). The diagram below (Figure 8-27) shows the same data, analysed by battery capacity.

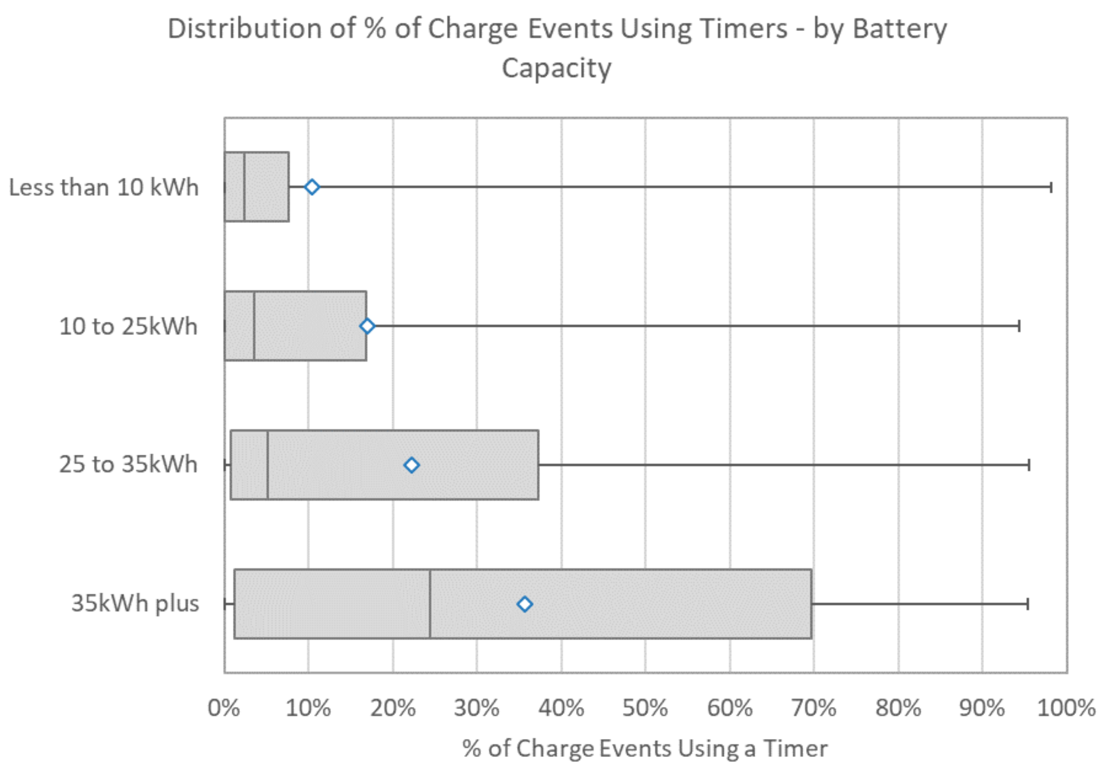

Figure 8-27: Use of Timers - by Battery Capacity

This also shows considerable variation within each of the categories, particularly in the upper quartile of the data. There is a trend towards increasing use of timers by participants with vehicles with larger batteries. This may be because their total energy consumption is higher, so the potential savings from overnight charging on a time of use tariff such as Economy 7 will be larger.

PEV type, or battery capacity alone does not appear to provide a good prediction of how likely a participant was to use a timer, because the range of timer use within these groups was large. The analysis which follows compares the use of timers amongst other groups.

When participants joined the trial, they were asked to supply their Meter Point Administration Number (MPAN). The first two digits of the MPAN number (e.g. 01 or 02) indicate whether the meter is single or dual rate. This does not show whether the meter was a smart meter and so capable of half hourly metering and therefore suitable for more complex ToU tariffs.

The box and whisker plot, Figure 8-28, below, compares the use of timers by participants with single or dual rate meters. Of the 554 participants with at least ten transactions, 93 had a dual rate meter (17%).

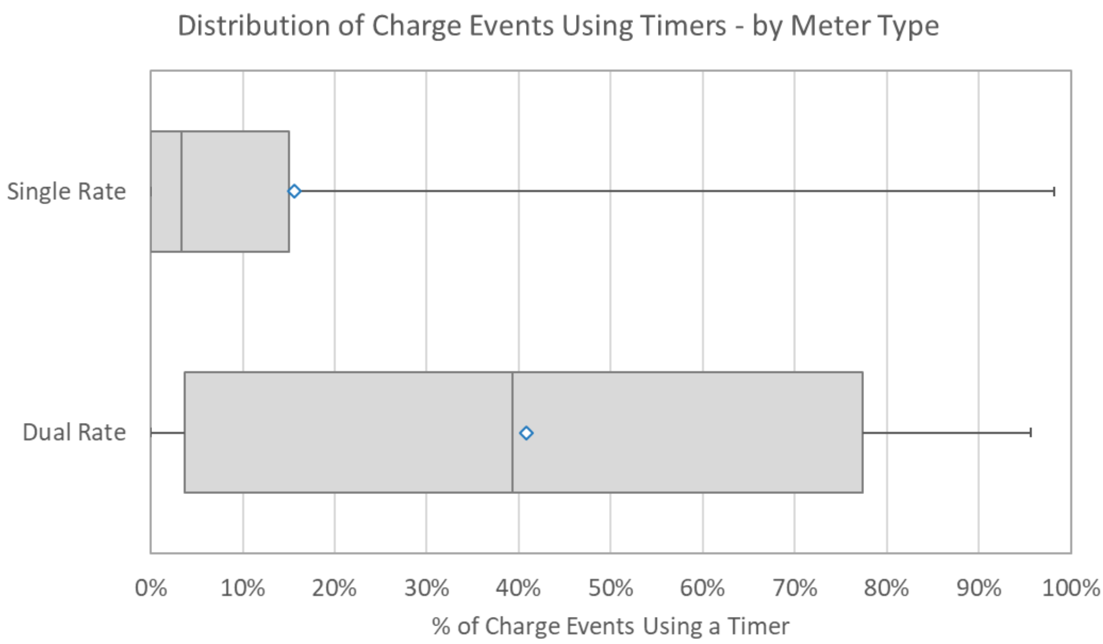

Figure 8-28: Use of Timers - by Meter Type (Single or Dual Rate)

This shows that participants with a dual rate meter were much more likely to use timers than those with single rate meters. Some participants with a single rate meter were still using timers. A participant has been defined as a 'frequent' timer user is they used a timer for at least 50% of their charging events. Participants with a dual rate meter were statistically significantly more likely to be a frequent timer user than those with a single rate meter (45% vs. 13%).

Within the 'dual rate' group there is still considerable variation. Figure 8-29, below, disaggregates the 'dual-rate' group by battery capacity.

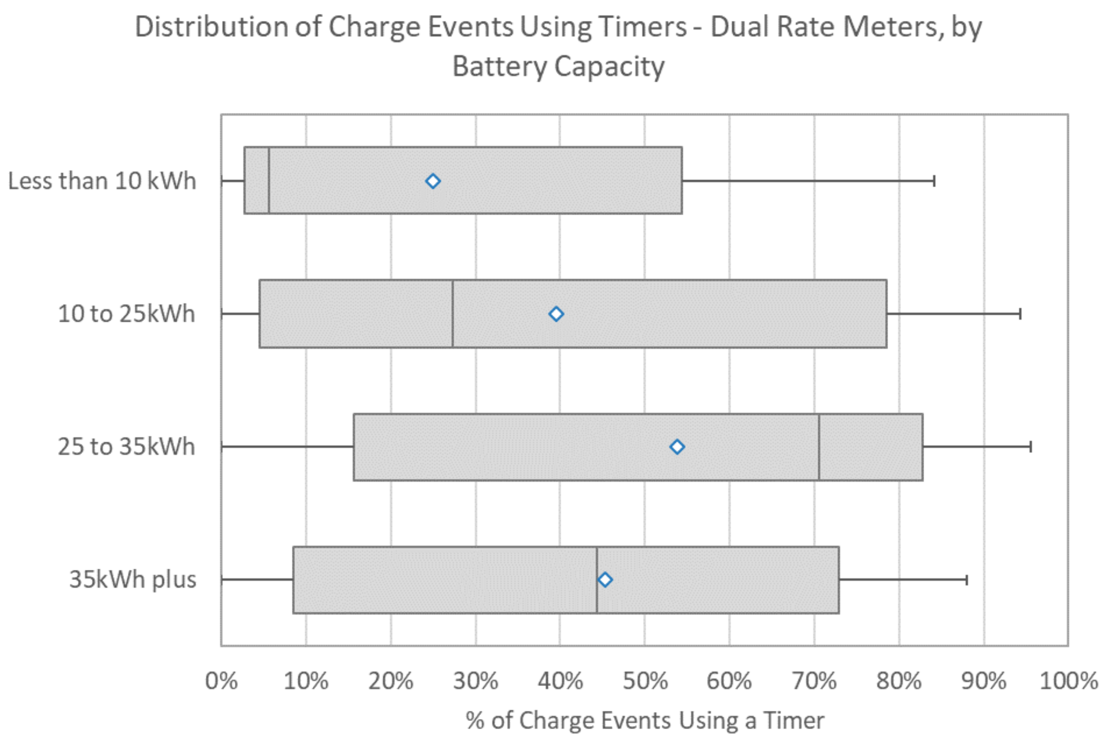

Figure 8-29: Use of Timers - Dual Rate Meters Only, by Battery Capacity

Again, this shows considerable variation in timer use within all four groups (wide interquartile range). The proportion of participants in each group which were 'frequent' timer users has been calculated and is shown in the table below.

Table 8-5: Proportion of Dual Rate Meter Participants who were 'Frequent Timer Users' by Battery Capacity

Battery Capacity	Number of Participants (with Timer Data and a Dual Rate Meter)	% who were 'Frequent Timer Users'
Less than 10kWh	24	29%
10 to 25kWh	24	42%
25 to 35kWh	24	63%
35kWh plus	21	48%

The only statistically significant difference[60] within this data is that a larger proportion of participants with dual-rate meter and a '25 to 35kWh' battery capacity were frequent timer users, compared to the 'Less than 10kWh' dual-rate meter group (29% vs. 63%).

As part of the Final Survey, participants were asked to select the type of electricity tariff they were on, from the following options:

[60] Z test. Z = 2.36 (value of 1.96 would indicate 5% confidence level.)

- Standard tariff
- Fixed price deal
- Economy 7 or Economy 10
- Specific EV tariff
- Other time of use tariff
- Other (please specify)
- Don't know
- Rather not say

The use of timers has been compared for four groups of responses from the options above. It is important to note that this data reflects the tariff the participant was on at the end of the trial, and so may have changed partway through the project.

- 'Standard tariff' or 'Fixed price deal' – i.e. a tariff which does not include a time of use element
- Economy 7 or Economy 10
- Specific EV tariff – may include a time of use element, depending on supplier
- Other time of use tariff

The table below shows the number of participants in each category (where data on timer use was available) and the proportion in each group who were 'frequent' timer users.

Table 8-6: Proportion of Participants who were 'Frequent Timer Users' by Electricity Tariff Type

Tariff Type	Number of Participants (with Timer Data)	% Frequent Timer Users
Standard tariff or fixed price deal	295	7%
Economy 7 or Economy 10	76	68%
Specific EV Tariff	40	20%
Other time of use tariff	3	67%

This analysis shows that participants on an Economy 7 or Economy 10 tariff were significantly more likely to be 'frequent' timer users than both those on a standard tariff/fixed price deal, and those on a specific EV tariff. Those on a specific EV tariff were significantly more likely to be frequent timer users than those on a standard tariff/fixed price deal.

Economy 7 and Economy 10 tariffs offer seven hours of cheaper electricity overnight. Economy 10 also includes three cheaper hours in the early afternoon. The tariff was introduced alongside storage heaters in the 1980s, so that the load from electric heating occurs overnight, when other demand is lower. Storage heating and Economy 7/10 are generally deployed together (i.e. it would be unusual to have storage heating without being on an Economy 7 or 10 tariff). This was traditionally used for areas/developments without a connection to the gas network. The electricity distribution network in these areas often has a 'night-time' peak, as a high proportion of homes in the area use night storage heaters controlled by the Economy 7/10 meter. This 'night-time peak' is included as part of the design of the electricity network in these areas.

The data above indicates that PEV drivers who are on an Economy 7 or Economy 10 tariff are likely to use a timer so that their vehicle begins charging overnight. In areas with existing night-storage heating load this could increase the load on the network beyond its capacity. A tariff incentive alone provides a stimulus to which drivers will respond but provides no means of managing this additional demand. In areas with a night-time peak as a result of a significant proportion of homes having night storage heaters it may be beneficial for demand from PEVs to occur at other times of the evening/night/early morning to avoid the two peaks (PEV load and heating load) coinciding.

PV generation allows drivers to charge their vehicle using the electricity generated at the property (if the vehicle is connected when the PV panels are generating). Participants were asked whether their home had PV generation as part of the recruitment survey and this data has been combined with the use of timers[61]. This has been combined with their meter type, and the way the participant uses their vehicle (from the baseline survey). To maximise the use of solar generation, a timer would be set to charge the vehicle during the daytime hours when PV generation is highest (depending on the orientation of the PV panels, roughly 8am – 4pm if due South). If the vehicle is used for either commuting or business, then it is less likely to be available for home charging during the day than one which is only used for 'social' trips.

[61] A small number of participants answered 'Not Sure' to this question, and they have been included with those who do not have solar generation.

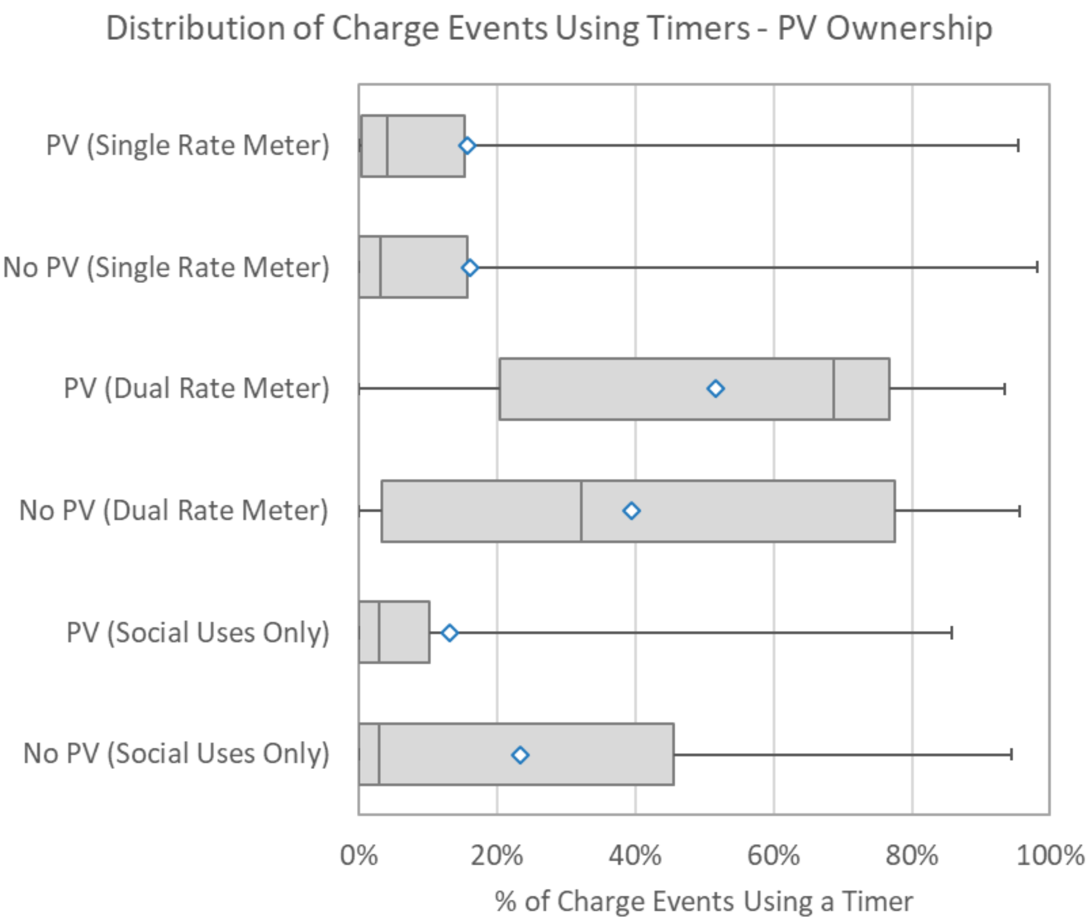

Figure 8-30: Use of Timers – by Meter Type, PV Generation and Vehicle Use

The table below compares the proportion of participants who were 'frequent timer users' across each of the six groups shown above.

Tariff Type	Number of Participants (with Timer Data)	% Frequent Timer Users
PV (Single Rate Meter)	92	13%
No PV (Single Rate Meter)	336	14%
PV (Dual Rate Meter)	21	62%
No PV (Dual Rate Meter)	63	43%
PV (Social Uses Only)	26	12%
No PV (Social uses Only)	57	25%

There are no statistically significant differences between the pairs of variables (e.g. PV or no PV for dual rate meters). The relationship between PV ownership, vehicle usage and use of timers is not clear. If the vehicle is at home during the day, then the owner may plug their vehicle in during the daytime and allow it to charge, without setting a timer.

8.8 Hot Unplugging

'Hot unplugging' refers to charge sessions where the vehicle was unplugged before the battery was full (i.e. current is still being drawn immediately before the vehicle is unplugged). This may be part of a participant's normal charging behaviour. However, any increase in hot unplug events during the smart charging trials would indicate that smart charging had the potential to inconvenience the participant. The prevalence of hot unplugging can be used alongside participant feedback about the trials (via the customer surveys) to assess the impact of smart charging. These sessions do not provide evidence of flexibility (unless a timer was used to delay the start of charging)

This sub-section shows the prevalence of 'hot unplugging' as part of charging sessions which took place before demand management was introduced. It includes data from 18,027 charging sessions, where 'current meter values' were available which allowed the start and end of charging to be detected and where these values indicated a charging rate of between 0.5 and 7.5kW. Values outside this range would suggest that the detection of either start or end charge is inaccurate. Using the plug-in and out times and the start and end of charging, two quantities have been calculated:

- $t_{\text{inactive start}}$: the time (minutes) between the vehicle being plugged in and charging beginning. If $t_{\text{inactive start}}$ is greater than or equal to 30 minutes then a timer was used (see Section 8.7)
- $t_{\text{inactive end}}$: the time (minutes) between the end of charging and the vehicle being unplugged.

These quantities have been combined as follows:

Table 8-7: Combinations of $t_{\text{inactive start}}$ and $t_{\text{inactive end}}$ used to define timer use and hot unplugging

$t_{\text{inactive start}}$	$t_{\text{inactive end}}$	Scenario	% of Transactions (Outside of Management)
Less than 30 minutes	15 minutes or greater	No timer used, did not hot unplug	68%
Less than 30 minutes	Less than 15 minutes	No timer used, but hot unplugged	18%
30 minutes or greater	15 minutes or greater	Timer used, did not hot unplug	13%
30 minutes or greater	Less than 15 minutes	Likely to be a departure timer	2%

A judgement must be made in order to set the threshold (value of $t_{inactive\ end}$) at which a charge event is judged to have been 'hot unplugged'. The choice of this value has the potential to bias the results:

- High value of $t_{inactive\ end}$: some charging events are falsely identified as 'hot unplugs' when in reality they were not. This would understate the flexibility available and so indicate a higher potential impact of smart charging.
- Low value of $t_{inactive\ end}$: some charging events which were hot unplugged would be excluded from the total, overstating the flexibility available and so suggesting that the potential impact of smart charging would be lower.

Sensitivity analysis has been completed to compare the number of charging events identified as 'hot unplugs' (second row in Table 8-7 above) with varying values for the $t_{inactive\ end}$ threshold value.

Table 8-8: Sensitivity Analysis for value of $t_{inactive\ end}$

Hot unplug when tinactive end less than	Number of Hot Unplugs Outside Management	% of Total
15 minutes	3,220	18%
10 minutes	2,891	16%
5 minutes	2,552	14%

There is a linear relationship between the proportion of charging events which were hot unplugged and the value of $t_{inactive\ end}$ used as the threshold. A value of 15 minutes has been chosen to avoid biasing the results in a way which would overstate the case for smart charging (minimising potential customer impact). All the analysis which follows in this and later sections uses a comparative analysis of the percentage of charge events which were hot unplugged and so a consistent threshold is used.

'Departure timers' (referenced in Table 8-7 above) are available in some makes/models of PEVs. This combines the features of a timer with pre-conditioning. For example, an off-peak price window may be set for 01:00 – 08:00, with the user having programmed their departure time to 07:00. The vehicle requires 21kWh to be fully charged and is rated at 7kW, therefore requiring three hours to charge. The departure timer would ensure that the vehicle began charging around 04:00 so it was finished at 07:00. This is not a true hot-unplug as the timing was scheduled to ensure charging finished at the unplug time. Outside of demand management 18% of charge events involved a hot unplug (17% and 19% of weekday and weekend charging events respectively). Figure 8-31, below, shows the time of day when people hot unplug, for weekday and weekends.

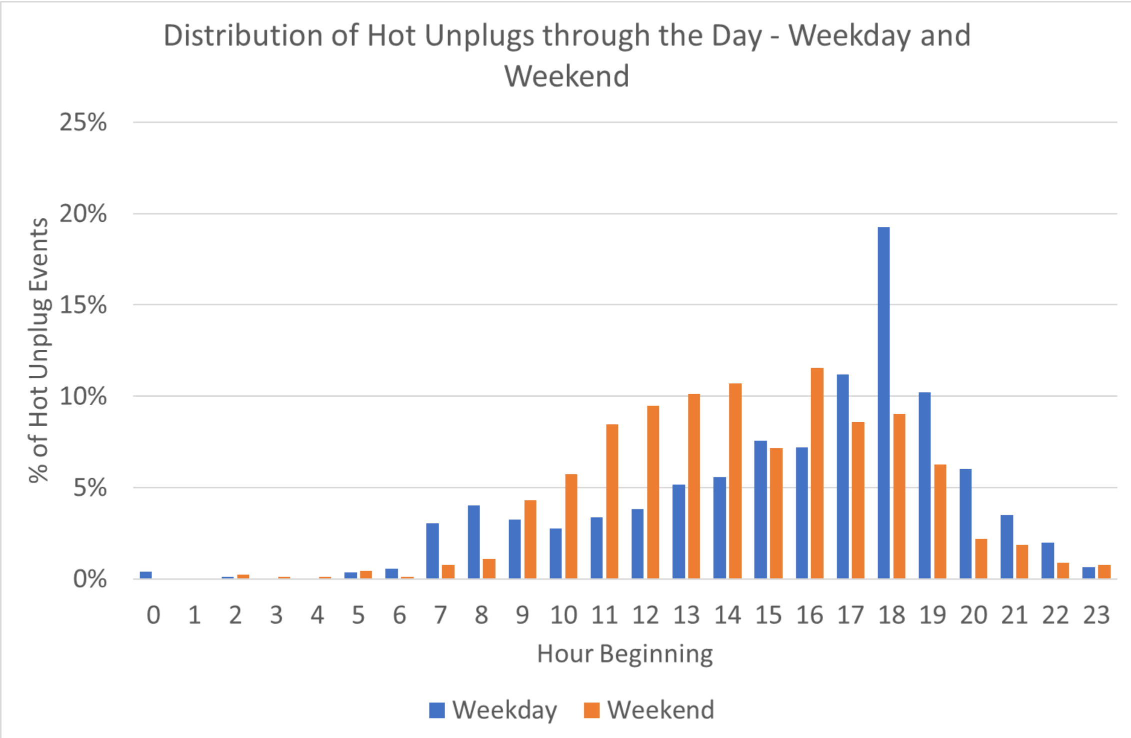

Figure 8-31: Distribution of Hot Unplugs by Time of Day - Weekday and Weekend

Hot unplugging is spread through the day. On weekdays it reaches a peak between 18:00 – 18:59, which accounts for 19% of hot unplug events. In this time period 56% of the vehicles unplugged were hot unplugged. The weekend does not have a pronounced peak, with the majority of events occurring between 11:00 and 19:59.

All participants may 'hot unplug' equally frequently, or it may be that a minority of participants are 'hot unplugging' very frequently (a similar distribution to timer use as shown above). This is shown in Figure 8-32, below.

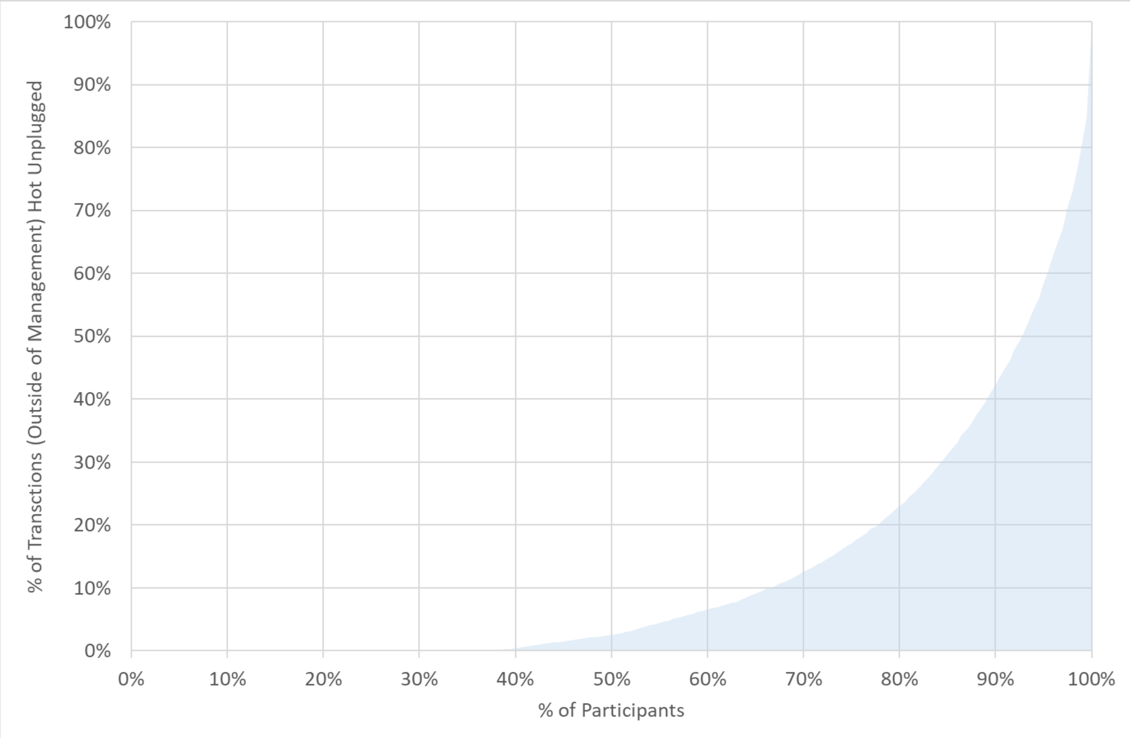

Figure 8-32: Hot Unplugging by Electric Nation Participants

Hot unplugging is spread amongst the trial population in a very similar way to timer use – with 20% of the population responsible for around 80% of hot unplugging events.

For each participant, the proportion of their transactions in which they 'hot unplugged' has been calculated. Participants are included in the distribution below if data is available for at least 10 charging events, leaving 404 participants. The box and whisker diagram, Figure 8-33, below shows the distribution of hot unplugging by PEV type.

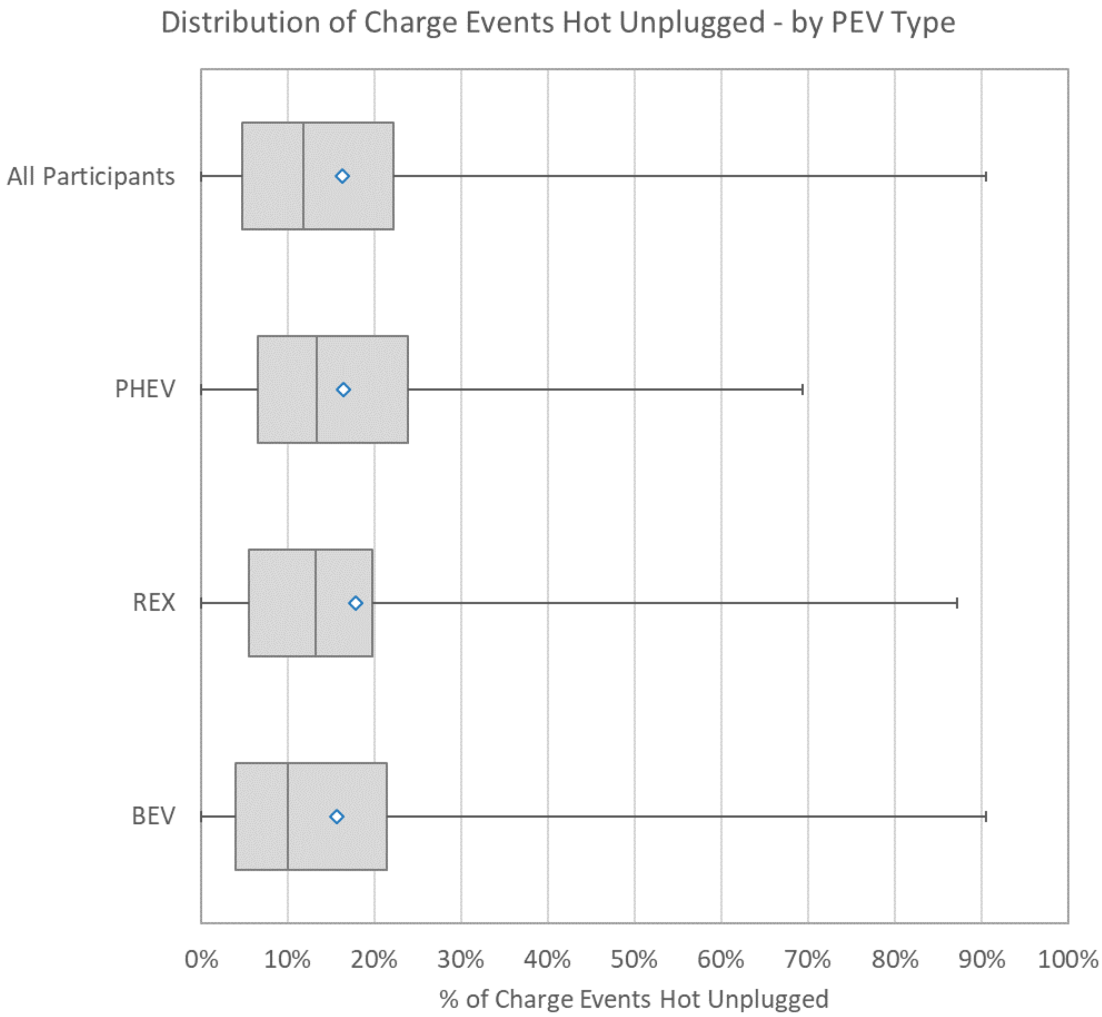

Figure 8-33: Distribution of % of Charge Events Hot Unplugged - by PEV Type

This shows little difference in the tendency to 'hot unplug' by vehicle type. Across all vehicle types 75% of the population 'hot unplug' less than 25% of the time.

Hot unplugging is a negative indicator of the level of flexibility available, as it indicates a charge session where the vehicle was charging for the full duration of the plug-in period. This concept is explored more in Section 8.9.

8.9 Flexibility

Flexibility is a key metric for the purposes of determining whether smart charging could potentially inconvenience drivers. If vehicles generally need to charge at the maximum possible rate for the entire plug-in duration, then any reduction in charging speed (through smart charging) would result in the vehicle having a lower state of charge (range) when it came to be unplugged. Conversely, if the vehicle charges for only a small proportion of a much longer plug-in time, then the charging rate can be reduced without impacting the state of charge when it is unplugged (i.e. the same energy is delivered over a longer time period).

The transaction data from the trial has been analysed to assess the flexibility available. Within this report 'Flexibility' has been calculated for each charging event using the following formula:

$$\text{Flexibility} = 1 - \frac{\text{Charging Duration (minutes)}}{\text{Plug in Duration (minutes)}}$$

So, a charging event where the charging duration = plug-in duration has a flexibility of 0, and one where the vehicle charged for an hour within a ten-hour plug-in period has a flexibility of 0.9 (or 90%). The flexibility has been calculated using processed transaction records, with the following criteria applied:

- Energy consumed must be between 0.5 and 100kWh (in common with all other analysis);
- Current meter values must be available for the transaction, in order to calculate the time when charging started and finished;
- The equivalent charging rate calculated by the database (i.e. dividing the consumed energy in kWh, by the charging duration in hours) must be between 0.5 and 7.5 kW[62].

  Logic has been developed to detect the end of charging cycles, when the current being drawn had declined. However, there is huge variety in the shape of charging cycles and events that happen mid-cycle, which leads to some inaccuracies in detecting this point.

  For example, a small number of charging events have been detected where the vehicle switches to a status of 'connected, not charging' (normally signifying that charging has finished) for a few minutes partway through charging. This causes the analysis to estimate the 'end of charging' prematurely, so the equivalent charging rate is implausibly high. Applying this criterion removes 7,652 of the 92,199 available (compared to using all records where the start and end of charging are known, however inaccurately); and
- Data from Trial 3 is excluded, to prevent the introduction of the time of use reward from influencing the results.

The graphs below include data from charging events which were managed as part of the trial. Management will have increased the charging duration (and so slightly decreased the

[62] Chargers supplied by Electric Nation have a nominal 7kW rating. However, the 'end of charging' time detected in many cases is partway down the 'tail' at the end of the charge cycle, slightly increasing the charging rate.

apparent flexibility), as the average current available decreased during management events. The flexibility shown below includes this effect.

The two graphs below are based on 62,198 and 22,349 charging events for weekdays (Figure 8-34) and weekends (Figure 8-35) respectively. In both cases the line shows the median (middle value) flexibility for transactions where the vehicle is plugged in in each hour. The edges of the shaded area show the interquartile range for each plug-in hour.

For example, in Figure 8-34, for all the weekday charge events where the vehicle was plugged in between 17:00 and 17:59 (local time):

- 75% of charging events have flexibility of more than 45%;
- 50% have flexibility of more than 79% - indicating that they are charging for only 21% of the time they are plugged in; and
- 25% have flexibility of more than 87%

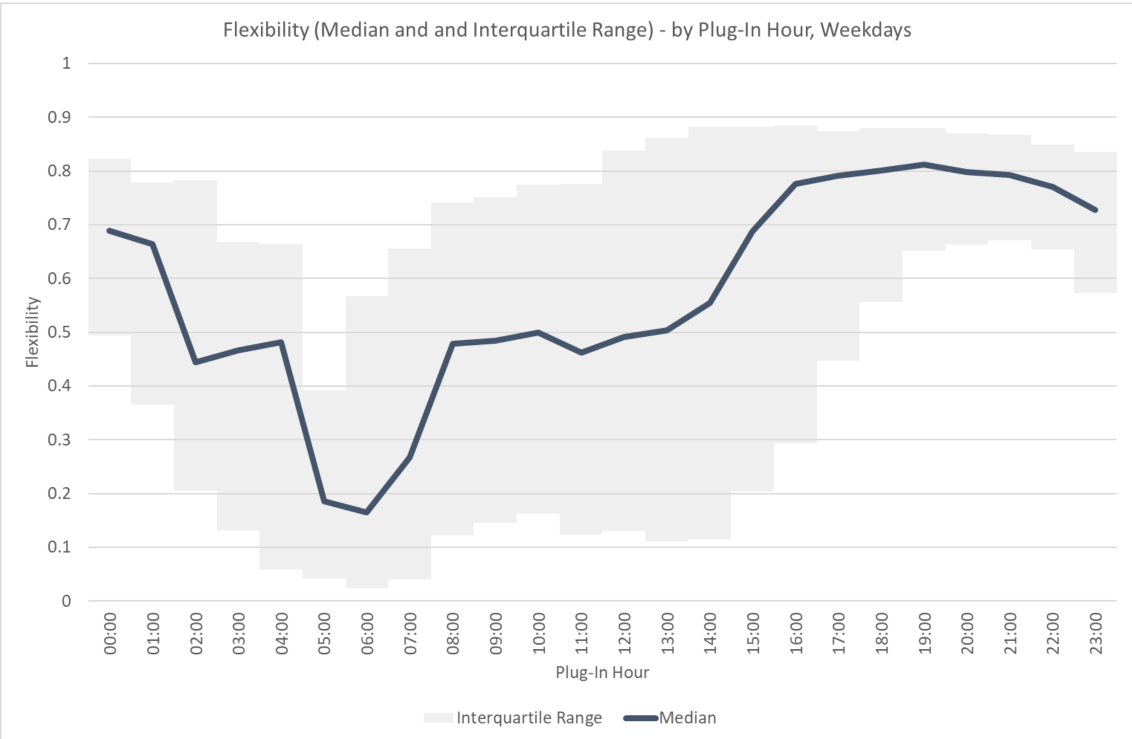

Figure 8-34: Flexibility - Median Value and Interquartile Range – Weekdays

Figure 8-34 shows that flexibility varies through the day on weekdays. Plug-ins which take place in the early part of the morning (5:00 – 6:59) have the least flexibility. Although this is based on a relatively small sample (284 charging events), it is also understandable, as the vehicles had not had the long overnight plug-in of those which connected in the evening/late at night, and the vehicle may be needed again later in the day.

Flexibility reaches a peak in the evening. This is advantageous as it aligns with the times when demand management may become necessary (see indicative capacity profiles, Figure 6-8 in Section 6.4.

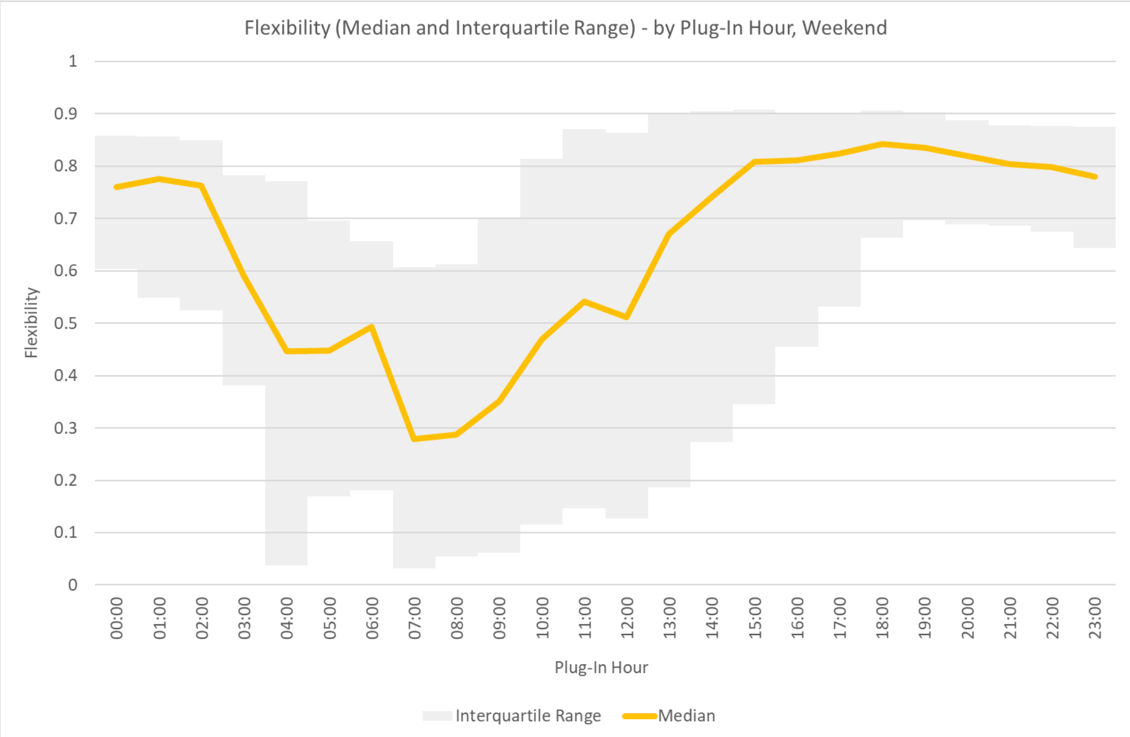

Figure 8-35: Flexibility - Median Value and Interquartile Range – Weekend

This shows a very similar pattern to the weekday graph (Figure 8-34) above, with flexibility reaching a peak in the early evening. The maximum flexibility is slightly higher at weekends, which may reflect the fact that drivers tend to unplug later in the morning on Sunday.

Flexibility may be influenced by the size of batteries being charged. For example, imagine two drivers both plug-in at 17:00 and unplug at 7:00 the next morning.

- The first driver owns a plug-in hybrid, rated at 16A (3.5kW), with a 12kWh battery which is completely discharged (e.g. an Outlander). This battery will take approximately 3.5 hours to charge, giving a flexibility of 75% (1 – 3.5/14); and
- The second driver owns a Tesla, rated at 32A (7kW), with a 70kWh battery which is 40% charged. This battery will take approximately 6 hours to charge, giving a flexibility of 57%.

Whether this is true at a population level will depend on the state of charge of batteries when they are connected to charge (if, in the example scenario outlined above the Tesla was connected when its state of charge was 65% then the flexibility of the two sessions would be equal).

The weekday data has been analysed for each of four categories of battery capacities, with the median lines shown on the graph in Figure 8-36, below.

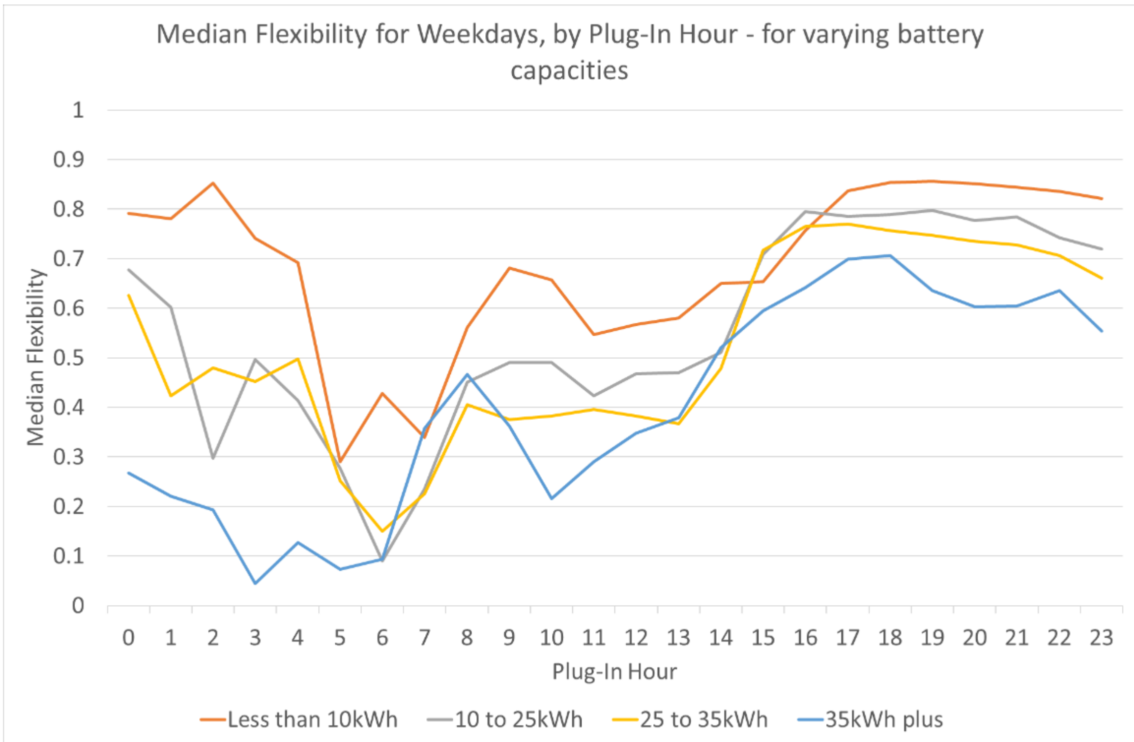

Figure 8-36: Median Flexibility (Weekdays) - by Battery Capacity

Across the majority of the day, vehicles with smaller battery capacities have greater median levels of flexibility. In the evening peak, when flexibility is most likely to be needed, vehicles with the largest batteries have relatively worse flexibility, but still offer at least 60% flexibility in half of cases. The flexibility figures from midnight to 6am are based on a very small number of plug-in events so may not be truly representative of actual flexibility.

The level of flexibility demonstrated in the graphs above suggests that smart charging was unlikely to inconvenience participants. However, only the customer research can confirm this, and this is explored in more detail in the Trial sections below.

8.10 PEV Demand Modelling

Much of this chapter so far has focussed on mass analysis of charging transactions for the trial population as a whole or sub-groups. It can be seen that there is considerable variation in charging behaviours amongst a population of PEV owners, depending on factors such as PEV type, battery size, home meter type, time of year, etc.

There is also considerable variation in PEV charging over time, hour of day, weekend/weekday and season – with reference to the proportion of the population actively charging at a particular time of day. Understanding and modelling this variation in power demand and energy consumption for groups of chargers is crucial to the assessment of existing electricity network performance as PEV charging demand grows in the future and for design of future network designs to accommodate PEV charging demand.

This section looks at this variation in PEV demand and presents models of demand developed for use in the Network Assessment Tool developed for Western Power Distribution under the “Modelling” strand of the Electric Nation project (see Section 3.1). The demand modelled below is based on ‘unrestricted’ demand – i.e. the level of additional demand which would be created by PEVs in the absence of any demand management/smart charging (unless otherwise stated).

8.10.1 Variation in Charging Demand

Figure 8-3, in Section 8.2, compares plug in time and start charge time across weekdays (based on the proportion of events which occurred in each hour). What this does not show is the effect of charge duration in terms of power drawn over time, and the potential impact of charging on electricity networks. The analysis presented in the rest of this section can be used to determine this effect. The methods used are explained in the following sections.

As shown in the preceding sections the variation in charging behaviours varies by weekday/weekend and seasonally. From a distribution network operator perspective, the worst-case impact of PEV charging is most useful in assessing the impact of charging on existing distribution networks and to set design standards for upgrading and building new networks. This occurs on weekdays in winter season. The following analysis focusses on this worst-case scenario, unless stated otherwise.

The analysis below presents the percentage of a given population of PEVs actively charging at any day and time. This has been calculated from individual transaction records, using the time charging began and the charge duration (calculated from the energy consumed and the nominal PEV rating of the vehicle associated with each charger). For example, charger ID ENA0226 was associated with participant EN1671. This participant’s registered PEV was a BMW i3 range extender with a nominal rating of 7kW (32A). If a transaction record indicated that charging began at 17:30 and 21kWh was consumed, then charging took place between 17:30 and 20:30 (three hours charging at 7kW to transfer 21kWh[63]).

By analysing this resulting data over a number of months (winter season in this case) and looking at weekdays only, the median percentage of PEVs charging over a day can be calculated.

Note that in this analysis active charge start has been assumed to be plug in time. This ignores use of timers, as this represents the worst-case scenario where PEVs plugged in during the late afternoon and early evening peak start charging immediately.

[63] This is a simplification as it assumes a linear charge at the maximum rate. Charging is likely to take slightly longer as the majority of vehicle’s decrease the charge rate as they approach 100% state of charge.

Median values are used in this analysis. Mean values are very similar.

Figure 8-37 shows the median percentage of the 7kW (charge rate) BEV and REX population charging on weekdays for winter during the trial (1 November 2017 – 31 March 2018 – this includes March 2018 owing to the very cold weather in this month ("the Beast from the East"). The profile of this graph shows a peak in the proportion of the population who are actively charging growing in the late afternoon, peaking around 19:00-20:30 and decaying overnight to a minimum at 06:30. In the morning there is a slight increase in charging that then plateaus through the remainder of the morning and afternoon to 15:30 when charging starts to rise.

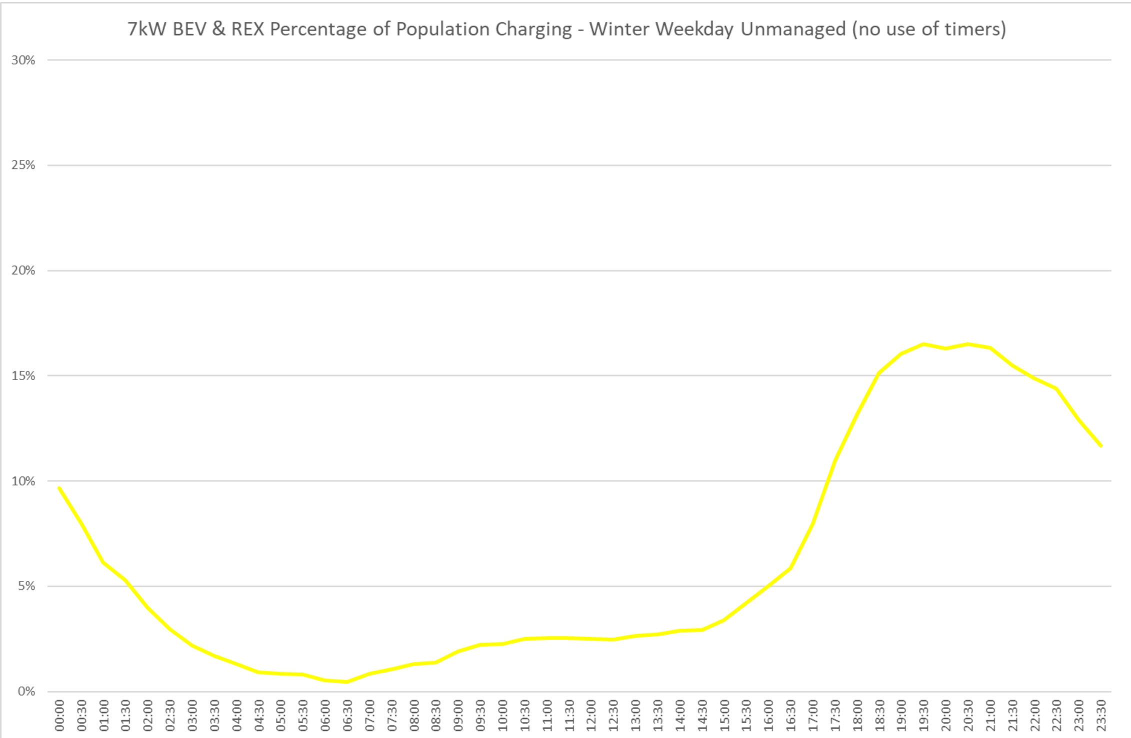

Figure 8-37: Percentage of Population Charging by Time of Day - Winter Weekday (Unmanaged) 7kW BEV and REX

A similar plot for 3.6kW charging PHEVs is shown in Figure 8-38 – note that the evening peak is both higher and sharper, illustrating that PHEVs are charged more frequently, but for shorter periods as their battery capacity is typically less than 15kWh.

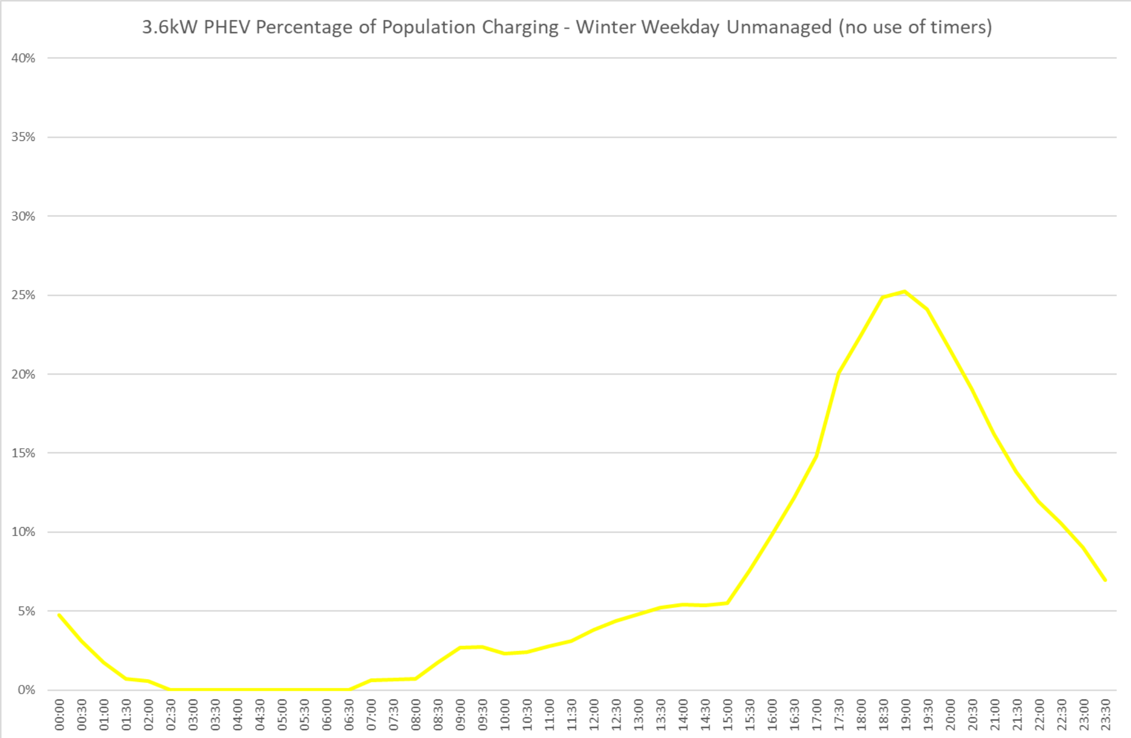

Figure 8-38: Percentage of Population Charging by Time of Day - Winter Weekday (Unmanaged) 3.6kW PHEV

The variance of the percentage of population charging at any time during any weekday can be split into deciles i.e. 10 sets of equal quantities of data. The boundaries between each represent the minimum, 10th percentile, 20th percentile, etc., to 90th percentile and maximum value of percentage of the population charging.

Figure 8-39 is a chart of this analysis for 7kW BEVs & REXs (analysed together because, as demonstrated earlier in this report the BMW i3 REX is charged in very much the same way as a small to mid-battery capacity BEV, see Figure 8-17). Each grey area indicates the spread of values in the decile for a particular half hour. So, for example, the top light grey area covers the values between the maximum percentage of vehicles that were charging in any half hour and the 9th decile (90th percentile). The yellow line remains the median value.

This shows that the variance from median varies through the day: from relatively low variance in the morning (minimum population charging at 6:30) to high variance during the evening peak – visible in the comparative distance between the extremes of the shaded area. So, for example, at 19:00, on 10% of winter days between 8% (the lowest number recorded) and 13% of the population was charging, but on another 10% of winter days between 20% and 26% (the maximum value recorded) of the population was charging.

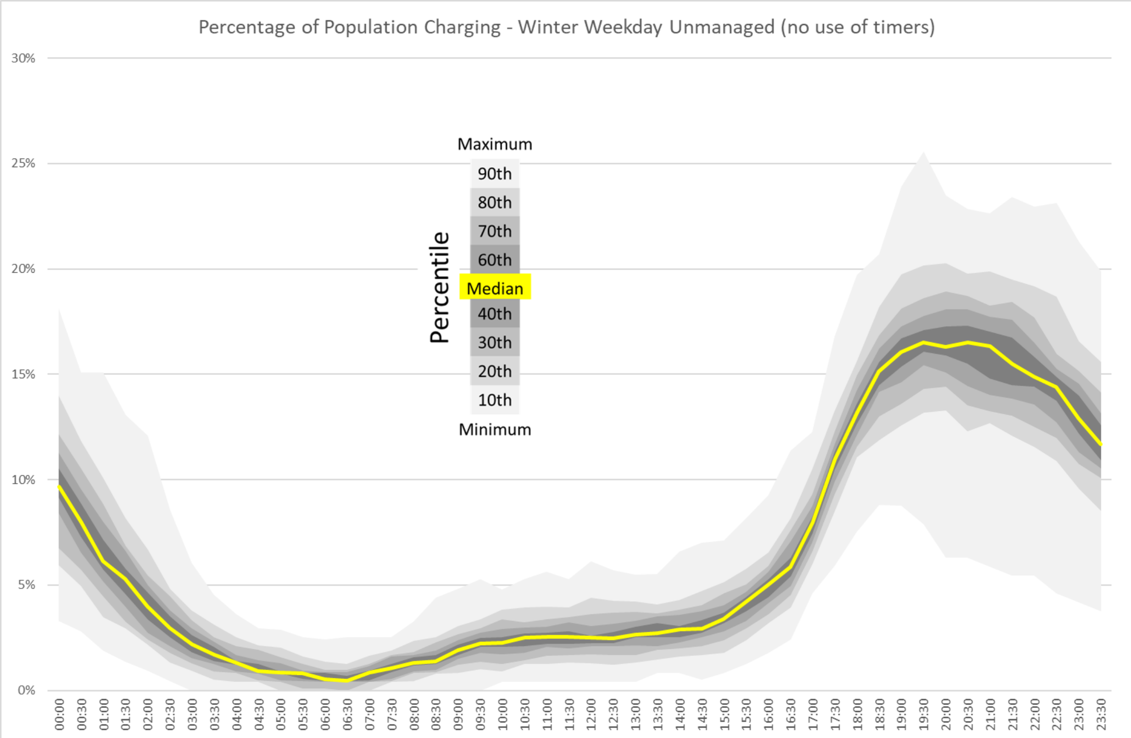

Figure 8-39: Variance in Percentage of Population Charging - Winter Weekday 7kW BEV and REX

Figure 8-40 is a similar plot for 3.6kW PHEVs, again variance is relatively low in early morning and high in the early evening peak, the maximum values relatively higher than BEVs and REXs as PHEVs are charged more frequently.

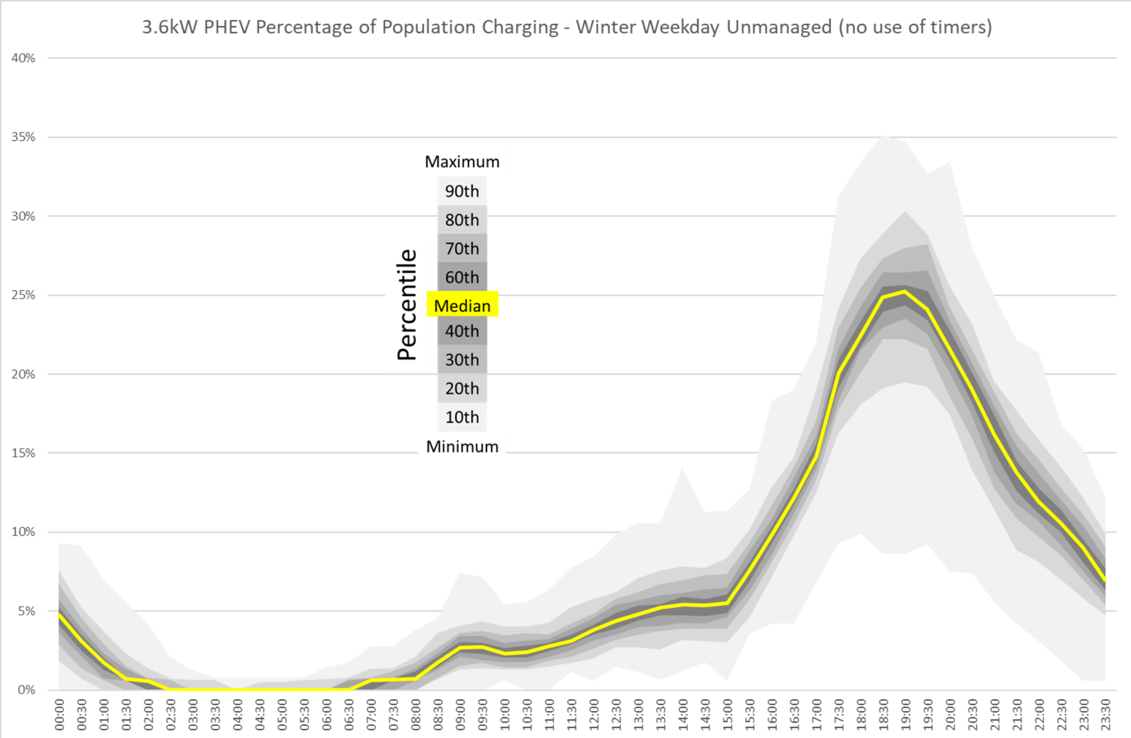

Figure 8-40: Variance in Percentage of Population Charging - Winter Weekday 3.6kW PHEV

Figure 8-39 shows that for 7kW BEVs and REXs over winter weekends, compared with weekdays, charging builds over the morning period, the evening peak is less high, but is still broad. The 3.6kW PHEV chart for weekends is similar, with charging reducing much faster in the late evening and after midnight (due to shorter charger durations for smaller batteries in PHEVs).

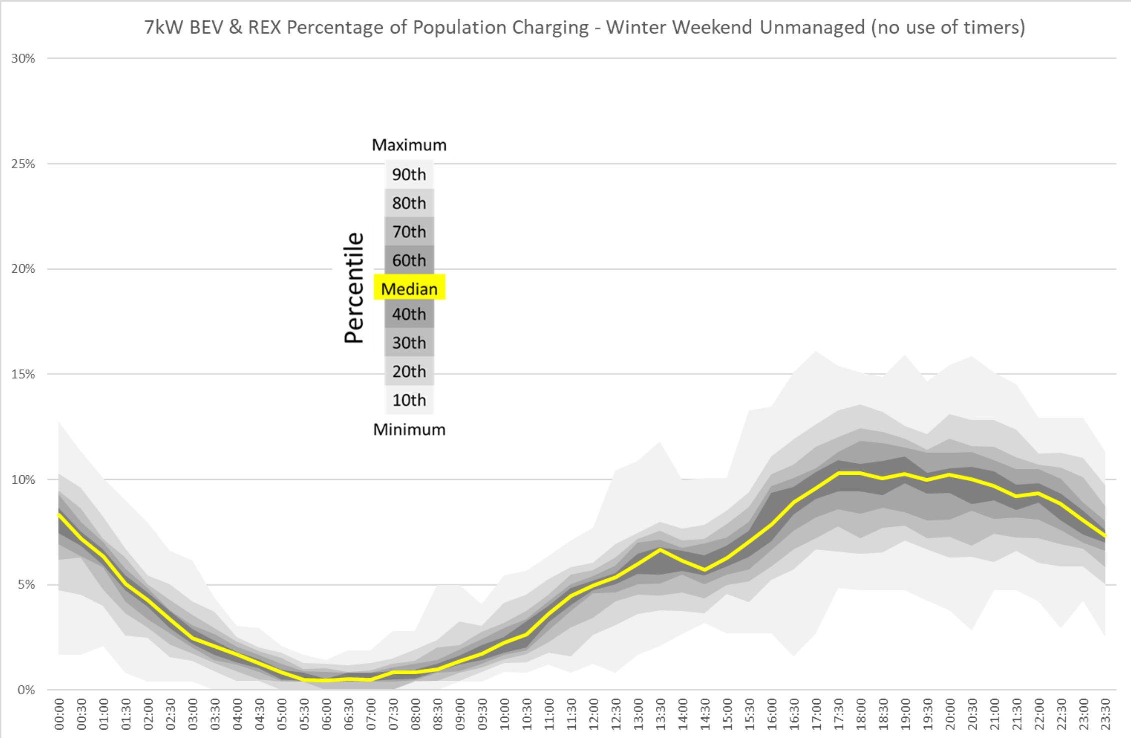

Figure 8-41: Variance in Percentage of Population Charging - Winter Weekend 7kW BEV and REX

This variance in the percentage of the population of PEVs charging over time can be exploited in modelling charging demand for electricity network assessment and design, especially where the network serves multiple domestic customers. As the number of customers increases, the potential number of PEVs also increases and the higher variance in demand can be utilised by taking diversity in charging behaviours into account, i.e. assuming that PEV drivers on a network do not all charge their PEVs at the same time. The same approach has been applied to LV network design for existing domestic load since the development of ACE49 in the 1970s. The remainder of this section describes the method used to derive models of PEV charging demand for use in the Electric Nation Network Assessment Tool.

8.10.2 Development of PEV Charging Demand Profiles

With the completion of the Electric Nation Smart Charging Trial, a full set of charging transaction data was available for the development of profiles of PEV charging demand that could be utilised by the Debut™ load flow engine[64] incorporated in the Network Assessment Tool.

The Debut™ load flow engine is used to calculate feeder (cable or overhead line) power flows and voltage drops for given network topologies and customer connections (i.e. houses, flats, etc. and commercial/industrial buildings). PEV demand models can be added

[64] The Debut™ load flow engine is EA Technology proprietary software, incorporated into WinDebut™ a low voltage distribution network tool used widely by GB DNOs.

to domestic customer demand models to then calculate the increased power flows and impact on voltage drop on the given network, as PEV uptake increases. These can then be compared to design standards and cable/overhead line and transformer ratings to assess whether the network can cope with increasing PEV charging demand and whether, and at what level of PEV penetration, the network will become overloaded.

The Debut™-engine requires demand profiles for loads on a low voltage/feeder, that act as scalable models of point demands on the network, such as homes and commercial customers (shops, offices, etc.). The models for homes and commercial customers were originally developed in the late 1970s and early 1980s and the principles of their development are described in Energy Networks Association (ENA) publication ACE 49. The models for PEV charging demand for use in the Network Assessment Tool must have the same format and be on a similar scale, i.e. for a single point load, to be compatible with the Debut™-engine and for resulting analysis to be sensible.

8.10.3 Using the ACE 49 approach

A key assumption within ACE 49 relating to domestic demand modelling is that the variance of demand in any half hour period is normally distributed, centred about a mean. Analysis of the Electric Nation transaction data shows that PEV charging within a population approximates to a normal distribution, but that the distribution can be skewed at certain times of day. In order to produce profiles for the Network Assessment Tool that are compatible with existing DNO demand planning approaches, it is necessary to follow the same methodology.

Variances in demand about the mean are attributed to a number of causes, categorised into 3 groups:

Firstly, variances in the behaviour of consumers of the same type (σ_1), i.e. homes of a similar size with particular attributes (such as with/without electric heating, electric cooking and so on). With PEV charging the analysis is focussing on a single point load, the EV charger. Individual consumers of the same type (e.g. all consumers with a BEV – which may be sub-categorised by battery capacity) use their chargers at different times and in different ways. For instance, one owner may charge their car every day for only one hour. Whereas another driver with the same BEV may charge less frequently but for longer intervals (e.g. every 4 days for 3 hours). There is also the difference in commuting/journey/travel distances that will cause an additional random variance.

Secondly, variances due to temperature sensitivity in demand (σ_2). Analysis of the Electric Nation trial data shows a distinct seasonal effect in PEV charging energy consumption. It is higher in winter than summer, which is thought to be due to both reduced battery efficiency in cold temperatures and increased passenger compartment heating demand in cold weather.

The final causes of variance are called 'residual causes' (σ_3) which encapsulate any other possible causes of deviation from the mean, such as parasitic electricity demands varying between vehicles, variance in battery temperatures at start of charge, etc.

The overall variance (σ)is given by:

$$\sigma^2 = (\sigma_1)^2 + (\sigma_2)^2 + ((\sigma_3)^2/N)$$

where N is the number of consumers (PEV drivers with home charger) in the sample.

When looking at the overall variance of real data, all of these contributions to the variance are intrinsically included.

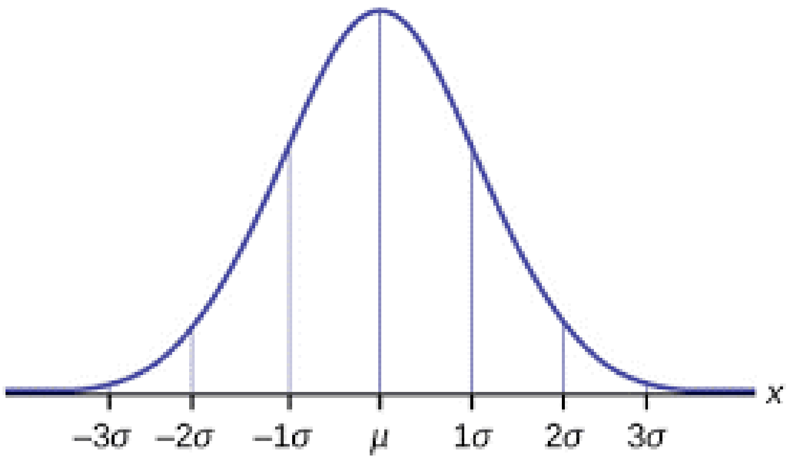

Figure 8-42: Frequency of Occurrence of Demand - Distribution

It should be noted that data collected from households (electricity consumption by a variety of appliances, lighting and heating) and PEVs are very different. An EV charger is essentially one (high power and energy consuming) appliance. A household is made up of multiple appliances. Household load is continuously varying due to contributions from lots of different types of appliances, whereas an EV charger is either 'on' or 'off'[65] and so is discrete in nature at an individual household level. In order to analyse large groups of PEVs, the percentage of PEVs 'charging' during half hour periods has been considered. This is a continuous data type and allows adoption of the method described here.

As stated in ACE Report No. 49[66]:

[65] The modelling described in this section is based on unrestricted (i.e. unmanaged) PEV demand, so the loading can be assumed to be 'on' (at maximum charge rate) or off. The case where the current available is temporarily reduced is not relevant for unrestricted demand.
[66] ENA 1981. "Report on Statistical Method for Calculating Demands and Voltage Regulations on LV Radial Distribution Systems". Energy Networks Association 1981.

“A low voltage distribution network must provide adequately but not over-generously, for the demands on each part of the network.”

“The design demand on which a network is based is critical in producing a network which is economically designed.”

If the median demand was chosen as the design demand, then in 50% of situations there would be an overload on the network. Conversely, if the maximum demand was chosen as the design demand then the network would be under-utilised for the vast majority of the year. A number of standard deviations can be added to the mean, in order to set the probability of there being an overload to a desired value. For instance, if one standard deviation is added to the mean to calculate the design demand, there would be a 15.9% chance of overload in a random situation. Two standard deviations added to the mean would give a 2.3% chance of overload. Setting this value (% chance of an overload) is a compromise between the risk of overload, vs. the additional costs associated with an under-utilised network.

ACE 49 goes on to state**:**

“A probability of 90% of operating within demand in a random situation during the central winter period is generally accepted as the optimal boundary”.

This judgement has been adopted for the purposes of this analysis.

This equates to adding 1.28 standard deviations to the mean.

And so:

Design Demand = Mean Demand + 1.28σ.

This can be represented by:

$$Design\ Demand = P + \frac{Q}{\sqrt{N}}$$

Where P is the mean demand for a given half hour, Q represents the deviation from the mean demand in that half hour and N is the number of consumers in the sample (or in this case, the number of chargers actively charging in that half hour).

The demand of a group of EV chargers can then be modelled:

$$Group\ Demand = N.P + Q\sqrt{N}$$

Utilising this equation and observed group demand for groups of particular types of plug in vehicle (BEV, by battery size, & hybrid), the values of P and Q can be derived.

Note that Debut™ utilises 'p' and 'q' values, which are derived by dividing 'P' and 'Q' by the total annual consumption (in 000's kWh) of that PEV type.

$$P=pC \text{ and } Q=qC$$

Where C is annual energy consumed in charging a PEV. This is analogous to energy consumed with a home, for which the same principle applies: some small houses with many occupants have higher energy consumption than larger houses with fewer occupants. Whereas two PEV drivers may have the same annual energy consumption, one may have a small battery vehicle and have a considerable commute. Meanwhile, another driver may have a larger battery but only drive a relatively small distance each day.

If the average annual consumption for a BEV is 3,000kWh, (approximately 8,000 miles driven), the P (mean demand) and Q (deviation from the mean demand) values at 5:00pm are:

$$P=1.5 \text{ and } Q=1.0.$$

Therefore:

$$p= 0.5 \text{ and } q= 0.333$$

Section 8.4 discusses annual energy consumption of PEVs in the trial.

8.10.4 Deriving P and Q values from the Electric Nation Trial Data

To derive P and Q values from the trial data it has been assumed that each half hour of the grouped PEV charging demand within the trial data, in a particular season, e.g. winter, represents a 'situation' and that for 90%[67] of these situations there should be no overload, i.e. that the Design Demand for the grouped PEV demand should not be exceeded.

The following trial data has been used in this analysis:

- PEV transaction data provides:
  - Date and time when a PEV was plugged in, and for the purposes of this analysis this is assumed to be the time when the PEV started charging. Use of timers to control charging is ignored. This provides a worst-case scenario, where all PEVs start charging as soon as plugged in;
  - The duration of the charge, calculated from the nominal charging rate of the PEV associated with a charger and the energy consumed during the charge; and

[67] This value can be changed, if required

  - The end of charging – calculated from start of charging and duration of the charge (rather than using the meter value-based analysis to find EndCharge described elsewhere in this report).
- Charger - PEV records (installation record) provides:
  - Nominal charging rate of PEV (as reported by trial participant/DriveElectric); and
  - Nominal battery capacity of PEV.

Analysis of transaction records and Charger-PEV records has highlighted some issues that have necessitated cleansing of the transaction records (and subsequently, the active charger population records, see below).

1. Within the CrowdCharge trial cohort, owing to equipment supplier and installer errors, mismatching of CrowdCharge Controller and Charger resulted in confusion of the location of the charger and so PEV identity associated with the charger. This resulted in transaction records for 22 CrowdCharge chargers being removed from the analysis sample (7,763 of total 151,508 CrowdCharge and GreenFlux transactions). This issue did not occur with the GreenFlux cohort.

2. Across both CrowdCharge and GreenFlux cohort transaction records there are a number of transactions (5,749 of remaining 143,835 transactions) that are deemed abnormally short, i.e. less than 15 minutes in duration. These fall into two general camps:

   - Those where charge duration and transaction duration are equal or very close – suggesting either user error or the PEV was required for a journey shortly after being plugged in.

   - Those where the transaction duration (plug-in duration) is significantly longer than charge duration – suggesting either the vehicle only required a very short charge or that the vehicle stopped charging for unknown reasons shortly after starting charge or some unknown error with the smart charging system stopped charging shortly after charge started.

   The possible reasons for these transactions being erroneous outweigh the reasons for why these transactions might be treated as good and therefore included in the analysis, and so they have been excluded from the analysis sample.

3. There are 621 transactions from the remaining 138,086 transactions that report energy consumed during the transaction as greater than 120% of the nominal battery capacity of the PEV associated with the charger reporting the transaction. The 20% excess energy demand limit is set to take into account “parasitic” energy demand in AC/DC conversion, battery temperature maintenance and passenger compartment conditioning. It is quite possible that these transactions are associated with a PEV other than the nominal trial PEV, e.g. visitors or the owner

bought a second PEV or replaced their original PEV during the trial. While efforts were made by DriveElectric to address these issues during the trial, the information received back from trial participants was not satisfactory.

To overcome this issue it was decided to exclude all transactions from the 7 chargers reporting more than 10% of transactions as over-large energy consumption (i.e. where this situation arose more regularly, suggesting that the registered PEV was incorrect, rather than a one-off occasion where another vehicle was charged). While leaving those with less than 10% of transactions being over-large as acceptable "noise" in the data. 1,176 of the remaining 138,086 transaction were excluded from the analysis sample.

Thus, 136,910 transactions were used in analysis to produce the P and Q values as described below.

4. Charger Communications performance throughout trial provides:
    - Data to derive group population on a weekly basis.

Charger communication performance varied on a charger by charger basis throughout the trial.

With respect to the GreenFlux trial cohort, if communications to a charger were lost for a period of time transaction records were held locally on the charger (not lost) and then were sent to the back office system (and then the Electric Nation database) when communications were re-established. Therefore, the transaction record for the charger can be deemed "good" (i.e. containing all the records) so long as communications were re-established at some point before the end of the project.

However, with respect to the CrowdCharge trial cohort, transactions which occurred during periods when communications were down were not recorded by the back office system and so were lost. This was rectified later in the trial (from June 2018 onwards), but was too late for the analysis of winter 2017/18 behaviour.

The calculation of the group charger population takes these factors into account.

Further, where chargers have been excluded from the analysis sample, they have also been removed from the active charger population record (i.e. the 22 CrowdCharge chargers with unknown location/vehicle and the 7 chargers with more than 10% of transactions with over-large energy consumption).

Finally, for a sample of data filtered to provide transaction data for a PEV profile, e.g. 3.6kW charging PHEVs, the population of active chargers is filtered to only include chargers with one or more transactions in the transaction list. Any charger associated with this PEV profile, reported as online during any part of the trial, but with no transactions is excluded from the analysis.

To derive PEV demand profiles, the percentage of the charger population that were charging was calculated for each half hour of each day during the trial (from week 20 2017 through to week 92 of the trial in 2018, to avoid Trial 3 transactions where customer plug in and charging behaviour were affected by the time of use tariff regime). The process can be summarised as:

1. For transactions for a sample of the trial data (e.g. PHEVs charging at 3.6kW);
2. For each transaction the half hours in which charging is active is calculated;
3. For each half hour in each day of the trial the number of active charging sessions is calculated;
4. This sum is then divided by the "active charger" population for the week number for the date in question, to calculate the proportion of the whole charger population actively charging in that half hour; and
5. This results in a matrix of each half hour proportion of chargers actively charging for each day of the trial.

To calculate P and Q values a range of dates were selected. For example, a winter profile was developed using data from between 1st November 2017 and 31st March 2018. March was included owing to the exceptionally cold weather that month.

P for each half hour in the selected date range can be taken as the mean value of the proportion of the active charger population who were actively charging in that period, multiplied by the nominal charging rate of the PEVs in the sample (3.6kW or 7kW).

The corresponding value of Q in that half hour can be obtained by finding the 90th percentile value of the proportion of chargers actively charging of the active charger population in that period:

$$Q = \sqrt{N}\ x\ (Weighted\ Mean - \ 90th\ Percentile)$$

N being the mean active charger population in week that the value of Q is selected from.

This process is repeated for all half hours of the day.

8.10.5 Data Processing Method

Raw Transaction Records

Two sub-sets of data are available:

- CrowdCharge transaction records; and
- GreenFlux transaction records.

Each is pre-processed in the trial database to provide:

- Charger ID
- Start Transaction (plug in date and time);
- Adjusted Start Transaction (adjusts UTC to GMT/BST – i.e. local time);
- Energy Consumed in transaction (kWh); and
- End Transaction (unplug date and time).

To process the data, the nominal charge rate of the PEV linked to the charger associated with the transaction is added.

The charge duration is then calculated (energy consumed/nominal charge rate) and the end of charge is estimated (from start charge which is assumed to be start transaction) and adjusted to GMT/BST as required.

Transactions are then evaluated and removed from the sample set, for the reasons described above:

- CrowdCharge transactions where there is confusion regarding charger location and associated PEV;
- Transactions less than 15 minutes; and
- All transactions for chargers with more than 10% of transactions where over-large energy consumption is recorded.

In addition, there are some transaction records from the beginning of the trial (before communications performance data was reliably recorded) and from the end part of the trial (sub-trial 3, where participant plug in behaviour changed markedly owing to the time of use tariff incentive[68]), so transactions in the following periods were filtered out of the dataset:

- For CrowdCharge, any transaction occurring before week 30 is filtered out – no comms data before week 30;
- For GreenFlux, any transaction occurring before week 20 is filtered out – no comms data before week 20;
- Trial 3 started during week 93 for GreenFlux, transactions from week 93 onwards filtered out; and
- Trial 3 started during week 97 for CrowdCharge, transactions from week 97 onwards filtered out.

The cleaned transaction dataset could then be filtered to find data subsets of transactions for different vehicle classes:

- Plug-in Hybrids (all rated at 3.6kW);
- 3.6kW Battery PEVs; and

[68] Trial 3 was excluded from the 'unrestricted' profiles as these were designed to reflect demand without a widespread uptake of Time of Use incentives. A separate profile 'Time of Use' profile was developed using the GreenFlux Trial 3 data and this is shown at the end of Section 8.10.6.

- 7kW Battery PEVs

It is also possible to split this data set by battery capacity (e.g. 35kWh plus, as presented elsewhere in this report), but this is of no practical benefit to the development of the Network Assessment Tool, because at the time of writing PEV uptake forecasts do not differentiate by this metric.

This produces a sample transaction file for further processing.

Raw Charger Communications Performance Data

This data set contains a weekly summary of communications performance for each charger in the trial, stated as percent of week that the charger was online, split by CrowdCharge and GreenFlux.

As previously stated, charger communication performance varied on a charger by charger basis throughout the trial. More details of this can be found in Section 5 of this report.

With respect to the GreenFlux trial cohort, if communications to a charger were lost for a period of time transaction records were held locally on the charger (not lost) and then were sent to the back office system (and then the Electric Nation database) when communications were re-established. Therefore, the transaction record for the charger can be deemed "good" (i.e. containing all the records) so long as communications were re-established at some point before the end of the project. The sum of all online chargers for each week is deemed to be the GreenFlux active charger population in a week.

However, with respect to the CrowdCharge trial cohort, transactions during lost communications were not recorded and so were lost[69]. Therefore, the active charger population of each week is deemed to be the sum of the percent online for each charger. In addition, any chargers removed from the transaction records for CrowdCharge, i.e. those where there was confusion about the charger location and associated PEV, were removed from the population count for the entire trial.

For both CrowdCharge and GreenFlux, the population counts are filtered for chargers in the selected, cleaned, transaction dataset. This excludes chargers for which there are no transactions listed from the population.

The group charger population calculation adds the GreenFlux and CrowdCharge populations together for further processing.

Transaction Data Pre-Processing

Some charging transaction records span the midnight period (e.g. 22:30 – 02:15). In order to ensure such transactions are recorded in the correct day of week, such transactions are split

[69] As previously mentioned, this was rectified later in the trial (June 2018 onwards), however, this is irrelevant to this analysis as winter 2017/18 has been used to derive the winter demand profile model.

into a pre-midnight and post-midnight transaction (e.g. 22:30-23:59 and 00:00-02:15). This ensures, for example, that a transaction spanning Sunday evening – Monday morning, is recorded as a weekend late evening transaction (up to midnight Sunday) and a weekday night transaction (from 00:00 Monday onwards).

Creating the Transaction Matrix

Taking the cleaned/filtered and midnight split transaction records and group charger populations data set, a transaction matrix can be derived. This is a summation of the population of chargers actively charging in each 10-minute period on a particular date, illustrated below.

Table 8-9: Matrix showing summation of active chargers in each 10 minute period

starting	0:00	00:10	00:20	00:30	…	23:30	23:40	23:50
Date 1	N_1	N_2	N_3	N_4	…	N_X	N_X	N_X
….	…	…	…	…	…	…	…	…
Date 2	N_X	N_X	N_X	N_X	…	N_X	N_X	N_X

10-minute periods are used to assist in improving the accuracy of identifying a maximum in a half hour period, so, for example:

> If there were 4 chargers continuing, starting or ending charging in the period between 01:00 – 01:30, what is the maximum number of chargers active in this period?
>
> For example:
>
> - Charger 1 charging throughout this half hour
> - Charger 2 starts charging at 01:23
> - Charger 3 starts charging at 01:03
> - Charger ends charging at 01:21

Half hourly analysis would say all 4 chargers were actively charging in this half hour. But 10-minute interval analysis would show that:

Table 8-10: Example of Use of 10 minute intervals to determine number of active chargers

Ten minutes starting	01:00	01:10	01:20
Charger 1	Charging	Charging	Charging
Charger 2			Charging
Charger 3	Charging	Charging	Charging
Charger 4	Charging	Charging	
Number of Active Charging Transactions	**3**	**3**	**3**

The maximum number of chargers actively charging in this half hour is therefore 3.

Creating Debut^{TM} Style Profiles

To create Debut^{TM} style demand profiles, the 10-minute charging matrix for a particular type of PEV is required along with the charger populations for that type of PEV throughout the trial.

A date range for analysis is selected (e.g. for a particular season).

The 10-minute matrix is converted to a half hourly maximum proportion of population charging matrix for each date selected (e.g. in the example above a population of 3 would be used). This is then used to derive a mean value (P) and variance Q for each half hour (as previously described this was originally based on the 90th percentile value. However, WPD prefer a maximum value to avoid under-statement of demand calculations on networks with small numbers of customers and (potentially PEVs), i.e. for networks with single digit customer values, 1, 2, 3, etc.), given the population of vehicles in each week of the selected date range for, standard Debut^{TM} profile configuration:

- Weekday 00:00-24:00 (48 values)
- Friday 23:30 – Saturday 03:00 (8 values)
- Sunday 12:00 – 13:30 (4 values)

This produces a full Debut^{TM} profile, with the required 60 half hour values (items) – 48 weekday values, plus 12 weekend values as shown above.

8.10.6 Resulting Debut^{TM} Profiles

Two key demand profiles have been derived for Winter:

- Plug-in hybrids with a nominal rating of 3.6kW

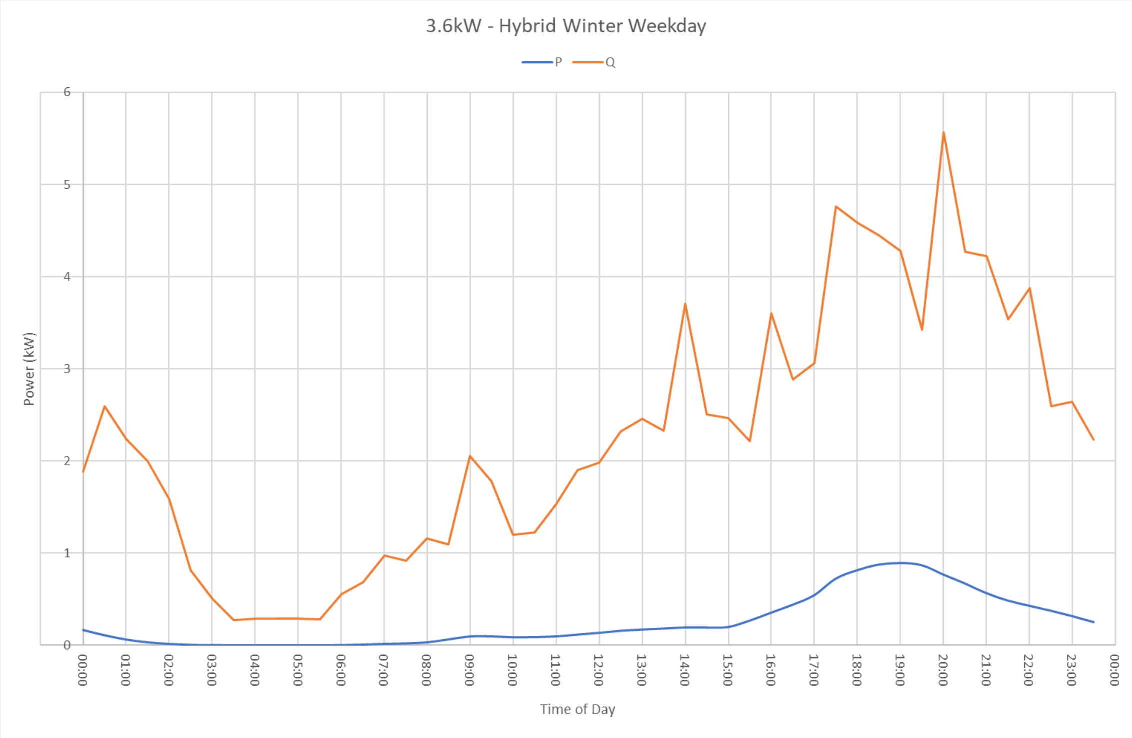

Figure 8-43: P and Q Profile - Winter Weekday 3.6kW PHEV

- Full battery electric vehicles with a nominal rating of 7kW (including BMW i3 range extender models, which were popular in the trial and were charged much like a full battery vehicle)

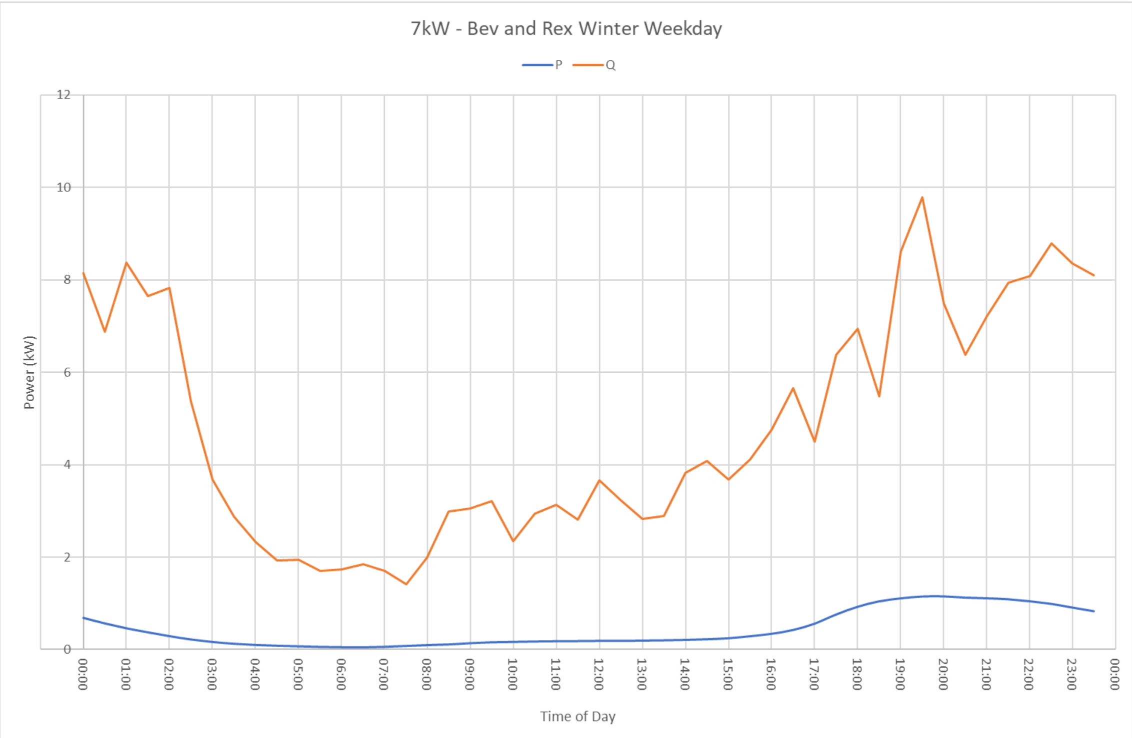

Figure 8-44: P and Q Profile - Winter Weekday 7kW BEV and REX

In both cases, in can be seen that the demand calculation, where N = 1 would result in a demand higher than the nominal charging power of the vehicle type at certain times of day. So, greater than 3.6kW or 7kW. This is an error caused by uncertainty in the population values used in analysis method: as previously explained unlike the GreenFlux chargers, which retained charging transaction records when offline, the CrowdCharge chargers did not do this, resulting in lost transaction records. This issue was addressed by using weekly average percentage online records for CrowdCharge chargers to calculate an "average" number of chargers online in a week. However, it appears that this method introduces a level of uncertainty into the analysis method.

For practical network assessment and design purposes, this overstatement of demand is an acceptable error as cable/overhead line sizes (ratings) and transformers ratings are a finite group of specific sizes/ratings. A designer would look at the design rating and pick the "next size up" to meet the design rating.

The effect of increasing numbers of PEVs within a feeder/network design is illustrated by the figure below, where increasing values of N (the PEV population) shows how the design demand per PEV tends towards P, the mean.

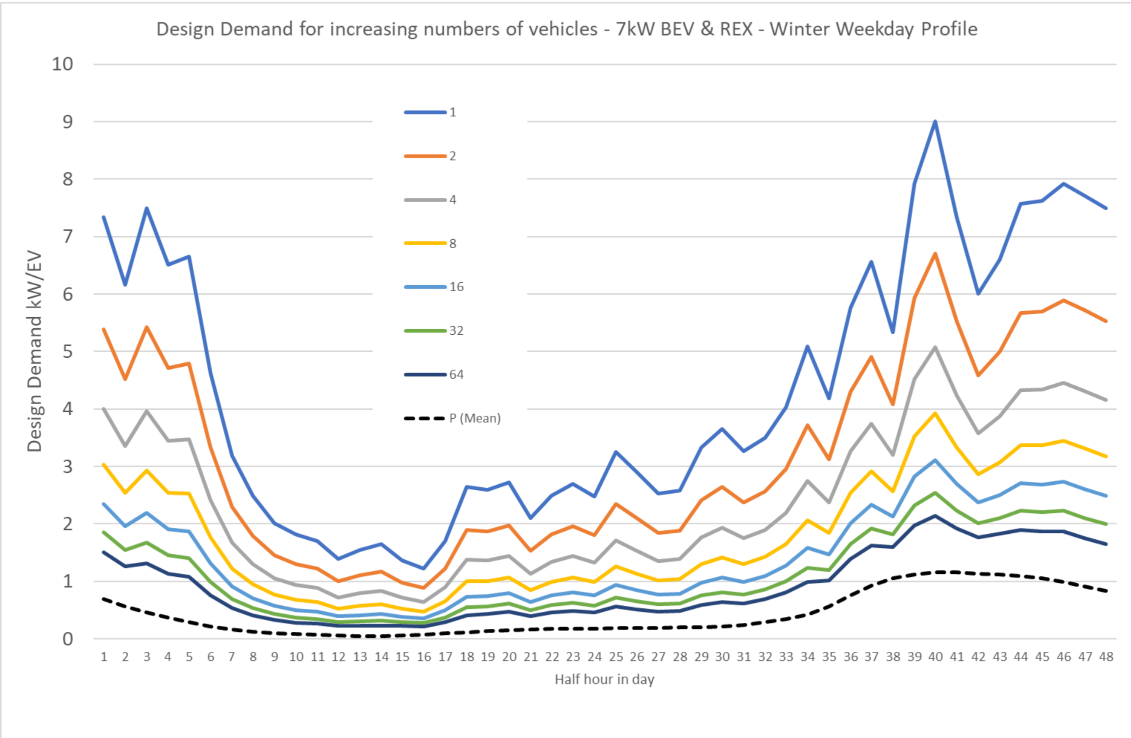

Figure 8-45: Design Demand (Winter Weekday, 7kW BEV and REX) for increasing numbers of vehicles

Two other demand profiles are required for the Network Assessment Tool, these being for 3.6kW plug-in hybrids and 7kW full battery electric vehicles (& REXs) under time of use tariff implementation (as implemented in Trial 3), where a marked change in plug in and charging behaviour was observed in the customer trial. These profiles, developed using GreenFlux only data (the half of the trial where the ToU implementation successfully altered the demand profile, see Section 12), are shown below:

- Plug-in hybrids with a nominal rating of 3.6kW:

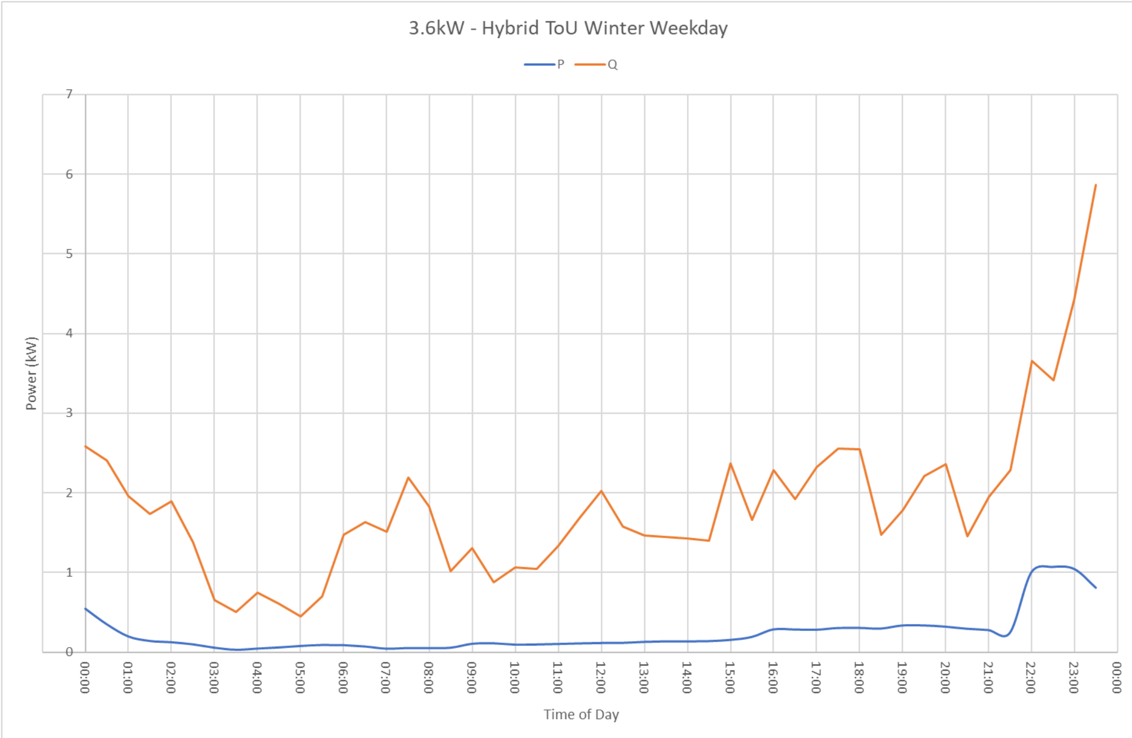

Figure 8-46: ToU P and Q Profile - 3.6kW PHEV

- Full battery electric vehicles with a nominal rating of 7kW (including BMW i3 range extender models, which were popular in the trial and were charged much like a full battery vehicle)

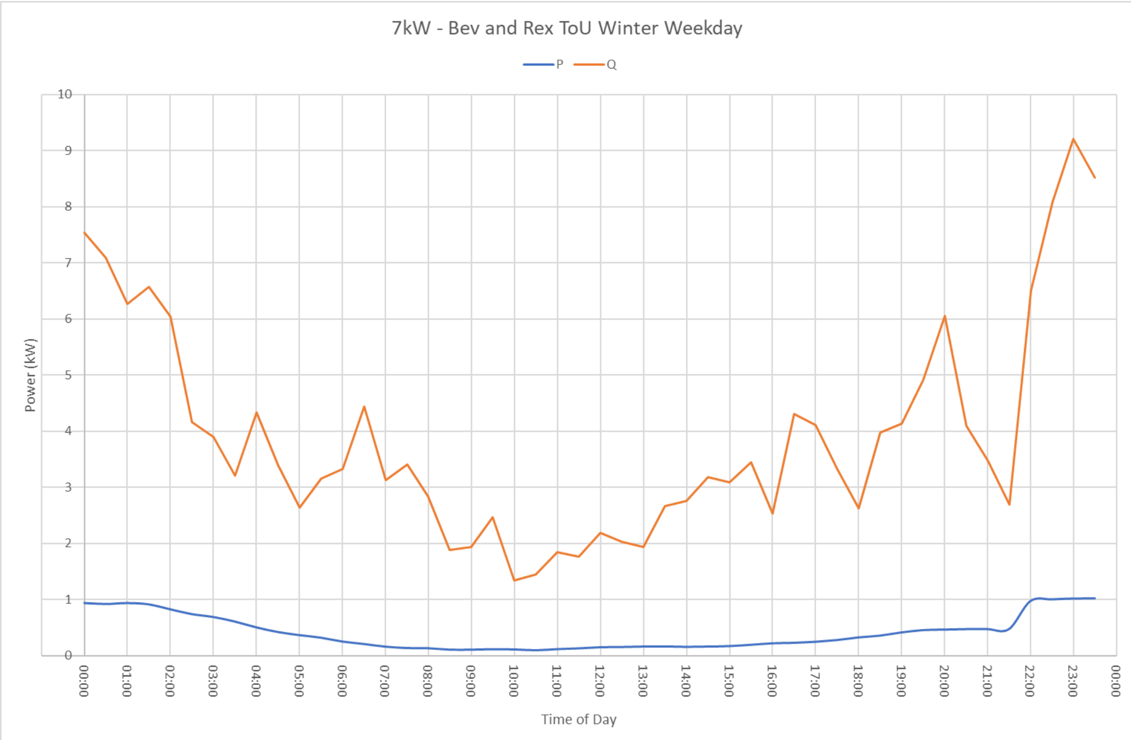

Figure 8-47: ToU P and Q Profile - 7kW BEV and REX

Again, the issue of overstatement of Q values caused by uncertainty in the population is apparent in both profiles.

In addition, it is clear that the late afternoon – early evening peak in the unmanaged profiles has been moved to late evening where there is a sudden rise in demand (caused by the trial time of use tariff boundary to cheap overnight pricing, where trial participants either opted to have the GreenFlux system manage their charging to be lowest cost or changed their charging behaviour to the same effect). This effect is discussed in more detail in Section 12.2.

This sudden increase in demand is undesirable for distribution networks (as well as National Grid and generators) but could be managed through smart charging systems.

The graphs below model two ways in which this sudden demand could be managed. Firstly, through randomising the start of each transaction after the overnight tariff boundary (at 22:00); or, secondly, by assigning individual chargers into a "delayed-start zone", where all transactions for chargers starting at the lower cost overnight rate (e.g. 22:00 in the case of the trial) are delayed by a fixed time. So, in this example zone 1 means charging doesn't start until 22:30, zone 2 23:00 and so on to zone 6 starting at 01:00 the next day.

- 3.6kW plug-in hybrid, random start after 22:00:

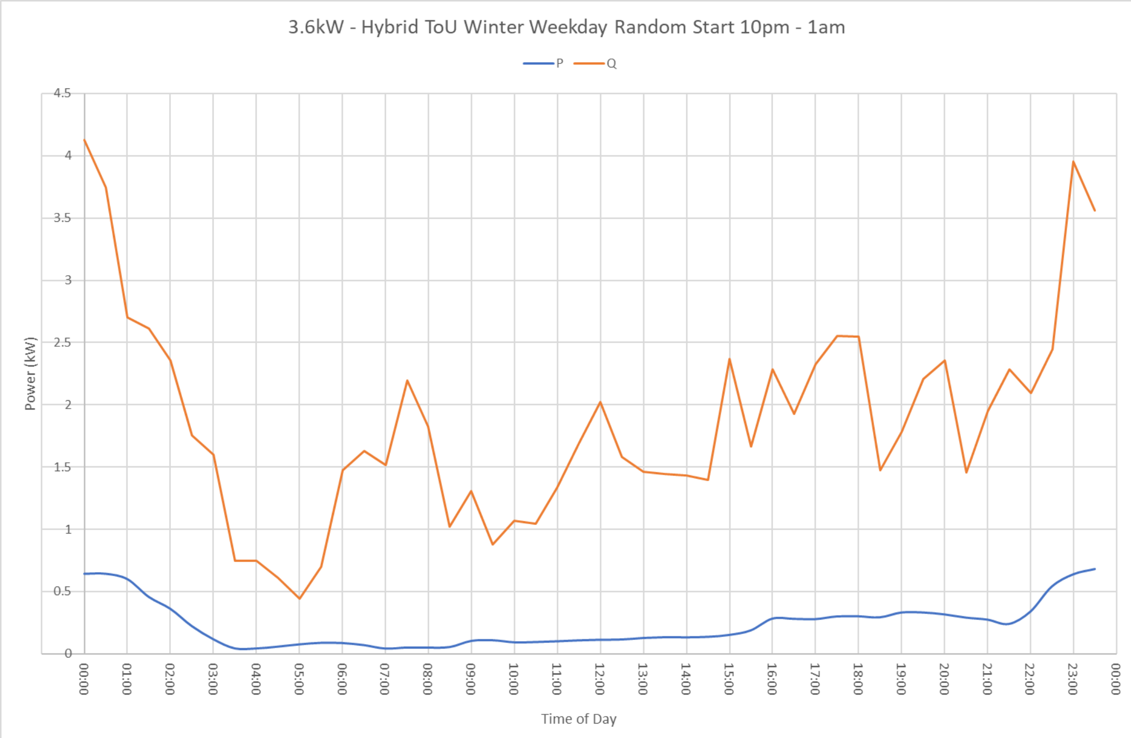

Figure 8-48: ToU Profile with Randomised Start Times 10pm - 1am - 3.6kW PHEV

- 7kW full battery electric Vehicle, random start after 22:00

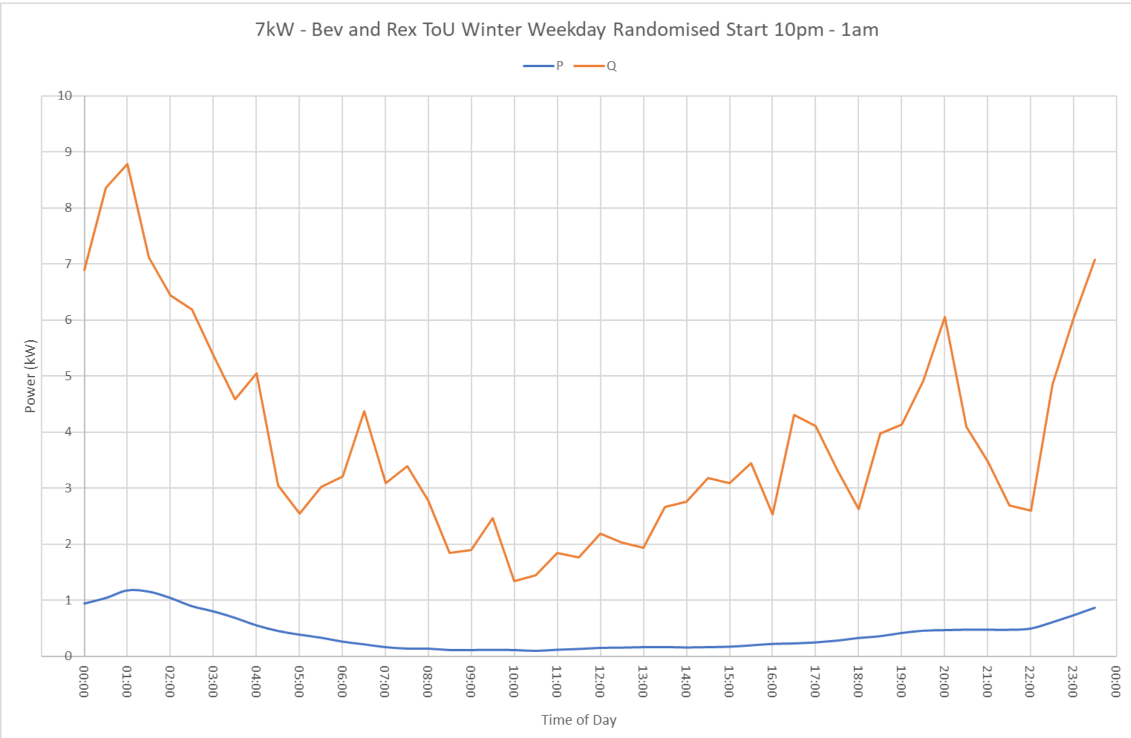

Figure 8-49: ToU Profile with Randomised Start Times 10pm - 1am - 7kW BEV and REX

- 3.6kW plug-in hybrid, zoned start after 22:00:

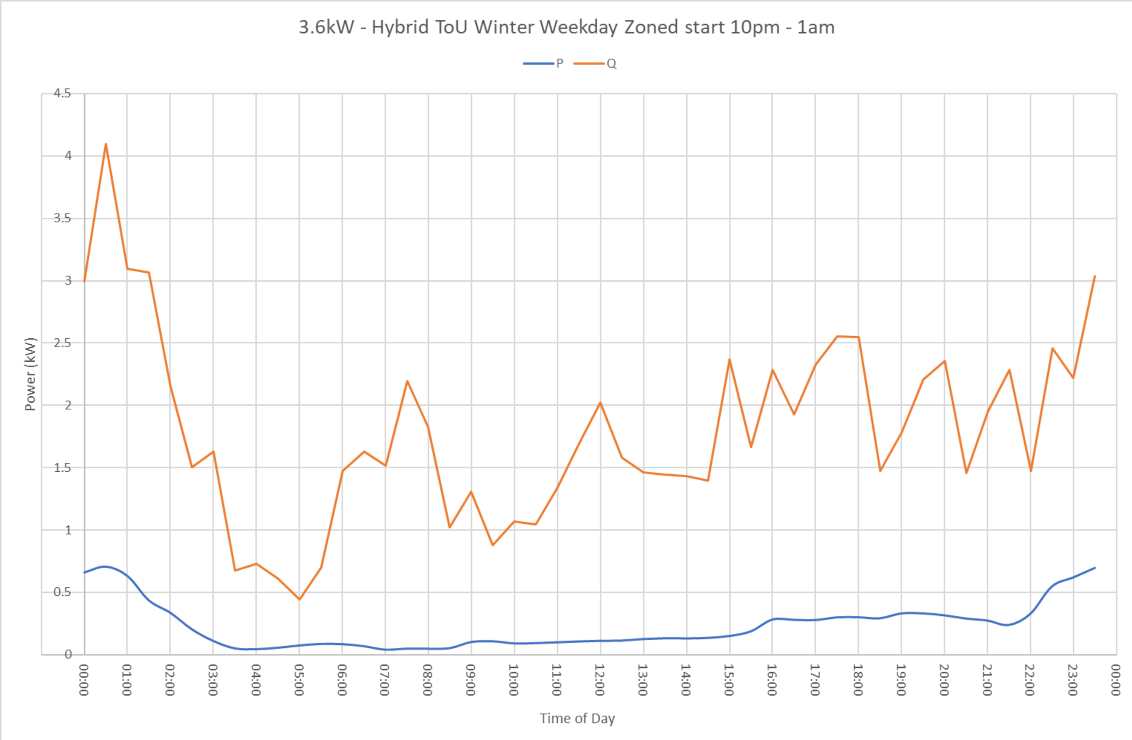

Figure 8-50: ToU Profile with Zoned Start Times 10pm - 1am - 3.6kW PHEV

- 7kW full battery electric Vehicle, zoned start after 22:00

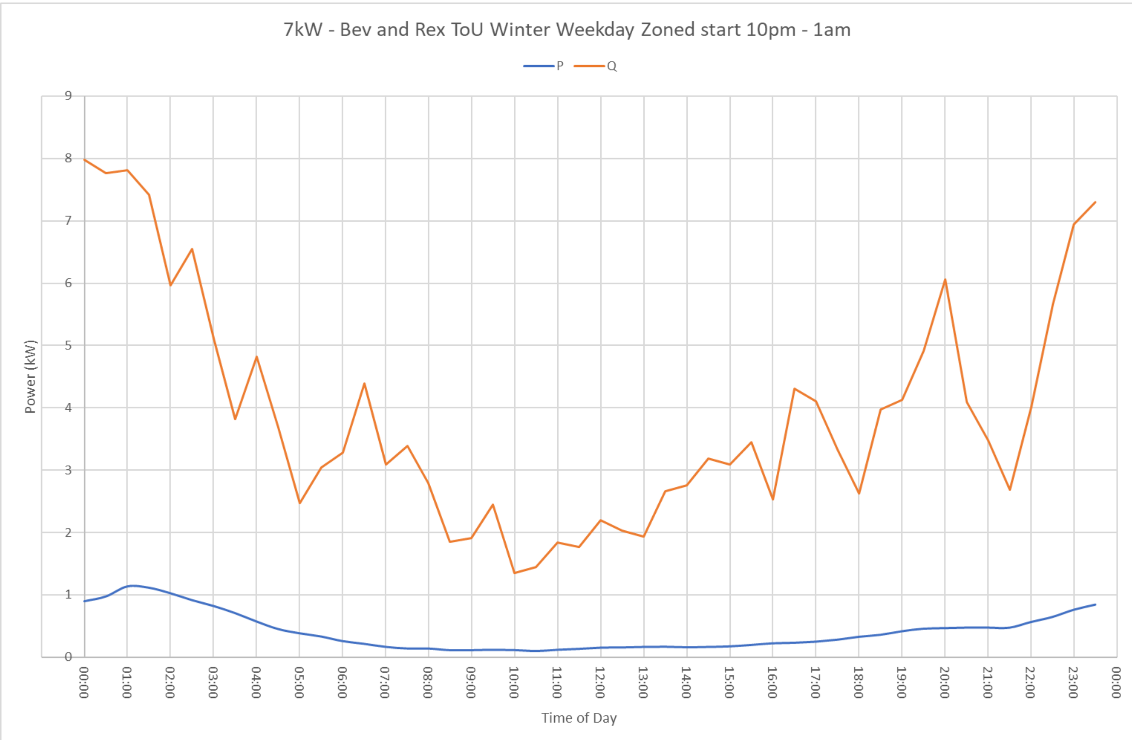

Figure 8-51: ToU Profile with Zoned Start Times 10pm - 1am - 7kW BEV and REX

Each of these methods to offset the sudden price boundary demand rise has its merits, and maybe incorporated into a future revision to the Network Assessment Tool.

8.11 Summary of Findings

- The most popular time to plug-in is between 17:00 and 19:00 on weekdays. During this period, typically 14% of the PEV population are charging their car.
- In the absence of other incentives, demand for vehicle charging peaks on weekdays between 19:00 and 20:00. This aligns with the existing peak in demand from other household loads, confirming the findings of many other innovation projects in this field.
- Data from Electric Nation shows significant flexibility is available to deliver energy during the window of time when vehicles are plugged in. This flexibility reaches a peak for vehicles plugged in between 17:00 and 19:00, where 75% of PEVs plugged in are charging for less than 50% of the time they are plugged in. This peak in flexibility coincides with network peak demand when smart charging is most likely to be necessary.
- Weekend demand is generally lower and more evenly distributed across the daytime.
- A minority of participants in the Electric Nation trial use timers to control the time when their vehicle begins charging. Between 17 and 20% of plug-in events involve the use of a timer. Approximately 20% of participants in the trial were responsible for 80% of charge events involving a timer, these participants are much more likely to have a dual-rate meter. Participants who stated that they were on an Economy 7 or 10 tariff were significantly more likely to use a timer frequently (for greater than 50% of their charge events) than those on a standard tariff or fixed price deal (68% vs. 7%).
- The median charging frequency across all participants is 0.52 charging sessions per day (i.e. charging every other day). Charging frequency is higher for those participants with the smallest battery sizes (0.73 sessions per day for vehicles with battery capacities of less than 10kWh, compared to 0.31 for the 35kWh plus group).
- A minority of participants (15%) charge at least once a day. This group is dominated by PHEV drivers (72% of those who charge once a day or more).
- Other factors which are linked to a lower home charging frequency include use of charging infrastructure away from home, particularly work-place charging, and low weekly mileage.
- Charging frequency varies through the year, from 0.65 (February) to 0.47 (August) sessions per day.
- Annual electricity from the Electric Nation home chargers is strongly dependent on battery capacity. PEVs with smaller batteries (<25 kWh) consumed 1,800 to 1,900kWh per year. PEVs with larger batteries (35kWh plus) consumed about 3,500kWh per year. This is comparable to the annual consumption of a non-

electrically heated home in the UK. Estimates for typical domestic electricity consumption values range from 1,900 (low) to 4,600 (high) kWh per annum[70].

- Drivers rarely wait until their vehicle's battery is at a very low state of charge before plugging in. PEVs with smaller batteries (<25kWh) usually re-fill 40 to 80% of their battery capacity on each charge. PEVs larger batteries (35kWh +) usually re-fill about 15% to 50% of their battery capacity on each charge.
- In most cases vehicles are fully recharged when they are unplugged. Before demand management was introduced, vehicles were 'hot unplugged' (i.e. unplugged whilst still charging) in 18% of charge events. On weekdays, vehicles are more likely to be hot unplugged during the evening peak (18:00 – 18:59).
- The data from the trial has also allowed development of EV demand profiles for use in network assessment and design, specifically the Electric Nation Network Assessment Tool.

[70] Typical Domestic Consumption Values published by Ofgem (Low – High Profile Class 1 Estimates). Available from: https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values 2017 data

9 Baseline Survey and Movement into Demand Management

All participants experienced a period of 'unmanaged' charging between the installation of their smart charger and being moved into the demand management trial. This allowed participants to become familiar with using and charging their PEV at home and establish (and prove) reliable communications between the charger and back office. This period varied between 22 and 531 days (some participants only took part in Trial 2 or Trial 3). The median value was 124 days. Further details of this process are given in Section 9.2.

This section details the results of the Baseline survey and then describes the process of moving participants into management for both CrowdCharge and GreenFlux.

9.1 Baseline Survey Results

Participants were invited to complete a Baseline survey approximately four to six weeks after their smart charger was installed. The purpose of the survey was to capture an understanding of participants' attitudes towards their charging arrangements and their charging behaviour once they had been driving their PEV for sufficient time to get used to it and develop a pattern of charging behaviour. The full text of the Baseline survey can be found in Appendix 5.

495 participants completed this survey. In most cases the Baseline survey was completed before the participant moved into demand management.

The scores given for acceptability and satisfaction with charging arrangements from the Baseline survey in Section 9.1.2 have been disaggregated into these groups, although the sample size is small for those who completed the survey after joining the management trial.

9.1.1 Charging Behaviour

Where Do Participants Usually Charge their PEV?

Participants were asked where they charge their PEV most often. Figure 9-1 shows that most participants usually charged their PEV at home.

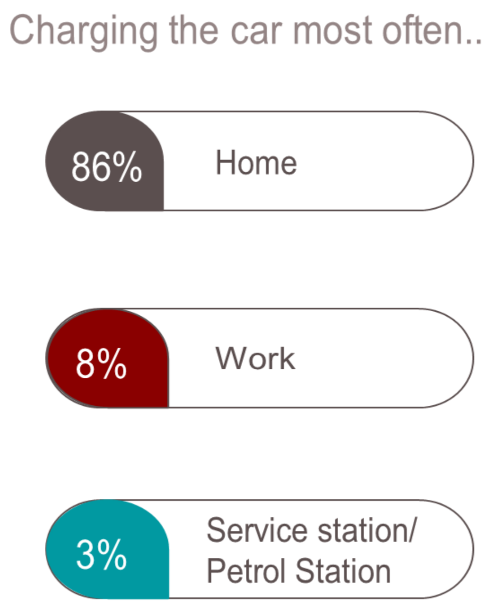

Figure 9-1: Where do you charge your PEV most often? (495 responses)

Participants were asked about other locations where they charge their PEV. Responses are shown in Figure 9-2.

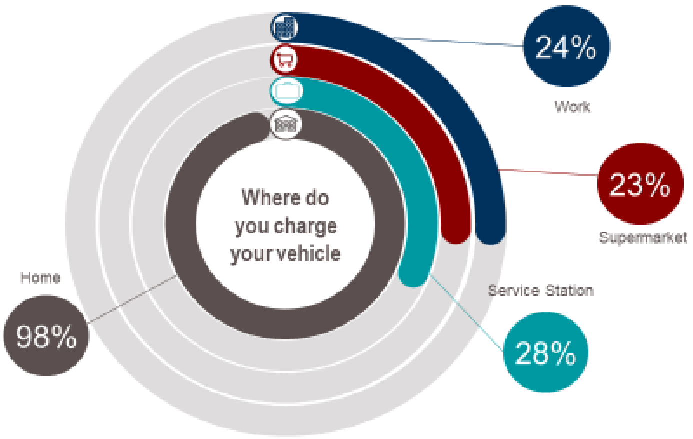

Figure 9-2: Where do you charge your PEV? (Base: All respondents, 495)

Nine participants (2%) stated that they did not charge their vehicle at home. There was still value in gathering their attitudes to charging because it may be useful to understand why people do not charge (or do so infrequently) at home when 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.

Figure 9-3 below, provides insight into how frequently participants charged their PEVs at other locations and when they were likely to use these chargers.

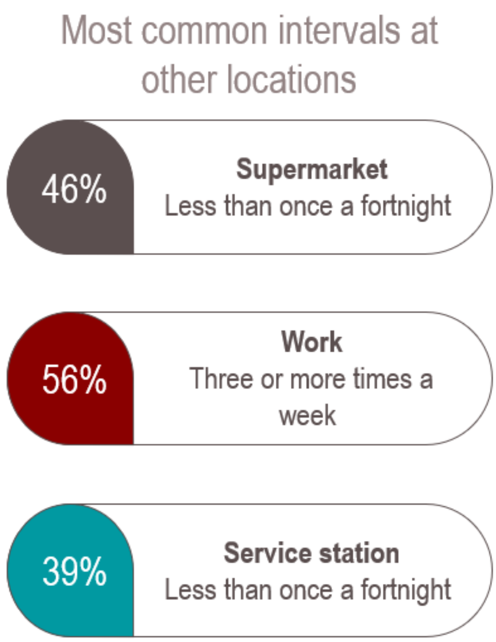

Figure 9-3: Frequency that participants charge their PEVs at locations other than home (All (487), Supermarket (112), Work (117), Service station (140))

Further details of this data are shown below:

Table 9-1: Charging Frequency at Different Locations

Location	Number of Participants who Selected Location	% of Respondents Selecting Each Frequency (of those who use each 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 a regular charging routine
Home	487	8%	30%	12%	22%	22%	2%	1%	2%
Motorway service station/ petrol station	140	1%	1%	2%	6%	16%	17%	39%	17%
On street charge point	37	0%	3%	0%	8%	24%	16%	41%	8%
Work	117	3%	18%	10%	26%	26%	10%	7%	0%
Supermarket/ shopping centre car park	112	1%	0%	1%	4%	16%	19%	46%	14%
Friend/relative's house	53	0%	0%	0%	0%	6%	9%	68%	17%
Other locations (please specify)	80	0%	0%	0%	4%	21%	15%	41%	19%

This shows that infrastructure away from the home tended to be used less frequently by Electric Nation participants. The 'other' infrastructure used most often was work based charging (used by 24% of respondents, with 83% of these respondents using this option at least once a week).

Participants who charged their PEVs at other locations were less likely to do so regularly, with the exception of those who regularly charged their vehicles at work. This may indicate that there could be the risk of a 'morning charging peak' in business districts as PEV ownership becomes more prevalent, though this was not investigated further as it was outside the scope of this project.

Charging at Home

Trial participants were asked to self-report what time of day they usually charged their PEV, when they charge it at home. Participants were given the option to choose more than one answer.

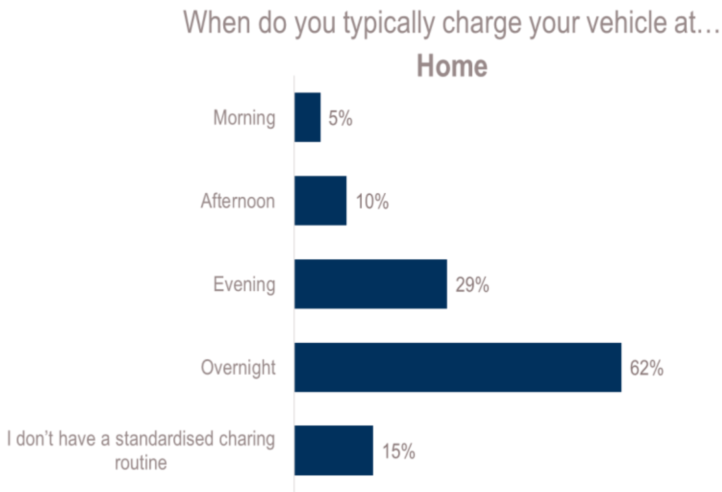

Figure 9-4: When do you usually charge your PEV when you charge at home? (487 participants)

Most participants stated that they charged their PEV either in the evening or overnight. The data above was self-reported by participants. Section 8.2 presents similar data, based on an analysis of data from smart chargers.

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

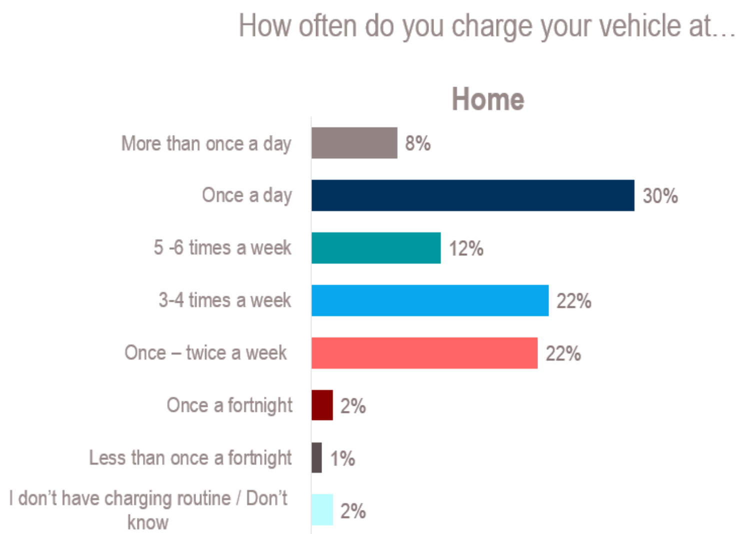

Figure 9-5: How frequently do you charge your PEV at home? (487 participants)

Figure 9-5 shows that over a third of participants said that they charged their PEV at home at least every day, but most said that they charged less frequently. This can be compared with the data from the smart chargers (rather than self-reported by participants) shown in Section 8.3.

9.1.2 Acceptability and Satisfaction with Charging Arrangements

Participants were asked a consistent set of questions in the Baseline survey and each of the three 'Trial' surveys. This allowed changes in attitudes to, and acceptance of, their current charging arrangements to be determined between Trial phases. The results of the 'Baseline' survey are presented below, disaggregated into two groups:

- Those who completed their Baseline survey before experiencing any management: either because the Baseline survey was completed before they were moved into the management trial, or because they had not been constrained before they completed the survey (92% of survey responses); and
- Those whose charging had been constrained before they completed the survey (8% of survey responses – 42 respondents).

Participants were asked to score the acceptability of their charging arrangements on a 1 to 10 scale (or to respond with "Don't know"). The results are shown in Table 9-2 below, disaggregated based on when they completed the Baseline survey.

Table 9-2: Acceptability of Charging Arrangements - Baseline Survey

Participant Group	Number of Respondents who provided a score	% of Respondents Scoring (Acceptability)		
		1 to 4	5 to 7	8 to 10
All	487	5%	19%	77%
Survey completed **before** experiencing management	445	5%	19%	76%
Survey completed **after** experiencing management	42	2%	17%	81%

A similar question asked participants to score their satisfaction with their current charging arrangements.

Table 9-3: Satisfaction with Charging Arrangements - Baseline Survey

Participant Group	Number of Respondents who provided a score	% of Respondents Scoring (Satisfaction)		
		1 to 4	5 to 7	8 to 10
All	492	5%	17%	78%
Survey completed **before** experiencing management	449	5%	17%	78%
Survey completed **after** experiencing management	42	2%	19%	79%

The small sample size in the 'after experiencing management' group prevents statistically significant conclusions being drawn from a comparison of the two groups. However, the data appears to indicate a similar pattern in both groups. The majority of participants gave high scores (8 to 10) for both acceptability and satisfaction.

Participants were also asked how willing they were to continue with their current charging arrangements. The proportion giving each of the possible responses is shown in the table below.

Table 9-4: Willingness to continue with current charging arrangements- Baseline Survey (Base: All = 495, Before = 452, After = 42))

Response	All Participants	Survey completed before experiencing management	Survey completed after experiencing management
"I am very willing to continue with this current charging arrangement indefinitely"	80%	81%	67%
"I am willing to continue with this current charging arrangement for a limited time only"	12%	11%	19%
"I would prefer alternative charging arrangements"	8%	7%	14%
"I cannot continue with these charging arrangements"	0%	0%	0%

The free text responses provided by those who responded with either of the last two answers ("prefer alternative arrangements" or "cannot continue" – 40 responses in total) have been categorised, with the results shown below.

Table 9-5: Reasons for Preferring Alternative Charging Arrangements (from 40 responses)

Response Category	Number of Responses from those who completed survey before management	Number of Responses from those who completed survey after management
Complexity/reliability /availability/price of public infrastructure	25	1
Would like three phase or induction charging at home	2	0
Would like work placed charging	2	1
Price to charge at home is too high (or would like off-peak charging to make it cheaper)	2	0
Physicality of charger or cable at home	0	2
Would like longer vehicle range	0	1
Slow charging at home	1	0
Moved to a new house, unhappy with fee to move charge point to new address	1	0
Reason not clear	1	1

Some sample quotations are shown below:

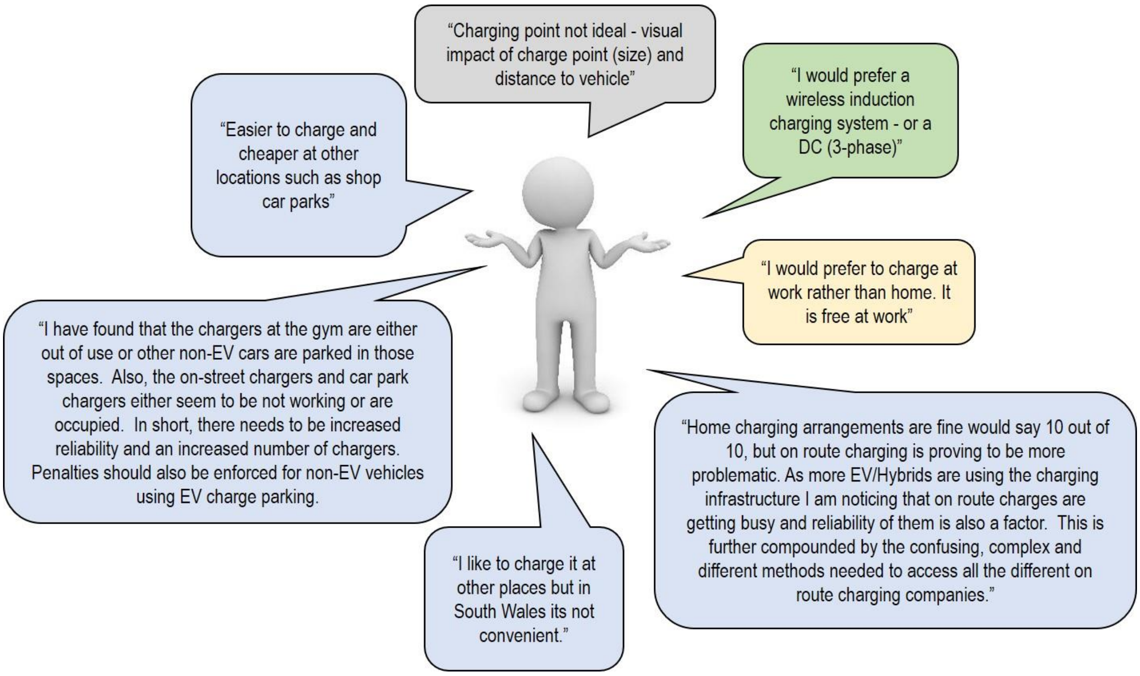

Figure 9-6: Quotations re: reasons for preferring alternative charging arrangements

Participants were asked about their level of concern with the upcoming charge management trials. The results are shown in Figure 9-7 below disaggregated by vehicle type.

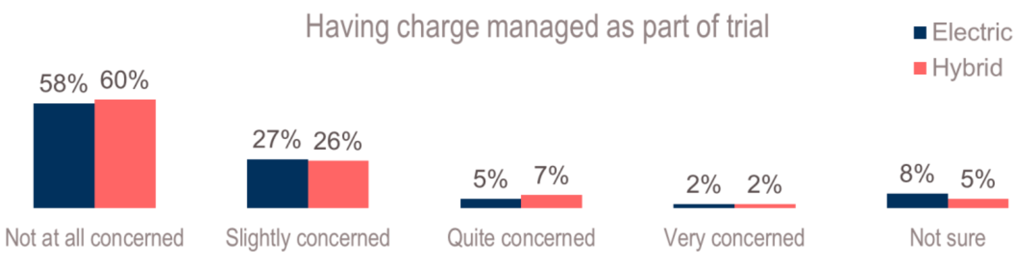

Figure 9-7: Level of Concern re: having charging managed - Baseline Survey. By PEV Type (Base: All respondents 498, Hybrid 258, Electric 240)

The results have also been analysed based on whether or not participants had experienced any management when they completed their Baseline survey.

Table 9-6: Level of Concern re: having charging managed - Baseline Survey

Participant Group	Sample Size	% of Responses				
		Not at all concerned	Slightly concerned	Quite concerned	Very concerned	Not sure
All	494	59%	27%	6%	2%	6%
Survey completed **before** experiencing management	452	58%	28%	6%	2%	6%
Survey completed **after** experiencing management	42	64%	21%	10%	0%	5%

Trial participants were made aware that the Electric Nation project would be trialling managed charging and that as trial participants their PEV charging would be subject to demand management in a broad sense. However, they were not 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. The proportion of respondents who were 'quite concerned' was slightly higher within the group who had moved into management when they took their Baseline survey (although the sample size was small, and the difference is not statistically significant[71]). Whether or not this relates to the experience of management is explored in more detail in Section 10.

9.2 Movement of Participants into Demand Management

For both CrowdCharge and GreenFlux, participants' chargers had to pass a series of tests before they could be moved into the demand management trials. These tests were put in place to ensure that the charger was controllable and that communications were reliable.

This section describes the process of moving participants to management for the CrowdCharge and GreenFlux trial cohorts. It also details the numbers of participants who passed each stage of testing before being moved into management and the reasons which prevented the remainder from joining the management trial.

9.2.1 CrowdCharge

Figure 9-8, below, shows the stages by which CrowdCharge participants entered demand management:

[71] Z -test. 5% confidence level.

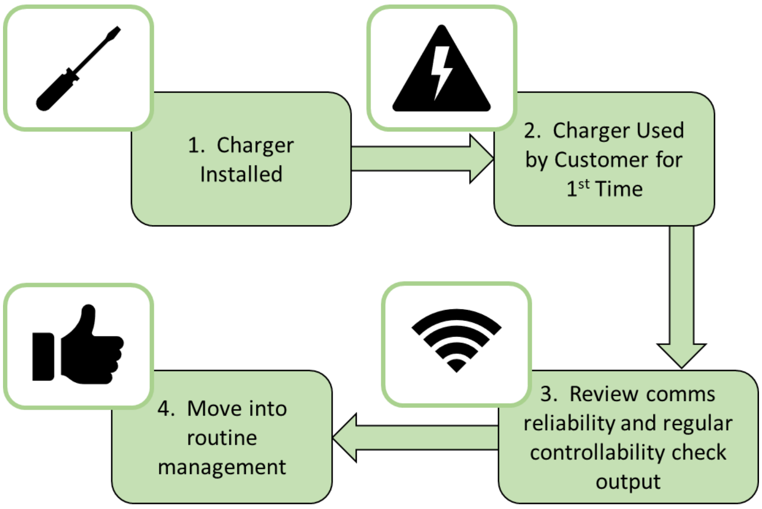

Figure 9-8: Process for moving CrowdCharge chargers into demand management

The number of chargers passing each stage by the end of the trial is shown in Table 9-7.

Table 9-7: Movement of CrowdCharge chargers into demand management

Stage	Number Passed Stage	Notes
1. Charger installed	328	
2. Charger used by participant for 1st time	307 of 328	A transaction record was not available for the remaining 21 chargers. There were a variety of possible causes for this: • Communications reliability – if chargers were not communicating with all parts of the back office then no transaction records would be available. • Charger not yet in use – e.g. car not yet delivered Charger not used because alternative charging infrastructure used – e.g. free charging at work
3. Review communications reliability and controllability	263 of 307 'used' chargers	44 chargers had been used but could not be transferred into routine management: • 22 were only communicating with part of the CrowdCharge system or had configuration problems with one part of the system. This prevented a controllability check taking place. • 20 either had no communication to any part of the CrowdCharge system, or the reliability of this was poor. 2 were communicating with all parts of the back-office system but hadn't been used for a significant period.
4. Move into routine management	263 of 328 installed chargers = 80%	263 chargers moved into the demand management trial between July 2017 and the beginning of October 2018.

Over the course of the project, 80% of the installed CrowdCharge chargers moved into demand management. 244 of the chargers moved into demand management during Trial 1, with the remaining 19 moving into management during Trial 2.

A controller software update had to be completed before a charger could move to Trial 2. The software update could be completed for 226 of the 244 chargers in Trial 1. This left a group of 18 chargers which remained under a Trial 1 regime.

Of the chargers which could not be moved into management:

- 32% had no record indicating that the charger had been used – in the majority of cases this is likely to be a communications problem;
- 34% had been used but were not communicating reliably with any part of the CrowdCharge system; and
- 31% were communicating with 'Hubeleon' but not the part of the CrowdCharge system which controlled the charger, due to configuration errors.

Further details of the communication and configuration errors experienced in the project are given in Table 5-4 and Section 5.3.2.

9.2.2 GreenFlux

Figure 9-9 below, shows the stages by which GreenFlux participants entered demand management.

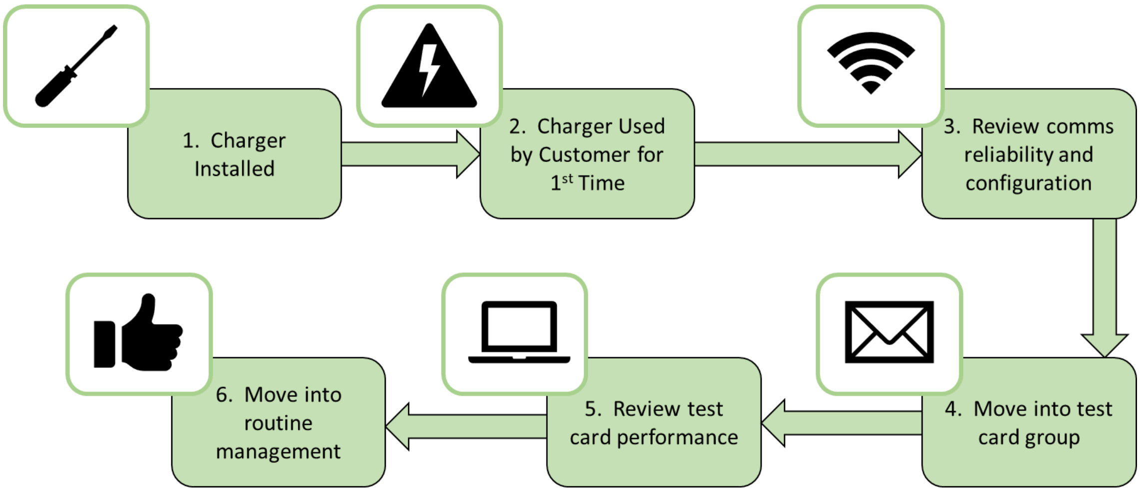

Figure 9-9: Process for moving GreenFlux chargers into demand management

The 'test card' phase was used to prove that smart charging would operate as expected on each individual charger; the tests used did not curtail charging in any way. Transactions which took place during the test card phase were reviewed by EA Technology and once three or four successful charging sessions were observed the charger would move into the routine management group. Any issues during the test card phase were referred to GreenFlux for further investigation and resolution.

The numbers which reached each stage on the diagram above are shown in Table 9-8, below.

Table 9-8: Movement of GreenFlux chargers into demand management

Stage	Number Passed Stage	Notes
1. Charger installed	344	
2. Charger used by participant for 1st time	337 of 344	Of the 7 chargers without a single transaction record, only two were online, suggesting that the main cause of the lack of transaction records was communications.
3. Review communications reliability and configuration	315 passed (of 337 which have been used)	315 chargers passed a review of their communications performance and configuration. Of the remaining 22 chargers (i.e. those that have been used but did not reach the test card phase): • 14 did not pass a check of their communications performance. • 7 had a variety of configuration problems which were not resolved by early October 2018 (in most cases because of poor communications) • 1 participant had left the project
4. Move into test card	315 into test card	315 chargers entered the test card phase since early July 2017.
5. Review test card performance	296 passed of 315 reviewed	The causes for failure at the test card phase were: • Charger offline (7 of 19): this prevented meter values being sent to the online portal, therefore the test card performance could not be evaluated. • Delayed meter values from charger (3 of 19): delayed meter values indicated a communication problem whereby chargers could send information out, but could not receive charging profiles from the back office. This led to problems with smart charging and so these participants were not transferred into routine management. • Lack of transactions in test card phase (3 of 19): successful transactions were required to pass this phase. These transactions had to occur when communications were working. • Failure at test card phase due to BMW[72] issue (2 of 19) • Unusual PEV/Charger behaviour in test card phase (2 of 19): these issues could not be resolved before early October 2018 and therefore these participants did not move into routine management. • Prior use of a timer (1 of 19): 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 consented to return to the test card phase and have passed through to routine management. One customer declined to re-join the trial and did not move to routine management. • Dropped out of the trial (1 of 19): this participant no longer owned a PEV.

[72] This was an intermittent issue with a BMW PHEV model, where charging would not commence after plug in, despite many attempts the cause of this problem remains undiagnosed.

Stage	Number Passed Stage	Notes
6. Move into routine management	296 of 344 installed chargers (= 86%)	296 chargers were moved into routine management between July 2017 and October 2018. Over the course of the project, 22 participants either left the project or were removed from the smart charging group for various reasons: • 11 (50%) due to an issue with vehicles which enter a hibernation state when paused, but do not restart when current is made available again. This group was is dominated by participants with a BMW PHEV model. This was investigated on the Electric Nation test rig. A combination of settings was found which resolved the issue in all the tests carried out. However, when deployed on vehicles in the field it was not successful in all transactions, these participants were removed from the trial. • 7 (32%) where unreliable communications resulted in chargers being repeatedly 'stuck' at 13A and this was insufficient for the customers involved. • 4 (18%) participants left the project for various reasons.

Over the course of the project, 86% of the Alfen chargers which were installed moved into demand management. The reasons why the remaining 48 chargers did not progress to demand management can be summarised as follows:

- 60% were related to communications – either from the outset meaning that no transaction records existed, or unreliable communications prevented the charger from entering the 'test card' phase, or communications failed during the 'test card' phase. Further details of the communication errors which occurred during the project are given in Section 5.3.3.
- 15% had configuration errors which prevented the charger being used for smart charging. In most cases communications problems prevented these configuration issues from being resolved.
- The remaining 25% of the issues come from multiple sources including participants leaving the project, chargers which were not used (without the participant formally leaving the trial) and the 'BMW' issue described in more detail below.

The table and bullet points above refer to a hibernation issue which prevented some participants from moving to the 'test card' phase and meant that others had to be removed from smart charging during the project. This issue was most prevalent amongst participants who owned BMW 330es, but also occurred on other BMW vehicles and some Volkswagen E Up! vehicles. In some cases when charging was paused (either due to a demand management event, or at the start of a GreenFlux charging cycle) the vehicles entered a "hibernation state" and did not begin charging again when current was made available. This led to participants who couldn't rely on the vehicle being charged and so these participants had to be removed from smart charging. Potential solutions were investigated on the test system by EA Technology, working with GreenFlux. However, no permanent solution could be found which was effective in the field. This issue only affected the GreenFlux part of the trial because CrowdCharge did not pause charging.

9.3 Summary

The key conclusions from the Baseline survey were as follows:

- Most trial participants who completed the survey usually charged their PEV at home, either in the evening or overnight;
- More than half of participants did not use their charger every day;
- Most were satisfied with their current, uncontrolled charging experience. This is significant because all future measurements of satisfaction were compared to this level of satisfaction; and
- Most were not concerned about the upcoming charge management trial. This may be related to the fact that many had access to another vehicle other than their PEV.

Over the course of the project, 80% of CrowdCharge and 86% GreenFlux participants moved into the demand management trials, described in the following sections.

10 Trial 1 Findings

Trial 1 refers to the first part of the demand management trials, where demand from groups of EV chargers was managed but the participants did not have a way of interacting with the system (e.g. to override a demand management event). This trial was active between June 2017 and May 2018 (GreenFlux) and June 2017 and July 2018 for CrowdCharge.

This section of the report describes the outcomes from Trial 1 for CrowdCharge and GreenFlux. In both cases the sub-sections outline:

- The power drawn from groups of EV chargers;
- The level of management which occurred, both at a group level, and how this varied between individual participants;
- The results of the customer research questionnaires undertaken in relation to Trial 1; and
- Key findings from this part of the trial, including exploring the relationship between the amount of management which participants experienced and their satisfaction with their charging arrangements.

10.1 CrowdCharge

10.1.1 Description of Trial

Trial 1 involved the simplest version of the CrowdCharge algorithm and system which was deployed during the project. The algorithm divided the available current equally amongst all participants. All chargers were allocated 32A when this was possible (regardless of the rating of the vehicle).

Demand management occurred when it was no longer possible to allocate 32A to all charging vehicles. When demand management was required, it was applied equally across all chargers.

For example, if the capacity limit (maximum current a group of chargers could draw) was 300A and nine chargers were connected then each would receive 32A (as 9 x 32 = 288A).

If a tenth charger connected then a limit of 30A would apply to each charger (10 x 32 = 320A, above the 300A limit, therefore each charger is allocated 300 ÷ 10 = 30A).

An example of a test performed on this algorithm is given in Section 4.8.1 of this report.

During this part of the trial there was no way for customers to interact with the system (i.e. no app was available).

The first group of participants moved into Trial 1 on 4th July 2017. Over the course of the Trial different seasonal capacity profiles were applied (see Figure 6-9). These profiles defined the amount of current that was available for groups of EV chargers. They applied over the following dates:

- Spring: 4th July – 15th August 2017;
- Summer: 15th August – 8th September 2017;
- Autumn: 8th September – 19th November 2017;
- Winter: 19th November 2017 – 8th April 2018 (a Christmas profile was applied from 20th December 2017 to 10th January 2018 which prevented any curtailment occurring);
- Spring: 8th April to 22nd May 2018; and
- 'Spring-Winter' Combined: 22nd May – 9th September 2018 (end of Trial 1).

The profiles broadly followed the seasons until the introduction of the 'Spring-Winter' combined profile. The winter profile remained active slightly beyond the end of the traditional winter period[73]. The weather in early March 2018 was particularly cold, so operating during this period using a winter profile exposed the participants to the most restrictive period of demand management (high vehicle energy demand, lowest amount of capacity available). The profiles remained in place for a few weeks after the cold weather had passed.

The 'Spring Winter' combined profile was introduced after the spring profiles had been in operation for a few weeks. Spring profiles increased the amount of capacity available for EV charging in the evening peak (see Figure 6-9). This increase in available capacity meant that no demand management was required. The capacity profiles were derived based on the rating of a real network and existing demand data. This was scaled to reflect the amount of management which would occur when 30% of vehicles are electric. It was decided, in consultation with WPD, to alter the profiles to ensure that management continued to occur. This would be representative of other networks where the available capacity was lower, or if PEV uptake was higher than 30%. It also allowed the project to continue to assess the acceptability of smart charging, as participants would continue to experience demand management. Further details are given in Appendix 1.

The results on group level demand and the periods when management was active at a group level presented in this section will focus on the time when winter profiles were in operation, as this represents the highest level of demand and the most severe period of management. Group level demand for summer and winter months are compared in Section 11.

The individual participant experience data includes the full duration of Trial 1 for each participant, in order to cover their experience of the whole of Trial 1.

[73] Elexon define winter as the period from 1st December until 28th (or 29th) February. https://www.elexon.co.uk/glossary/bsc-season/ Accessed August 2019

10.1.2 Demand Profiles

Throughout the project, chargers were part of groups. This simulated a scenario where all the chargers in a group were being supplied from a single substation with a given amount of capacity available. Each CrowdCharge charger reported the current being drawn (in Amps) for each minute during the active part of the charge session.

The total current (or power) demand for the group has been calculated for each minute by totalling the demand from individual chargers. This has been analysed to obtain seasonal demand profiles – e.g. showing the average current drawn at each time of day, or particular percentile values (e.g. 90th percentile).

It is important to note that the peak demand shown in the profiles will have been constrained by demand management. Unconstrained demand from groups of EV chargers would be higher.

This section shows demand profiles for the winter period, using data from 11th January to 7th March 2018[74]. Profiles below are expressed in Watts per Charger in Group. The following conversions have been made:

- Current Drawn in Amps has been converted to power in Watts using an assumed voltage of 240V; and
- The total demand is a function of the number of chargers in the group. Total demand (in Watts) has been divided by the number of chargers in the group at the time so that groups from different points in the project (where different number of chargers were in the group) are comparable.

Profiles have been developed by combining data across the winter period (11th Jan. to 7th March 2018), either by both day of the week and time, or by weekday/weekend and time. During this period, the group size varied between 149 and 167 chargers. This is accounted for using the 'demand per charger in group'. Various quantities can be derived for each data-point. For example:

- Maximum: the maximum demand which occurred at a given day and time across the period being analysed;
- 90th Percentile: demand was lower than this value on 90% of days; and
- Average: the average demand at a given day and time across the period being analysed.

Figure 10-1 shows each of these three quantities, for weekdays during winter in Trial 1 (11th Jan to 7th March).

[74] Similar time periods were analysed for both CrowdCharge and GreenFlux. The GreenFlux data includes inaccurate data for when management occurred in the period from 17th November to 18th December. For this reason, the demand profiles have been calculated for January to March for both CrowdCharge and GreenFlux.

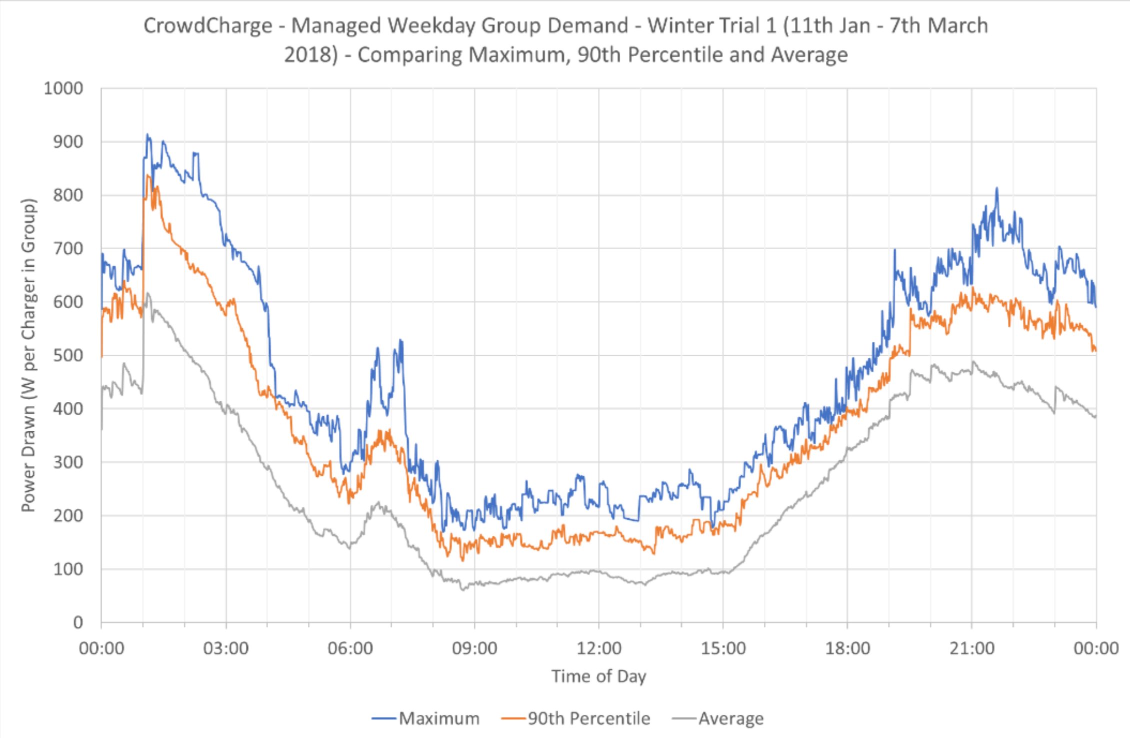

Figure 10-1: Comparison of Maximum, 90th Percentile and Average Demand (CrowdCharge Winter Weekday)

This graph illustrates the variability in the current drawn at each time of day during the trial, with the evening peak - typically 100W per charger higher on the 90th percentile day compared to the average, with maximum demand higher again. The shape of the graph shows the variation in demand across the day, with the following main points:

- A steady increase in demand from the middle of the afternoon (15:00) until around 21:00;
- In this case, the evening peak demand has been restricted by the use of demand management, so the 'unrestricted' profile would result in a different shape. This is explored in Section 8.10;
- A sudden increase in demand is observed at 01:00. This increase is not seen in the GreenFlux group (see Section 10.2.2). Charging that begins at this time is likely to be a result of participants using a timer to take advantage of cheaper electricity overnight. For example, although only 0.8% of CrowdCharge weekday plug-in events occurred between 00:00 and 01:59, 10% of charge events began in the same period – as a result of participants using timers. Further analysis of the data shows that although the proportion of participants who have a dual-rate meter are comparable between the GreenFlux and CrowdCharge cohorts (15% vs. 19%) it appears that CrowdCharge participants with a dual-rate meter were more likely to use timers than their GreenFlux counterparts – resulting in the observed night time peak; and
- A small increase in demand occurs between 06:00 and 07:30, probably from participant's making use of the 'pre-heat' function on their vehicles. This increase in demand was not large enough to require demand management.

Figure 10-2 compares the 90th percentile weekday and weekend demand curves. Weekdays and weekends are typically considered separately within planning due to differences in electricity demand. In this case, this is supported by the differences in charging behaviour shown in Section 8. A correlation test between the 'weekday' and 'weekend' datasets in the graph below gives a value of 0.75[75].

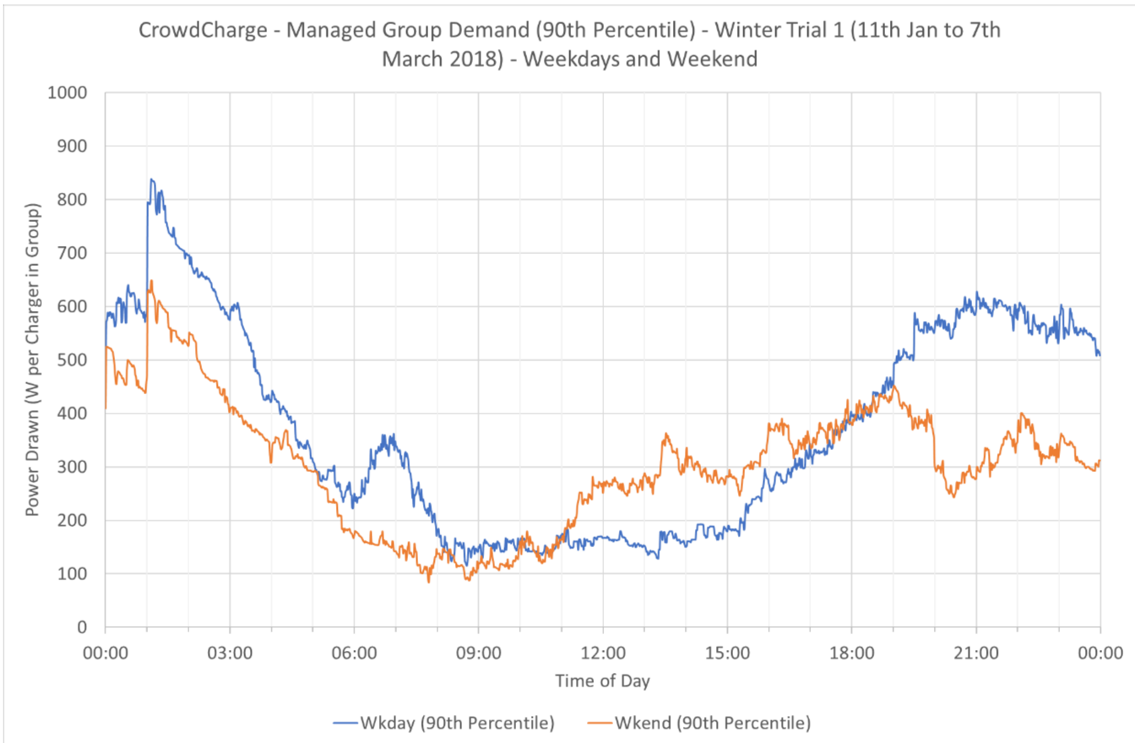

Figure 10-2: CrowdCharge Trial 1 - Comparing Winter Demand - Weekday and Weekend (90th Percentile)

This shows a lower peak demand (both overall peak, and evening peak) at the weekend. The early morning demand pick-up is absent and demand over lunchtime and the early afternoon is higher. The lower weekend evening peak (compared to weekdays) aligns with the amount of management which took place at weekdays and weekends (see next section). Demand increases at 01:00 on both weekdays and at the weekend, although the size of the increase is smaller at the weekend. This may indicate that although fewer participants are connecting their cars to charge at the weekend, those who use a timer continue to do so at the weekend. 1.6% of CrowdCharge weekend plug-in events occurred between 00:00 and 01:59. However, 10% of charging events began during the same time period.

The profiles shown above have grouped all weekdays (Monday – Friday) and weekend days (Saturday and Sunday) together. There may be trends within the week – for example higher

[75] This value provides an indication of the degree of correlation between two datasets, on a scale from -1 to 1, where +1 signifies perfect positive correlation, -1 perfect negative correlation and 0 no correlation.

demand on Mondays compared to Fridays. Figure 10-3 shows the 90th percentile of group demand (W per charger in the group) from the winter period, shown across seven days.

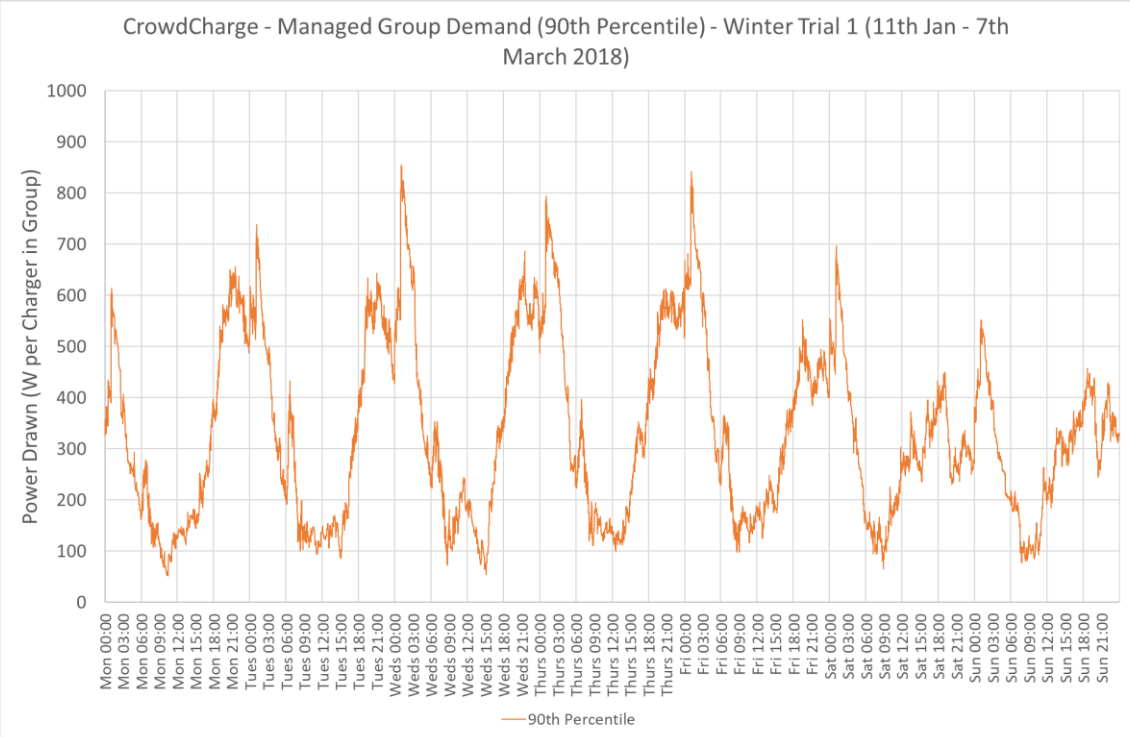

Figure 10-3: CrowdCharge Winter Trial 1 - 7 Day Demand Curve (90th Percentile)

This shows a similar pattern of demand from Monday – Thursday. In all cases there are two peaks: one in the evening and another at 01:00 (caused by the increased tendency of CrowdCharge participants with dual rate meters to use timers). Weekend demand is considerably lower, with greater daytime demand. Demand on Friday is of a similar shape to other weekdays, but the magnitude of the peaks in demand is smaller. The reasons for the lower Friday/weekend demand will vary depending on participants lifestyles but were beyond the scope of the project and could be a topic for future research.

10.1.3 Occurrence of Demand Management – Group Level

As described above, during Trial 1, CrowdCharge chargers began to be managed when it was no longer possible to allocate all active chargers 32A. As described in Section 6.6.1, the charge control log has been used to show when management was active during Trial 1.

Throughout Trial 1, 25 different capacity profiles were implemented which varied with season and the number of chargers in the group. The capacity profiles were scaled so that management would occur at the same frequency as the number of chargers in the group was increased (see graph, Figure 4-10). This figure also shows the time periods when different seasonal profiles were applied. The amount of management varied between seasons due to variations in the available network capacity and underlying demand from EV chargers (e.g. lower demand in summer due to warmer temperatures).

Table 10-1 summarises the seasonal profiles used, and the resulting amount of management (at a group level).

Table 10-1: CrowdCharge Trial 1 Seasonal Profiles and Amount of Group Level Management

Seasonal Profile	Number of Minutes Active	Number of Managed Minutes	% of Minutes with Active Management
Spring	123,030	64	0%
Summer	45,240	0	0%
Autumn	93,660	11	0%
Winter	170,880	22,272	13%
Spring Winter Combined	157,110	10,884	7%

This sub-section shows the frequency and restrictiveness of management at a group level when winter profiles were active (20th November – 19th December 2017 and 11th January – 7th April 2018, inclusive), as management was extremely infrequent on all other profiles, apart from the 'Spring Winter' combined profile. This shows the most restrictive part of Trial 1.

Figure 10-4 shows the percentage of days, at each time of day, when management was active, separated by weekdays and weekends.

This shows that management was active on all weekdays during the winter period, and most weekend days. Management was confined to the evening peak – occurring between 16:23 and 22:25 (although management after 21:30 was infrequent) on weekdays and 16:00 and 20:59 at the weekend. Management was less frequent at the weekend, and events were shorter.

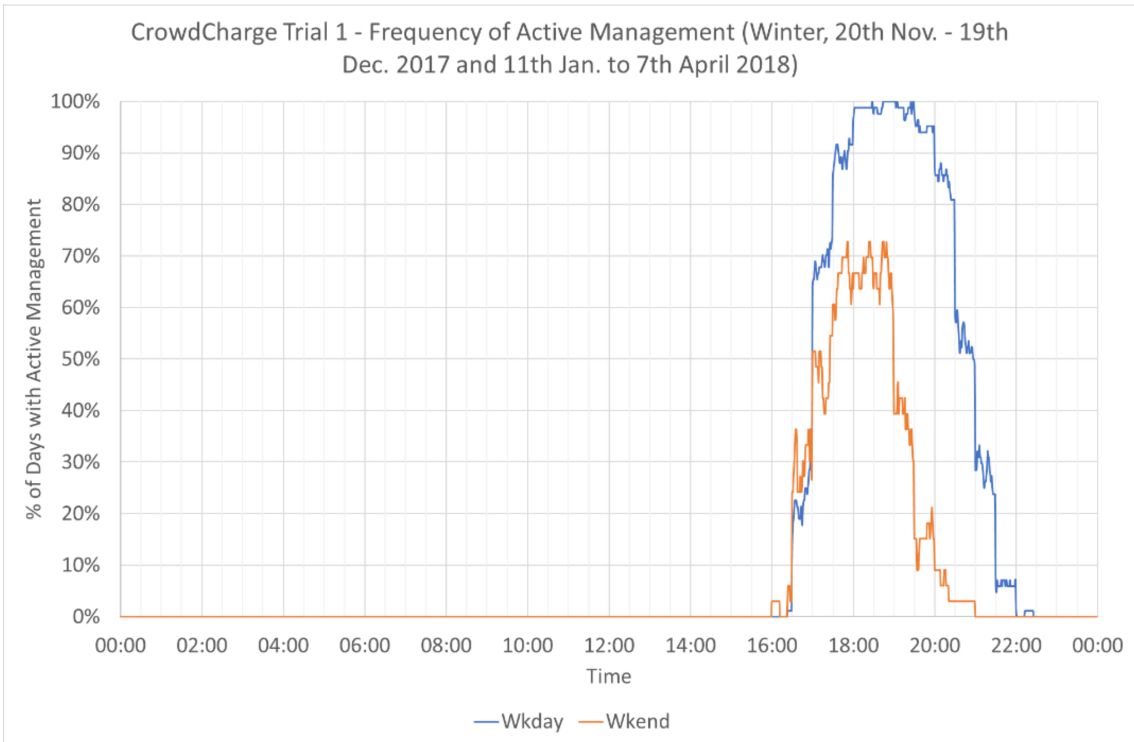

Figure 10-4: Group Level Management CrowdCharge Trial 1 - Winter

As the CrowdCharge system gave the same current limit to each charger during Trial 1, the restrictiveness of management at a group level can be shown using the current allocated to chargers, by time of day. Figure 10-5 and Figure 10-6 below, show this data for the period when management could have been active (16:00 – 22:30 for weekdays, and 15:30 – 21:00 for weekends). The shaded grey area in each graph represents the extreme limits of the amount of current available (maximum and minimum). The average current available at each time of day is shown by the blue line.

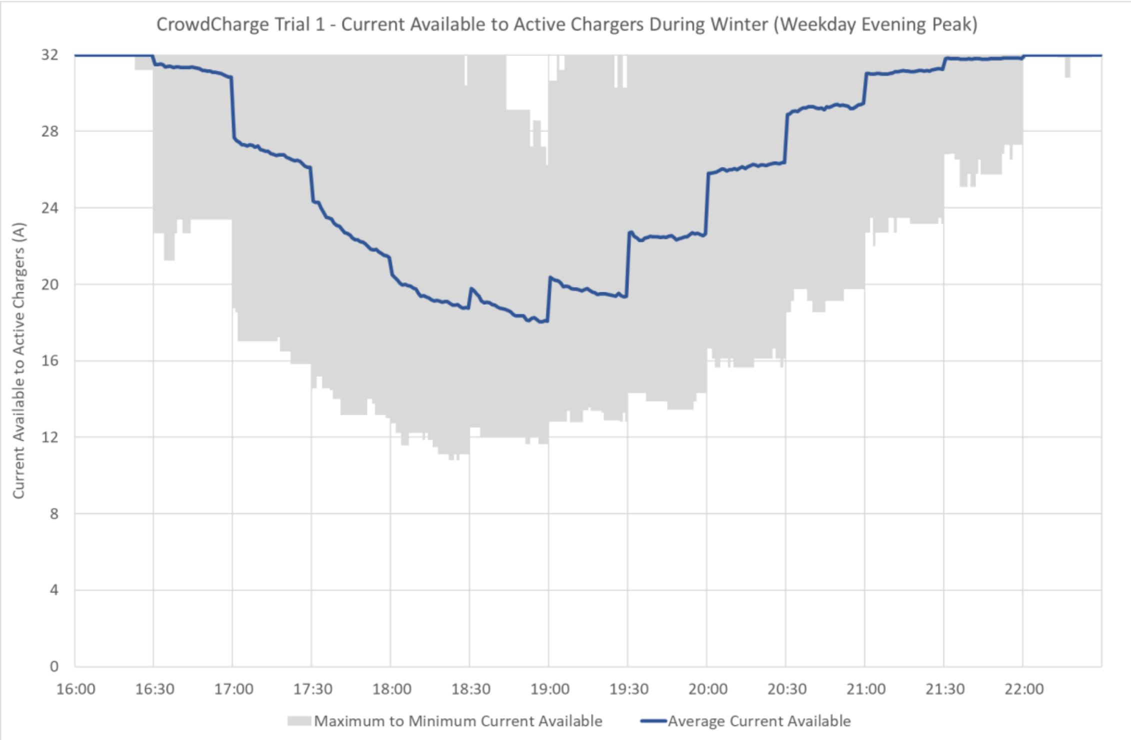

Figure 10-5: CrowdCharge Trial 1 (Winter) - Amount of Current Available to Active Chargers in Evening Peak (Weekdays)

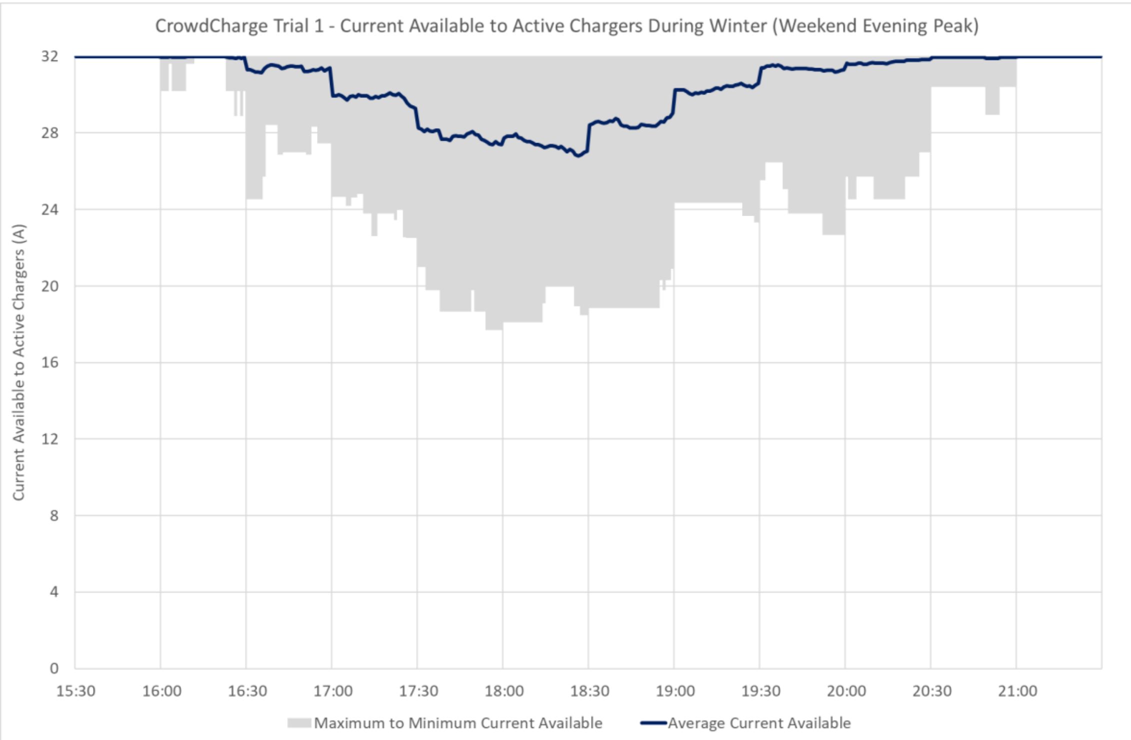

Figure 10-6: CrowdCharge Trial 1 (Winter) - Amount of Current Available to Active Chargers in Evening Peak (Weekend)

This shows that as well as being less frequent at weekends, management was also less restrictive. Both the minimum current available, and the average current available was higher at the weekend, compared to weekdays.

These graphs also indicate that project participants with vehicles rated at 16A (3.6kW) will have been curtailed less than those with vehicles rated at 32A (7kW). Management was active on all weekdays during this period, but on 42% of weekdays the minimum current available was more than 16A – so drivers of vehicles rated at 16A would not have experienced any curtailment on these days. This is explored in more detail in the following section.

10.1.4 Participant Experience of Management

Participant's experience of management will vary, as illustrated in the examples below:

- A participant who is on a dual-rate tariff, such as Economy 7[76] and always uses a timer to ensure their car charges using cheap electricity (e.g. between 00:00 and 07:00): none of their sessions would have been curtailed (management only happened in the evening peak);
- A participant with a vehicle rated at 32A who does most of their home charging during the evening peak, on weekdays: during the winter period, the majority of their charging sessions would have been managed (see Figure 10-5); and
- A participant with a vehicle rated at 16A who sometimes charges in the evening peak, and sometimes during the middle of the day: this participant would experience occasional management when their 'evening peak' charging sessions overlapped with days with particularly restrictive management, where the current limit was reduced below 16A.

These examples show how the amount of management which participants experienced varied, based on their charging behaviour and their vehicle rating.

This section outlines the amount of management which participants experienced in Trial 1. The key findings section (see Section 10.1.6) combines this data with the results of the Trial 1 survey to explore any link between the amount of management participants experienced in Trial 1, and their satisfaction with their charging arrangements.

One way in which management could have affected participants is to cause an increase in the proportion of charge events where vehicles were 'hot unplugged' (i.e. unplugged whilst still charging). Management reduces the current available to a charging vehicle, so may have led to vehicles not being fully charged when they were unplugged.

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[76] The off-peak 7 hours on an Economy 7 tariff vary by region always occur overnight. 00:00 – 07:00 has been chosen as an example. In some areas cheap rate begins at 01:00. Further details of Economy 7 are available online, including at: https://www.ovoenergy.com/guides/energy-guides/economy-7.html Accessed August 2019

Outside of demand management, the CrowdCharge participants who took part in Trial 1 'hot unplugged' the vehicle for 1,388 of 7,363 charging events (where data is available to calculate start and end of charging) = 18.9%.

During Trial 1 CrowdCharge participants 'hot unplugged' the vehicle for 4,055 of 24,079 events = 16.8%.

The rate of hot unplugging therefore declined slightly once participants had been moved into management[77].

Data from the trial (transactions, meter values and the charger control log showing when management was active at a group level) has been used to evaluate each transaction during Trial 1 and determine whether it was curtailed (managed).

For example, for a group of chargers that were being managed between 18:00 and 20:00, the lowest available current per charger during this event was 20A. A car rated at 32A charging during this time would be curtailed, whereas one rated at 16A would not.

For each participant, data from smart chargers has been used to calculate:

- How many times they charged their vehicle (at home) during the time when they were participating in Trial 1;
- How many of these charging sessions were curtailed (where meter values are available); and
- To what degree they were curtailed (more details below).

27,598 charging events took place during Trial 1 (where consumed energy was 0.5 to 100kWh). 2,226 charging events were constrained (8%).

'Current meter value' data has been used to determine whether a charge session was constrained. The same data is used to calculate the time when charging began and ended (this is available for 23,771 of the events (86%)). However, charge events were only constrained if they took place when the charger was communicating with CrowdCharge (and so would have sent meter values). So, any events where a start and end charge time cannot be determined due to an absence of meter values were not managed.

245 participants were part of at least one Trial 1 group, and transaction data is available for 239 of these participants. The remaining six participants may have lost their communications connection, not used their charger (unlikely, given the duration of Trial 1), or left the project.

59 participants (25%) were never managed.

[77] Z test comparing % of charging events hot unplugged between trials, using number of charging events as the sample size. Z =-3.99 (value of 1.96 would indicate 5% confidence level).

The spread of the proportion of events which were curtailed is shown in Figure 10-7, separated by participants whose registered vehicle was rated at 16A and 32A (3.6kW and 7kW respectively). This is based on the 239 participants who charged their vehicle during Trial 1.

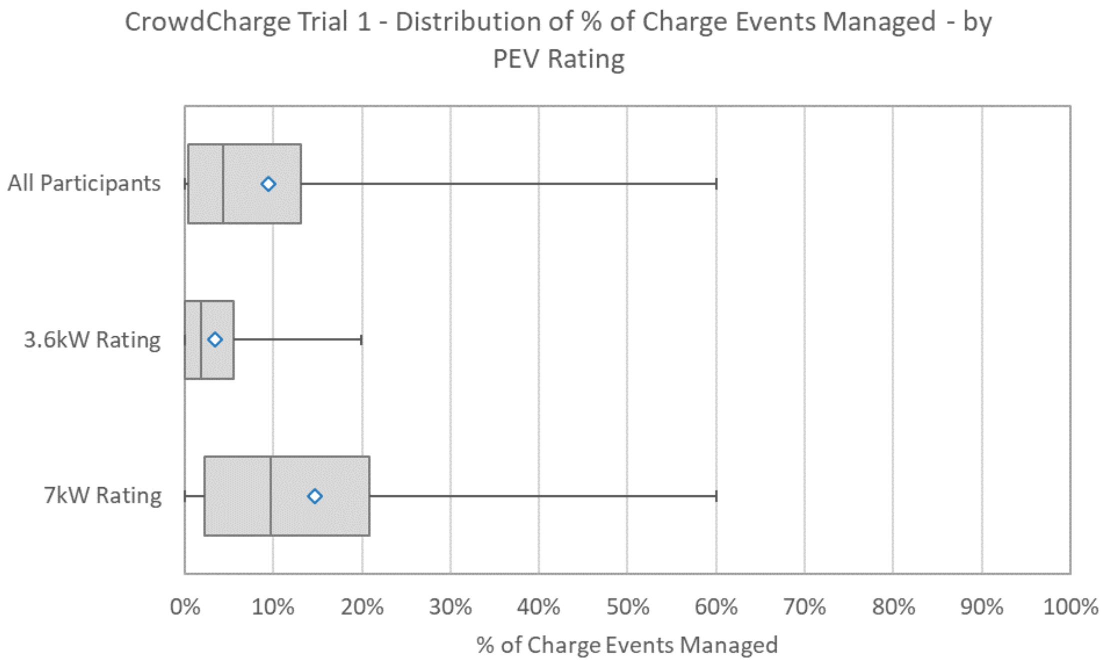


Figure 10-7: % of Charge Events Managed - by PEV Rating (for 239 participants who charged their vehicle during Trial 1)

This shows that participants with vehicles rated at 3.6kW were less likely to have experienced demand management, as indicated by the group current limit data in the previous section.

It is important to remember that, during Trial 1 the CrowdCharge algorithm did not differentiate between 16A (3.6kW) or 32A (7kW) vehicles. So, if 600A was shared between 30 active chargers then all chargers would receive an allocation of 20A. This is a considerable constraint for 32A vehicles, but no constraint for 16A vehicles.

Dividing the data using other characteristics of the vehicles (instead of rating), such as battery capacity or EV type shows greater variation within categories (particularly for the BEV category, as this is a mix of 3.6kW and 7kW vehicles).

The box and whisker diagram above (Figure 10-7) shows a general trend towards participants with 3.6kW vehicles experiencing less management than those with 7kW vehicles, but there is still considerable variation within categories. The data has been further sub-divided to include the use of timers, used by participants to move their charging to the overnight period, where no management took place.

Across the whole of Trial 1, 8% of charge events were managed. For events where a timer was used this percentage drops to 1%.

For each participant, the proportion of their charge events involving a timer has been calculated. A participant has been defined as a 'frequent' user of a timer if they used one for more than 50% of their charge events. 60 of the 239 participants who charged during Trial 1 are 'frequent' timer users under this definition. Participants have been split by both vehicle rating, and whether they are a 'frequent' timer user. The resulting distribution of management is shown in Figure 10-8.

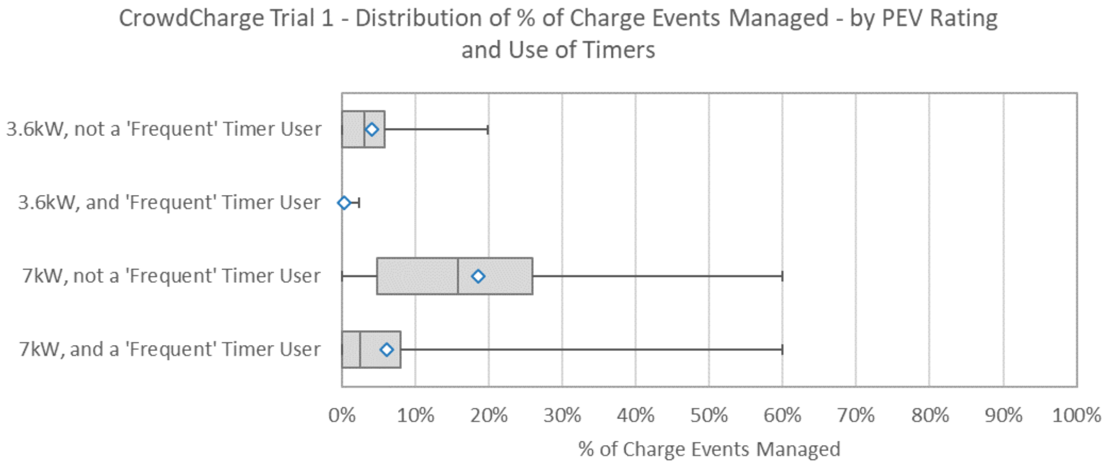


Figure 10-8: % of Charge Events Managed - by PEV Rating and Use of Timers (for 239 participants who charged their vehicle during Trial 1)

This shows that management was extremely rare for participants with vehicles rated at 3.6kW who used timers frequently. Management was most frequent (median of 16%) for owners of 7kW rated vehicles who did not use a timer frequently. Participants with a 7kW vehicle who used a timer have still experienced some management, but this is most likely to have taken place during charging sessions when they did not use their timer.

The analysis above is based on a binary 'managed' or 'not managed' flag applied to each charging event. It does not include how restrictive the management was.

For example, consider a demand management event which lasted 2 hours (120 minutes), with 20 minutes having a current limit per charger of less than 16A (the remaining 100 minutes less than 32A, but greater than 16A).

If two vehicles (one rated at 32A and one at 16A) charged throughout the event both would be flagged as 'managed' but the restriction experienced by the 32A car (120 minutes at less than its maximum rate) would be much greater than that experienced by the 16A one (20 minutes at less than its maximum rate).

A measure has therefore been developed to assess how restrictive management was for each managed charging event using the quantities described below:

- For each minute, using the current meter value data (amps drawn) the following has been calculated:
    - Power Drawn (kW)[78] = (Current Drawn x 240V)/1000; and
    - Energy Consumed in Minute (kWh) = Power Drawn (kW) x 1/60;
- Start of charging time = the time when charging began (estimated using current meter values, where available);
- EndCharge = several methods are used to detect the end of charging, due to variations in the profile of current drawn (variations occur between vehicles and starting state of charge), the following hierarchy has been applied:
    - The time at which the current being drawn had declined to less than 25% of the amount allocated for 15 minutes continuously;
    - If the above criteria was not met, and the charger reported Status = 2 (i.e. vehicle charging) for 20 minutes (continuously) prior to being unplugged, then EndCharge = the unplug time; or
    - If neither of the above criteria were met, then EndCharge = the first time the charger reports a Status = 1 (car connected but not charging), after charging began.
- Actual Charging Time = EndCharge – Start of Charging Time. The time the vehicle took to charge;
- Consumed Energy between Start of Charging Time and EndCharge (kWh)= the summation of the 'Energy Consumed in Minute' for each minute which falls between the start and end of charging;
- Max. Amps Drawn = the maximum current drawn during the charging session;
- Max. Power Drawn (kW) = (Max Amps Drawn x 240V) /1000) (converting current to power, with an assumed voltage of 240V);
- Theoretical Minimum Charging Time = Consumed Energy between Start of Charging Time and EndCharge / Max. Power Drawn (i.e. the time it would take to transfer the consumed kWh if the session occurred at the maximum rate throughout); and
- Restriction = 1 – (Theoretical Minimum Charging Time /Actual Charging Time)

Using these values, a charging session with a short and low level constraint would have a lower 'Restriction' value than one with a longer period of constraint, as the difference between the theoretical minimum charging time and actual charging time would be lower in the first case.

[78] This approach assumes unity power factor. It is recognised that this is a simplistic approach, but it enables the comparative rate of energy delivery to be determined. It is recognised that this approach will not produce accurate values for absolute energy consumption. Analysis of energy consumed in transactions (e.g. that presented in Section 8.4) is based on transaction records, where energy consumed is taken from the chargers energy meter.

A restriction value is calculated where the following criteria are met:

- Transaction was managed;
- Start Charge, End Charge, Max. Amps Drawn and Energy Consumed between start and end of charging are all populated and not zero (i.e. meter values available for the transaction);
- The equivalent charge rate calculated using Start Charge, End Charge and the total consumed energy for the transaction is between 0.5 and 7.5kW. The criteria was applied in order to exclude transactions where the End Charge time is inaccurate – further details of this are given in Section 8.9); and
- The energy consumed between Start of Charging and EndCharge is at least 30% of the total amount for the transaction[79].

There were 2,226 managed charging events during Trial 1. Applying the criteria above means a value for restriction can be calculated for 2,072 of the events (93%).

The 'Restriction' value applies to each managed transaction. A single metric needs to be derived for each participant to describe their overall experience of Trial 1. For the purposes of this analysis the median (i.e. middle value) for each participant has been calculated (based only on those transactions which were managed).

A single figure has been derived 'CrowdCharge Management Factor' which summarises both the frequency with which participants were managed, and the restrictiveness of this management (N.B. a similar metric 'GreenFlux Management Factor' has also been derived, but the two are not comparable):

CrowdCharge Management Factor (each participant)	=	% of Events Managed × Median Restriction Value for Managed Transactions

Three real examples from the CrowdCharge data are given below:

- Participant EN1092 charged 183 times during Trial 1, none of their transactions were curtailed. No 'CrowdCharge Management Factor' has been calculated, and this participant will be included in the analysis of effect of management on participant satisfaction with their charging arrangements in a 'never managed' group;

- Participant EN1462:
    - Charged 69 times during Trial 1, 6 charging events were curtailed, so % of Events Managed = 9%;

[79] 'Start' and 'End of Charging' have been calculated based on the meter values. The EndCharge detection is not completely reliable in all cases (for example it can be triggered by a single 'Status 1' partway through a cycle, if the first two criteria described above are not met). It is necessary to provide a further confirmation that the apparent rate of energy delivery is consistent with the rating of the charger. This excludes these potentially inaccurate charge sessions from affecting the restrictiveness figures for a participant.

  - The Restriction Values for these six events were: 6.2%, 8.7%, 12.8%, 15.4%, 17.3% and 19.4%. The median value of these is 14.1% (half-way between 12.8% and 15.4%); and
  - CrowdCharge Management Factor = 9% x 14.1% = 1.23%; and

- Participant EN1527:
  - Charged 61 times during Trial 1, ten charging events were curtailed, so % of Events Managed = 16%;
  - The Restriction Values for these ten events were: 8.7%, 37.4%, 74.0%, 74.2%, 76.2%, 76.7%, 76.9%, 80.8%, 81.5%, 82.4%. The median value is 76.5%; and
  - CrowdCharge Management Factor = 16% x 76.5% = 12.54%

Therefore, participants who experience management less frequently, or less restrictively have a lower 'CrowdCharge Management Factor' than those who have experienced more, or more restrictive management.

The distribution of 'CrowdCharge Management Factor' across the population of 176 CrowdCharge participants where a Management Factor has been calculated[80], is shown in Figure 10-9, split by PEV rating.

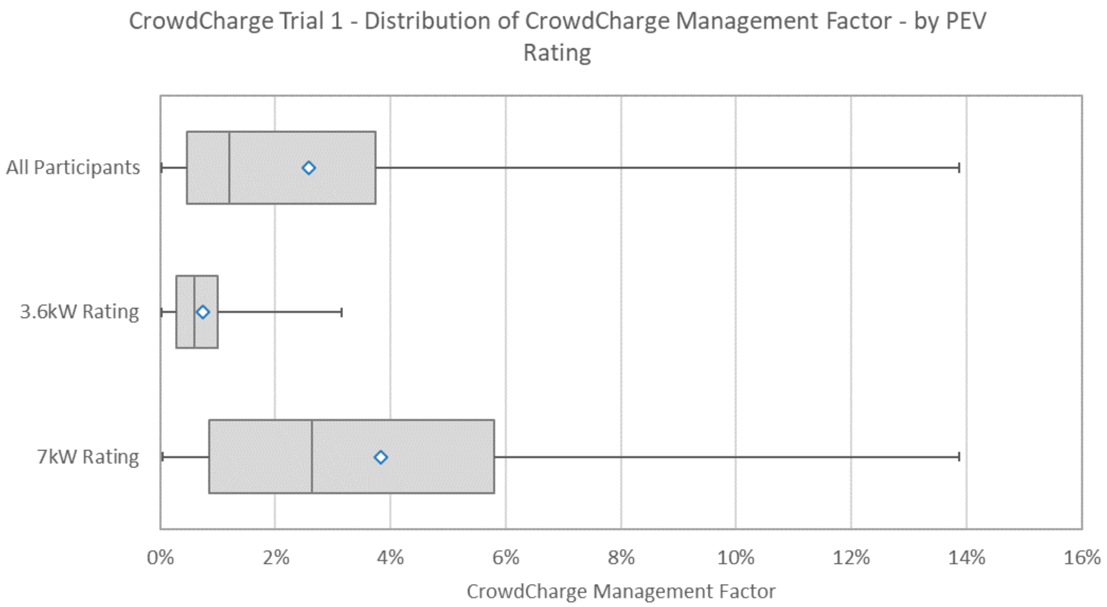


Figure 10-9: Trial 1 CrowdCharge Management Factor (for 176 participants who experienced management) - by PEV Rating

This shows that CrowdCharge management factor varied between 0.87% and 13.9%. The median value across all managed participants was 1.2%. Participants with vehicles rated at

[80] Most of the remaining Trial 1 participants did not experience any management. Four participants were managed for one (three participants) or two (one participant) of their transactions. However, all their managed transactions failed the tests described above, so a management factor cannot be derived.

7kW experienced more restrictive management than those with 3.6kW vehicles (median of 2.6% vs. 0.6%). The link between 'CrowdCharge Management Factor' and participants' satisfaction with their charging arrangements is explored in the key findings section (see Section 10.1.6).

10.1.5 Customer Research Results

Customer research surveys were carried out throughout the project by Impact. The aim of these surveys was to collect both quantitative and qualitative data from participants on their charging behaviour and attitudes to smart charging. The majority of the questions were the same as those included in the Baseline survey (see Section 9.1). This allows the attitudes of participants to be compared in different periods of the trial – in this case, before and after demand management. The same group of participants have been included within the comparative analysis in this section – i.e. CrowdCharge participants who completed both a Baseline and Trial survey.

After a participant had been subject to demand management for at least four weeks, they were issued a survey invitation by Impact. If a participant had completed the Recruitment and Baseline surveys, they were eligible for a £10 online voucher for completing this survey.

Trial participants were not informed when they were moved into demand management; in effect the trial participants were blind to the change. However, some may have noticed changes to their EV charging sessions as a consequence of demand management.

The Trial 1 survey was open for responses between 15/01/2018 and 28/04/2018. The full text of the Trial 1 survey can be found in Appendix 6. The table below shows the response rate from CrowdCharge participants to the Trial 1 survey.

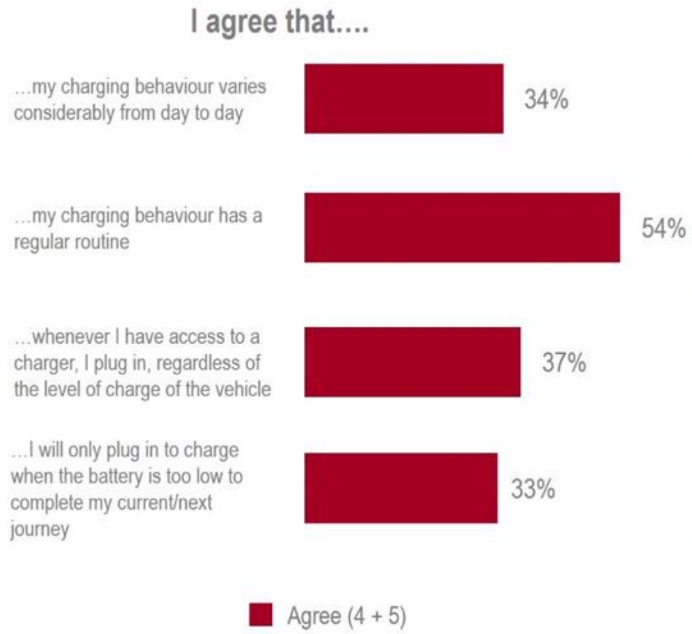
Table 10-2: CrowdCharge Trial 1 Customer Survey Response Rate

	Surveys Issued	Surveys Completed	Response Rate (%)
CrowdCharge Trial 1	143	134	94%

Participants were only invited to complete a Trial 1 survey if they had moved into a management group during Trial 1, had completed both a baseline and recruitment survey, and had been part of Trial 1 for at least four weeks by the end of the survey period. The amount of management which Trial 1 participants experienced varied (see Figure 10-7). The link between the amount of management which participants experienced and the scores they provided for satisfaction/acceptability is explored in Section 10.1.6.

10.1.5.1 Reported change in charging behaviour

The introduction of demand management may have led some participants to change their charging behaviour. For example, they may have become more concerned that they may not receive a full charge when required, so they might have begun to plug in more regularly. Participants were therefore asked about their charging behaviour and this was compared to the baseline survey results (i.e. before management). Comparison of their responses to the baseline data suggests that charging behaviour had not changed significantly. Figure 10-10 shows a breakdown of the responses across the whole cohort and by vehicle type, for Trial 1 only.



Fuel Type		
PHEV (47)	BEV (69)	REX (18)
28%	41%	28%
70%	43%	56%
49%	30%	28%
28%	36%	33%

Figure 10-10: Reported charging behaviour by whole cohort and type of vehicle (Base: all Trial 1 survey respondents - 134)

When these results are compared to the equivalent breakdown in the baseline survey (for the same group of respondents – i.e. those that completed a Trial 1 survey), there are no statistically significant changes at either the whole population level, or within any individual vehicle type. Participants adopted similar charging 'strategies' when they completed the baseline and Trial 1 surveys.

When asked if they had actively changed their charging behaviour (Figure 10-11), 9% (12 participants) of respondents stated that they had. More than half of these (60%, or 7 participants) stated their charging frequency had decreased.

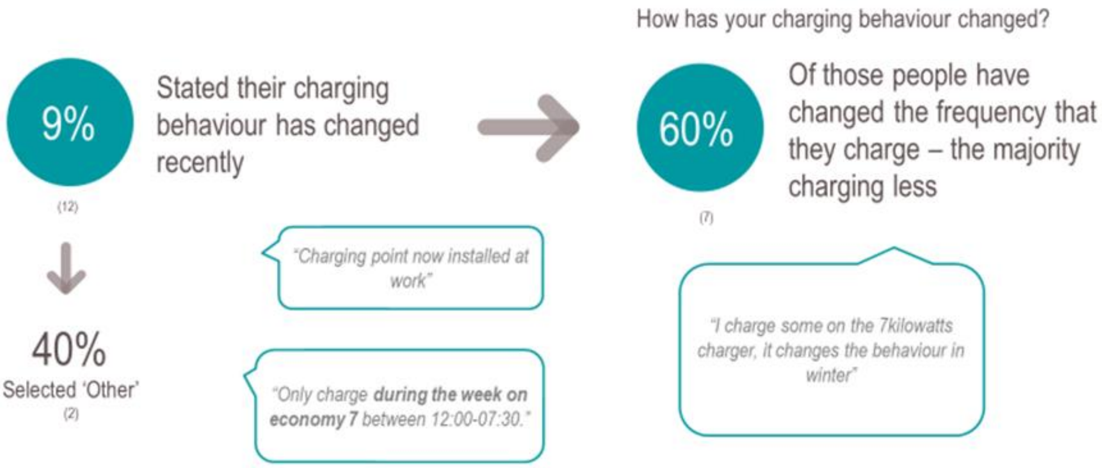
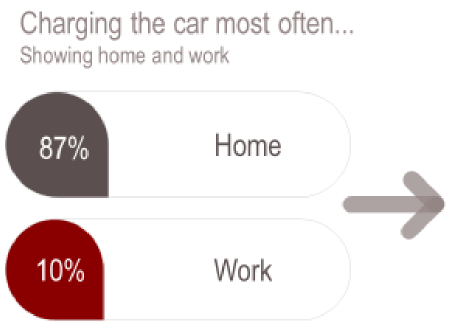


Figure 10-11: Stated change in charging behaviour (12 respondents out of 134 surveys)

The free-text responses from participants whose behaviour had changed did not show a link between the introduction of demand management and changes in behaviour.

Participants reported that on the whole they had not changed where they were likely to charge their vehicle (Figure 10-12). Charging at home was still the most popular location amongst trial participants. This would appear to indicate that demand management did not cause participants to seek out alternative charging arrangements.



Charging car most often by Home vs. Work

Battery Size				Fuel Type		
<10 kWh	10-25kWh	26-35 kWh	>35 kWh	PHEV	BEV	REX
90% (28)	98% (39)	85% (35)	64% (14)	94% (44)	81% (56)	89% (16)
6% (2)	3% (1)	12% (5)	23% (5)	4% (2)	13% (9)	11% (2)

Figure 10-12: Where did participants charge their vehicle most frequently (Base: 134 responses)

Participants with larger batteries were more likely to charge their vehicle at work than other participants[81]. However, behaviour around charging location remained unchanged since the baseline survey and was dominated by home charging.

[81] Statistically significant. Z test. Z value = 2.12 (a value of 1.96 would indicate confidence at the 5% level).

10.1.5.2 Frequency of charging

Participants were asked how frequently they charged their vehicle at each of the locations they indicated that they used for charging. These responses were compared to the replies received in the baseline survey for home (Figure 10-13) and work (Figure 10-14).

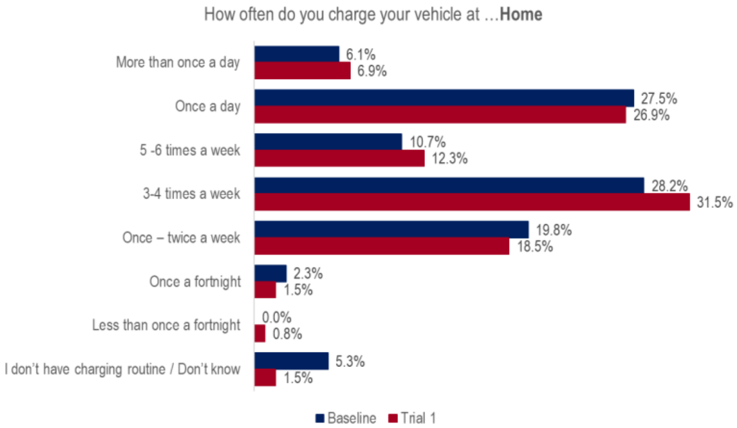


Figure 10-13: How often do you charge your vehicle at home (Base: Baseline = 131, Trial 1 = 130, one participant who indicated that they charged at home no longer did so when they completed the Trial 1 survey)

Examining the responses of those who participated in both surveys, there appears to have been a shift to more frequent charging (e.g. an increase in the proportion of respondents indicating they charged 5 – 6 times a week or more). However, this change is not statistically significant[82].

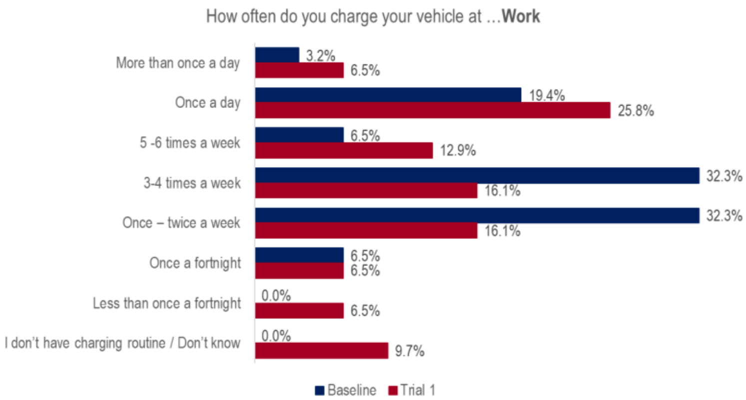


Figure 10-14: How often do you charge your vehicle at work (Base: 31 respondents in both surveys)

Charging frequencies at work appear to have increased: there was a decrease in the proportion of participants reporting a charging frequency of '3 to 4 times a week' and 'once to twice a week' and an increase the proportion charging '5 to 6 times a week' or more. However, the small sample size means this change was not statistically significant[83].

[82] Z test. Z value of 0.29 (a value of 1.96 would indicate confidence at the 5% level).
[83] Z test. Z value of 1.31.

Participants were asked when and where they typically charge their vehicle, this was also compared to the Baseline responses. The results are shown below for home (Figure 10-15) and work (Figure 10-16).

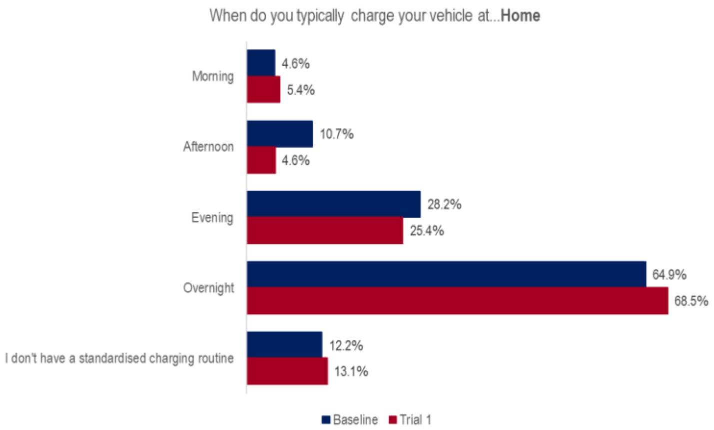


Figure 10-15: When do you typically charge your vehicle at home? (Base: Baseline = 131 respondents, Trial 1 = 130 respondents). Participants could select more than one option

Overall these results align with the pattern of demand from PEV charging shown in Section 8. Comparison of the two survey results shows a decrease in the proportion of respondents charging at home during the afternoon and evening, offset by increased charging in the morning or overnight. However, this change was not statistically significant[84].

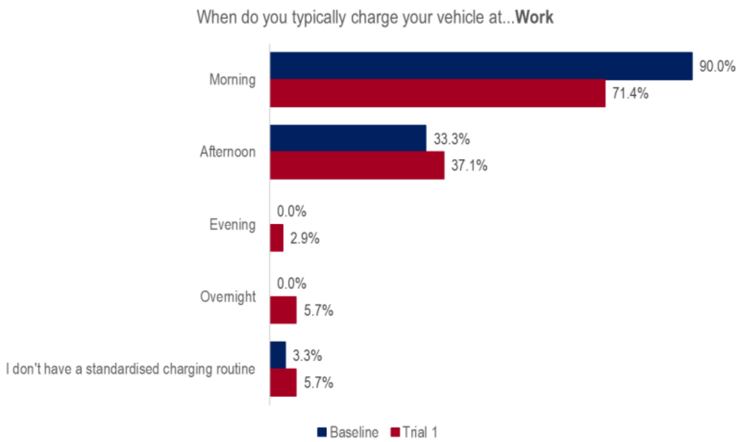


Figure 10-16: When do you typically charge your vehicle at work? (Base: 31, both surveys). Participants could select more than one option

The proportion of respondents charging at work during the morning decreased, offset by an increased proportion of respondents charging in the afternoon, evening or overnight.

[84] Z test. Z value of 0.79.

Neither change was statistically significant at the 5% level[85] due to the small sample size (only 31 respondents stating they charged at work).

10.1.5.3 Acceptability and satisfaction with charging arrangements

One of the key elements of the Electric Nation project is to understand the customer acceptability of smart charging. Therefore, participants were asked the same questions about the acceptability of, and satisfaction with, their current charging arrangements at several points during the trial. These results are reported below, with further detail linking the amount of management experienced and these survey results given in Section 10.1.6. The results reported in this section are for the 131 participants who responded to both the Baseline and Trial 1 surveys. Results from all respondents can be found in Appendix 2.

Participants were asked whether their current charging arrangements were acceptable, using a score between 1 and 10. Figure 10-17 shows that proportion of participants who rated their charging arrangements as highly acceptable (scores of 8, 9 and 10). The slight increase shown below was not statistically significant[86]. In terms of the trial outcomes, this indicates that customer experience during Trial 1 (i.e. management as shown in Section 10.1.4) did not cause any statistically significant change (positive or negative) in the proportion of respondents who rated their charging arrangements as highly acceptable.

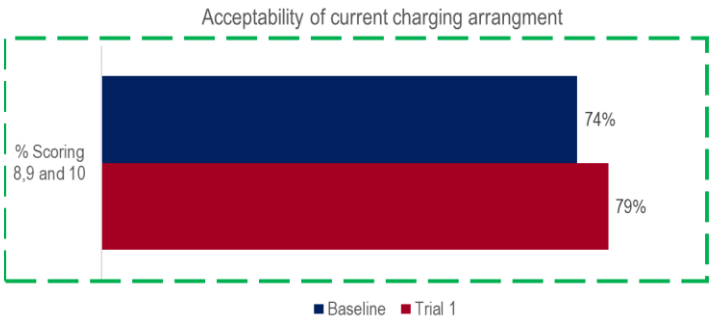


Figure 10-17: Acceptability of current charging arrangements (Base: Baseline = 130 respondents, Trial 1 = 131 – excludes those who answered 'don't know')

This data was disaggregated further to examine acceptability amongst different groups of participants. This showed that:

- BEV drivers were more likely to rate their charging arrangements as highly acceptable when compared to PHEV drivers (85% scoring 8, 9 or 10 compared to 70% of PHEV drivers). This result was statistically significant at the 10% level[87].

[85] Decrease in proportion charging in the morning at work - Z value of 1.86 (value of 1.96 would indicate confidence at the 5% level, value of 1.64 would indicate confidence at 10% level). Increase in proportion charging in the afternoon, evening and overnight – Z value of 1.0.
[86] Z test. Z value = 0.95.
[87] Z test. Z = 1.91 (value of 1.96 would be required for confidence at 5% level, value of 1.64 at 10% level).

- Participants with a battery size of 25 to 35kWh were significantly[88] more likely to rate their charging arrangements as highly acceptable when compared to the 10 to 25kWh group (88% of 25 to 35kWh group scored 8, 9 or 10, compared to 69% of 10 to 25kWh group).

Participants were also asked to score their satisfaction with their current charging arrangements. Some participants may be dissatisfied with a solution but are prepared to accept it. Asking participants about satisfaction therefore provides an additional metric via which customer attitudes to smart charging can be understood.

Figure 10-18 compares the level of satisfaction with current charging arrangements for the whole trial population in Trial 1 (top bar) and before management (bottom bar).

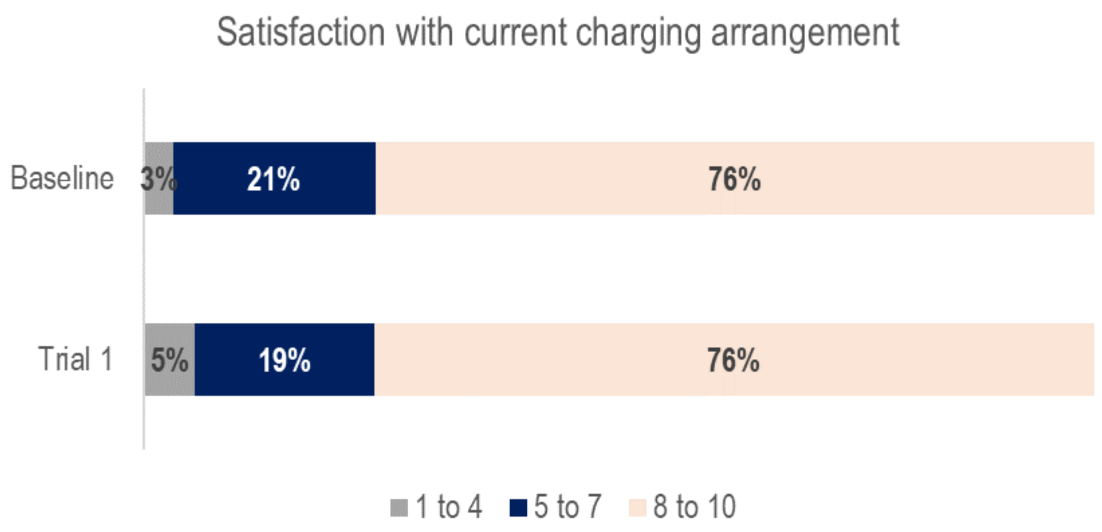


Figure 10-18: Satisfaction with current charging arrangements (Base: Baseline = 131, Trial 1 = 132, excludes those who answered 'don't know')

The level of satisfaction with current charging arrangements remained very similar between the two surveys. They change shown above (e.g. decrease in neutral scores between Baseline and Trial 1) are not significant[89]. The proportion of participants who were 'highly satisfied' (scores 8 to 10) remained static.

The Trial 1 results are shown below, disaggregated by vehicle type.

[88] Z test. Z = 2.07.
[89] Z test. Z = 0.51.

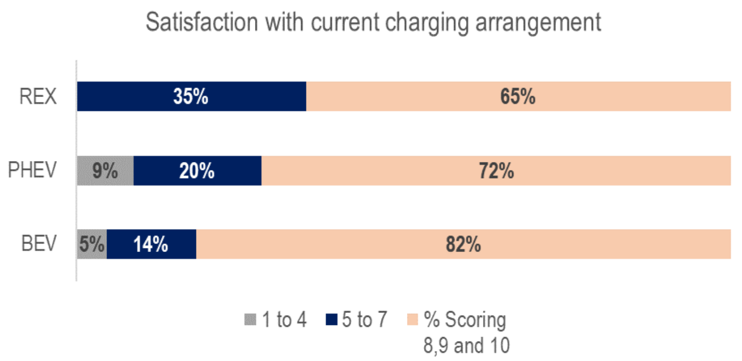


Figure 10-19: Trial 1 Satisfaction results by PEV Type (Base: REX 20, PHEV 46, BEV 66)

The table below compares the proportion of participants who were highly satisfied (score of 8 to 10) in the Baseline and Trial 1 surveys, by PEV type and battery capacity.

Table 10-3: Comparison of % of Respondents Giving Satisfaction Scores 8, 9 and 10 between Baseline and Trial 1

Group		Sample Size	% of Survey Responses Scoring 8 - 10	
			Baseline	Trial 1
PEV Type	REX	20	75%	65%
	PHEV	46	65%	72%
	BEV	66	83%	82%
Battery Capacity	Less than 10kWh	31	65%	71%
	10 to 25kWh	35	76%	71%
	25 to 35kWh	43	84%	86%
	35kWh+	23	74%	70%

No sub-group had a statistically significant change in the proportion of participants who were highly satisfied between the Baseline and Trial 1 surveys.

Participants were also asked about their willingness to continue with the current charging arrangements. Figure 10-20 shows the breakdown of results for all respondents who completed both a Baseline and Trial 1 survey.

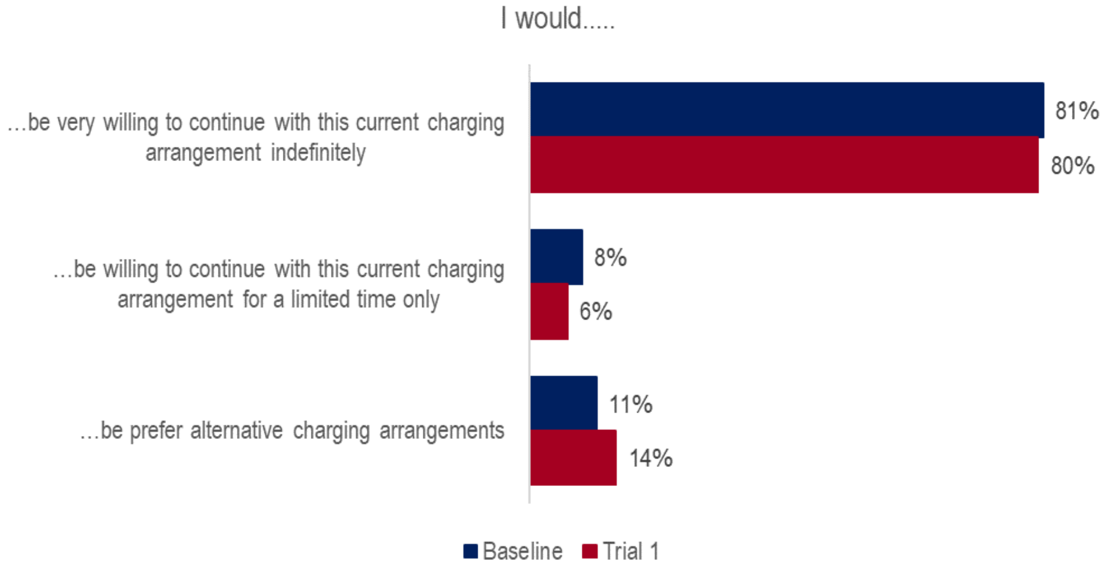


Figure 10-20: Willingness to continue with charging arrangements (Base: 132 for both surveys)

Overall, sentiment remained similar to the Baseline survey. The changes in each category between the two surveys were not statistically significant.

Table 10-4 disaggregates both the Baseline and Trial 1 results by vehicle type, showing the proportion of respondents who would be willing to continue with their charging arrangements indefinitely.

Table 10-4: Proportion of Participants Willing to Continue with Charging Arrangements Indefinitely - by PEV Type

Group		Sample Size	% of Survey Respondents Willing to Continue with Charging Arrangements Indefinitely	
			Baseline	Trial 1
PEV Type	REX	20	95%	75%
	PHEV	46	76%	74%
	BEV	66	80%	86%

The largest change in the proportion of respondents willing to continue with their charging arrangements indefinitely occurred in the 'REX' group. This result is statistically significant at the 10% level (rather than the 5% level used elsewhere in this report), partly due the low sample size involved. The reasons for this are not clear. The link between the amount of management experienced and satisfaction/acceptability is explored in Section 10.1.6.

When participants were asked to explain the reasons for their answer, many expressed dissatisfactions with the public charging infrastructure (Figure 10-21).

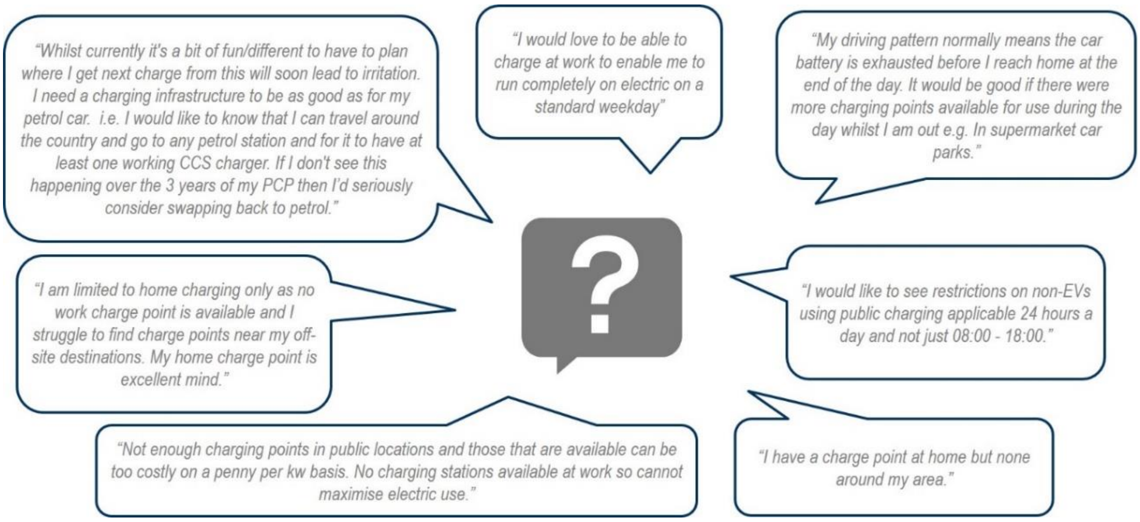


Figure 10-21: Why did you say that? (Base: 134)

Others expressed difficulties with the physical characteristics of the charger (Figure 10-22).

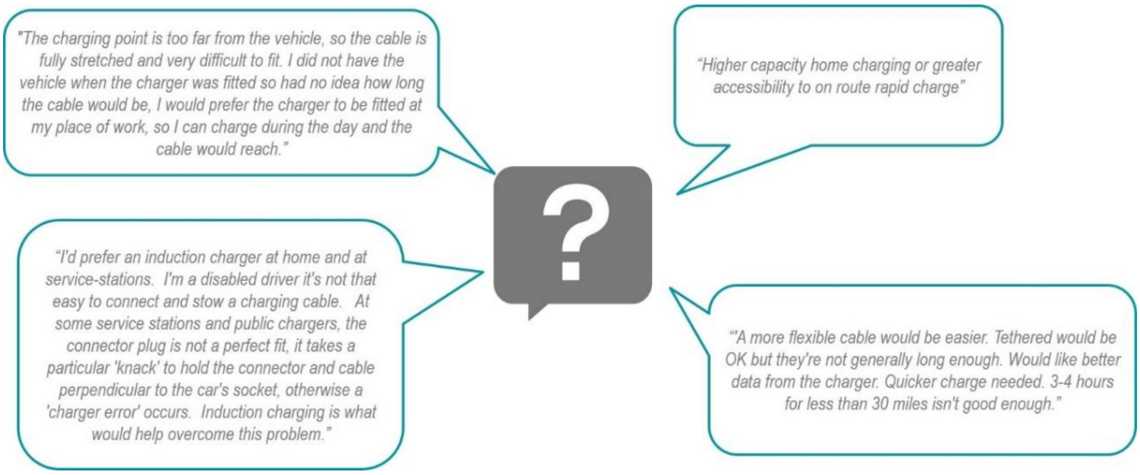


Figure 10-22: Why did you say that (Base: 134)

Participants were asked whether they were concerned about having their charging managed as part of the trial. The results for the whole CrowdCharge cohort are shown below, compared to the baseline survey results.

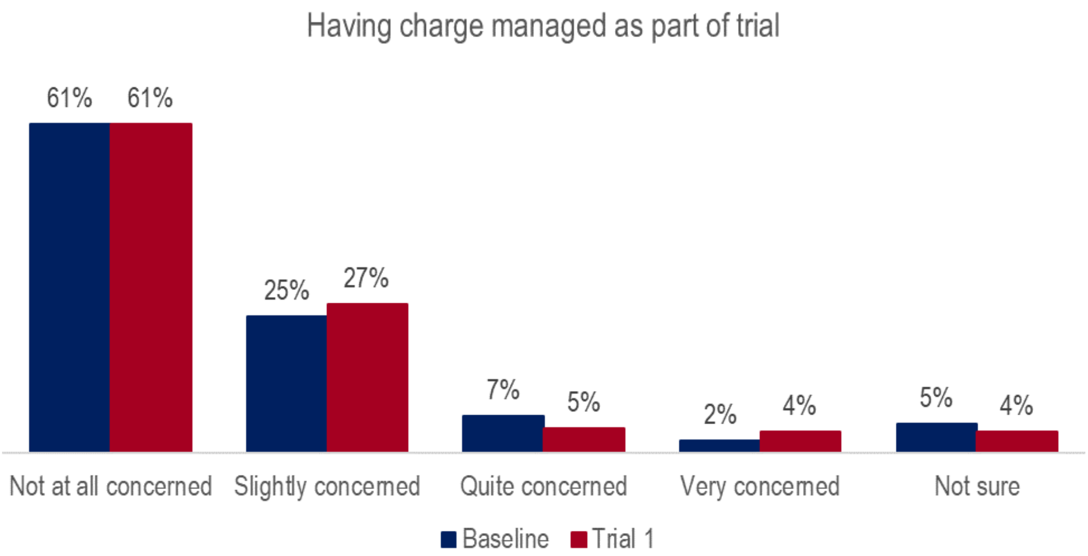


Figure 10-23: Concern re: Demand Management (Base: 134 for Baseline and Trial 1)

The results are very similar between the Baseline and Trial 1 surveys (i.e. no statistically significant changes). The proportion of respondents who were 'not at all concerned' in each battery capacity group is shown below.

Table 10-5: Proportion of Participants willing to continue with charging arrangements indefinitely by battery capacity group (Baseline and Trial 1)

Battery Capacity	Sample Size	% of Respondents 'Not At All' Concerned (Trial 1)
Less than 10kWh	31	68%
10 to 25kWh	35	54%
25 to 35kWh	43	53%
35kWh plus	23	74%

Analysis of the results above show that the largest difference (occurring between the '35kWh plus' and '25 to 35kWh' groups is statistically significant at the 10% level[90] (rather than the 5% level used elsewhere – partly due to the small sample size).

Participants were asked to explain the reason for their response. A sample of the reasons given by those who were not concerned about demand management are shown below (Figure 10-24).

[90] Z Test. Z = 1.66

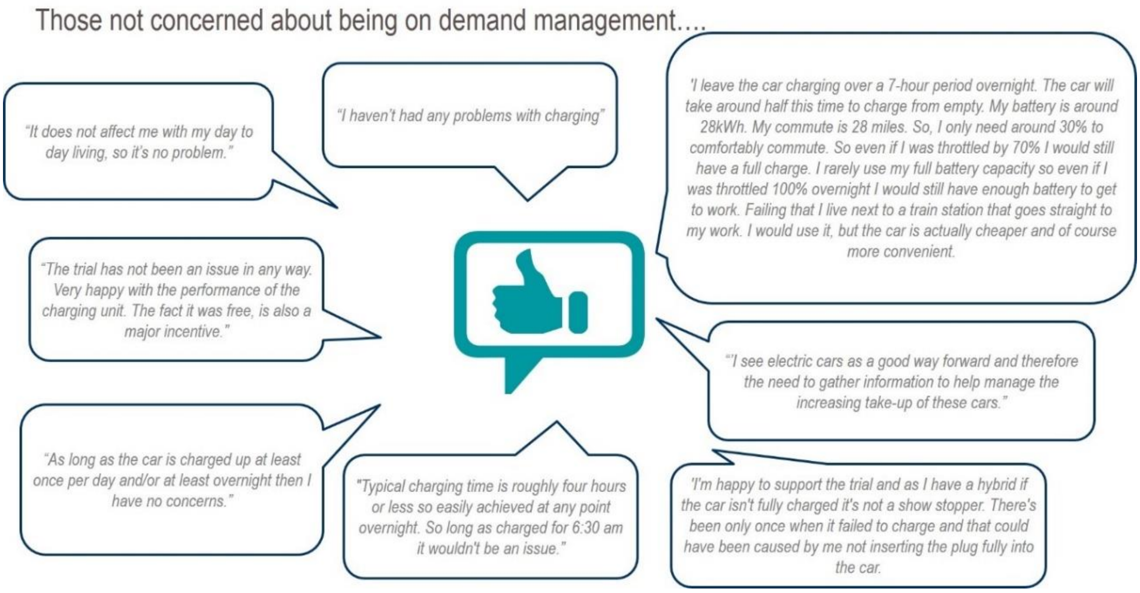


Figure 10-24: Why did you say that? (Base: 134)

A sample of the reasons given by those who were concerned about demand management are shown below (Figure 10-25).

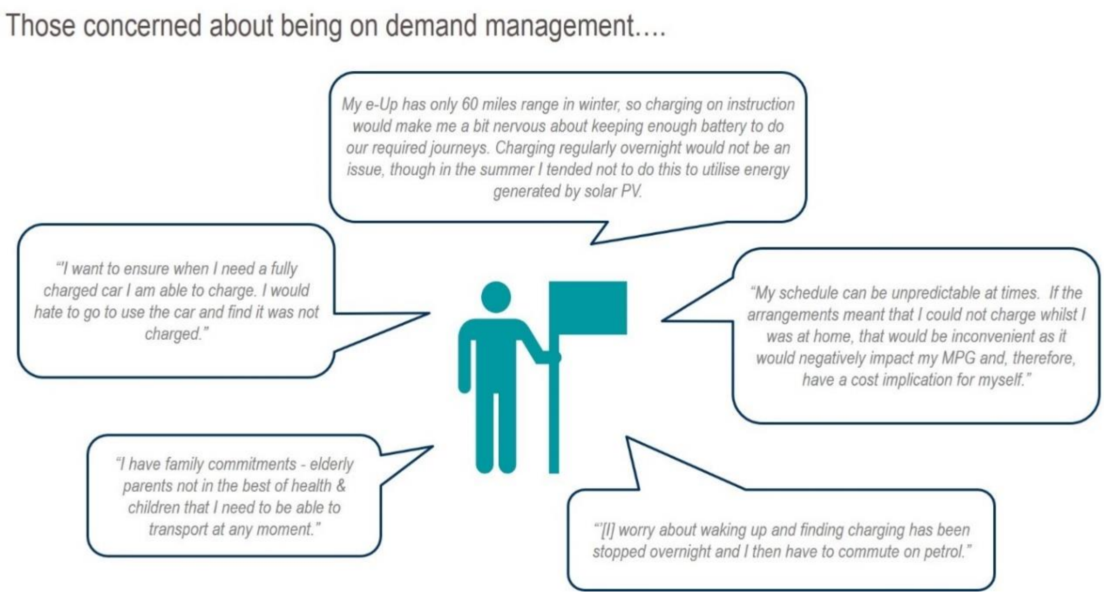


Figure 10-25: Why did you say that? (Base: 134)

10.1.5.4 Trial 1 Findings from Focus Groups

At the end of the trial, a focus group was held in which further qualitative information was collected from a small group of participants (there were five participants in the focus group; one additional participant took part in an in-depth telephone interview). Some of the information provided in relation to Trial 1 is shown below.

In general, CrowdCharge focus group participants did not notice their demand being managed during Trial 1. For most, they charged their cars overnight and as long as it was charged in the morning, they were happy. This aligns with the data shown above regarding the 'hot unplug' rate and the flexibility evident in Section 8. For this reason, as well as agreeing with the reasoning behind the need to manage demand, CrowdCharge participants were very accepting of their Trial 1 experience.

A selection of quotes is shown below:

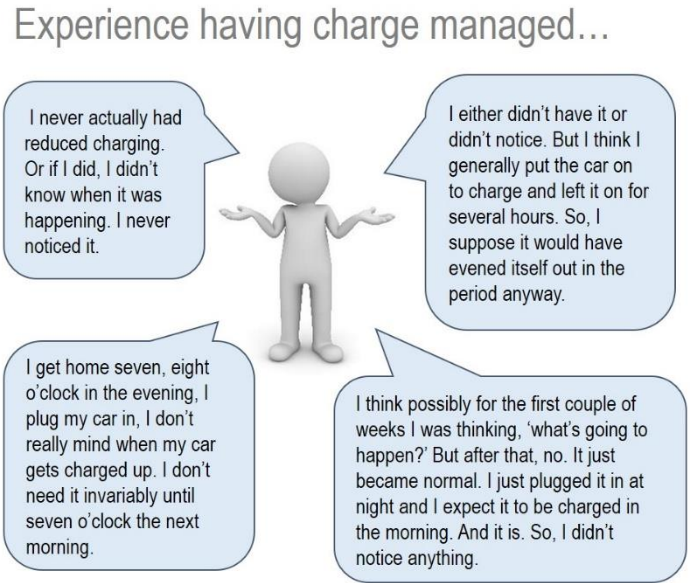


Figure 10-26: CrowdCharge Focus Group Quotations on the Experience of Having Managed Charging

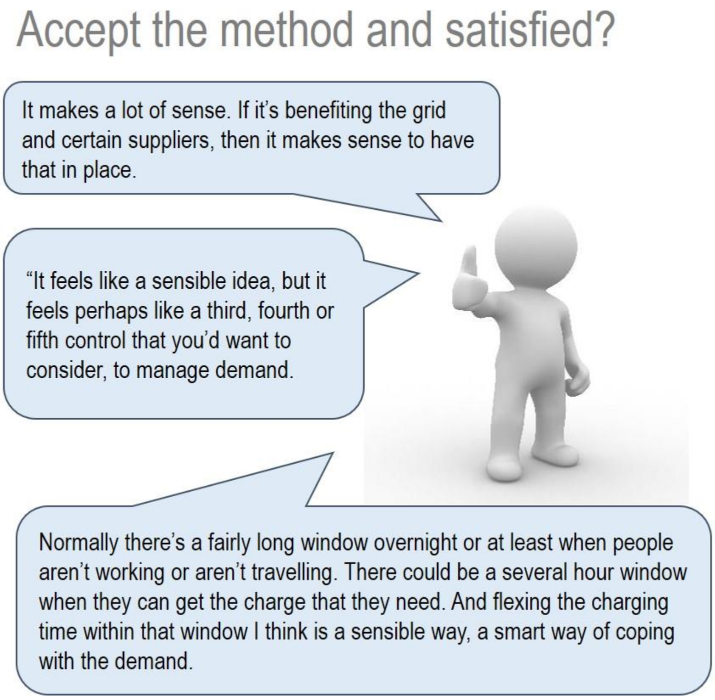


Figure 10-27: Focus Group Quotations regarding the acceptability and satisfaction with Trial 1

Some challenges and concerns were expressed by focus group participants regarding Trial 1 and these are shown below. Overall, there remained some anxiety that their vehicles would not be charged by the time they wanted to drive, and some participants wanted more information to be available to them.

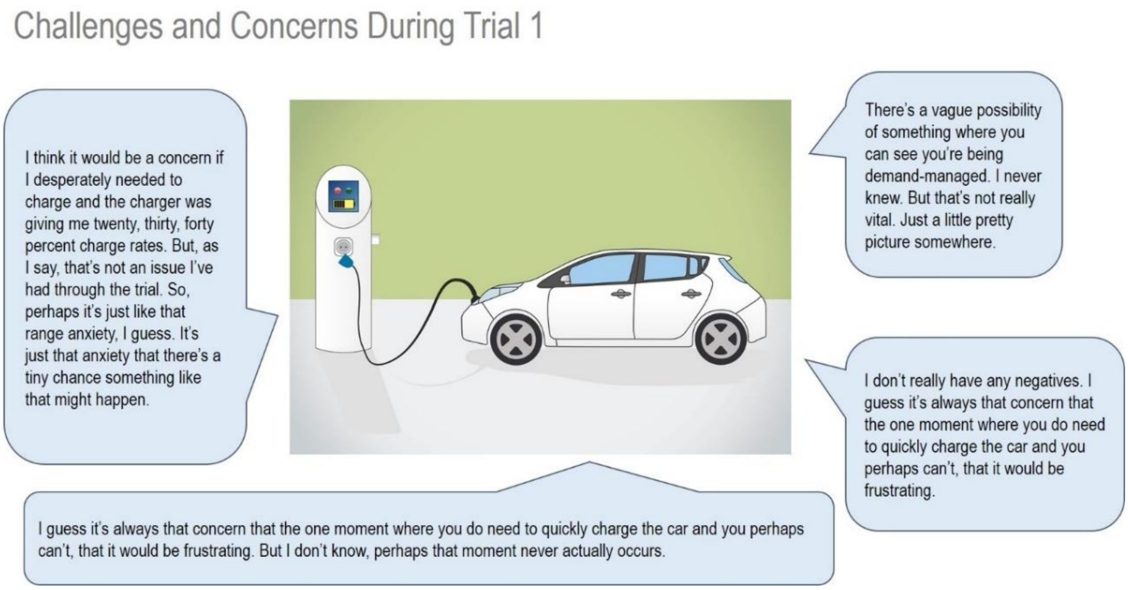


Figure 10-28: Focus Group Quotations relating to challenges and concerns in Trial 1

10.1.5.5 Summary

To summarise, a comparison of the acceptability and satisfaction scores given by the participants who completed both a Trial 1 and Baseline survey showed no statistically significant change in either metric – despite the levels of management shown in Sections 10.1.3 and 10.1.4. The majority of participants continued to have very few concerns about having their charge managed as part of the Electric Nation project.

10.1.6 Key Findings – CrowdCharge Trial 1

- In the evening peak, the 90th Percentile peak demand was approximately 600W per charger (e.g. in a group of 100 chargers the peak demand during the evening would be less than 60kW on 90% of days). This demand was constrained by the use of demand management. Unrestricted demand would be higher.
- A second, higher peak in demand occurred at approximately 01:00, with a 90th percentile value of 825W per charger.
- During Trial 1 management was frequently active during the evening peak, particularly on weekdays. This management occurred when the total demand from EV chargers (if they were all given their maximum allocation of current) exceeded the amount of current available in the capacity profile.
- Demand management led to individual chargers having their charging rate reduced (e.g. from 32A to 17A). This did not lead to an increase in the proportion of charging events where vehicles were not fully charged when unplugged. In fact, amongst participants who took part in Trial 1 there was a statistically decrease in the proportion of charging events which were 'hot unplugged' from this proportion dropped from 18.9% (outside of management) to 16.8% (during Trial 1).
- 8% of charging events during Trial 1 were constrained by demand management (2,226 charging events).
- 75% of participants experienced some management of their charging events.
- Participants with 32A vehicles experienced more management than those with 16A vehicles. The management they experienced was also more restrictive.
- Participants who used timers most frequently experienced less management. Timers are generally used to move charging to the overnight period, when management was not active.
- Table 10-6 below, relates the scores given for participants **satisfaction** with their current charging arrangements in the Trial 1 survey to values of CrowdCharge Management Factor (i.e. 86% of participants who were not managed in Trial 1 gave a satisfaction score of 8 – 10):

Table 10-6: Relationship between Amount of Management and Satisfaction Scores

Group	Sample Size[91]	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
Not Managed During Trial 1	22	0%	14%	86%
CrowdCharge Management Factor 1st Quartile	28	7%	7%	86%
CrowdCharge Management Factor 2nd Quartile	21	5%	24%	71%
CrowdCharge Management Factor 3rd Quartile	32	3%	25%	72%
CrowdCharge Management Factor 4th Quartile	25	0%	28%	72%

This shows that increasing amounts of management do not lead to higher rates of dissatisfaction. There is a trend towards neutrality for groups of participants who experienced more restrictive management. Combining the 'never managed' and '1st Quartile' groups shows that 10% of these participants gave a neutral score, compared to 28% of the '4th Quartile' group – a statistically significant difference[92].

[91] Sample sizes are not equal between the quartiles as the survey response rate varied.
[92] Z test. Z = 2.0

- Table 10-7 relates the scores given by participants for the **acceptability** of their current charging arrangements in the Trial 1 survey to values of CrowdCharge Management Factor (i.e. 91% of participants who were not managed during Trial 1 gave an acceptability score of 8 – 10)

Table 10-7: Relationship between Amount of Management and Acceptability Scores

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
Not Managed During Trial 1	23	0%	9%	91%
CrowdCharge Management Factor 1st Quartile	28	0%	14%	86%
CrowdCharge Management Factor 2nd Quartile	21	5%	19%	76%
CrowdCharge Management Factor 3rd Quartile	32	9%	25%	66%
CrowdCharge Management Factor 4th Quartile	25	0%	20%	80%

This shows a similar trend to the satisfaction results, although slight differences in the scores mean that there are no statistically significant differences. This supports the conclusion that during Trial 1 there was no relationship between levels of acceptance and the amount of demand management participants experienced.

- There was no statistically significance difference between the Baseline and Trial 1 surveys for the proportion of participants who were willing to continue with their charging arrangements indefinitely (Baseline = 81%, Trial 1 = 80%).
- Participants who expressed dissatisfaction with their charging arrangements were more likely to cite causes such as charging infrastructure away from home, the physical location of the charger, or issues with the cable, than concerns about smart charging.
- The focus group responses from CrowdCharge Trial 1 participants indicated that the participants were often not aware that demand management had occurred.

10.2 GreenFlux

10.2.1 Description of Trial

Trial 1 involved deployment of the simplest version of the GreenFlux smart charging system. Throughout the trial, GreenFlux could determine whether a car was rated at 16A or 32A each time the vehicle was plugged in. The algorithm then allocated 16A or 32A to that charging transaction, depending on the vehicle's nominal charging power.

Demand management occurred when it was no longer possible to allocate all vehicles their maximum rating (either 16A or 32A).

For example, if the capacity limit was 300A and six 32A and six 16A cars were charging then all vehicles would be given their maximum allocation ((6 x 32) + (6 x 16) = 288A). If another 16A vehicle connected then management would become active (total demand = 288A +16A = 304A, with the constraint shared amongst the group[93].

This approach meant that the number of chargers which could be active before management would occur for a given capacity limit depended on the mix of 16A and 32A vehicles connected.

In the 300A example, between 9 (all 32A) and 18 (all 16A) chargers could be active before management began.

An example of the testing of this system can be seen in Section 3 of this report (Section 4.8.2). During this part of the trial there was no possibility for customers to interact with the GreenFlux system (i.e. no app available).

The first group of participants moved into Trial 1 on 11th July 2017. Over the course of the Trial different seasonal profiles were applied (see Figure 4-12), over the following dates:

- Summer: 11th July – 22nd September 2017;
- Autumn: 22nd September – 17th November 2017;
- Winter: 17th November 2017 – 12th April 2018 (a Christmas profile was applied from 18th December 2017 to 4th January 2018 which prevented any curtailment occurring);
- Spring: 12th April to 23rd May 2018; and
- 'Spring-Winter' Combined: 23rd May – 30th May 2018 (end of Trial 1).

The use of different seasonal profiles in the GreenFlux group was similar to the CrowdCharge part of Trial 1, and the reasons for this are given in Section 10.1.1.

[93] The exact method used for sharing the constraint is part of GreenFlux's proprietary algorithm, so limited details are included within this report. An example of a constraint being shared amongst chargers can be found in Figure 4-11 in Section 4.8.2.

The results on group level demand and the periods when management was active at a group level presented in this section will focus on the time when winter profiles were in operation, as this represents the highest level of demand and the most severe period of management. The individual participant experience data includes the full duration of Trial 1 for each participant in order to cover their experience of the whole of Trial 1.

10.2.2 Demand Profiles

This section sets out the power demand for groups of GreenFlux chargers, in a similar manner to that shown for CrowdCharge above (see Section 10.1.2).

Two pieces of data were supplied by GreenFlux in relation to the current drawn and allocated to GreenFlux chargers:

- Current meter values, reported once every three minutes showing the current being drawn by each active charger; and
- Allocation data showing the current allocated to each active charger by the GreenFlux back office, reported for each 15-minute block of time (e.g. 10:00 – 10:15).

Profiles of power demand (and the occurrence of management at a group level, see Section 10.2.3) are based on the 15-minute data, therefore the current drawn by each charger has been averaged across the relevant 15-minute period (e.g. if current drawn was reported at 10:02, 10:05, 10:08 and 10:11 then these four values would be averaged to give the average current drawn in the 10:00 – 10:15 block).

This section shows demand profiles (total power drawn for groups of chargers) for the winter period, using data from 4th January to 7th March 2018 (allowing comparison with the CrowdCharge profiles above). During this time, the groups contained between 143 and 209 chargers. Profiles below are expressed in Watts per Charger in Group. The following conversions have been made:

- Current Drawn in Amps has been converted to power in Watts using an assumed voltage of 240V; and
- The total demand is a function of the number of chargers in the group. Total demand (in Watts) has been divided by the number of chargers in the group at the time, so that groups from different points in the project (where different number of chargers were in the group) are comparable.

Profiles have been developed by combining data across the winter period (5th Jan. to 11th March 2018), either by both day of the week and time, or by weekday/weekend and time. Data from earlier in winter (November and December) has been excluded due to data inaccuracies, meaning it was not clear when and to what extent management was active. Further details of this are given in Section 10.2.3.

Figure 10-29 shows the maximum, 90th percentile and average demand for the Trial 1 group on weekdays between 5th January and 11th March 2018 (inclusive).

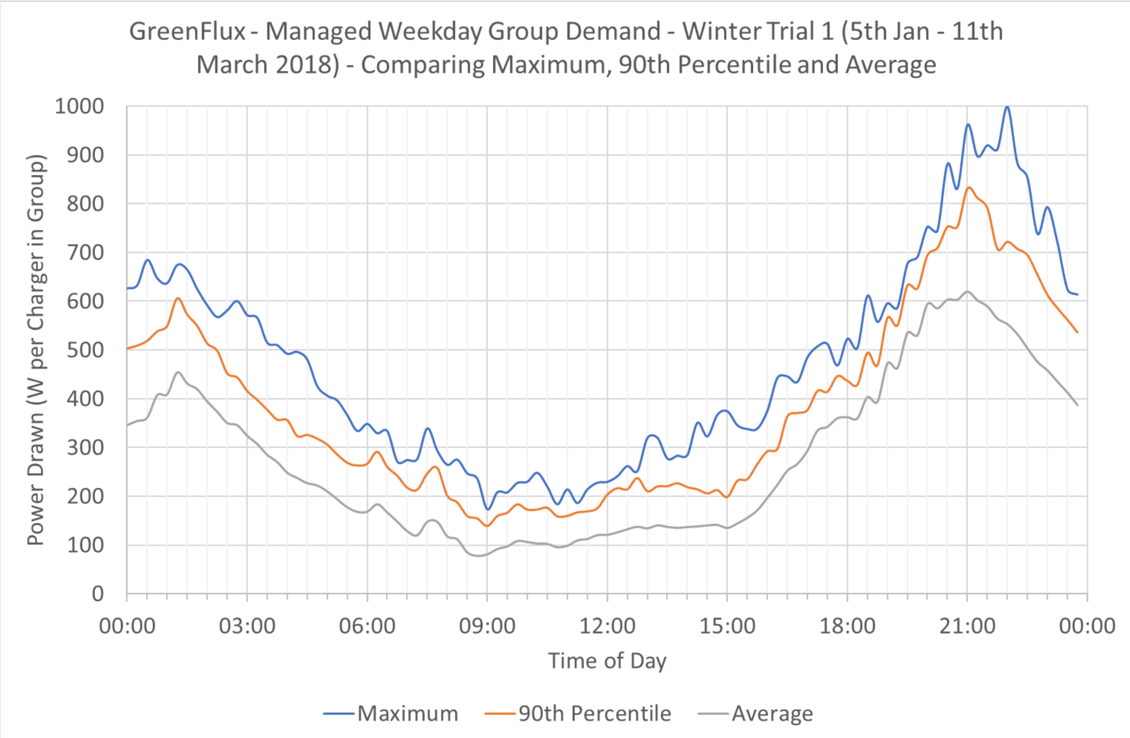


Figure 10-29: GreenFlux Winter Trial 1 Managed Group Demand - Weekdays (Maximum, 90th Percentile, Average)

This graph illustrates the variability in the current drawn at each time of day from day to day, with the evening peak typically 200W per charger higher on the 90th percentile day compared to the average, and maximum demand higher again. The shape of the graph shows the variation in demand across the day, with the following main points:

- A steady increase in demand from the middle of the afternoon (15:00) until around 21:00;
  - In this case the evening peak demand has been restricted by the use of demand management, so the 'unrestricted' profile would result in a different shape. This is explored in Section 8.10;
- A slight increase in demand is observed between 00:00 and 01:30, compared to the declining demand prior to this. The change is not as pronounced as for the CrowdCharge group, see 10.1.2.
  As explained above, further analysis of the data shows that although the proportion of participants who have a dual-rate meter are comparable between the GreenFlux and CrowdCharge cohorts (15% vs. 19%) it appears that CrowdCharge participants with a dual-rate meter were more likely to use timers than their GreenFlux

counterparts[94] – resulting in the higher observed night time demand in the CrowdCharge group; and

- A small increase in demand occurs around 7:30, probably from participant's making use of the 'pre-heat' function on their vehicles. This increase in demand was not large enough to require demand management.

Figure 10-30 compare the 90th percentile weekday and weekend demand curves.

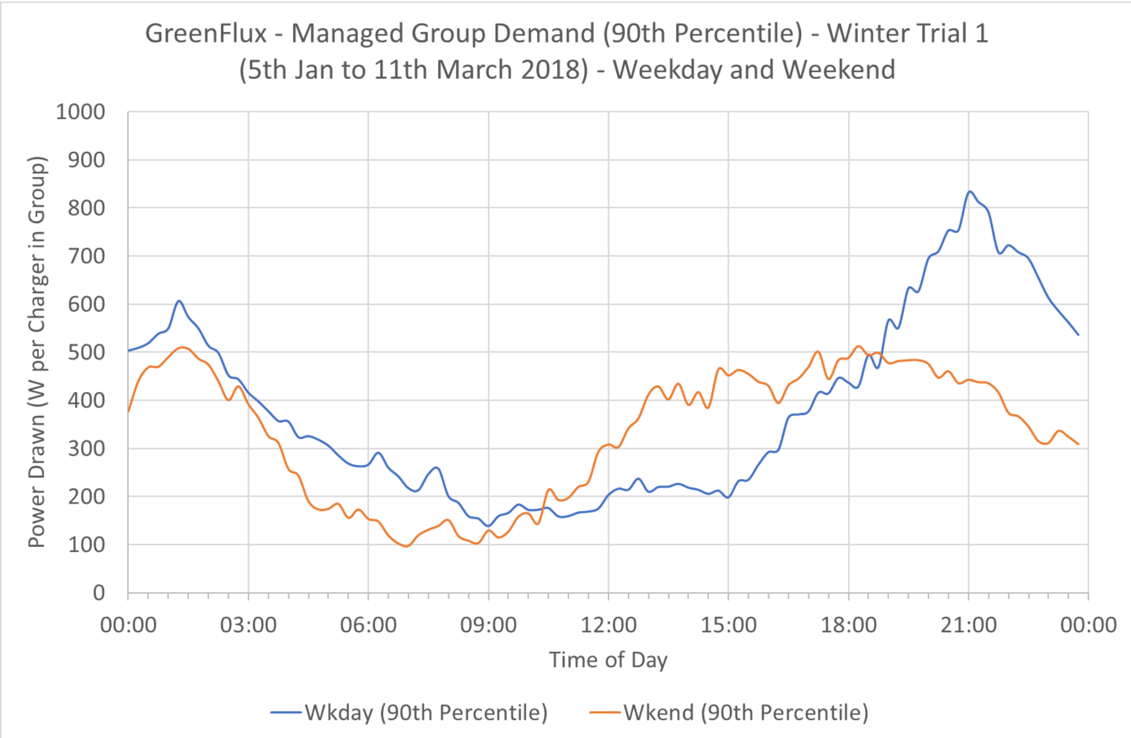


Figure 10-30: GreenFlux Winter Trial 1 Managed Group Demand - Comparing Weekday and Weekend (90th Percentile)

This shows a much flatter demand curve on weekends, as demand during the early afternoon is higher than on weekdays. Demand in the evening is lower (peak of 500W per charger at 18:00 at the weekends, compared to 830W per charger at 21:00 on weekdays). The lower weekend evening peak (compared to weekdays) aligns with the amount of management which took place at weekdays and weekends (see next section). An increase in demand in the early hours of the morning still occurs, potentially indicating that although fewer participants are connecting their cars to charge at the weekend, those who use a timer continue to do so at the weekend.

The profiles shown above grouped all weekdays (Monday – Friday) and weekend days (Saturday and Sunday) together. There may be trends within the week – for example higher

[94] The reasons for this difference are not clear. Participants were randomly allocated to either CrowdCharge or GreenFlux. They were not provided with any differing information that may have led to the CrowdCharge group choosing to use timers.

demand on Mondays compared to Fridays. Figure 10-31 shows the 90th percentile of group demand (W per charger in the group) from the winter period, shown across seven days.

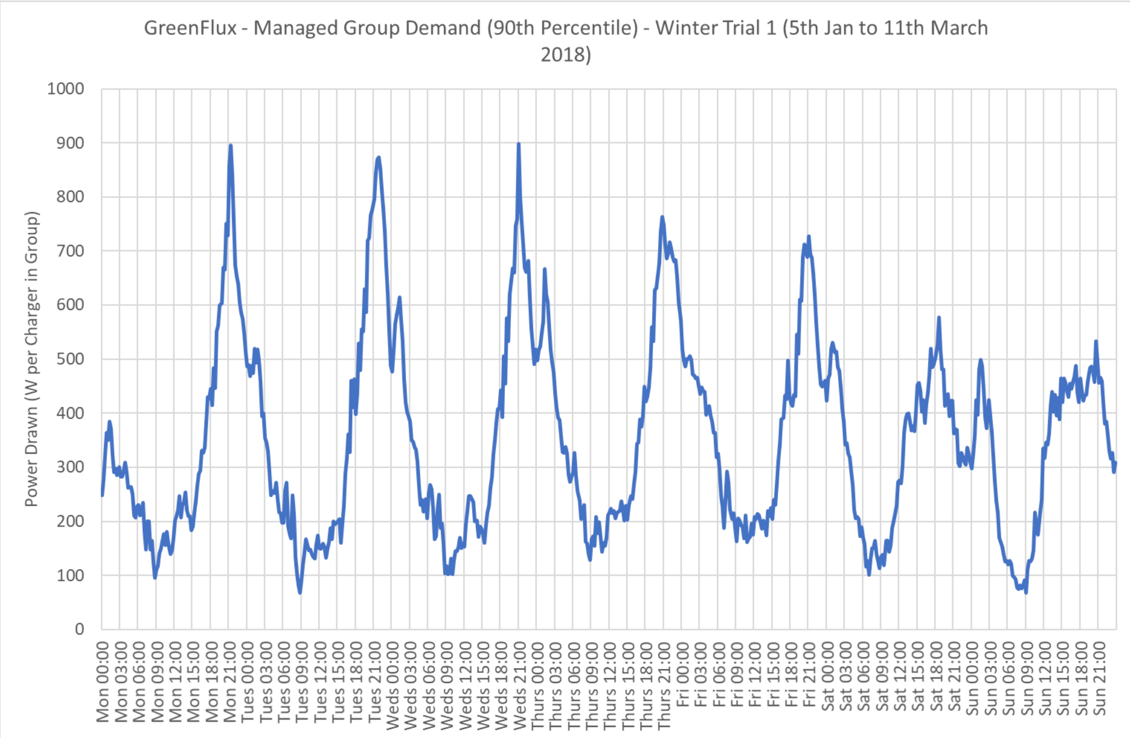


Figure 10-31: GreenFlux Winter Trial 1 Managed Group Demand - 7 Day (90th Percentile)

This shows a similar pattern of demand from Monday – Wednesday in all cases, with two peaks: one in the evening and another, smaller peak at around 01:30. Weekend demand is considerably lower, with greater daytime demand. Demand on Thursday and Friday is of a similar shape to other weekdays, but the magnitude of the peaks in demand is smaller. As participants were randomly allocated to either CrowdCharge or GreenFlux, there is no clear reason for the difference between the two groups.

10.2.3 Occurrence of Demand Management – Group Level

As described above, during Trial 1 GreenFlux began to constrain charging when it was no longer possible to allocate all active chargers their required 16A or 32A (based on a test of the car's nominal charging rate at the start of each charging event). Management was deemed to be active when the total current allocated to chargers[95] was within 13A of the capacity limit (e.g. if the capacity limit was 500A and 490A were allocated to chargers in the group, then management was active).

[95] Allocations to individual chargers of 13A were excluded from these totals. Once charging was complete a charger moved to a 'low priority' status and allocated either 13A or 0A. Management became active when it was not possible to allocate the maximum rating to all chargers in the 'normal' priority group. Low priority chargers were only allocated current if some remained after all 'normal priority' chargers had received a full allocation.

Throughout Trial 1, 17 different capacity profiles were implemented which varied with season and the number of chargers in the group. The capacity profiles were scaled so that management would occur at the same frequency as the number of chargers in the group was increased (see graph, Figure 4-12).

This figure also shows the time periods when different seasonal profiles were applied. The amount of management varied between seasons due to variations in the available network capacity and underlying demand from EV chargers (e.g. lower demand in summer due to warmer temperatures).

Table 10-8 summarises the seasonal profiles used through Trial 1 and the resulting amount of management at a group level.

Table 10-8: GreenFlux Trial 1 - Seasonal Profiles Used and Amount of Management

Seasonal Profile	Number of Minutes Active	Number of Managed Minutes	% of Minutes with Active Management
Spring	59,040	0	0%
Summer	104,580	585	0.6%
Autumn	80,580	420	0.5%
Winter[96]	140,640	3,435	2.4%
Spring Winter combined	10,080	690	6.8%

Management occurred less frequently than for the CrowdCharge group. This may be due to a more efficient distribution of current (allocating only 16A to 16A vehicles, rather than 32A to all). Management was more frequent for the short period at the end of Trial 1, when the 'Spring Winter' combined profile was active. However, this group consisted of 59 chargers, so the diversity factor was lower, potentially increasing the potential for management (for example, management in summer only occurred in the first group, containing only 16 participants).

This section shows the frequency of management when winter profiles were active, (excluding the period containing inaccurate data) – 5th January to 10th April 2018, as management was much less frequent on all other profiles, apart from the 'Spring Winter' combined profile. The 'Spring-Winter' period has not been used in this analysis as it was only used at the end of Trial 1, when the majority of GreenFlux participants had transferred into Trial 2. Small groups of chargers have less diversity, leading to demand management occurring more frequently. This section focuses on the most restrictive part of Trial 1 experienced by the majority of participants.

[96] The period from 17th November to 18th December has been excluded from the winter analysis due to inaccuracies in the data available for the group which was operational during this period.

Figure 10-32 shows the percentage of days, at each time of day, when management was active, separated by weekdays and weekends.

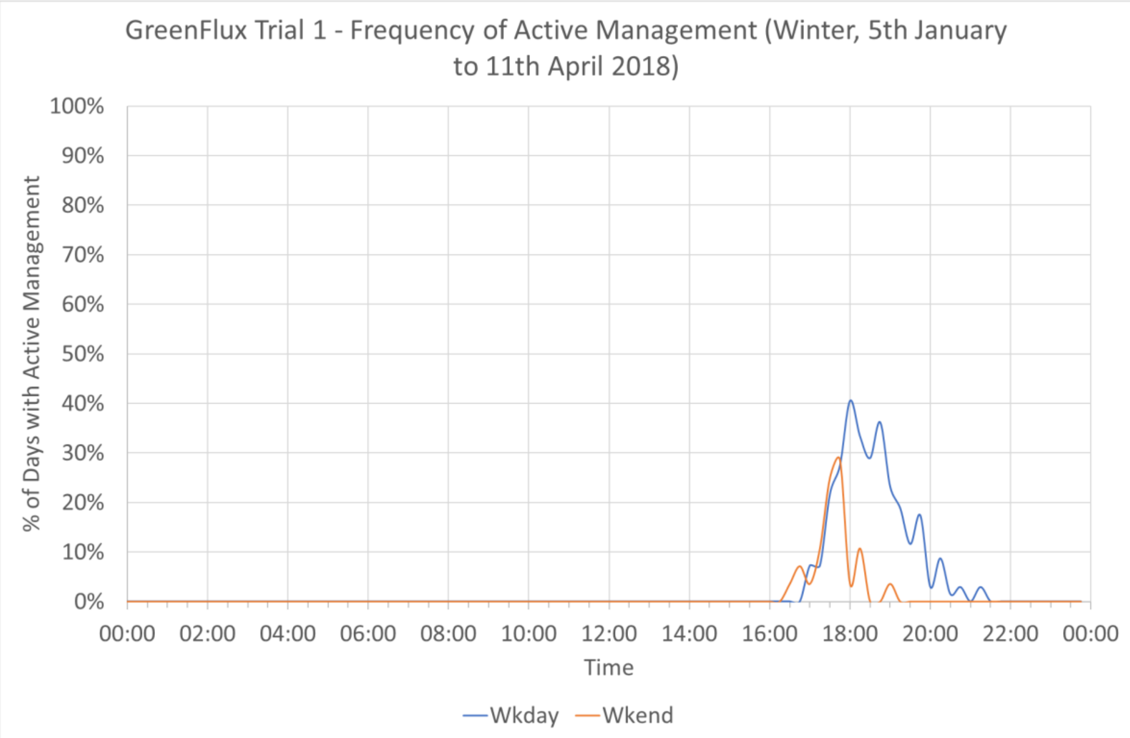


Figure 10-32: GreenFlux Winter Trial 1 - % of Days with Active Group Level Management

This shows that management only occurred during the evening peak, with management occurring between 17:00 and 21:15 on weekdays and 16:30 and 19:00 at the weekend. Management occurred on around 40% of weekdays and 30% of weekend days.

The impact this management had on individual participants is explored in detail in the next section.

10.2.4 Participant Experience of Management

Participants' experience of management varied for similar reasons to those outlined for CrowdCharge. Participants who rarely charged in the evening peak may never have experienced any management, whereas someone who habitually charged in the evening peak may have been constrained regularly.

This section outlines the amount of management which participants experienced, including the level of restriction they experienced. The key findings section (see Section 10.2.6) combines this data with the results of the Trial 1 survey to explore any link between the amount of management participants experienced in Trial 1 and their satisfaction with their charging arrangements.

One way in which management could have affected participants is to cause an increase in the proportion of charge events where vehicles are 'hot unplugged' (i.e. unplugged whilst still charging). Management reduces the current available to a charging vehicle, so may have led to vehicles not being fully charged when they were unplugged.

Outside of demand management the GreenFlux participants who took part in Trial 1 'hot unplugged' their vehicles for 1,186 of 8,066 charging events (where data is available to calculate start and end of charging) = 14.7%.

During Trial 1 GreenFlux participants 'hot unplugged' the vehicle for 2,887 of 19,119 events = 15.1%.

Across the population, there is no significant change[97] in the hot unplug rate that could have been attributed to demand management. This is to be expected, based on the level of flexibility available when management is active (see Figure 8-34).

Data from the trial (transactions, current meter values and allocation data) has been used to evaluate each transaction during Trial 1 and determine where or not it was curtailed (managed). The way in which restrictions are shared out means that not all participants who were charging during a demand management event would necessarily experience any curtailment.

For example, if ten chargers were active (five 16A vehicles and five 32A) then they would require 240A to charge without any restrictions. If the capacity limit for a one-hour period was 224A then one charger would experience curtailment in each 15 minute period, so during the one-hour long demand management event no more than four of the ten active chargers would be curtailed[98].

For each participant data from smart chargers has been used to calculate:

- How many times they charged their vehicle (at home) during the time when they were participating in Trial 1;
- How many of these charging sessions were curtailed (where meter values and allocation data are available); and
- To what degree they were curtailed (more details below).

22,974 charging events took place during Trial 1 (where consumed energy was 0.5 to 100kWh). Meter value and 15-minute allocation data has been used to determine whether individual charging sessions were managed.

[97] Z test comparing % of charging events hot unplugged between trials, using number of charging events as the sample size. Z =-0.84 (value of 1.96 would indicate 5% confidence level).
[98] The algorithm used to share this constraint is commercially sensitive. An illustrative example is provided in Figure 4-11.

Meter data is not available for charge sessions which took place when chargers were offline. This applies to 3,855 of the 22,974 charging events (17%). It is not possible to determine what level of constraint participants experienced during the charge events where current meter value data is not available. There are therefore 19,119 charging events where it is possible to show whether these events were managed. Of these, 3,306 events where constrained (17%).

241 participants were part of at least one Trial 1 group and transaction data is available for 225 of these participants.

Participants are included in the analysis below where they have more than five transactions during Trial 1, and where it is possible to determine whether their transactions were managed in at least 20% of their charging events. 215 participants meet these criteria. Of these 215 participants, 19% experienced no management.

The spread of the proportion of events which were curtailed is shown in Figure 10-33, separated by participants whose registered vehicle was rated at 16A (3.6kW) and 32A (7kW).

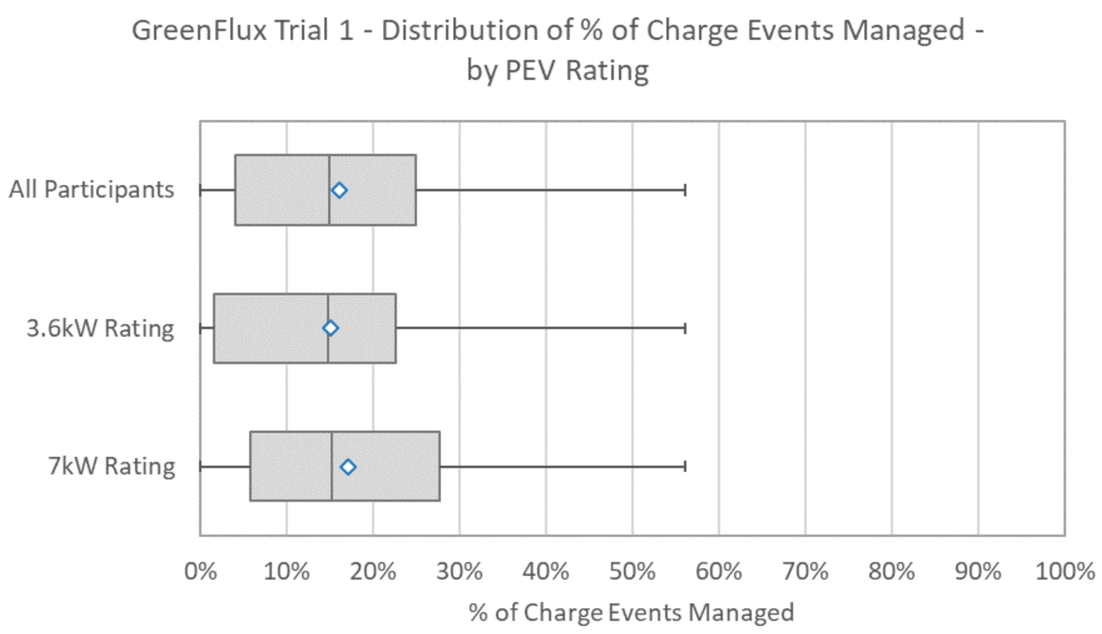


Figure 10-33: GreenFlux Trial 1 - % of Charge Events Managed - by PEV Rating

This shows that the number of times participants were managed during Trial 1 was not related to the rating of their vehicle. This is to be expected based on the GreenFlux algorithm, as 16A and 32A vehicles are equally likely to be managed. Other factors are more likely to influence how much management a participant experiences, particularly the use of timers.

For each participant, the proportion of their charge events involving a timer has been calculated. In the equivalent analysis of CrowdCharge participants presented in Section 10.1.4, participants were defined as a 'frequent' user of a timer if they had used one for more than 50% of their charging events. The same definition was applied to the GreenFlux cohort, and under this definition 44 of the 215 participants were 'frequent' timer users. The resulting distribution of management is shown in Figure 10-34, below.

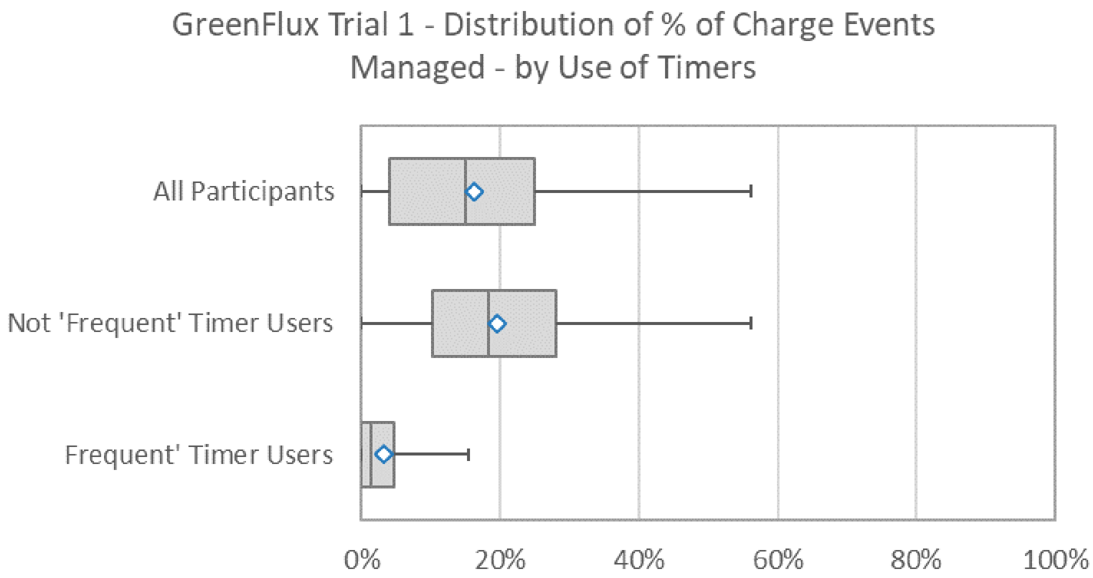


Figure 10-34: GreenFlux Trial 1 - % of Charge Events Managed - by Use of Timers

This shows that participants who use a timer frequently (more than 50% of their charging events) experienced management significantly[99] less frequently than those who used a timer less. The 'frequent' timer group accounted for 3,016 of the total charge events, but only 92 of these were managed (3.05%). The other group of Trial 1 participants (i.e. not frequent timer users) accounted for 16,049 charge events, of which 3,199 were managed (20%).

Figure 10-32 shows the times when management was active during Trial 1 and the frequency of this management. It shows that management was only active between 17:00 and 21:15 on weekdays and 16:30 and 19:00 at the weekend. Management occurred on around 40% of weekdays and 30% of weekend days. Therefore, participants who mainly charged outside of these time windows will have experienced less management than those who regularly charge in the evening peak. Each transaction has been evaluated to show whether or not it began between 16:00 and 19:59 Monday – Friday ('Began in Weekday Evening Peak').

[99] Z test. Z = 23.1 (value of 1.96 would indicate 5% confidence level)

Figure 10-35 shows the relationship between how many charging transactions began in the weekday evening peak, and how many transactions were managed, split by PEV rating (3.6kW and 7kW). Each dot on the graph represents a participant.

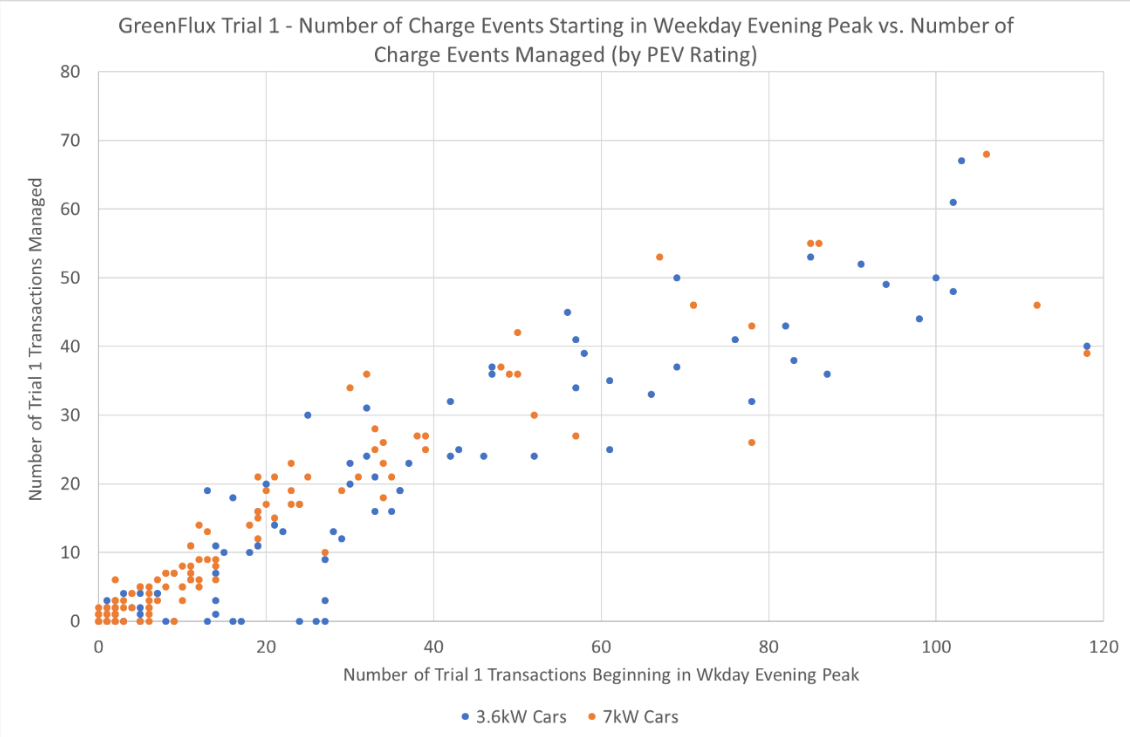


Figure 10-35: GreenFlux Trial 1 - Relationship between Number of Charge Events Beginning in Weekday Evening Peak and Number Managed

(N.B. "Beginning in Weekday Evening Peak" is defined as events where charging began between 16:00 and 19:59 Monday – Friday).

This shows correlation between the number of charge events which began in the weekday evening peak and the amount of management experienced[100]. Some variation between participants is to be expected, as management was only active on around 40% of weekdays during the winter period. It is possible that one participant's charging events happened to overlap with these days and another's occurred on the 60% of days which weren't managed. There is no clear difference between vehicles rated at 3.6kW or 7kW (as expected, see Figure 10-33).

The analysis above is based on a binary 'managed' or 'not managed' flag applied to each charging event. It does not include how restrictive the management was.

[100] Correlation function used to analyse the degree of correlation between 'Number of Charge Events Beginning in Weekday Evening Peak' and 'Number of Charge Events Managed'. Correlation value of 0.92 for both 3.6 and 7kW vehicles. Both of these values are statistically significant.

For example, a one-hour long charging event where the charger was paused for 15 minutes and another three-hour long charging event with a single 15-minute pause would both be flagged as 'managed'.

A measure has therefore been developed to show how restrictive management was for each charging event, using the quantities described below:

- Start of Charging Time= the time when charging began;
- $t_{Low\ Priority}$= the time when the current being drawn by the vehicle had reduced to 25% of the available current (e.g. drawing less than 8A when allocated 32A). This is used for the 'end of charging' time;
- Length of Time at Normal Priority = $t_{Low\ Priority}$ – Start of Charging Time (minutes) (equal to the charging duration);
- Number of Reduced or Zero Allocations = when GreenFlux curtail a charging session they receive an allocation value which is less than the maximum required (32 or 16A), or zero (a pause in charging). Each of these allocations last for 15 minutes; and
- Length of Time Managed = 15 x Number of Reduced or Zero Allocations (i.e. the length of time (in minutes) for which charging was curtailed).

The last two quantities are combined for all transactions which were managed, as follows:

$$\text{\% of Time Transaction Managed} = \frac{\text{Length of Time Managed (mins)}}{\text{Length of Time at Normal Priority (mins)}} \times 100$$

So, for the two examples above:

- A one-hour charging event where the charger was paused for 15 minutes:
  % of Time in Transaction Managed = 15 / 60 = 25%

- A three-hour charging event with a single 15-minute pause:
  % of Time in Transaction Managed = 15 /(3 x 60) = 8%

Using this measure, the restrictiveness of all of a participant's individual charging events can be calculated. The experience a participant had across each Trial is then related to the combination of these individual charging events. For the purposes of this analysis the median (i.e. middle value) for each participant has been calculated (based only on those transactions which were managed).

A single figure has been derived, 'GreenFlux Management Factor', which summarises both the frequency with which participants were managed, and the restrictiveness of this management (N.B. the CrowdCharge and GreenFlux Management Factors are not comparable):

GreenFlux Management Factor (each participant) "	=	% of Events Managed X Median % of Time in Transaction Managed

Three real examples from the GreenFlux data are given below:

- Participant EN1705:
    - Charged 27 times during Trial 1, none of their transactions were curtailed;
    - No 'Management Factor' has been calculated, and this participant will be included in the analysis of effect of management on participant satisfaction with their charging arrangements in a 'never managed' group;
- Participant EN1684:
    - Charged 54 times during Trial 1, 19 charging events were curtailed, so % of Events Managed = 35%;
    - % of Time in Transaction Managed for these nineteen events was: 3.6%, 4.6%, 5.6%, 5.9%, 6.3%, 6.7%, 7.7%, 10.0%, 10.0%, 12.5%, 15.4%, 15.8%, 18.3%, 20.2%, 25.4%, 27.4%, 28.8%, 37.8%, and 38.7%. The median value of these is 12.5%; and
    - GreenFlux Management Factor = 35% x 12.5% = 4.4%.
- Participant EN1671:
    - Charged 14 times during Trial 1, seven charging events were curtailed, so % of Events Managed = 50%;
    - % of Time in Transaction Managed for these seven events was: 10.5%, 17.7%, 18.2%, 19.1%, 19.1%, 33.6% and 38.2%. The median value of these is 19.1%; and
    - GreenFlux Management Factor = 50% x 19.1% = 9.6%

Therefore, participants who experience management less frequently, or for a lower proportion of their transactions have a lower 'GreenFlux Management Factor' than those who have experienced more, or more restrictive management.

The distribution of 'GreenFlux Management Factor' across the population of 175 GreenFlux participants who experienced some management during Trial 1 is shown in Figure 10-36, split by PEV rating.

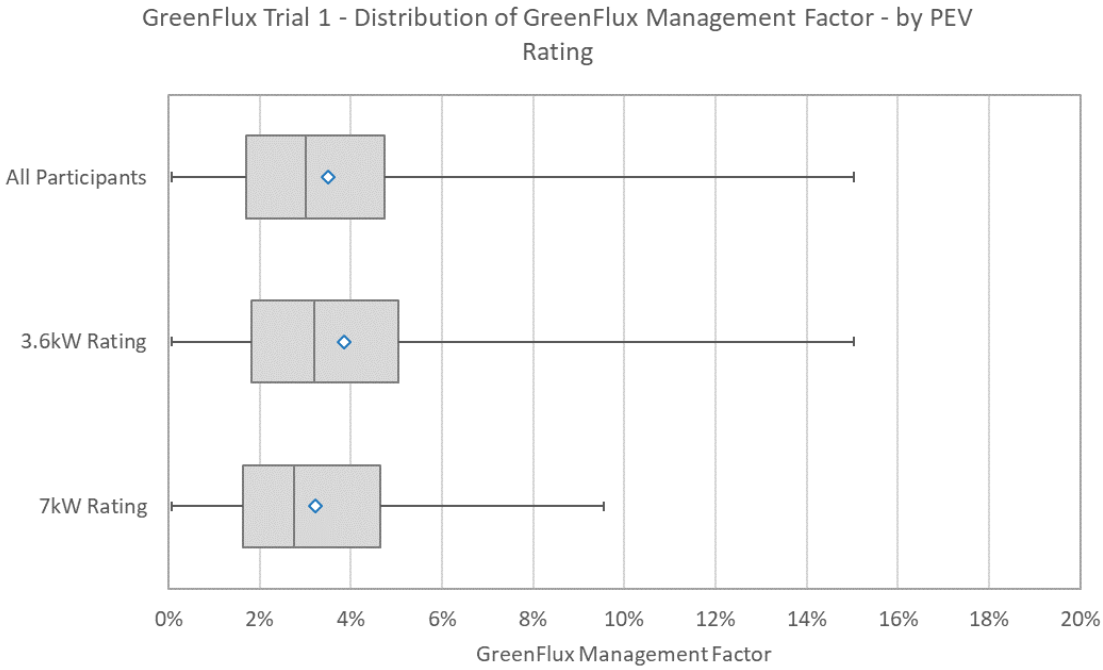


Figure 10-36: GreenFlux Trial 1 - GreenFlux Management Factor - by PEV Rating

This shows that GreenFlux Management Factor varied between 0.07% and 15%. The median value was 3%. There was not a strong relationship between PEV rating (3.6kW or 7kW) and GreenFlux Management Factor. The link between 'GreenFlux Management Factor' and participants satisfaction with their charging arrangements is explored in the key findings section (see Section 10.2.6).

10.2.5 Customer Research Results

GreenFlux participants were issued with a Trial 1 survey in same way as their CrowdCharge counterparts. After a participant had been subject to demand management for at least four weeks, they were issued a survey invitation by Impact. The Trial 1 survey covered many of the same quantitative and qualitative questions as the Baseline survey, in order to assess changes in behaviour and attitudes between the two stages of the project (before and after management was introduced). If a participant had completed the Recruitment and Baseline surveys, they were eligible for a £10 online voucher for completing this survey.

Trial participants were not informed when they were moved into demand management; in effect the trial participants were blind to the change. However, some may have noticed changes to their EV charging sessions as a consequence of demand management.

The Trial 1 survey was open for responses between 15/01/2018 and 28/04/2018. The full text of the Trial 1 survey can be found in Appendix 6. The table below shows the response rate from GreenFlux participants to the Trial 1 survey.

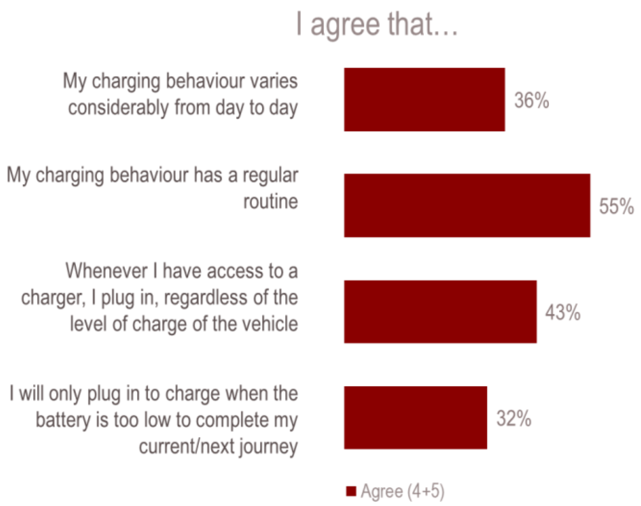
Table 10-9: GreenFlux Trial 1 Survey Response Rate

	Surveys Issued	Surveys Completed	Response Rate (%)
GreenFlux Trial 1	167	144	86%

Participants were only invited to complete a Trial 1 survey if they had moved into a management group during Trial 1, had completed both a baseline and recruitment survey, and had been part of Trial 1 for at least four weeks by the end of the survey period.

10.2.5.1 Reported change in charging behaviour

GreenFlux participants were asked about their charging behaviour as part of the Trial 1 survey. This can be compared against the equivalent results in the Baseline survey to show whether the introduction of demand management led to any changes in charging behaviour. Figure 10-37shows a breakdown of the responses across the whole cohort and by vehicle type.



Fuel Type		
PHEV (55)	BEV (68)	REX (21)
31%	44%	24%
67%	44%	57%
56%	31%	48%
31%	37%	19%

Figure 10-37: Reported charging behaviour by whole cohort and type of vehicle (144 survey responses)

When these results are compared to the equivalent breakdown in the baseline survey (for the same group of respondents – i.e. those that completed a Trial 1 survey), there are no statistically significant changes at either the whole population level, or within any individual vehicle type. Participants adopted similar charging 'strategies' when they completed the baseline and Trial 1 surveys.

When asked if they had actively changed their charging behaviour, 13% (18 participants) of respondents stated that they had. 44% of these, or 8 participants, stated they had changed the frequency with which they charged their vehicle (Figure 10-38).

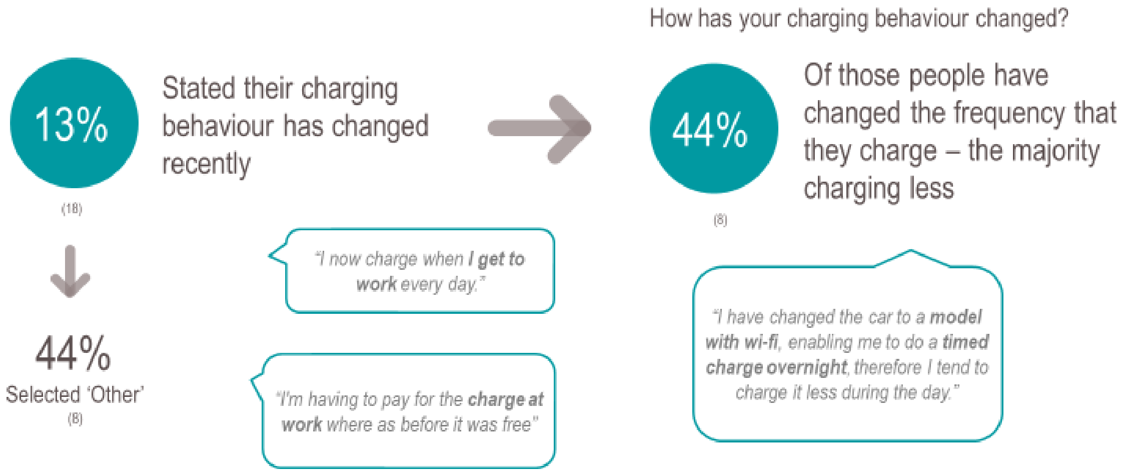
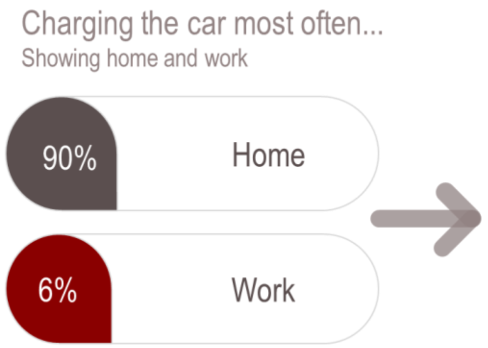


Figure 10-38: Stated changed in charging behaviour (18 respondents out of 144 surveys)

Participants reported that, on the whole, they had not changed where they were likely to charge their vehicle. Charging at home was still the most popular location (Figure 10-39) during Trial 1.



Charging car most often by Home vs. Work

Battery Size				Fuel Type		
<10 kWh	10-25kWh	26-35 kWh	>35 kWh	PHEV	BEV	REX
100% (36)	93% (38)	91% (40)	70% (16)	98% (54)	82% (56)	95% (20)
0% (0)	2% (1)	9% (4)	17% (4)	2% (1)	10% (7)	5% (1)

Figure 10-39: Where do participants charge their vehicle most frequently (based on 144 responses)

Participants with larger batteries[101], or whose vehicles are BEVs were more likely to charge their vehicle at work than other participants[102]. However, behaviour around charging location remained unchanged, with home charging continuing to dominate.

10.2.5.2 Frequency of charging

Participants were asked how frequently they charged their vehicle at each of the locations they indicated that they used for charging. These responses were compared to the replies received in the baseline survey for home (Figure 10-40) and work (Figure 10-41).

[101] Statistically significant. Z test. Z value = 2.2 (a value of 1.96 would indicate confidence at the 5% level), comparing those with a 35kWh plus battery to all other respondents.
[102] Statistically significant. Z test. Z value = 1.97, comparing those with a BEV to all other respondents.

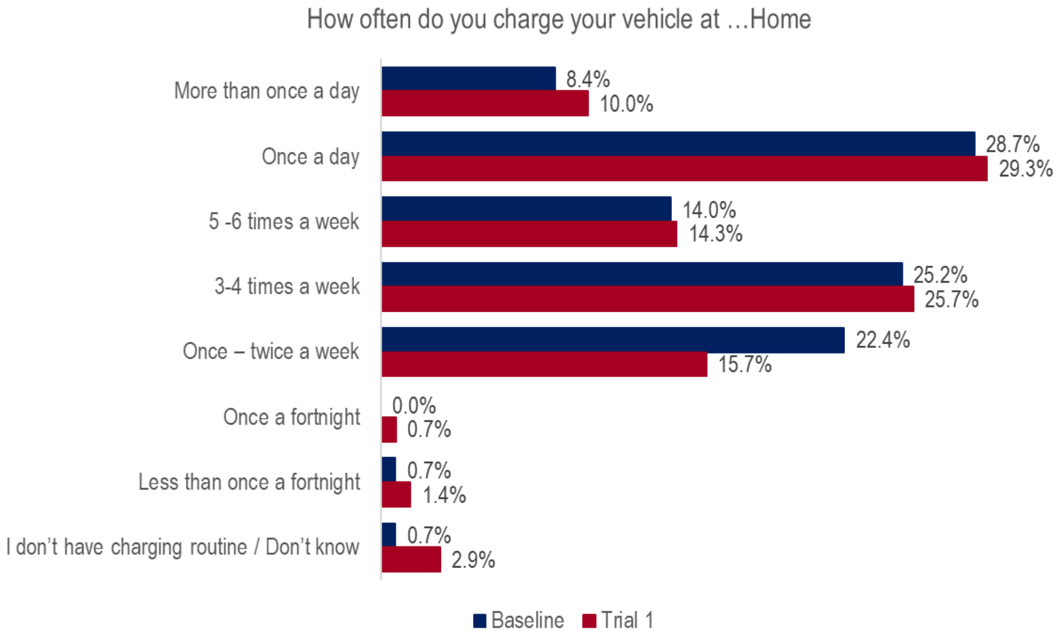


Figure 10-40: How often do you charge your vehicle at home (Base: Baseline = 143, Trial 1 = 140 - not all survey respondents charged at home in both surveys)

Examining the responses of those who participated in both surveys, there appears to have been a shift to more frequent charging (e.g. an increase in the proportion of respondents indicating they charged 5 – 6 times a week or more from 51% in the Baseline survey to 54% at Trial 1). However, this change is not statistically significant[103].

[103] Z test. Z value of 0.42 (a value of 1.96 would indicate confidence at the 5% level) (combining 'More than once a day', 'Once a day' and '5 to 6 times a week' responses.

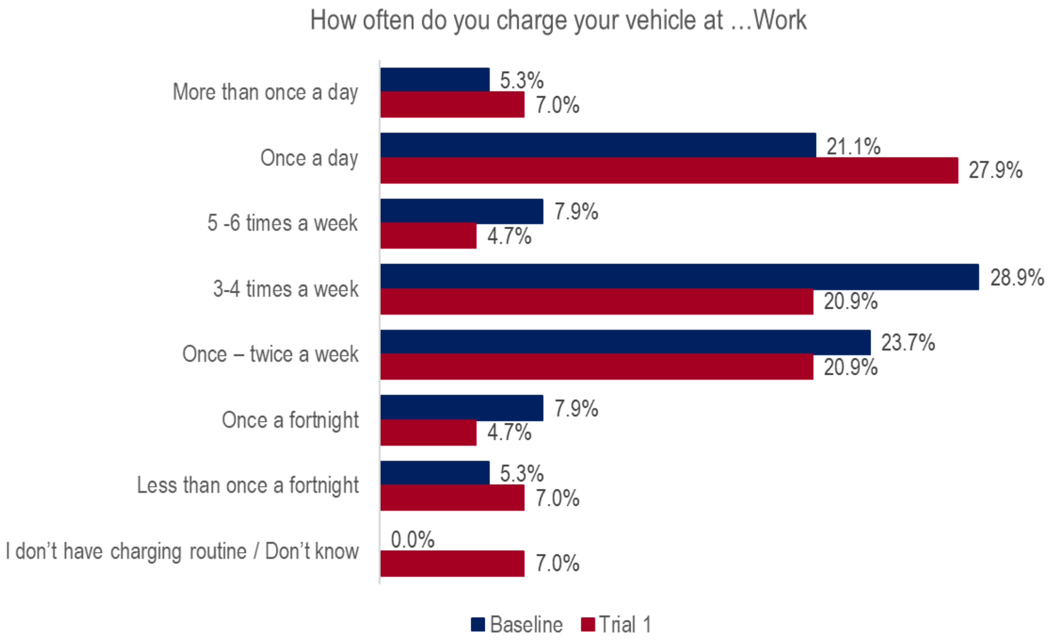


Figure 10-41: How often do you charge your vehicle at work (Base: Baseline = 38, Trial 1 = 43 - not all survey respondents charged at work in both surveys)

Participants were asked when they typically charge their vehicle, and this was also compared to the Baseline responses, both at home (Figure 10-42) and at work (Figure 10-43). There were limited changes to participant behaviour for both home and work-based charging – no statistically significant differences.

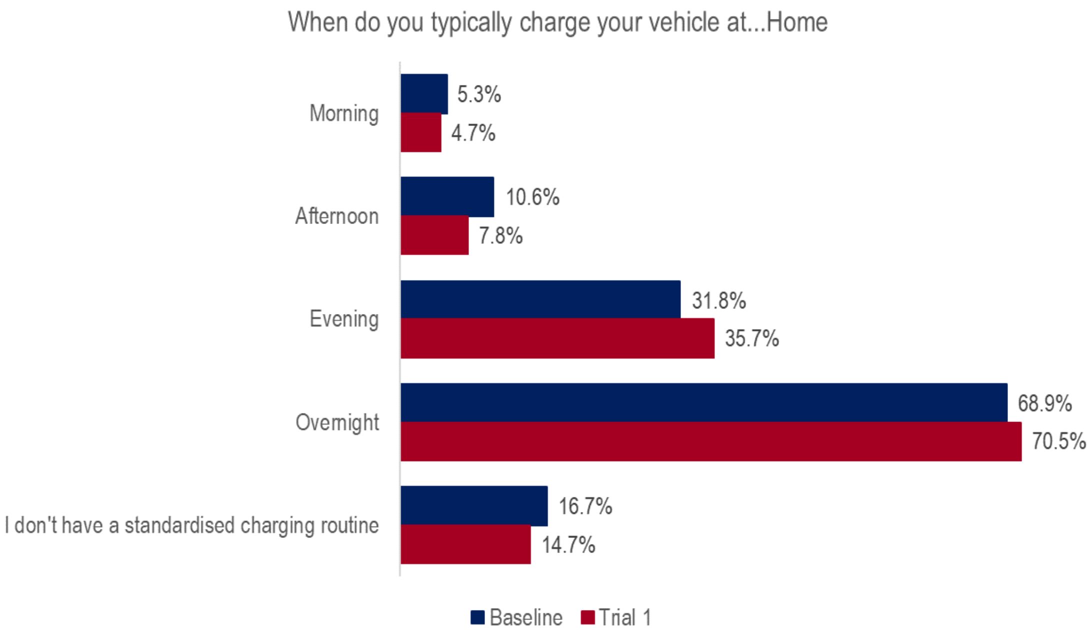


Figure 10-42: When do you typically charge your vehicle at home? (Base: Baseline = 132 responses, Trial 1 = 129 responses - some participants no longer charged at home in Trial 1). Respondents could select multiple options

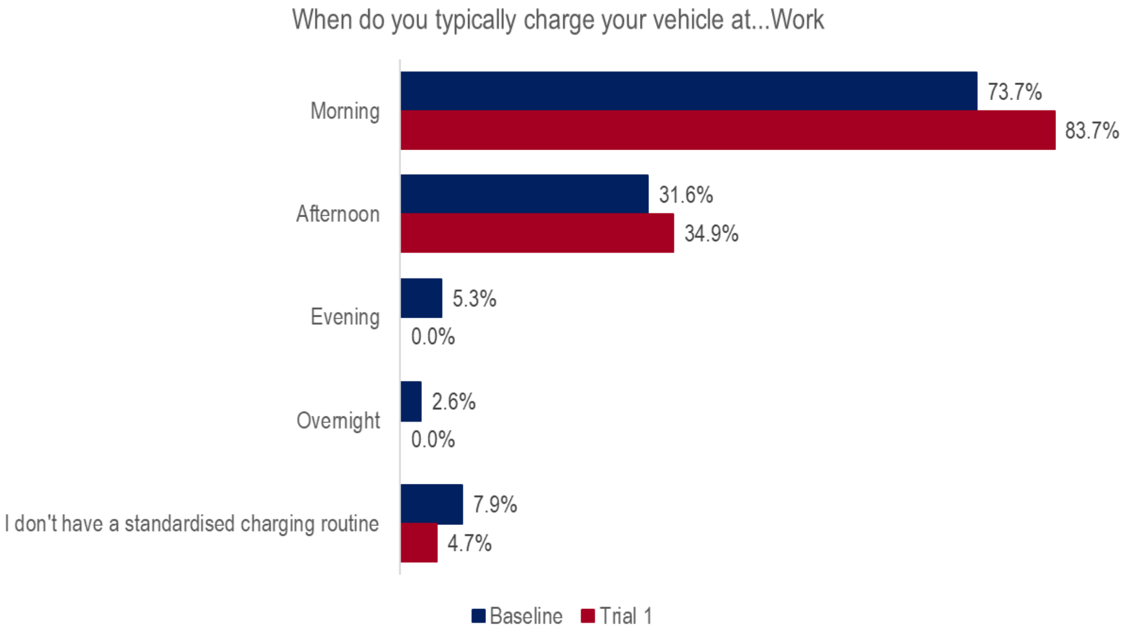


Figure 10-43: When do you typically charge your vehicle at work? (Base: Baseline = 38 responses, Trial 1 = 43 responses - some participants only selected work in one survey). Respondents could select multiple options

10.2.5.3 Acceptability and satisfaction with charging arrangements

One of the key elements of the Electric Nation project is understand the customer acceptability of smart charging. Therefore, participants were asked the same questions about the acceptability of, and satisfaction with, their current charging arrangements at several points during the Trial. These results are reported below, with further detail linking the amount of management experienced and these survey results given in Section 10.2.6. The results reported in this section are for the 143 participants who responded to both the Baseline and Trial 1 surveys. Results from all respondents can be found in Appendix 3.

Participants were asked whether the current charging arrangements were acceptable, by providing a score between 1 and 10. Figure 10-44 shows the proportion of participants who rated their charging arrangements as highly acceptable (scores of 8, 9 and 10) for the Baseline and Trial 1 surveys.

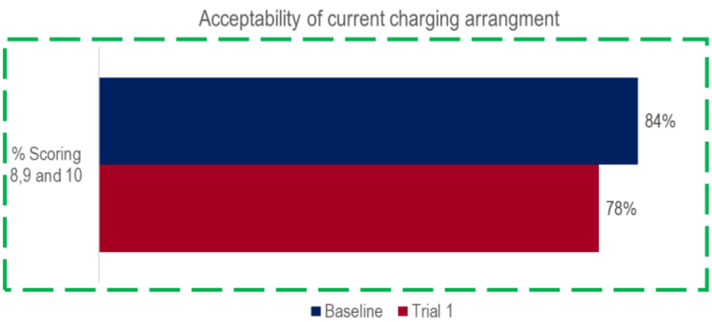


Figure 10-44: Acceptability of current charging arrangements (Base: Baseline = 141, Trial 1 = 143 (excludes 'don't know' responses))

Although the results above show a slight decrease in the proportion of respondents reporting the highest levels of acceptability between the Baseline and Trial 1 surveys, this difference is not statistically significant[104].

The Trial 1 results shown below, disaggregated by both vehicle type and battery capacity.

Table 10-10: % of Respondents Scoring Charging Arrangements as Highly Acceptable - Baseline and Trial 1 by PEV Type and Battery Capacity

Group		Sample Size (Baseline/Trial 1) – excluding 'don't know' responses)	% of Survey Responses Scoring 8 – 10 (Acceptability of Charging Arrangements)	
			Baseline	Trial 1
PEV Type	REX	Baseline = 24 Trial 1= 24	79%	75%
	PHEV	Baseline = 52 Trial 1 = 53	83%	83%
	BEV	Baseline = 65 Trial 1= 66	86%	74%
Battery Capacity	Less than 10kWh	Baseline = 34 Trial 1 = 35	79%	80%
	10 to 25kWh	Baseline = 39 Trial 1 = 39	90%	87%
	25 to 35kWh	Baseline = 44 Trial 1 = 44	86%	80%
	35kWh plus	Baseline = 24 Trial 1 = 24	75%	56%

The largest decreases in the proportion of participants who rated their charging arrangements as highly acceptable occurred in the 'BEV' and '35kWh plus' groups:

- The proportion of BEV drivers rating their satisfaction as highly acceptable dropped from 86% at the Baseline survey to 74% at the end of Trial 1. This result was statistically significant at the 10% level (rather than the 5% level used elsewhere in this report)[105].
- Due to the small sample size the change in acceptability in the '35kWh plus' group between Baseline and Trial 1 was not statistically significant. However, this group were significantly less likely to rate their charging arrangements as highly acceptable when compared to the other three battery capacity groups[106].

Participants were also asked to score their satisfaction with their current charging arrangements. Some participants may be dissatisfied with a solution but are prepared to accept it. Asking participants about satisfaction therefore provides an additional metric via

[104] Z Test. Z = 1.29
[105] Z Test. Z= 1.72 (a value of 1.64 indicates confidence at the 10% level, a value of 1.96 would be required for the 5% level).
[106] Z test. Z = 1.98 (35kWh plus and Less than 10kWh), 2.77 (35kWh plus and 10 to 25kWh) and 2.10 (35kWh plus and 25 to 35kWh).

which customer attitudes to smart charging can be understood. Figure 10-45 compares the level of satisfaction for the whole trial population, comparing Trial 1 with the Baseline survey results.

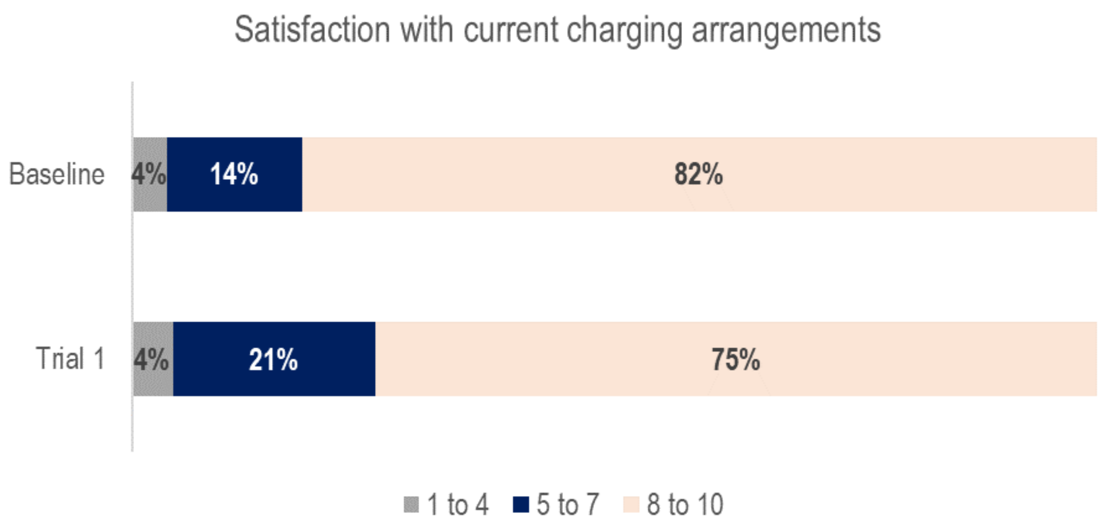


Figure 10-45: Satisfaction Scores - Baseline and Trial 1 (Base: Baseline = 142, Trial 1 = 143, excludes 'don't know' responses)

There were no statistically significant changes between the Baseline and Trial 1 surveys[107], despite the levels of demand management shown in Sections 10.2.3 and 10.2.4.

The Trial 1 results are shown below, disaggregated by vehicle type.

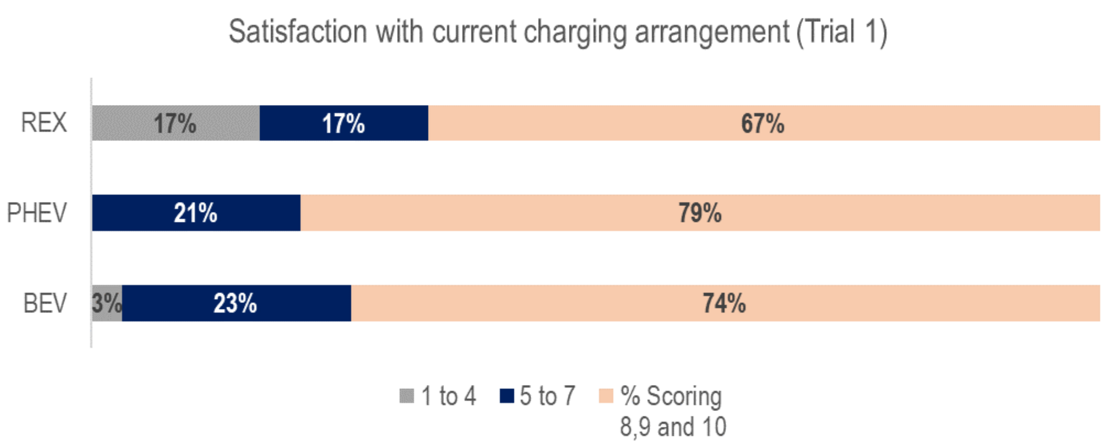


Figure 10-46: Satisfaction Scores - Trial 1 Disaggregated by PEV Type (Base: REX = 24, PHEV = 53, BEV = 66, excludes 'don't know' responses)

[107] Z Tests. % Scoring 8, 9 or 10 Z = 1.43, % Scoring 5, 6 or 7 Z = 1.55, % Scoring 1 to 4 Z = 0

The table below compares the proportion of participants who were highly satisfied (score of 8 to 10) in the Baseline and Trial 1 surveys, by PEV type and battery capacity.

Table 10-11: Satisfaction Scores - Baseline and Trial 1 - Disaggregated by PEV Type and Battery Capacity

Group		Sample Size (excluding those answering 'don't know')	% of Survey Responses Scoring 8 - 10	
			Baseline	Trial 1
PEV Type	REX	Baseline = 24 Trial 1 = 24	78%	67%
	PHEV	Baseline = 52 Trial 1 = 53	78%	79%
	BEV	Baseline = 66 Trial 1 = 66	80%	74%
Battery Capacity	Less than 10kWh	Baseline = 34 Trial 1 = 35	77%	74%
	10 to 25kWh	Baseline = 39 Trial 1 = 39	79%	87%
	25 to 35kWh	Baseline = 44 Trial 1 = 44	85%	73%
	35kWh+	Baseline = 25 Trial 1 = 25	72%	60%

Statistical analysis has been used to compare the proportion of participants who were highly satisfied – both comparing Baseline to Trial 1 for each category and comparing the Trial 1 scores between sub-categories. The only significant difference is that the proportion of participants with '35kWh plus' vehicles who were highly satisfied was significantly lower in Trial 1 than drivers of '10 to 25kWh' vehicles[108]. The reasons behind these differences are not clear. The survey results for the acceptability of, and satisfaction with, current charging arrangements have been linked to participants experience of management during Trial 1 and these results are included in the key findings section (10.2.6) below.

Participants were also asked about their willingness to continue with the current charging arrangements. Figure 10-47 shows the proportion of participants who gave each response in the Baseline and Trial 1 surveys (for only those participants who completed a Trial 1 survey).

[108] Z test. Z = 2.48

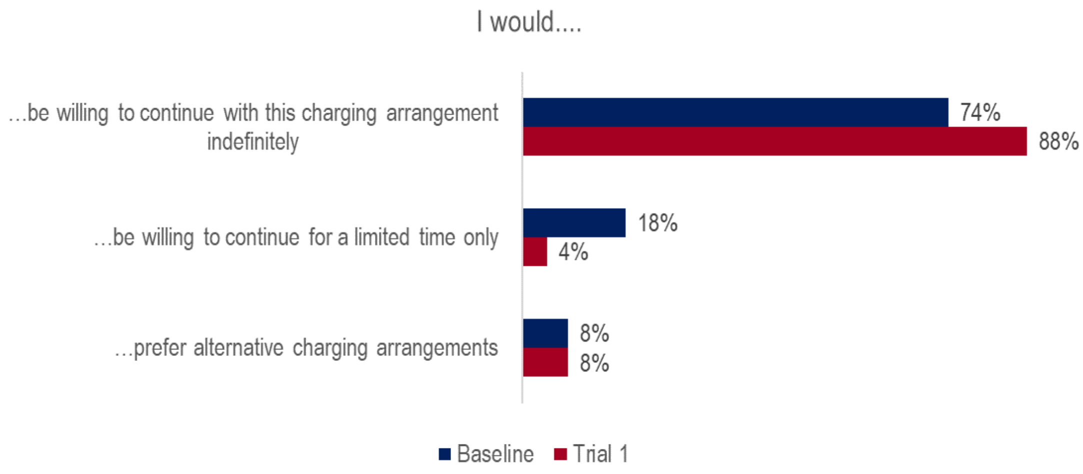


Figure 10-47: Willingness to continue with current charging arrangements (Base: Baseline and Trial 1 = 139, respondents who gave an answer in both surveys)

The increase in the proportions of participants willing to continue indefinitely and decrease in those willing to continue for a limited time only between the Baseline and Trial 1 are both statistically significant[109].

Table 10-12 disaggregates both the Baseline and Trial 1 results by vehicle type, showing the proportion of respondents who would be willing to continue with their charging arrangements indefinitely.

Table 10-12: % of Respondents willing to continue with charging arrangements indefinitely - Baseline and Trial 1 - by PEV Type

Group		Sample Size	% of Survey Respondents Willing to Continue with Charging Arrangements Indefinitely	
			Baseline	Trial 1
PEV Type	REX	22	68%	91%
	PHEV	53	74%	85%
	BEV	64	77%	89%

The increases amongst both REX and BEV drivers were statistically significant at the 10% level[110].

[109] Z test. For proportion of participants willing to continue indefinitely Z = 2.98, for proportion of participants willing to continue for a limited time only Z = 3.73.
[110] Z Test. REX Z = 1.89, BEV Z = 1.81 (value of 1.64 indicates confidence at the 10% level, 1.96 would be required for confidence at the 5% level).

Nineteen respondents provided reasons for their response. These are summarised in Figure 10-48, below and are mainly related to public charging infrastructure.

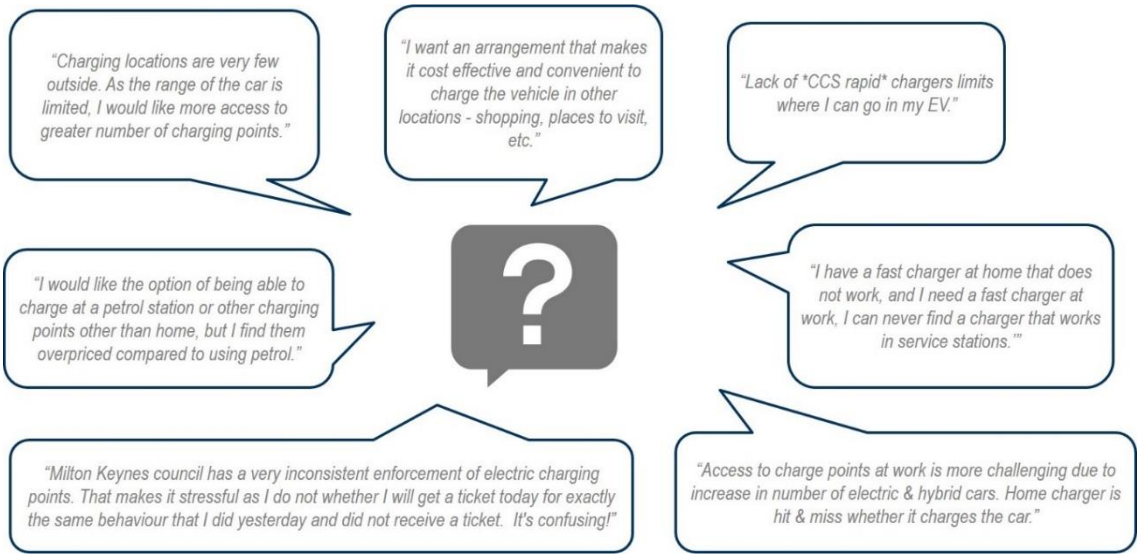


Figure 10-48: Why did you say that? (All respondents = 19)

Willingness to continue in demand management was impacted by teething problems that some participants experienced with their smart charger. Relevant responses are shown in Figure 10-49.

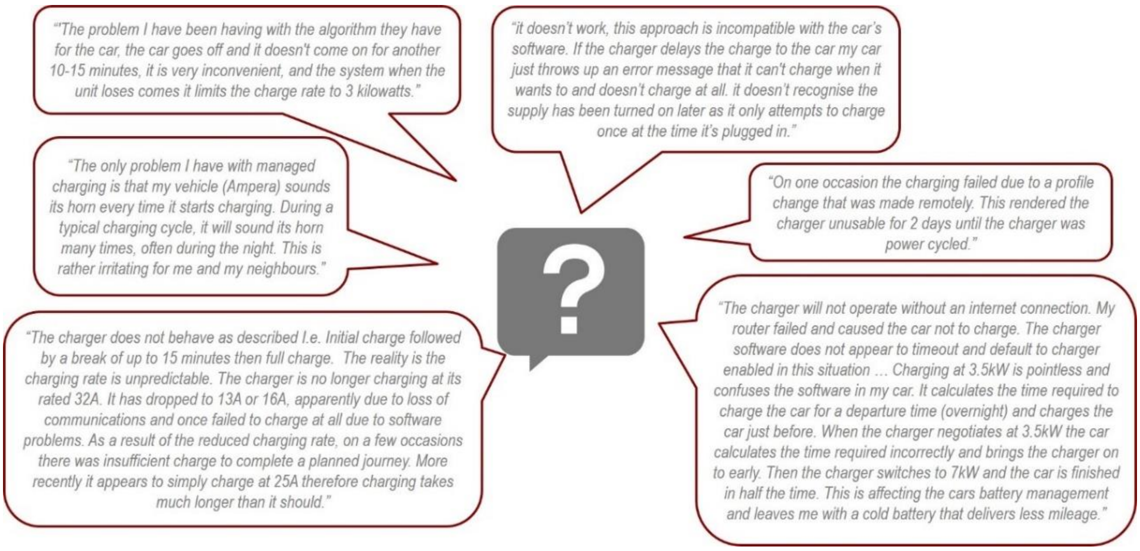


Figure 10-49: Why did you say that?

Participants were asked whether they were concerned about having their charging managed as part of the trial (Figure 10-50). The results for the whole of the GreenFlux cohort are shown below, compared to the baseline survey results.

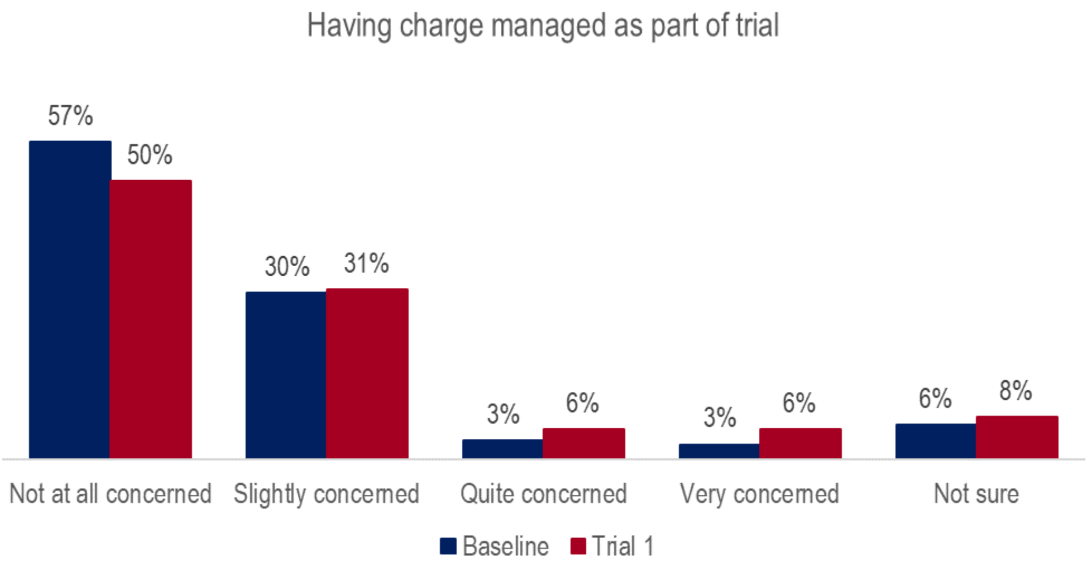


Figure 10-50: How do you feel about having your charging arrangements managed as part of the trial? (Base: Baseline and Trial 1 = 143)

There was no statistically significant change in the proportion of participants who were concerned about management between the Baseline and Trial 1 surveys[111].

The table below compares the proportion of participants who were 'Not at all concerned' and 'Quite' or 'Very concerned' for each battery capacity group in the Trial 1 survey.

Table 10-13: % of Respondents Expressing Varying Levels of Concern re: Management in the Trial 1 Survey - by Battery Capacity

Battery Capacity Group	Sample Size	% of Respondents (Trial 1 Survey)		
		'Not at all concerned'	'Slightly concerned'	'Quite' or 'Very Concerned'
Less than 10kWh	35	54%	31%	9%
10 to 25kWh	39	51%	36%	5%
25 to 35kWh	44	57%	23%	9%
35kWh plus	25	32%	36%	28%

Participants with vehicles in the '35kWh plus' category were statistically less likely to be 'not at all concerned' when compared with those in the 'Less than 10kWh' (10% confidence level) and '25 to 35kWh' (5% confidence level) categories[112].

[111] Z test. 'Not at all concerned' Z = 1.19, 'Slightly concerned' Z = 0.18, 'Quite concerned' Z = 1.22, 'Very concerned' Z = 1.22, 'Not sure' Z = 0.66.
[112] Z test. Z (35kWh plus and Less than 10kWh) = 1.69 (value of 1.64 required for 10% confidence level), Z (35kWh plus and 25 to 35kWh) = 2.00 (value of 1.96 required for 5% confidence level).

Participants with the largest batteries were significantly more likely to be ‘quite’ or ‘very’ concerned about demand management when compared to all three other groups (10% confidence level for ‘Less than 10kWh’, 5% confidence level for the other two groups)[113].

Figure 10-51 shows the sentiments of some participants who expressed no concerns about participating in the trial.

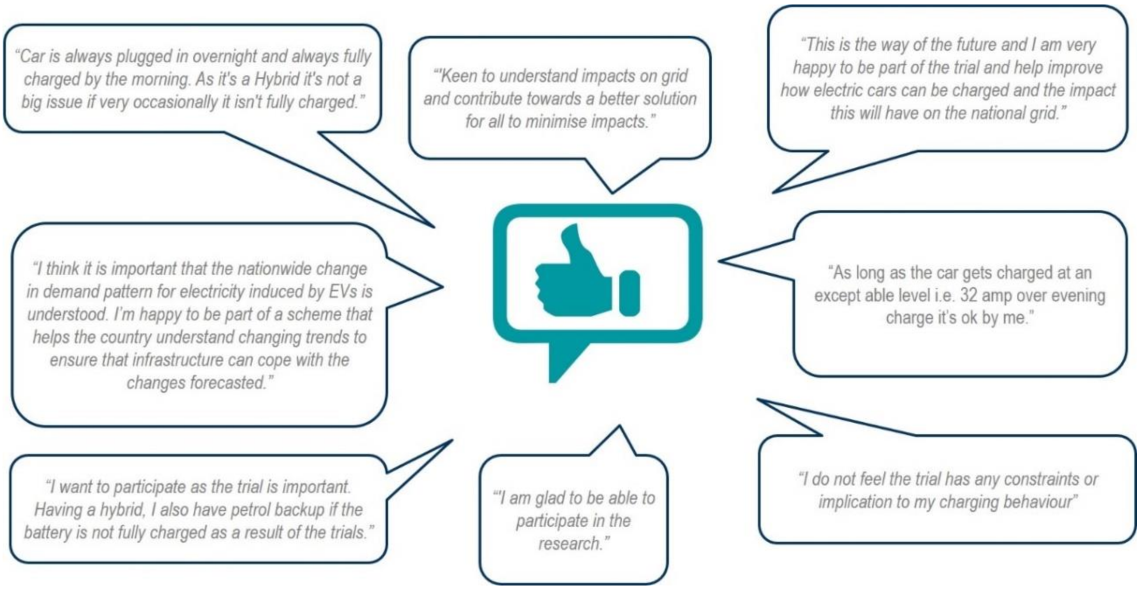


Figure 10-51: Why do you say that - those who were not concerned

However, other participants expressed some concerns reflected in Figure 10-52 below. Some of these concerns relate to the concept or potential of demand management (e.g. “If I plug it in and I need five hours charge and I only get three I won’t have enough for my next journey”). Others are as a result of issues experienced during demand management.

[113] Z test. Z (35kWh plus and Less than 10kWh) = 1.94, Z (35kWh plus and 10 to 25kWh) = 2.59 and Z (35kWh plus and 25 to 35kWh) = 2.08.

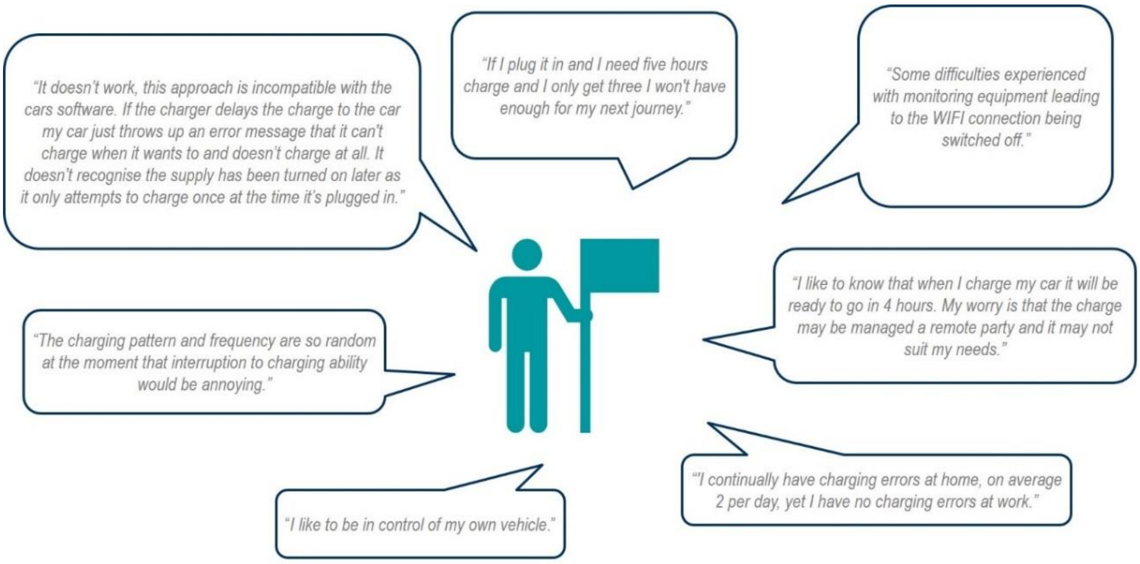


Figure 10-52: Why do you say that - those who were concerned

10.2.5.4 Trial 1 Findings from Focus Groups

At the end of the Trial a focus group was held in which further qualitative information was collected from a small group of seven participants. Some of the information provided in relation to Trial 1 is shown below.

GreenFlux participants expressed some anxiety about their charging during Trial 1, and a couple experienced technical issues during this phase of the project. These issues included their vehicle beeping each time charging was paused and restarted, and some vehicles not fully recharging. However, this did not impact overall acceptability, often due to the fact that another vehicle was available. Some of the quotes below may be based on concerns which stem from a lack of knowledge of what management was occurring. A selection of quotes about participants experience during Trial 1 is shown below.

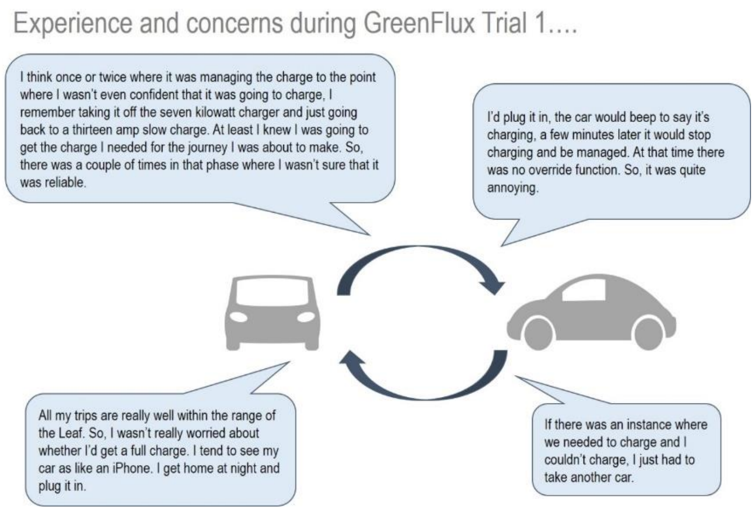


Figure 10-53: GreenFlux Experiences and Concerns during Trial 1 from Focus Group

Participants also discussed the principle of demand management as part of the focus groups. The vast majority believed demand management is needed and is a sensible initiative. However, there was cynicism from one respondent about the possible effects if demand management was not used (see the quote on the left-hand side of the diagram below).

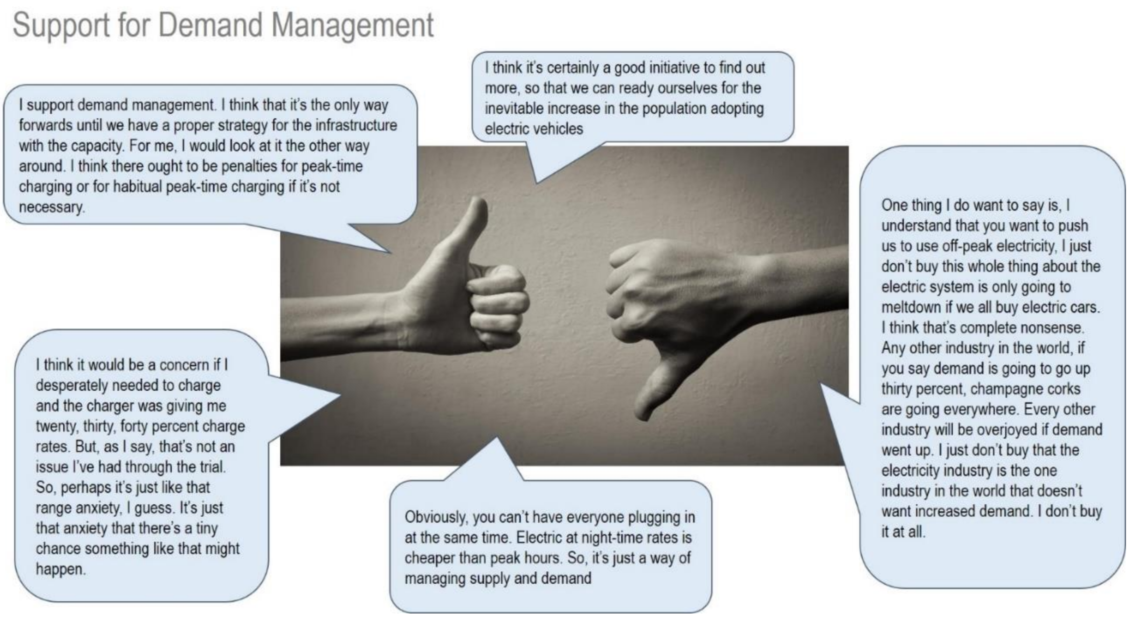


Figure 10-54: Participants Support for the Principle of Demand Management (GreenFlux Focus Group, Trial 1)

10.2.5.5 Summary

To conclude, GreenFlux participants as whole showed no statistically significant change in either acceptability or satisfaction between the Baseline and Trial 1 surveys. Participants with vehicles with the largest batteries (35kWh and above) were slightly less likely to rate the acceptability of their charging arrangements highly at the end of Trial 1. They were also more likely to be 'quite' or 'very' concerned about demand management. At a population level, the willingness to continue with their current charging arrangements indefinitely had increased between the Baseline and Trial 1 surveys.

10.2.6 Key Findings – GreenFlux Trial 1

- The 90th Percentile peak demand was approximately 830W per charger (e.g. in a group of 100 chargers the peak demand would be less than 83kW on 90% of days). This demand was constrained by the use of demand management – unrestricted demand would be higher.
- Management was active less frequently in the GreenFlux group (compared to CrowdCharge), as vehicles which were rated at 16A were only allocated 16A (rather than 32A, the nominal charger rating). This meant that the available capacity could be shared across a larger number of active chargers before management became necessary.

- Management was active on around 40% of weekdays in the evening peak (17:00 – 21:15) during the 'winter' period (January – April 2018). This led to individual chargers having their charging paused, or the rate reduced, for short periods (15 minutes).
- 17% of charging events during Trial 1 were constrained by demand management (3,306 charging events).
- 81% of participants experienced some management of their charging events during Trial 1.
- Curtailing of charging events during demand management made no statistically significant difference to the proportion of charging events where the vehicle was unplugged before the battery was fully charged (14.7% outside of management, 15.1% during Trial 1, for Trial 1 participants).
- Charging constraints were shared equally amongst participants who vehicles were rated at 16A or 32A, with similar proportions of events being curtailed in each group, and similar values for GreenFlux Management Factor.
- Participants who use a timer frequently (defined as for at least 50% of their transactions) were managed significantly less frequently than other participants.
- Table 10-14 below, relates the scores given for participants **satisfaction** with their current charging arrangements in the Trial 1 survey to values of GreenFlux Management Factor:

Table 10-14: Relationship between GreenFlux Management Factor and Satisfaction Scores

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
Not Managed During Trial 1	11	0%	18%	82%
GreenFlux Management Factor 1st Quartile	26	4%	19%	77%
GreenFlux Management Factor 2nd Quartile	35	0%	29%	71%
GreenFlux Management Factor 3rd Quartile	33	6%	18%	76%
GreenFlux Management Factor 4th Quartile	28	4%	11%	86%

This shows that increasing amounts of management do not lead to higher rates of dissatisfaction. There is no consistent trend between the amount of management experienced and proportion of participants who were either "highly satisfied" or "neutral".

- Table 10-15 below, relates the scores given by participants for the **acceptability** of their current charging arrangements in the Trial 1 survey to values of GreenFlux Management Factor.

Table 10-15: Relationship between GreenFlux Management Factor and Acceptability Scores

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
Not Managed During Trial 1	11	0%	9%	91%
GreenFlux Management Factor 1st Quartile	26	8%	19%	73%
GreenFlux Management Factor 2nd Quartile	35	3%	23%	74%
GreenFlux Management Factor 3rd Quartile	33	3%	18%	79%
GreenFlux Management Factor 4th Quartile	28	0%	11%	89%

This shows no relationship between the amount of management participants experienced and the acceptability of their charging arrangements. For example, the breakdown in the 'never managed' group is similar to the group with the highest (top 25%) values for GreenFlux Management Factor.

- There was a slight increase (statistically significant) in the proportion of participants who were willing to continue with their charging arrangements indefinitely at the end of Trial 1, compared to the baseline survey (before management) (88% compared to 74%)

- Participants who expressed dissatisfaction with their charging arrangements were more likely to cite causes such as charging infrastructure away from home, although some had experienced occasional technical problems from demand management. These technical problems were also mentioned by participants in the focus group.

11 Trial 2 Findings

Trial 2 refers to the second part of the demand management trials, where demand from groups of EV chargers was managed in a similar manner to Trial 1 and participants were able to interact with the smart charging systems from both CrowdCharge and GreenFlux.

This trial was active between May and October 2018 (GreenFlux) and July and November 2018 (CrowdCharge).

This section of the report describes the outcomes from Trial 2 for CrowdCharge and GreenFlux. In both cases the sub-sections outline:

- The power drawn from groups of EV chargers, focussing on comparing demand in winter (Trial 1 data) to summer (Trial 2 data);
- The level of management which occurred, both at a group level, and how this varied between individual participants;
- The results of the customer research questionnaires undertaken in relation to Trial 2;
- The level to which participants interacted with the apps introduced by CrowdCharge and GreenFlux; and
- Key findings from this part of the trial, including exploring the relationship between the amount of management which participants experienced and their satisfaction with their charging arrangements.

11.1 CrowdCharge

11.1.1 Description of Trial

Trial 2 introduced the journey planning app and also involved changes to the CrowdCharge algorithm which determined the current allocated to chargers during demand management events.

The web-based app launched by CrowdCharge for Trial 2 allowed participants to register for an account and confirm their vehicle details. They could then enter three different pieces of information which would be used as part of the smart charging algorithm:

- State of charge of the vehicle – requested each time the app was launched;
- Regular journeys – the participant entered a start and end point, a time of departure and which days the regular journey occurred (e.g. Monday – Friday); and
- One-off journeys – as above, but a specific departure date and time were selected.

All chargers continued to be allocated the maximum possible current when sufficient capacity was available based on the capacity profile. In some cases, 16A was allocated (where a participant had registered a vehicle with their app account which was only available as a 16A option). If demand management was required then the current allocated to individual chargers varied, depending on the amount of energy they needed and their journey requirements.

For example, if demand management was required at 18:00 one evening and a participant had a planned journey of 50 miles, departing at 21:00 the same evening, they would receive a higher current allocation than another driver whose next planned journey was 20 miles long, departing at 7:30 the following morning.

If no journey plans had been entered then the system used a default journey (50 miles, departing four hours after plug-in) to prioritise the current allocation if demand management was necessary. In all cases the energy requirement for each vehicle was determined using a conservative assumption for vehicle efficiency (miles/kWh), and either the journey length from the planner, or the 50 mile default.

An example of a test performed on this algorithm is given in Section 4.9.1 of this report (see Figure 4-13).

The first group of participants moved into Trial 2 on 13th June 2018. Participants were moved over from Trial 1 to Trial 2 in batches, as they were invited to register for an app account and the software on the CrowdCharge controller was updated.

The 'Spring-Winter' combined capacity profile was used throughout Trial 2 to ensure that some management was still required. As described in Section 6.4, capacity profiles set out the available current for a group of chargers, and so determined how likely it was that demand management would occur.

This section of the report will focus on power demand from the group of chargers during summer (late July and August, to allow comparison with the winter profiles shown in Trial 1 above). The incidence of management at a group level presented in this section is based on the period from 2nd August to 12th November, when at least 100 chargers were part of Trial 2. The individual participant experience data includes the full duration of Trial 2 for each participant, in order to cover their experience of the whole of Trial 2.

11.1.2 Demand Profiles

As described above Trial 2 was in operation between July and November 2018. The resulting power demand from groups of chargers will be used for two purposes:

- Comparing winter (Trial 1) and summer (Trial 2) demand (this section)[114]; and
- Assessing the impact of the time of use incentive introduced in Trial 3 on group demand (Section 12)

[114] This comparison is based on the real-world demand from groups of chargers under management. As described elsewhere the shape of these profiles are influenced by the use of management (e.g. restricting the peak demand), and therefore the capacity profiles used.

The meter value data from individual chargers has been aggregated up to a group level and converted to power (rather than current) in the same way as described in Section 10.1.2.

This section shows demand profiles for the summer period, using data from 26th July to 1st September 2018 (inclusive). Profiles below are expressed in W per Charger in Group. The graph below shows the maximum, 90th percentile and average demand for weekdays during summer in Trial 2 (26th July – 1st September 2018).

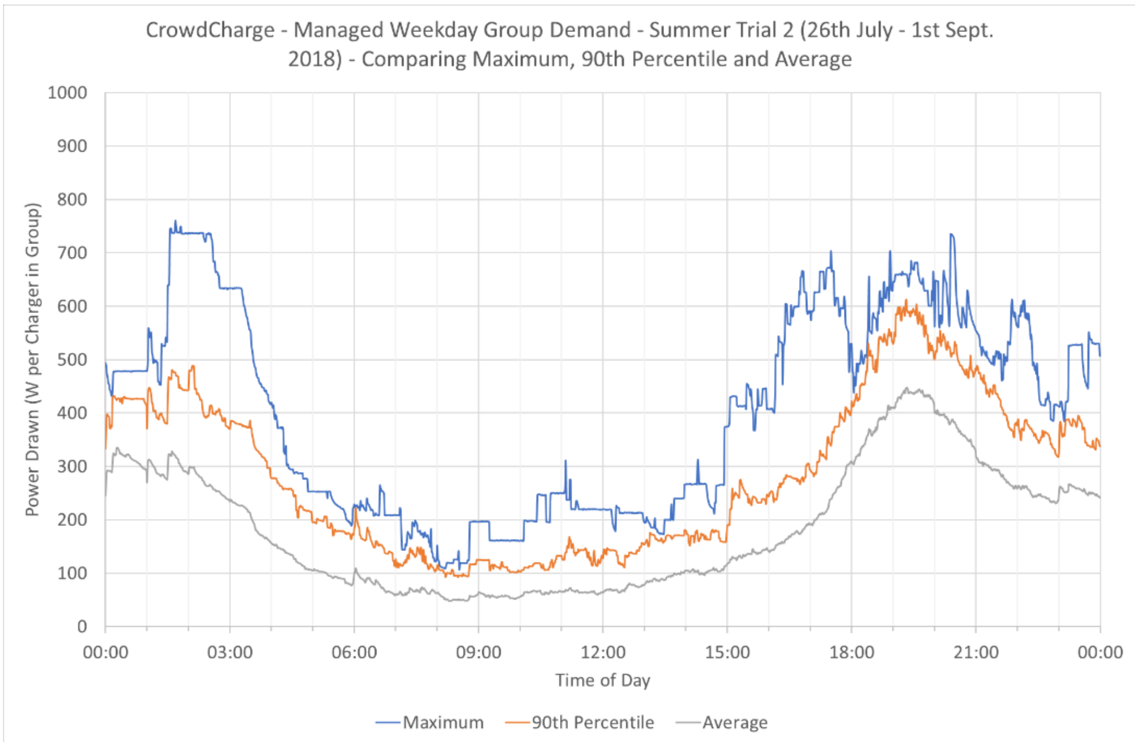


Figure 11-1: Managed Weekday Demand - CrowdCharge Summer Trial 2 (Maximum, 90th Percentile and Average)

This graph illustrates the variability in the current drawn at each time of day from day to day, with the largest differences between the 90th percentile and 'maximum' days, particularly around 01:30. The shape of the graph shows the variation in demand across the day, with the following main (based on the shape of the average and 90th percentile curves) points:

- A steady increase in demand from the middle of the afternoon (15:00) until around 19:30;
- In this case the evening peak demand has been restricted by the use of demand management, so the 'unrestricted' profile would result in a different shape, and this is explored in Section 8.10; and
- There is another peak in demand at 01:30. Note that the average size of this peak in summer is much less than in the equivalent peak in winter.

The graph below compares the 90th percentile weekday and weekend demand curves for the summer period (weekday in Figure 11-4, weekend in Figure 11-5).

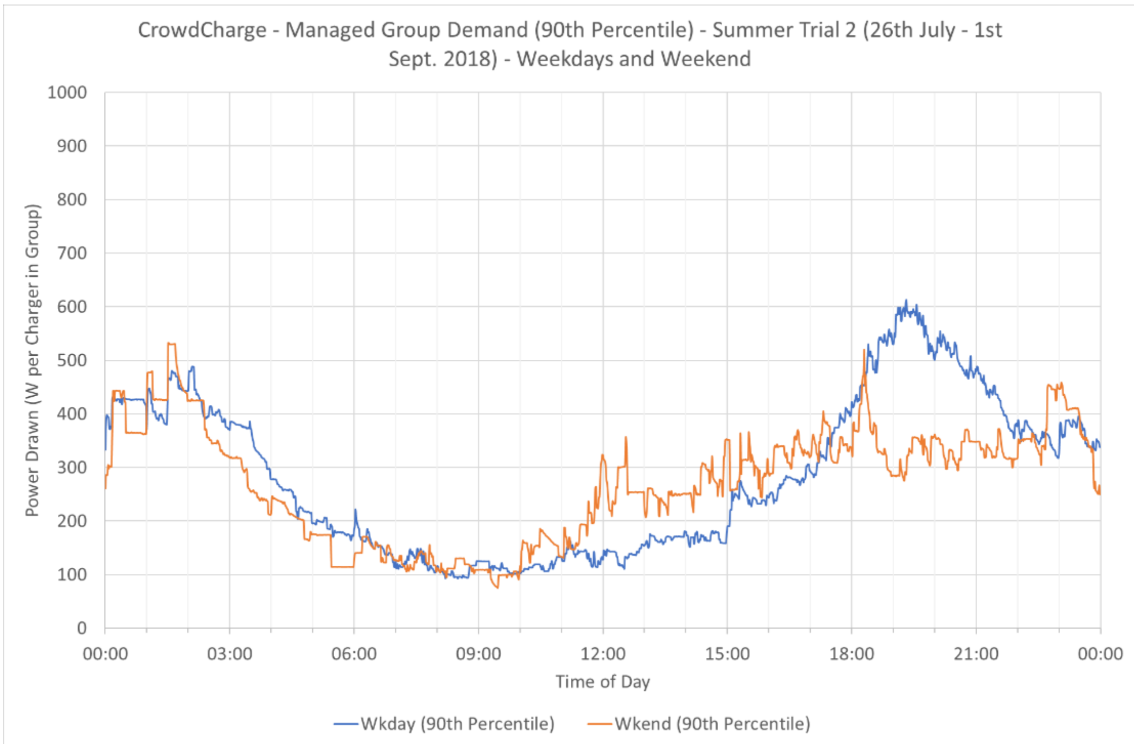


Figure 11-2: Comparing Managed Weekday and Weekend Demand - CrowdCharge Summer Trial 2 (90th Percentile)

This shows a lower peak demand (both overall peak, and evening peak) at the weekend. Demand over lunchtime and the early afternoon is higher. The lower weekend evening peak (compared to weekdays) aligns with the amount of management which took place at weekdays and weekends (see next section). Demand increases between midnight and 02:00 on both weekdays and at the weekend, to a similar degree.

The profiles shown above have grouped all weekdays (Monday – Friday) and weekend days (Saturday and Sunday) together. There may be trends within the week – for example higher demand on Mondays compared to Fridays. The graph below shows the 90th percentile of group demand (W per charger in the group) from the summer period, shown across all seven days of the week.

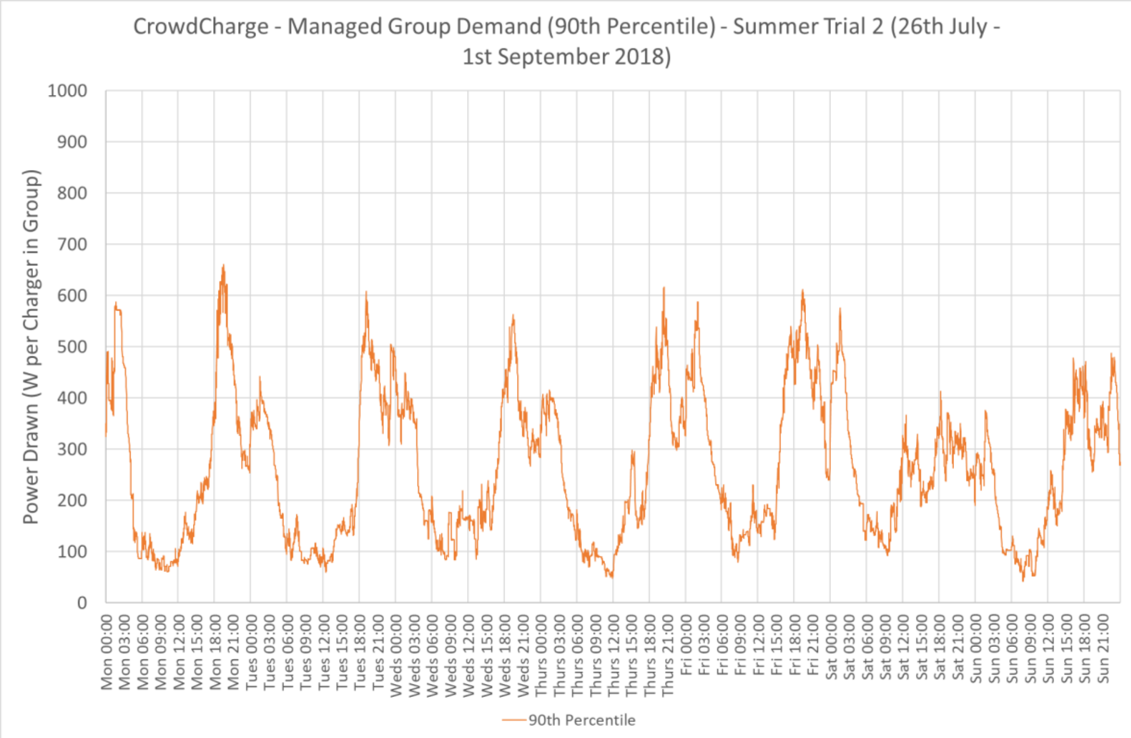


Figure 11-3: Seven Day Managed Demand - CrowdCharge Summer Trial 2 (90th Percentile)

This shows a similar pattern of demand across all weekdays, with two distinct peaks - one in the evening and another smaller one at 01:00 (caused by the tendency of CrowdCharge participants with dual rate meters to use timers). Weekend peak demand is considerably lower, with greater demand during the day.

The graphs below compare winter and summer demand for weekdays and the weekend.

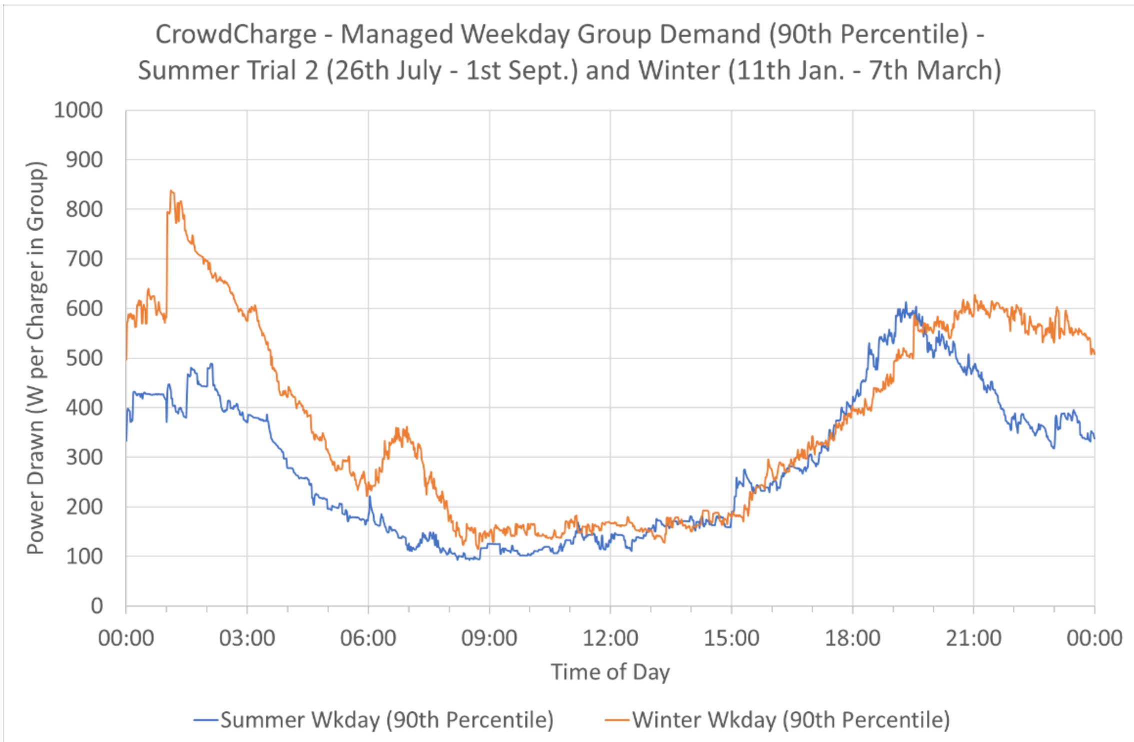


Figure 11-4: Comparing Weekday Managed Demand (CrowdCharge) - Summer and Winter (90th Percentile)

In both winter and summer, the evening peak demand has been constrained using demand management. The capacity profiles used in winter and summer had a very similar amount of power available in the evening peak, as the ‘combined spring-winter’ profile was used during the summer months (compare the winter and spring-winter combined in Figure 6-9). The similarity in capacity profiles during the evening means that the peak power demand is very similar. The total energy demand in the peak is higher in the winter (the area under the orange curve between 18:00 and 00:00 is significantly larger than the area under the blue curve over the same period). This is likely to be due to the increased energy demand for EVs during the winter.

The evening peak occurs earlier in the summer and is much shorter. The demand in the early hours of the morning is considerably lower in the summer (450W per charger compared to 825W per charger in the winter). The increase in demand between 06:00 and 08:00 (believed to be due to vehicle pre-conditioning) is absent, probably due to warmer weather.

Figure 11-5 below shows that daytime demand at the weekend is very similar in winter and summer. Overnight charging demand is slightly higher in winter. This load is likely to be due to participants charging their car via the use of a timer.

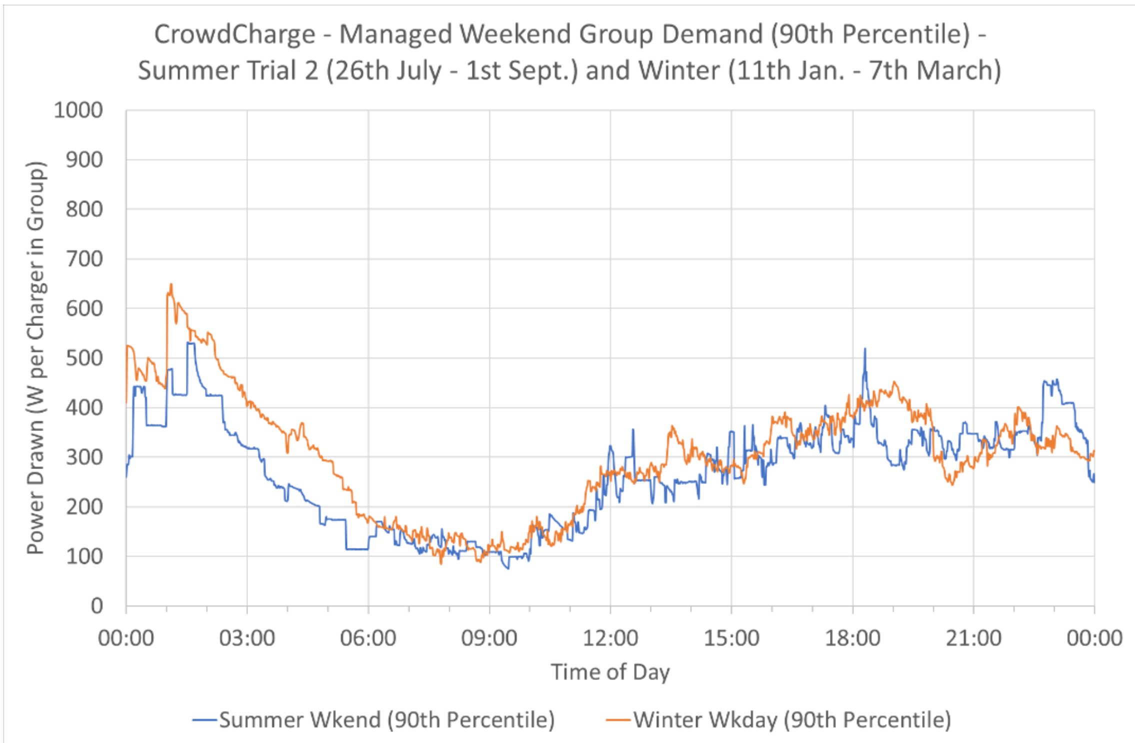


Figure 11-5: Comparing Weekend Managed Demand (CrowdCharge) - Summer and Winter (90th Percentile)

11.1.3 Occurrence of Demand Management – Group Level

The analysis presented for Trial 1 (Section 10.1.3) used the 'Charger Control Log' supplied by CrowdCharge to show when management was active, and the amount of current available to each active charger. However, changes to the algorithm used to control chargers between Trial 1 and Trial 2 meant that the charge control log was no longer available.

The CrowdCharge system allocates current to each active charger and this is recorded in the 'meter values' data for each charger. Each charger was allocated its full rating by the CrowdCharge system, if this was possible within the capacity limit. If this was not possible, then the allocation was reduced, with the value varying between chargers (based on information entered in the app, or the assumed default journey, as described in Section 11.1.1).

Demand management has been assumed to be active at a group level when the total current allocated to active chargers by the CrowdCharge system was greater than or equal to 95% of the capacity limit.

Seven groups were used during Trial 2, increasing in size as participants were transferred from Trial 1 to Trial 2. All groups operated under a 'Spring-Winter' combined profile, scaled to reflect the number of participants within the group.

Table 11-1 below summarises the groups, the number of participants in each, and the resulting amount of management (at a group level).

Table 11-1: Trial 2 CrowdCharge Groups and Amount of Management

Group	Dates Active	No. of Chargers in Group	No. of Minutes Active	No. of Managed Minutes	% of Minutes with Active Management
CCAppPilot01	13th June to 15th July	20	45,780	2997	6.5%
CCAppPilot02	15th to 25th July	40	14,460	872	6.0%
CCAppPilot03	25th July to 1st August	70	10,020	374	3.7%
CCAppPilot04	1st to 8th August	100	10,140	374	3.7%
CCAppPilot05	8th August to 9th September	216	46,080	1,609	3.5%
CCAppPilot06	9th September to 6th November	245	83,580	4,107	4.9%
CCAppPilot07	6th to 13th November	225	8,820	308	3.5%

This sub-section shows the frequency of management at a group level from 2nd August to 12th November, inclusive. Earlier groups with a smaller number of chargers tended to lead to more frequent management, as the diversity of the charging load was lower.

Figure 11-6 below shows the percentage of days, at each time of day, when management was active, separated by weekdays and weekends.

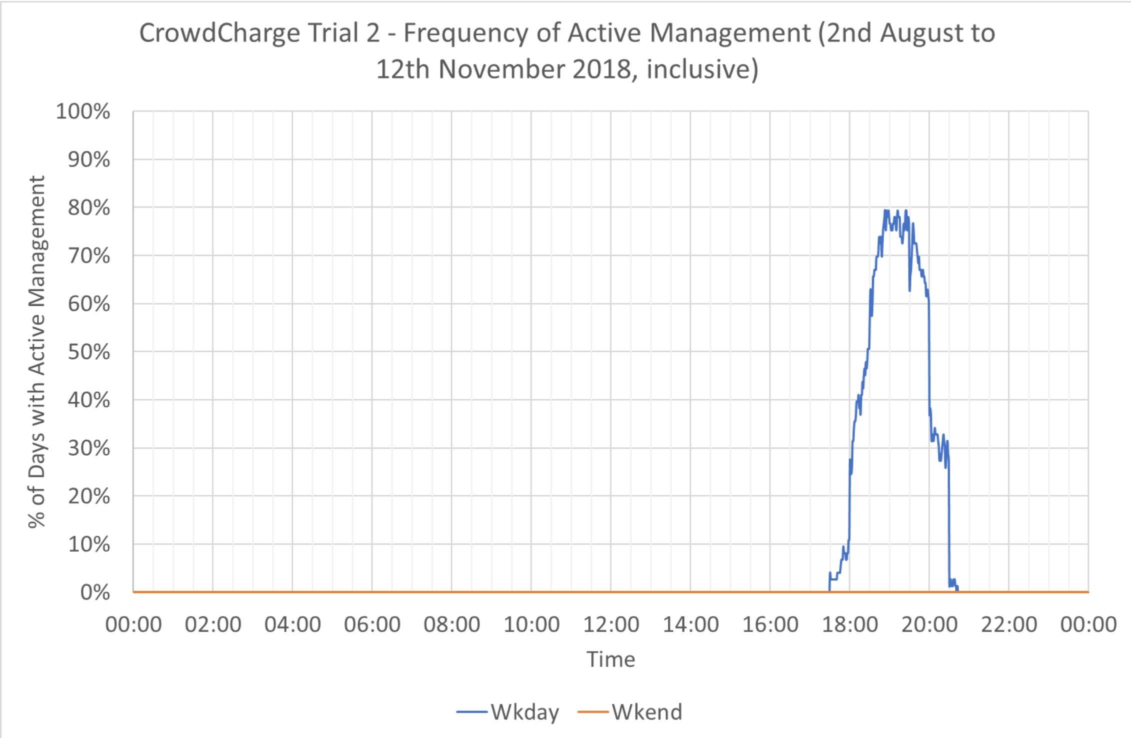


Figure 11-6: % of Days with Active Management (CrowdCharge Trial 2) Weekdays and Weekend

This shows that management was active on the majority of weekdays, although less frequently and for a shorter time window than during Trial 1 in the winter. Management occurred between 17:30 and 20:42 in Trial 2, compared to 16:23 to 22:25 in Trial 1. No management occurred at the weekend during Trial 2. In contrast, 70% of weekend days in winter during Trial 1 were managed. There are multiple reasons behind this change:

- Lower demand for EV charging due to seasonal differences;
- The CrowdCharge algorithm in Trial 2 distinguished between 16A and 32A cars in some cases meaning a larger number of active chargers could be accommodated before management was necessary; and
- Slightly less restrictive capacity profiles ('Spring-Winter combined' vs. 'Winter').

When management was active during Trial 2, the current allocated to individual chargers varied based on the journey plans that had been entered into the CrowdCharge app. It is therefore not possible to show graphs similar to Figure 10-5 and Figure 10-6 for Trial 2.

11.1.4 Participant Experience of Management

Participant's experience of management will vary, as described in previous sections. This section outlines the amount of management which participants experienced during Trial 2, including the level of restriction they experienced (using the 'CrowdCharge Management Factor' metric described in Section 10.1.4).

The key findings section (see Section 11.1.7) combines this data with the results of the Trial 2 survey to explore any link between the amount of management participants experienced in Trial 2, and their satisfaction with their charging arrangements.

One way in which management could have affected participants is to cause an increase in the proportion of charge events where vehicles are 'hot unplugged' (i.e. unplugged whilst still charging). Management reduces the current available so may have led to vehicles not being fully charged when they were unplugged. Figure 11-7 below shows the proportion of charge events which were 'hot unplugged' outside of management, during Trial 1 and during Trial 2, based on only the participants who took part in Trial 2.

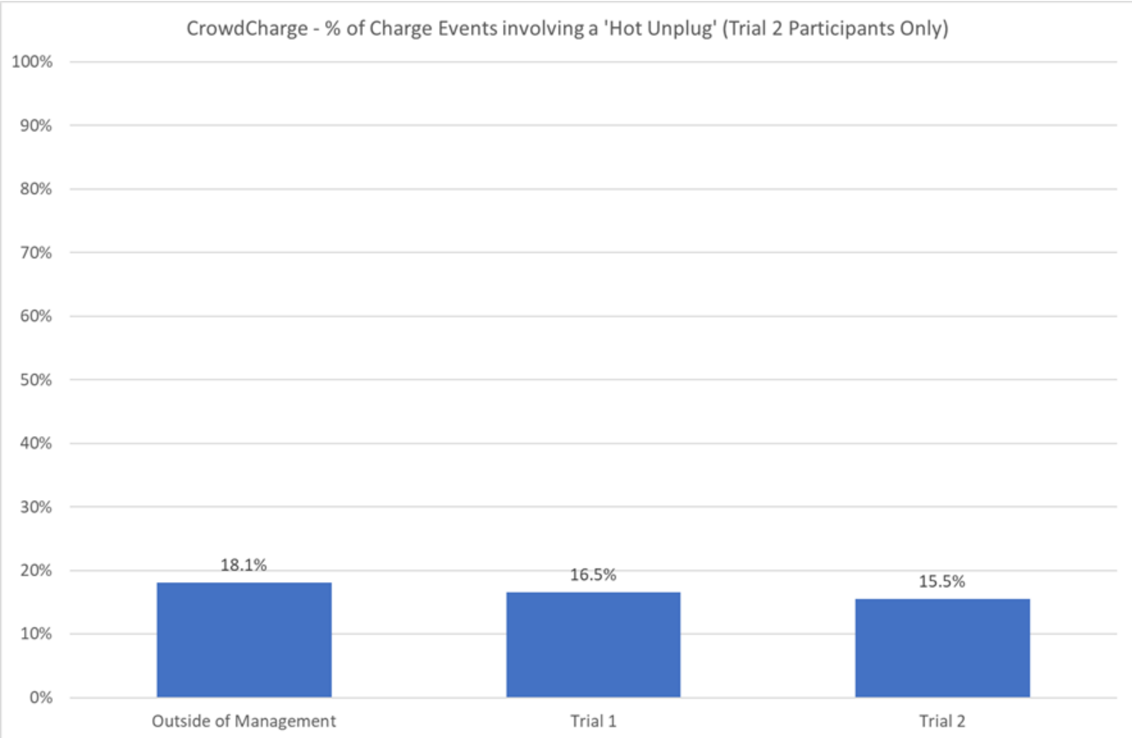


Figure 11-7: Proportion of charge events involving a 'hot unplug' (Outside Management, Trial 1, Trial 2)

This shows a slight decline in the hot unplug rate between Trial 1 and Trial 2 and between Trial 2 and the period before management began. Both decreases are statistically significant[115], which provides an indication that management did not cause widespread inconvenience to participants i.e. there was no increase in vehicles being unplugged before being fully charged. The decrease shown is likely to be a combination of seasonal affects and changing charging behaviour amongst participants, particularly with regard to the higher hot unplug rate outside management when participants were relatively inexperienced PEV drivers.

[115] Trial 2 compared to Trial 1 – Z = 2.51 and Trial 2 compared to 'Outside of Management' – Z = 4.87 (value of 1.96 would indicate confidence at the 5% level)

Data from the trial (transactions and current meter values) has been used to evaluate each transaction during Trial 2 and determine whether or not it was curtailed (managed). For each participant, data from smart chargers has been used to calculate:

- How many times they charged their vehicle (at home) during the time when they were participating in Trial 2;
- How many of these charging sessions were curtailed (where current meter values and allocation data are available);
- To what degree they were curtailed, using the Restriction figures outlined in Section 10.1.4; and
- The 2nd and 3rd points have been combined into the CrowdCharge Management Factor for each participant who was managed during Trial 2.

12,756 charging events took place during Trial 2 (where consumed energy was 0.5 to 100kWh). 491 charging events were constrained (3.8%). In Trial 1 2,226 charging events were managed (of 27,598) – 8.1%. This represents a statistically significant decrease[116]. 'Meter value' data has been used to determine whether a charge session was constrained. The same data is used to calculate the time when charging began and ended (this is available for 12,107 of the events (95%)). However, charge events were only constrained if they took place when the charger was communicating with CrowdCharge (and so would have sent meter values), so any events where a start and end charge time cannot be determined due to an absence of meter values were not managed.

245 participants were part of at least one Trial 2 group and transaction data is available for 232 of these participants. The remaining thirteen participants may have lost their communications connection, not used their charger, or left the project. 104 participants experienced management at least once (45%). The spread of the proportion of events that were curtailed is shown below, separated by participants whose registered vehicle was rated at 16 and 32A.

[116] Z Test. Z Value = 16.02 (value of 1.96 would indicate a 5% confidence level)

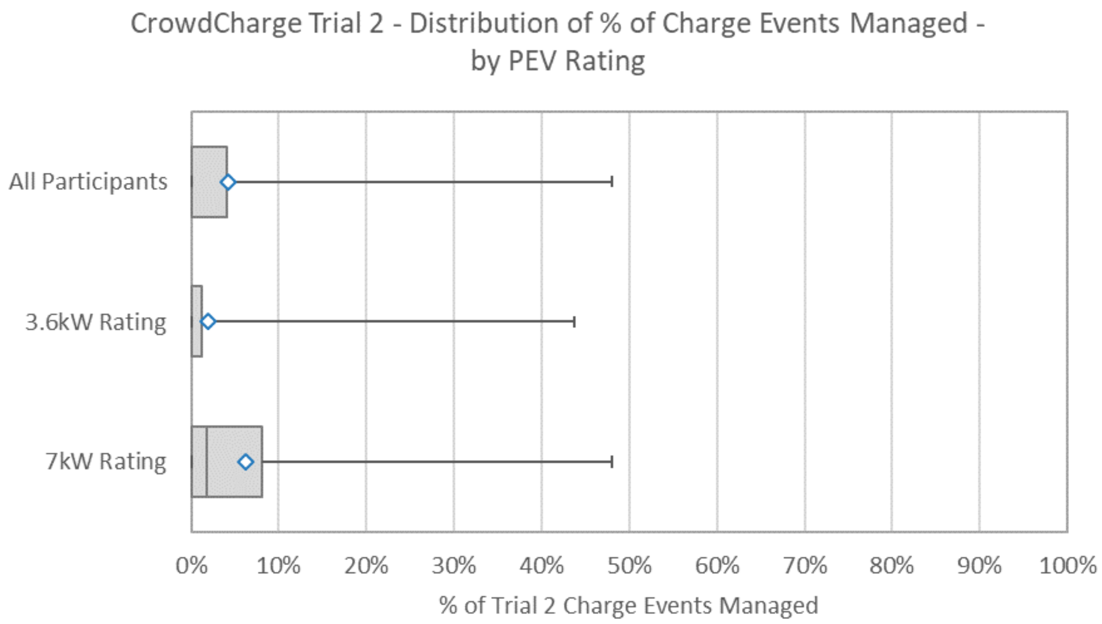


Figure 11-8: % of Charge of Events Managed CrowdCharge Trial 2 - by PEV Rating

Participants with 7kW vehicles continued to be managed more often than those with 3.6kW vehicles (average of 6% and 2% respectively). 6.1% of the 5,404 transactions involving PEVs rated at 7kW compared were managed, compared to 2.2% of the 7,352 involving 3.6kW vehicles – a statistically significant difference[117]. Management was slightly less active at a group level during Trial 2 (management active for 4.7% of duration of Trial 2, compared to 5.6% of Trial 1). 213 participants took part in both Trial 1 and 2. Of these:

- 21% experienced no management in either trial;
- 13% were managed for a greater proportion of their charging events in Trial 2 (compared to Trial 1); and
- 66% were managed for a smaller proportion of their charging events during Trial 2 (compared to Trial 1).

Management was active between 17:30 and 20:42 on weekdays during Trial 2 (no management took place at weekends). Therefore, participants who mainly charged outside of these time windows will have experienced less management than those who regularly charged in the evening peak. Each transaction has been evaluated to show whether or not it began between 16:00 and 19:59 Monday – Friday ('Began in Weekday Evening Peak'). Figure 11-9 below shows the relationship between how many charging transactions began in the weekday evening peak, and how many transactions were managed, split by PEV rating (3.6kW and 7kW). Each dot on the graph represents a participant.

[117] Z test. Z = 11.309

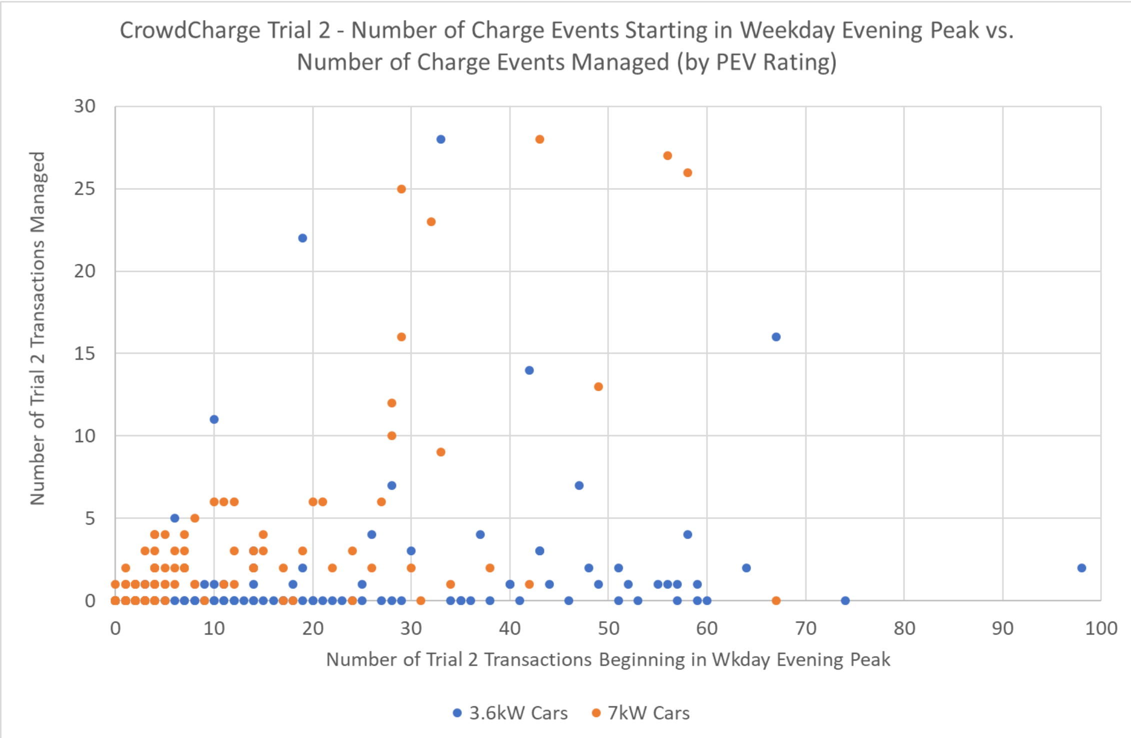


Figure 11-9: CrowdCharge Trial 2 No. of Charge Events Started in Weekday Evening Peak vs. No. Managed - by PEV Rating

(N.B. "Beginning in Weekday Evening Peak" is defined as events where charging began between 16:00 and 19:59 Monday – Friday)

There is wide variation in the data linking number of charging events in the evening peak with number of managed charging events. One potential reason for this variation is use of the app. A participant who entered a regular journey for their daily commute would be more likely to be managed during the evening peak than a participant who had not entered any information (assuming there were no other planned journeys in the evening).

The 'Restriction' and 'CrowdCharge Management Factor' metrics were introduced in Section 10.1.4. A restriction value has been calculated for all managed transactions where the following criteria were met:

- Transaction was managed;
- Start Charge, End Charge, Max. Amps Drawn and Energy Consumed between start and end of charging are all populated and not zero (i.e. meter values available for the transaction);
- The equivalent charge rate calculated using Start Charge, End Charge and the total consumed energy for the transaction is between 0.5 and 7.5kW. The criteria was applied in order to exclude transactions where the End Charge time is inaccurate – further details of this are given in Section 8.9; and
- The energy consumed between Start of Charging and EndCharge is at least 30% of the total amount for the transaction (to remove transactions where calculated EndCharge is inaccurate).

There were 491 managed charging events during Trial 2. Applying the criteria above means a value for restriction can be calculated for 475 of the events (97%). 104 participants experienced management during Trial 2. A CrowdCharge Management Factor has been calculated for 102 participants[118], using the formula below:

$$\text{CrowdCharge Management Factor (each participant)} = \text{\% of Events Managed} \times \text{Median Restriction Value for Managed Transactions}$$

(N.B. CrowdCharge Management Factor and GreenFlux Management Factor values are not comparable)

The box and whisker diagram below (Figure 11-10) shows the variation of CrowdCharge Management Factor, by PEV rating.

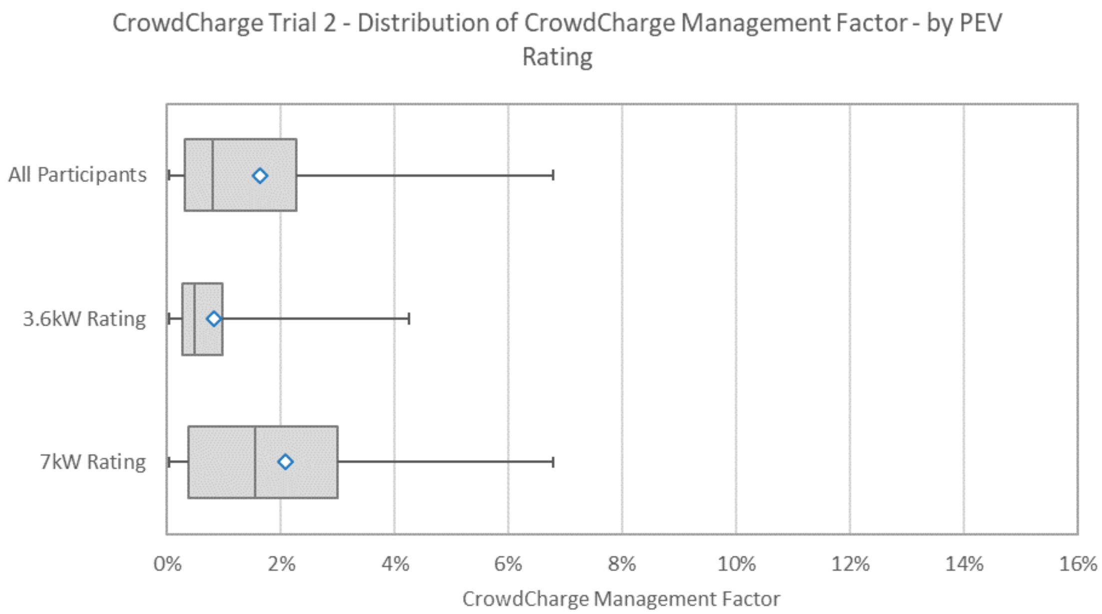


Figure 11-10: CrowdCharge Trial 2 Distribution of CrowdCharge Management Factor - by PEV Rating

This shows that participants with 7kW vehicles tended to have a higher management factor (i.e. they were managed more often and/or to a greater degree) than participants with 3.6kW vehicles.

The box and whisker diagram below compares the distribution of CrowdCharge Management Factor between Trial 1 and Trial 2.

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[118] The remaining two participants were each only managed for a single charging event, and this single transaction did not meet the criteria to allow a restriction value to be calculated.

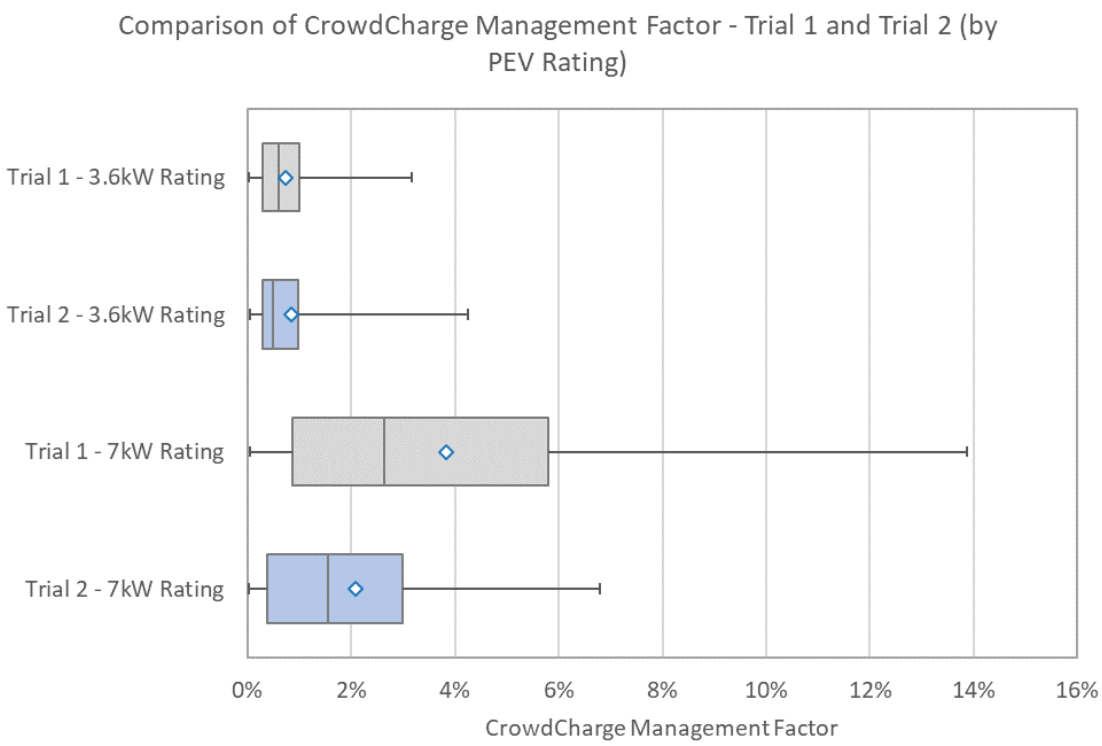

Figure 11-11: Comparison of CrowdCharge Management Factor - Trial 1 vs. Trial 2 (by PEV Rating)

Comparing the trials:

- For participants with 3.6kW rating, there was a statistically significant increase[119] in the proportion of participants who experienced no management during Trial 2. During Trial 1, 35% of participants with 3.6kW vehicles experienced no management, compared to 66% in Trial 2;
- For participants (with 3.6kW vehicles) who were managed, the distribution of CrowdCharge Management Factors are comparable (shown in the box and whisker diagram above);
- Participants with 7kW vehicles were also significantly[120] less likely to have experienced management during Trial 2. 45% of Trial 2 participants with 7kW vehicles experienced no management, compared to 16% in Trial 1; and
- For those who did experience management, it tended to be less restrictive in Trial compared to Trial 1.

[119] Z Test. Z Value of -4.6 (value of 1.96 would indicate a 5% confidence level)
[120] Z Test. Z Value of -5.0.

11.1.5 App Usage

When participants were moved into Trial 2, they were invited to register for a CrowdCharge account. Once the account was active they could use the web-based app to view information on their charging history and enter three different pieces of information which would be used as part of the smart charging algorithm:

- State of charge of the vehicle – requested each time the app was launched;
- Regular journeys – the participant entered a start and end point, a time of departure and which days the regular journey occurred (e.g. Monday – Friday); and
- One off journeys – as above, but a specific departure date and time were selected.

This section outlines the level of interaction between participants and the CrowdCharge app, both in terms of setting up an account and entering the different types of information.

Two snapshots were provided by CrowdCharge showing the number of data entries made for each participant of each type (number of regular journeys, number of one-off journeys, number of state of charge entries). The first included all data entries between the participants' app registration and 11th October 2018, and the 2nd all the data entries between 11th October 2018 and 7th January 2019 (the end of the trial). The CrowdCharge system does not allow data to be provided for a configurable date range – i.e. to split the data between Trial 2 and Trial 3 based on the date when Trial 3 began (13th November 2018 for most participants). Therefore, for the purposes of this data analysis, entries prior to 11th October have been included in the 'Trial 2' analysis and all entries after this are considered in the Trial 3 section.

11.1.5.1 Account Registrations

Based on records provided by DriveElectric and CrowdCharge, 236 participants were invited to sign-up for a CrowdCharge account when they moved into Trial 2. Sign-up was optional but encouraged as signing up for an account (and entering data) provided a way for participants to ensure they received enough charge during management events.

Information has been provided by DriveElectric showing the date at which each participant completed the registration and set-up process. Figure 11-12 below shows the number of participants who had registered for an app account, by week number, throughout the duration of Trial 2, alongside the number of invitations issued.

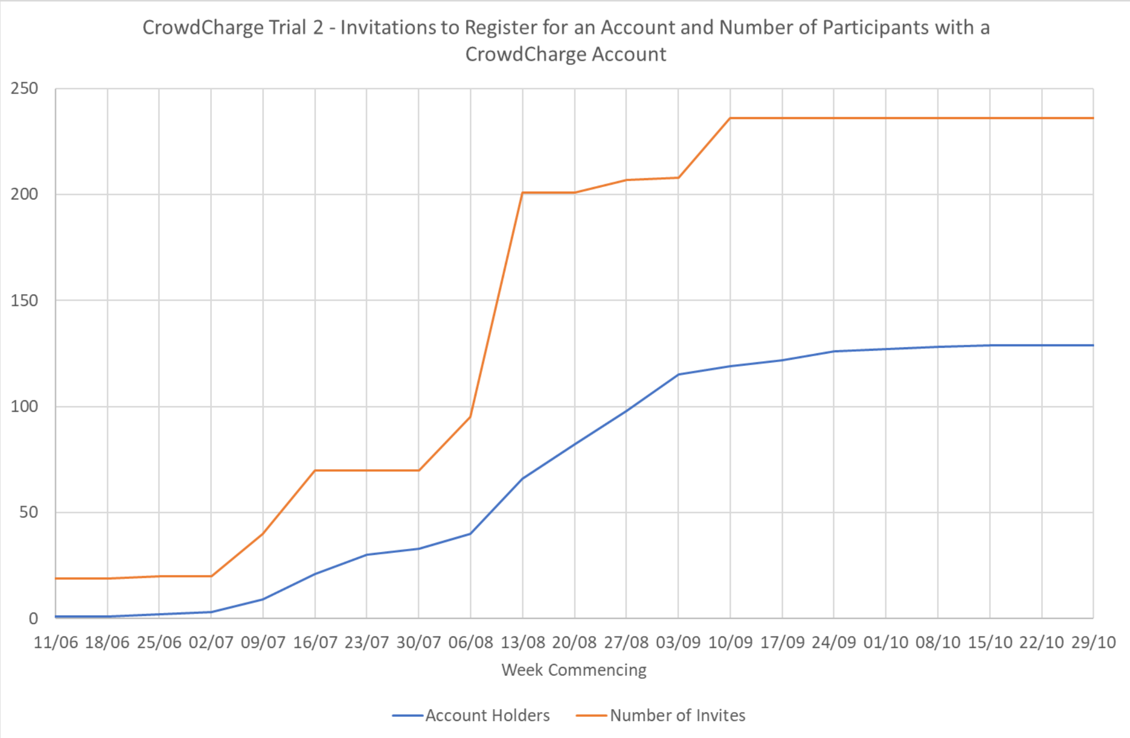

Figure 11-12: CrowdCharge Trial 2 App Registrations and Invitations

This shows the number of account holders following a similar shape to the number of invitees, with slightly delayed step changes in number of account holders aligned with each batch of invitations being issued. The delay is primarily due to the setup procedure in the CrowdCharge back office. Overall, throughout the course of Trial 2 (up to and including w/c 29th October 2018) 236 invites were issued and 129 participants registered for an account (55%). Various factors could influence the likelihood of a participant signing up.

Table 11-2 below summarises the Trial 2 sign-up rates in various groups.

Table 11-2: Trial 2 App Sign-Up Rate for various participant/vehicle attributes

Attribute	Group	Number of Invites	Number of Trial 2 Registrations	Sign-Up Rate (%)
All participants		236	129	55%
PEV Type	PHEV	91	47	52%
	REX	26	17	65%
	BEV	119	65	55%
Battery Capacity	Less than 10kWh	70	32	46%
	10 to 25kWh	61	38	62%
	25 to 35kWh	58	34	59%
	35kWh plus	47	25	53%

Attribute	Group	Number of Invites	Number of Trial 2 Registrations	Sign-Up Rate (%)
Age	No response	19	6	32%
	18 to 25	4	2	50%
	26 to 35	23	14	61%
	36 to 45	61	36	59%
	46 to 55	64	36	56%
	56 to 64	41	24	58%
	65+	24	11	46%
Uses of the Vehicle	No response	78	45	58%
	Social Only	37	13	35%
	Business and Commuting	54	33	61%
	Commuting	45	29	64%
	Business	22	9	41%
Level of Concern re: Management*1	No response	77	44	57%
	Not sure	6	4	67%
	Not at all concerned	103	46	45%
	Slightly concerned	38	29	76%
	Quite or very concerned	12	6	50%
Charging Frequency*2	0 to 0.26 sessions per day (CrowdCharge 1st Quartile)	47	24	51%
	0.26 to 0.56 sessions per day (CrowdCharge 2nd Quartile)	53	31	59%
	0.56 to 0.80 sessions per day (CrowdCharge 3rd Quartile)	51	32	63%
	More than 0.80 sessions per day (CrowdCharge 4th Quartile)	52	30	58%
Amount of Management in Trial 1	Not Managed during Trial 1 (or weren't part of Trial 1)	77	45	58%
	CrowdCharge Management Factor – 1st Quartile	41	22	54%
	CrowdCharge Management Factor – 2nd Quartile	40	22	55%
	CrowdCharge Management Factor – 3rd Quartile	41	19	46%
	CrowdCharge Management Factor – 4th Quartile	37	21	57%

**1 : The most recent survey response (either Trial 1 or Baseline survey) has been used for each participant.*
**2: Charging frequency has been calculated across all participants (rather than only those invited to app) therefore the number of invites in each quartile are not equal.*

When comparing the sign-up rate of different groups to the population as a whole, only the following groups have statistically significant differences:

- Those who used their vehicle for social purposes only were **less** likely to sign-up for an account than the population as a whole[121]. The reasons for this could include lower potential consequences of demand management, or they may have been charging at times when demand management was unlikely;
- Those who had not completed the Recruitment survey (i.e. age unknown – the "no response" group) were **less** likely to sign-up for an account than the population as a whole[122]. By not completing the first survey in the trial these participants demonstrated a lack of engagement with the project, which may perhaps explains the low app sign-up rate;
- Those who were "not at all concerned" about management were **less** likely than the population as a whole to sign-up for an app account[123];
- Conversely, those who were "slightly concerned" about management were **more** likely than the population as a whole to sign-up for an app account[124]. However, this trend did not extend to the other groups of participants who were concerned about management.

Comparisons have also been made within groups (e.g. is the difference in sign-up rate between the 'PHEV' and 'BEV' groups statistically significant?). This analysis shows:

- Participants who used their vehicle for social purposes only were significantly **less** likely to sign-up for the app than those who used their vehicle for 'business and commuting'[125], or commuting[126].
- Those who were slightly concerned about management were significantly **more** likely to sign-up for an app account compared to those who were not at all concerned[127]. However, this trend did not continue – those who were either quite or very concerned did not sign-up to the same extent.

[121] Z test. Z = 2.60
[122] Z test. Z = 2.11
[123] Z test. Z = 2.72
[124] Z test. Z = 2.93
[125] Z test. Z = 2.44
[126] Z test. Z = 2.61
[127] Z test. Z = 3.27

11.1.5.2 Data Entry

Once participants had registered for a CrowdCharge account, they were able to enter three different pieces of information which would be used as part of the smart charging algorithm:

- Regular journeys – participant entered a start and end point, a time of departure and which days the regular journey occurred (e.g. Monday – Friday);
- One off journeys – as above, but a specific departure date and time were selected; and
- State of charge of the vehicle – requested each time the app was launched.

The algorithm would then use the journey plans, along with a recent state of charge estimation (if available) to assess the time available to deliver the required energy and so prioritise vehicles if demand management was necessary.

This section of the report reviews the frequency with which participants entered the information above during Trial 2. As described above, CrowdCharge were only able to supply two snapshots showing the total number of data entries of each type which had been made – one on the 11th October and a second on 7th January. This section therefore considers data entered from participants registration until 11th October (therefore missing the last month of Trial 2).

128 participants had an operational CrowdCharge account by 11th October. Of these 128 participants, 83 had made at least one data entry (65%). This can be further broken down by information type:

- 41% (of the 128 participants with an account) had entered at least one regular journey;
- 25% had entered at least one 'one-off' journey; and
- 57% had entered their vehicle state of charge at least once.

For each participant the number of days for which they had had a CrowdCharge account before 11th October is known. The frequency with which they entered each piece of data has been calculated and converted to entries per week. This calculation has been made for the 126 participants who had had an account for at least a week by the 11th October. The box and whisker diagram below (Figure 11-13) shows the distribution of data entry frequency for the three data types. The 'all data types' figure considers the total data entries made for each participant (regular journeys + one offs + state of charge).

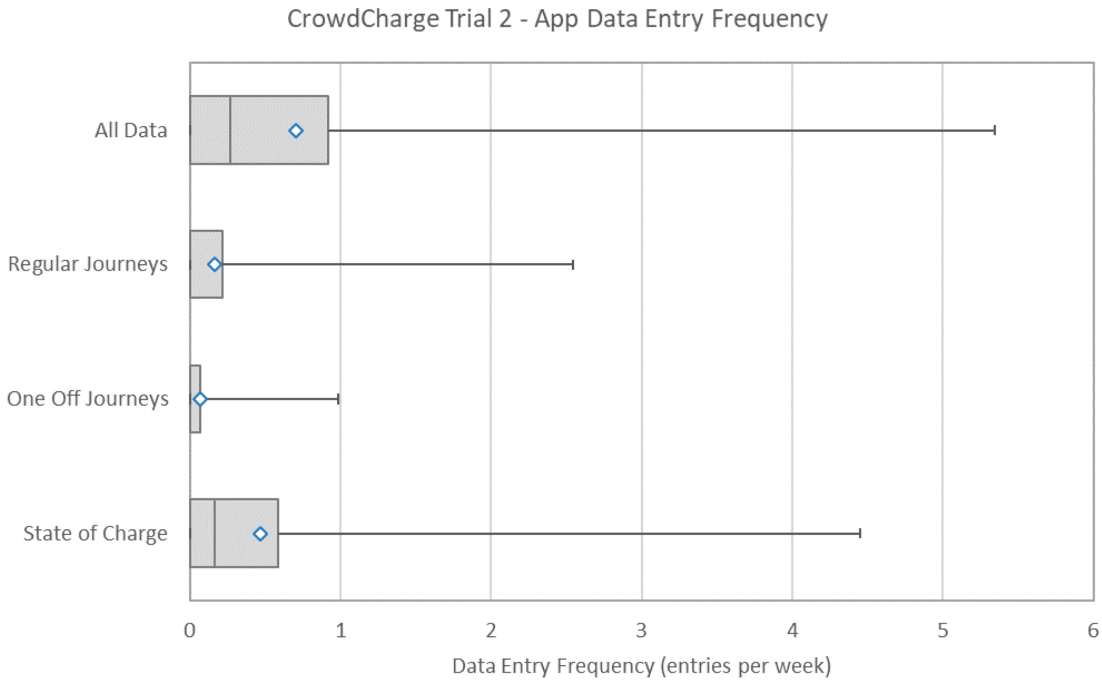

Figure 11-13: CrowdCharge Trial 2 App Data Entry Frequency - by Data Type

This shows that, for all three data types, the majority of participants entered data very infrequently. The upper quartile in all cases is very large (compared to the first to third quartiles). State of charge was entered most frequently. This is to be expected as a participant may have only needed to input regular journeys once (e.g. entering a commute or other regular journeys) when they first registered for an account and one off journeys may not have occurred (or the participant may not have considered it necessary to enter the data).

For the app to be used to prioritise chargers effectively, the CrowdCharge algorithm needs to be aware of the energy required to meet the journey requirement i.e. the energy necessary for the journey (journey distance from the plan x efficiency assumption) minus the energy already in the battery (state of charge at plug in). In the absence of an up-to-date figure from app entries, the system fell back on either a historical estimate of state of charge (based on previous transactions) or a conservative assumption of 10%. The app and accompanying instructions therefore encouraged participants to enter State of Charge each time they charged their car. For each participant who had an app account, where an average charging frequency could be calculated from at least six months of data, the frequency at which they entered state of charge has been divided by the charging frequency. If the participant had entered State of Charge every time they charged, then this would equal 1.

The histogram below (Figure 11-14) shows the distribution of these values.

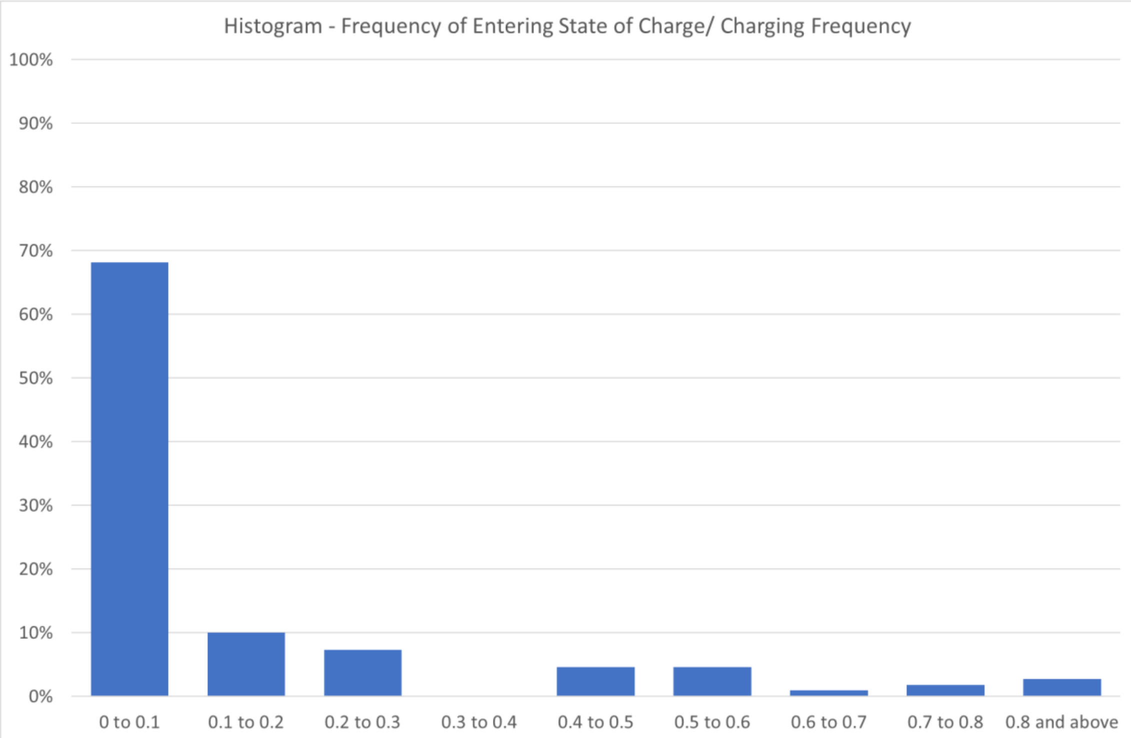

Figure 11-14: Histogram - Frequency of Entering State of Charge/ Charging Frequency

This illustrates that the majority of participants entered their vehicle state of charge much less frequently than they charged their car. 78% of participants entered their state of charge for less than 20% of their charging events (i.e. 78% of participants in the 0 to 0.1 and 0.1 to 0.2 categories on the histogram above).

An example of the variation in app data entry rates is shown in the box and whisker diagram below, for PEV type.

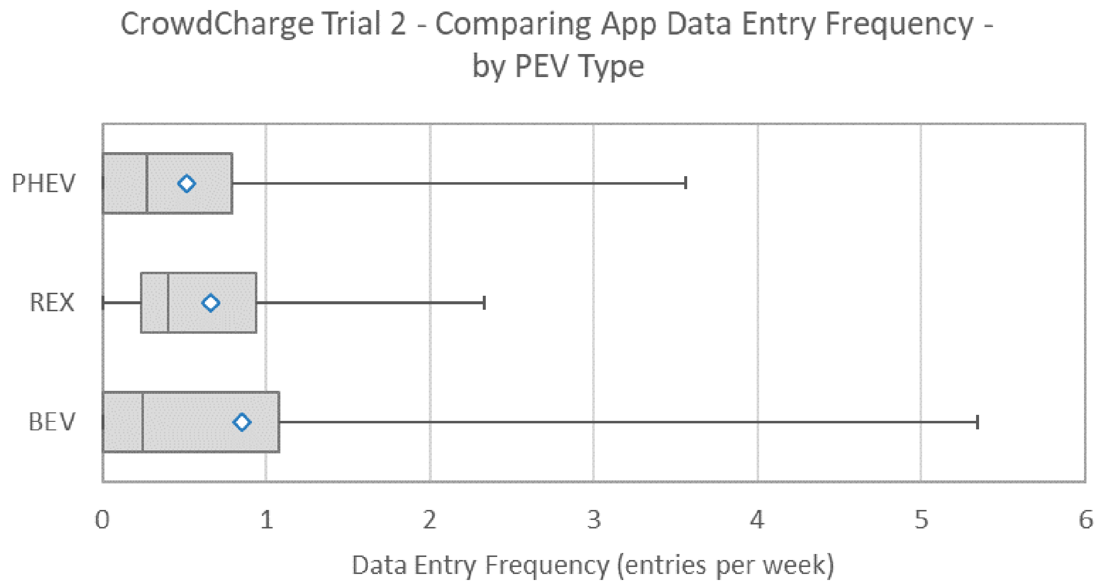

Figure 11-15: CrowdCharge Trial 2 - Comparing App Data Entry Rates by PEV Type

The same factors have been used to compare the average data entry frequency for each group.

Table 11-3: App Data Entry Rates for different vehicle/participant attributes

Attribute	Group	Average Data Entry Frequency (all data types, entries per week)
All participants		0.70
PEV Type	PHEV	0.52
	REX	0.66
	BEV	0.85
Battery Capacity	Less than 10kWh	0.51
	10 to 25kWh	0.90
	25 to 35kWh	0.70
	35kWh plus	0.66
Age	No response	1.10
	18 to 25	0.46
	26 to 35	0.43
	36 to 45	0.72
	46 to 55	0.69
	56 to 64	0.58
	65+	1.09

Attribute	Group	Average Data Entry Frequency (all data types, entries per week)
Uses of the Vehicle	No response	0.81
	Social Only	0.65
	Business and Commuting	0.46
	Commuting	0.68
	Business	1.16
Level of Concern re: Management*1	No response	0.82
	Not sure	0.15
	Not at all concerned	0.63
	Slightly concerned	0.79
	Quite or very concerned	0.16
Charging Frequency*2	Less than six months data available	0.76
	0 to 0.26 sessions per day (CrowdCharge (CC) 1st Quartile)	0.97
	0.26 to 0.56 sessions per day (CC 2nd Quartile)	0.50
	0.56 to 0.80 sessions per day (CC 3rd Quartile)	0.56
	More than 0.80 sessions per day (CC 4th Quartile)	0.82
Amount of Management in Trial 1	Not Managed during Trial 1 (or weren't part of Trial 1)	0.71
	CrowdCharge Management Factor – 1st Quartile	0.53
	CrowdCharge Management Factor – 2nd Quartile	0.88
	CrowdCharge Management Factor – 3rd Quartile	0.49
	CrowdCharge Management Factor – 4th Quartile	0.87

**1: This data uses the most recent response from each participant – i.e. the level of concern they reported on the Trial 1 survey if available, otherwise the baseline survey response is used.*
**2: Charging frequency has been calculated as the average value between December 2017 and November 2018, where at least six months data was available.*

Despite some apparent differences in the average data entry rate for different groups shown in Table 11-3 above, the variation within groups was large. This is evident from the box and whisker diagram comparing data entry rates for each PEV type (Figure 11-15). The large variation within groups means that the none of the differences shown above were statistically significant[128].

[128] Tested using 't test' (Significance Test – Independent Means), using a 5% confidence interval.

11.1.6 Customer Research Results

Trial 2 participants were asked to complete a survey by Impact at least six weeks after they were invited to sign-up for a CrowdCharge account (i.e. moved into Trial 2). Those who completed the survey were rewarded with a £10 Amazon voucher (on condition that they had also completed the Recruitment and Baseline surveys). All qualifying Trial 2 participants were invited to complete a survey, regardless of whether they signed up for a CrowdCharge account.

The Trial 2 survey consisted of many of the same quantitative and qualitative questions that appeared in the Baseline and Trial 1 surveys, allowing attitudes towards charging arrangements to be tracked through the different phases of the project. In addition, the Trial 2 survey collected information about participants use of the app.

The Trial 2 survey was open for responses between 1st August and 19th November 2018. The full text of the CrowdCharge Trial 2 survey can be found in Appendix 7. The response rate is shown below (Table 11-4).

Table 11-4: Trial 2 CrowdCharge Customer Survey Response Rate

	Surveys Issued	Surveys Completed	Response Rate (%)
CrowdCharge Trial 2	236	168	71%

All participants who were invited to complete a Trial 2 survey took part in Trial 2 (i.e. their charger was part of a Trial 2 group), and had been invited to sign up to the app. Due to variations in charging behaviour, and the fact that signing up to the app was optional, the 168 respondents contained a mix of management experiences and use of the app.

11.1.6.1 Reported change in charging behaviour

Participants were asked about their charging behaviour in Trial 2, and whether this had changed since they last completed a survey (either the Trial 1 or Baseline). Most (83% of responses) reported that their charging behaviour had not changed substantially since Trial 1, where trial participants were subjected to charge management with no information and no app (only 17% reported that they had changed their behaviour). The free text responses to this part of the survey detailed the reason for any change in charging behaviour. These are shown below, but did not include either smart charging or the app.

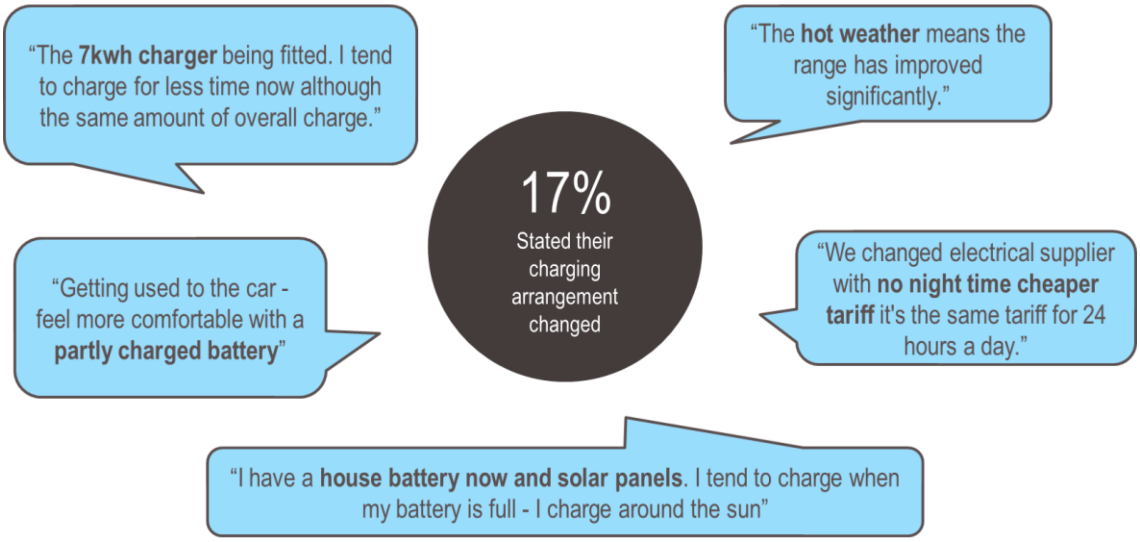

Figure 11-16: Reported changes in charging behaviour (Base: 168 - all respondents)

Few participants reported any change in their charging behaviour, and a detailed presentation of this behaviour is given in Section 10.1.5.

11.1.6.2 Attitudes to the App

Trial 2 was the first part of the project in which participants could use an app to interact with the smart charging system. The Trial 2 survey therefore focussed on participants awareness of the app and its features, their reasons for using (or not using) it and collecting feedback on it (e.g. ease of use, additional features). This sub-section reports the results of these questions. This is linked to participant's attitudes towards their charging arrangements and management in the next sub-section, to show the effect of the app. The questions asked to participants varied depending on whether or not they said they were aware/had used the app. The base in each case is included in the caption for each figure.

The first question sought to measure the level of awareness of the app amongst trial participants and how many participants had used the app. Each participant had received multiple invitations to sign-up to the app from DriveElectric.

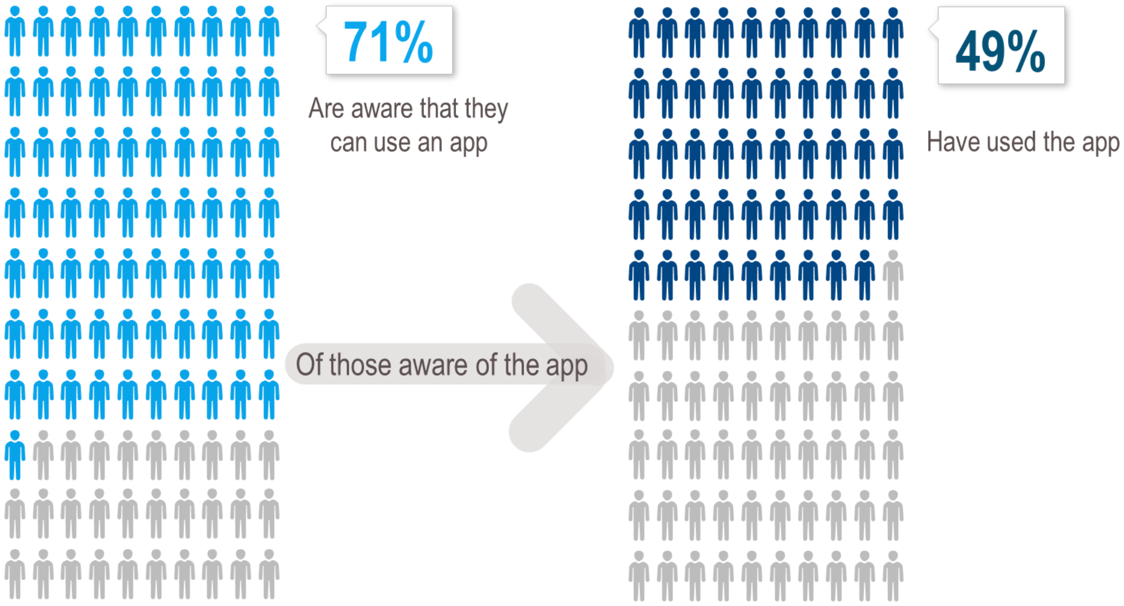

Figure 11-17: Are you aware that you can access an app to interact with your smart charging system? (Base: 168) Have you used the app? (Base: 119 - those aware of the app)

The majority of CrowdCharge trial participants who responded to the survey were aware of the app. However, only around half of those aware of the app had used it. Section 11.1.5.1 above shows that 55% of those invited to sign-up for an account did so. The lack of awareness of the app (29% of survey respondents) accounts for some of those participants who did not sign-up.

Participants were asked for the reasons why they did, or did not, use the app. The most common reasons given are illustrated in the two diagrams below.

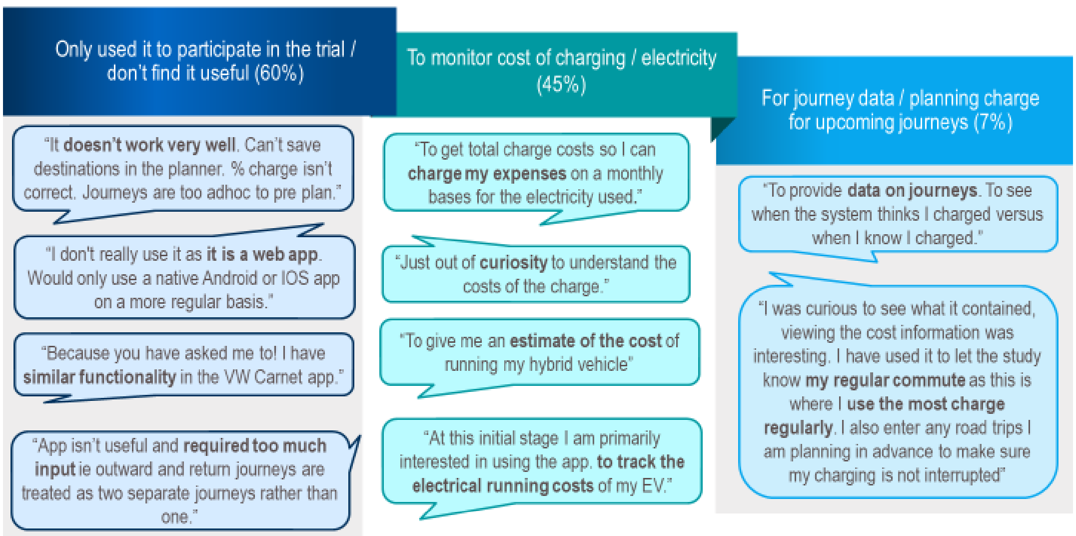

Figure 11-18: Can you explain why you used the app? (Base: 119 – all those who said they'd used the app. Responses provided by 58)

This that shows the most common reasons for using the app were either to try it out (as it was part of the trial) or to access details of previous charge sessions. The features relating to interacting with the smart charging system (i.e. entering journey plans to assist in prioritisation during demand management) was mentioned by only a small minority of respondents (7%).

The free text responses below were provided by respondents who were aware of the app but had not used it.

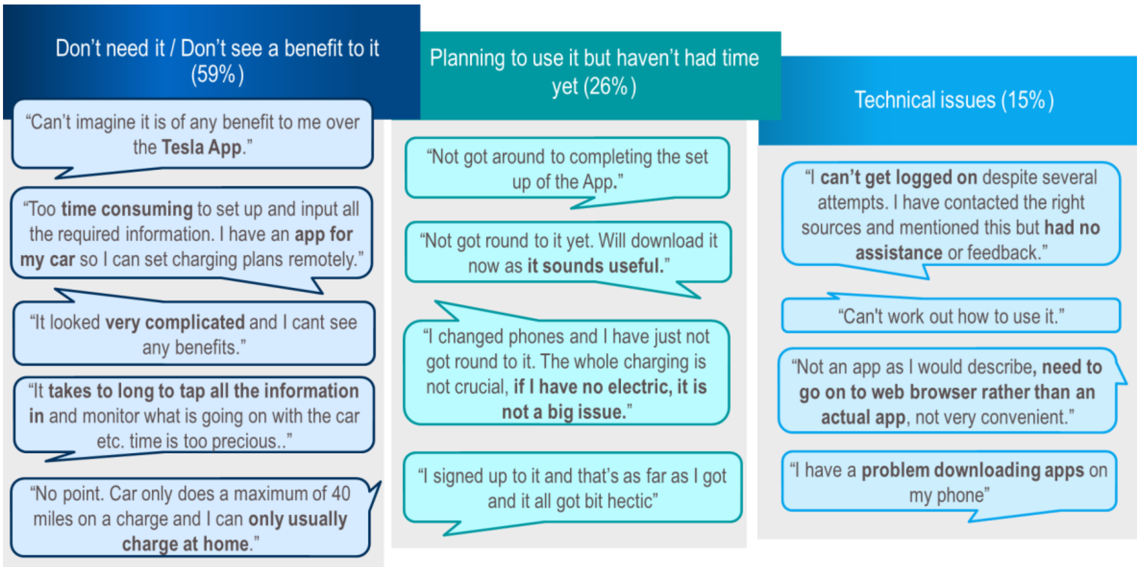

Figure 11-19: Why have you not used the app? (Base: 61 – all those who said they had not used the app)

The most common reasons were a lack of clarity around the benefits of using the app and the balance of time required to enter the information and the benefit received.

Participants who had stated that they were aware of the app were asked if they knew about its various functions and if they had used them. In each case the percentage represents the proportion of respondents who were aware of/had used the function.

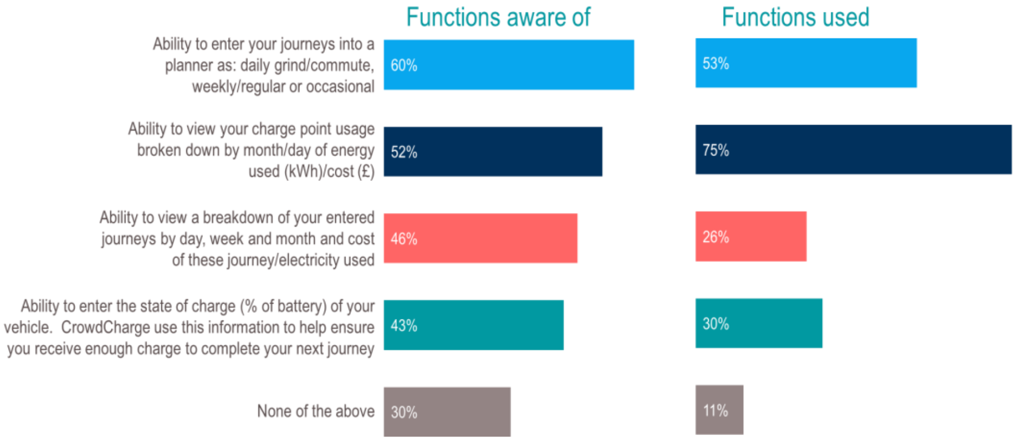

Figure 11-20: Are you aware of the following functions? (Base: 119 – all those aware the app was available). Which of the following functions have you used? (Base: 53 – those who said they'd used the app and were aware of at least one function)

Awareness of some of the apps functions was low. Amongst participants who had used the app, viewing charging history was the most used function. The functions which related to prioritisation during demand management (entering journey plans and state of charge) were not widely used, aligning with the findings reported in Section 11.1.5.

Participants who had used the app were asked how easy they found it to use.

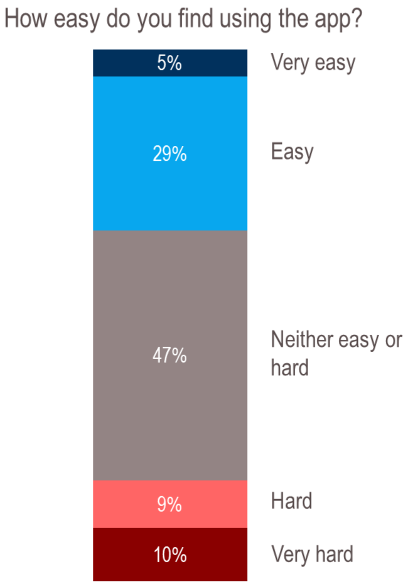

Figure 11-21: How easy do you find using the app? (Base: 58 - all those who said they had used the app)

A third of participants who had used the app thought that it was easy to use. However, a fifth found it was hard to use.

All survey respondents were then asked if they would continue to use the app.

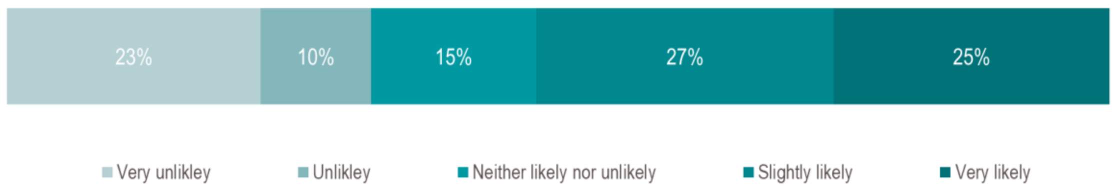

Figure 11-22: How likely are you to use the app going forward? (Base: 168 – all survey respondents)

52% of CrowdCharge participants stated that they were likely (based on 'Very likely' and 'Slightly Likely' responses) to continue using the app. Amongst only those who said they had used the app (a group of 58 respondents) 47% said they were either "very likely" or "slightly likely" to use the app going forward. Around a quarter of all respondents stated that they were very unlikely to continue to use it (compared to 17% amongst those who said they had used the app). 'Use' of app as reported by participants may well relate to the functions they were using at the time of completing the survey (most commonly viewing charge point usage), rather than the journey planning elements which related to the smart charging algorithm.

Participants were asked to identify other functions that they would expect to be part of the app's functionality (if they were aware the app was available). Most CrowdCharge participants who responded to the survey did not expect to see any other functions on their app (or hadn't used it) (63% of respondents). The chart below shows the most commonly suggested features:

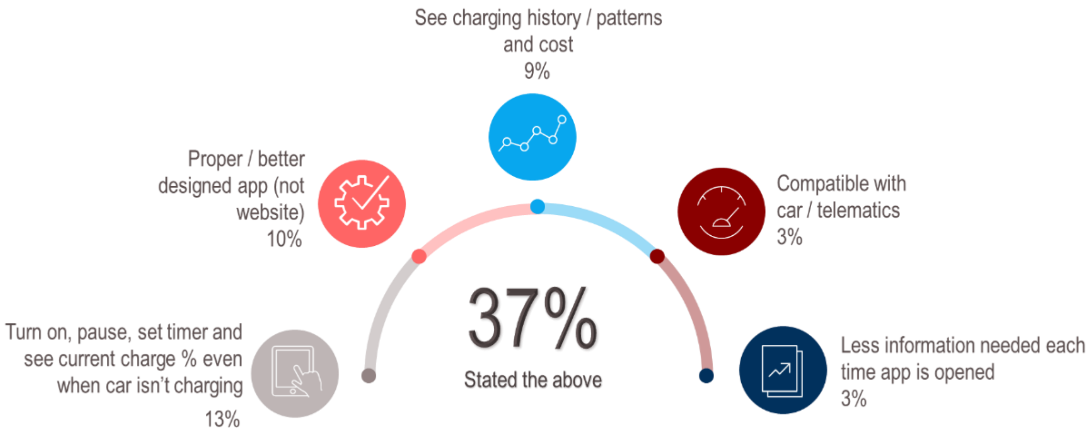

Figure 11-23: Are there any other features that you expected to see on the app (Base: 119 – those aware of the app)

Some of the functions suggested (e.g. "see charging history/patterns and cost") were already part of the app, while others were not possible. Optimising the design of the app (e.g. converting to a Android/iOS app, and reducing data entry requirements) was suggested by 13% of survey respondents (15 participants of the 44 who suggested additional features).

11.1.6.3 Acceptability and satisfaction with charging arrangements

One of the key elements of the Electric Nation trial is to understand the acceptability and smart charging amongst participants, and the factors which affect this. Participants were asked a consistent series of questions at multiple points through the project – before management (the Baseline survey, see Section 9.1), as part of Trial 1 (see Section 10.1.5), Trial 2 (this section) and Trial 3 (Section 12.1.6). This allows participants' attitudes towards their charging arrangements to be compared through the trial as they experienced different aspects of smart charging.

This section shows the results of this part of the survey and compares the responses to those received in the Baseline and Trial 1 surveys, showing the effect that the availability of an app has. Section 11.1.7 relates these scores to the amount of management a participant experienced and their use of the app (based on data received from CrowdCharge). Throughout this section, data is shown for only those participants who completed all three surveys being compared – i.e. the Baseline, Trial 1 and Trial 2. Some of these participants had chosen to sign-up for an app account and some had not. The results of several questions have been disaggregated based on app usage and the results of this analysis is shown in Section 11.1.7. Results from all respondents can be found in Appendix 2.

Participants were asked to rate the acceptability of their current charging arrangements on a scale of 1 (completely unacceptable) to 10 (completely acceptable). Figure 11-24, below, shows the proportion of participants who rated their charging arrangements as highly acceptable (gave a score of 8, 9 or 10) for the Baseline, Trial 1 and Trial 2 surveys.

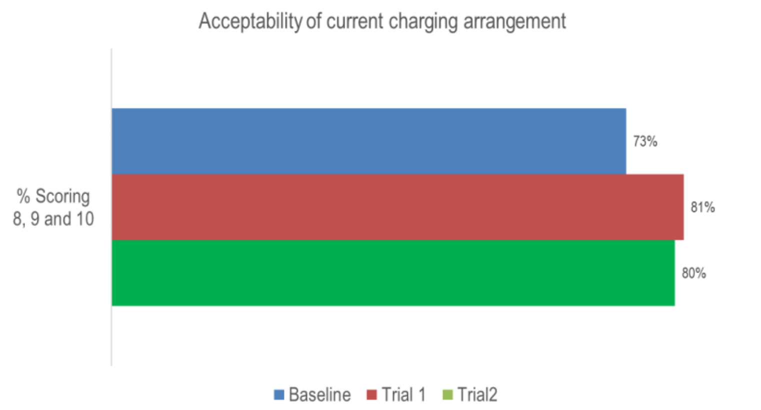

Figure 11-24: Acceptability of current charging arrangements (Base: Baseline (96), Trial 1 (95), Trial 2 (94), excludes those who answered 'don't know')

There was a slight decrease in acceptability between Trial 1 (demand management, no app) and Trial 2 (demand management, with app) but this was not statistically significant[129]. Figure 11-24 also shows a small increase in acceptability between the Baseline and Trial 2 surveys but, again, this is not statistically significant[130].

[129] Z test. Z value = 0.95
[130] Z = 1.14

Participants were also asked to the score their satisfaction with their charging arrangements on a 1 to 10 scale. Figure 11-25 compares the level of satisfaction for those answered all three surveys.

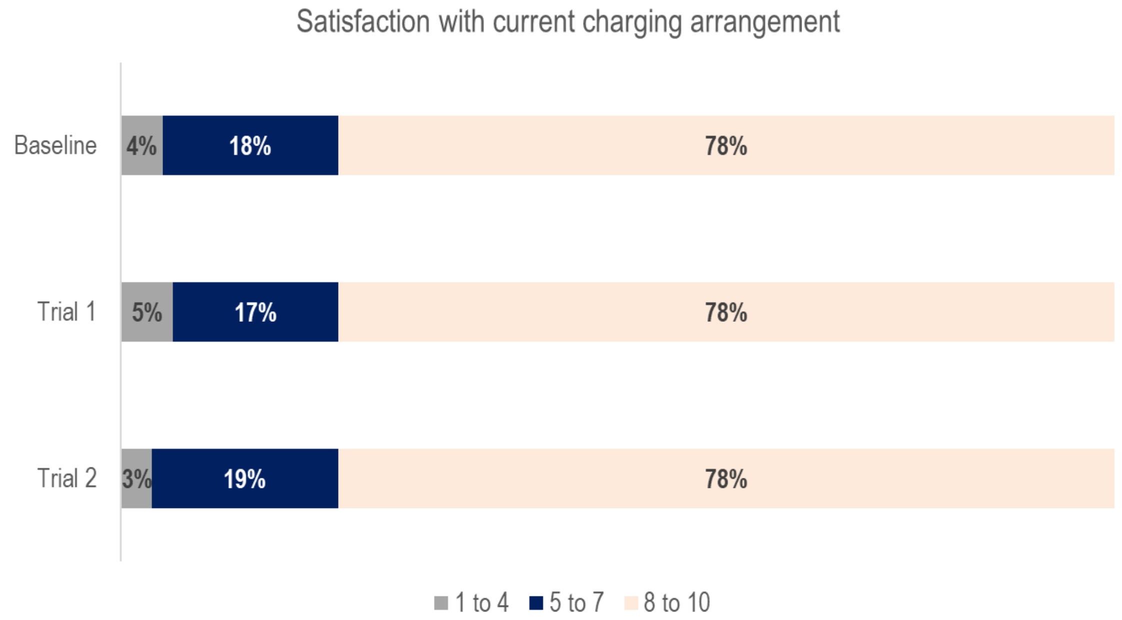

Figure 11-25: CrowdCharge Satisfaction with Current Charging Arrangements - Baseline, Trial 1 and Trial 2 (Base: Baseline 96, Trial 1 96, Trial 2 96)

The level of satisfaction with current charging arrangements remained very similar between the three surveys with the proportion of participants who were ‘highly satisfied’ (scores 8 to 10) remaining static across all three surveys. The changes between the 'very dissatisfied' (scores 1 to 4) and 'neutral' (scores 5 to 7) in the three surveys are not statistically significant[131].

[131] Z test. ‘Very dissatisfied’ Z = 0.71. ‘Neutral’ Z = 0.42

Table 11-5 compares the proportion of participants who were highly satisfied (score of 8 to 10), disaggregated by PEV type and battery capacity.

Table 11-5: Satisfaction Scores by PEV Type and Battery Capacity

Sub-Group		Sample Size	% of Survey Responses Scoring 8 - 10		
			Baseline	Trial 1	Trial 2
PEV Type	REX	14	79%	79%	86%
	PHEV	38	66%	66%	61%
	BEV	44	89%	89%	91%
Battery Capacity	Less than 10kWh	26	62%	65%	54%
	10 to 25kWh	25	80%	72%	84%
	25 to 35kWh	33	85%	91%	88%
	35kWh+	12	92%	83%	92%

No sub-group had a statistically significant change in the proportion of participants who were highly satisfied between the Baseline and Trial 2, or Trial 1 and Trial 2 surveys. However, the satisfaction levels between the subgroups varies considerably. For example, there is a statistically significant difference in the 'highly satisfied' BEV and PHEV participants in the Trial 2 survey (91% vs. 61%)[132]. There is also a statistically significant difference between the 'highly satisfied' participants with battery capacities 'Less than 10kWh' in the Trial 2 survey compared with battery capacities in the '10 to 25kWh group (54% vs. 84%)[133].

The key findings section links the acceptability and satisfaction scores to participants' experience of management during Trial 2, and their use of the app.

Participants were also asked to state for how long they would be willing to continue with their current charging arrangements. Figure 11-26 shows the breakdown of results for all participants who completed a Baseline, Trial 1 and Trial 2 survey.

[132] Z = 3.22
[133] Z = 2.31

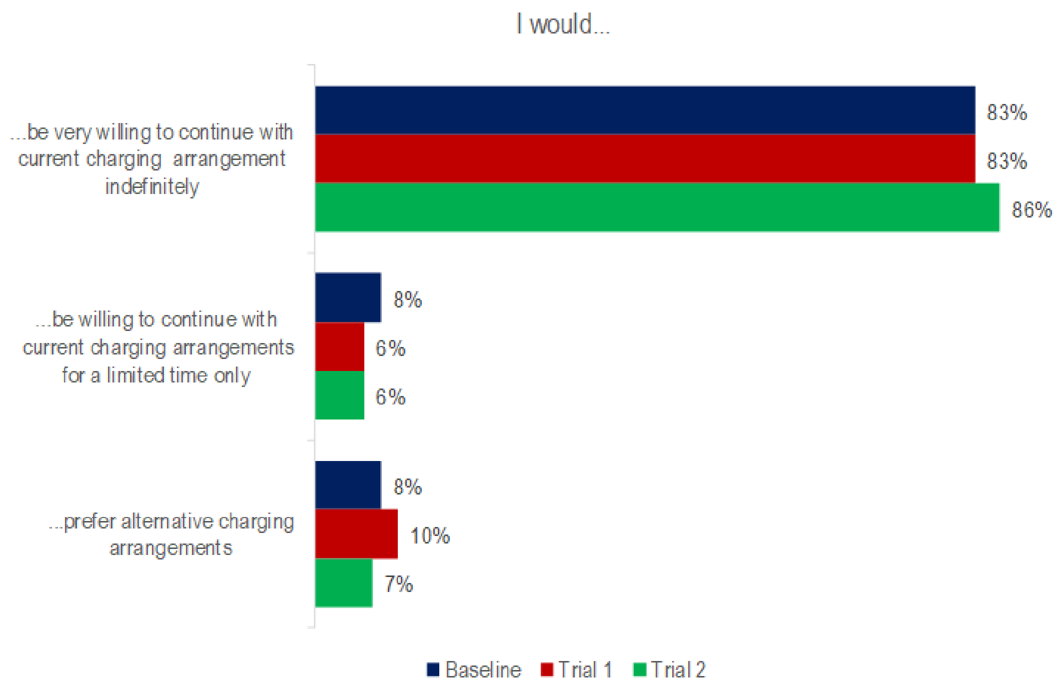

Figure 11-26: CrowdCharge Willingness to Continue with Charging Arrangements (Base: Baseline 96, Trial 1 96, Trial 2 96)

Overall, participants' views remained similar across all three surveys. The changes in each category between the Trial 1 and Trial 2 surveys were not statistically significant.

Table 11-6 disaggregates the Baseline, Trial 1 and Trial 2 surveys by vehicle type and shows the proportion of respondents who were willing to continue with their charging arrangements indefinitely.

Table 11-6: % of Participants willing to continue with charging arrangements indefinitely - Baseline, Trial 1 and Trial 2 - by PEV Type

Group		Sample Size	% of Survey Respondents Willing to Continue with Charging Arrangements Indefinitely		
			Baseline	Trial 1	Trial 2
PEV Type	REX	14	100%	79%	86%
	PHEV	38	76%	76%	84%
	BEV	44	84%	91%	89%

The largest change in the proportion of respondents willing to continue with their charging arrangements indefinitely occurred in the 'REX' group (79% vs. 86%)[134], although due to the small sample size this was not statistically significant.

[134] Z = 0.49

No group had a statistically significant change in the proportion of participants who were willing to continue with their charging arrangements indefinitely between the three surveys. There were differences between the groups in the Baseline survey (although these are not statistically significant) but in the Trial 2 survey the willingness to continue indefinitely was broadly similar between the groups.

Participants were asked about their concerns regarding smart charging. The results from Baseline (before management), Trial 1 (management, but no app) and Trial 2 surveys are shown below.

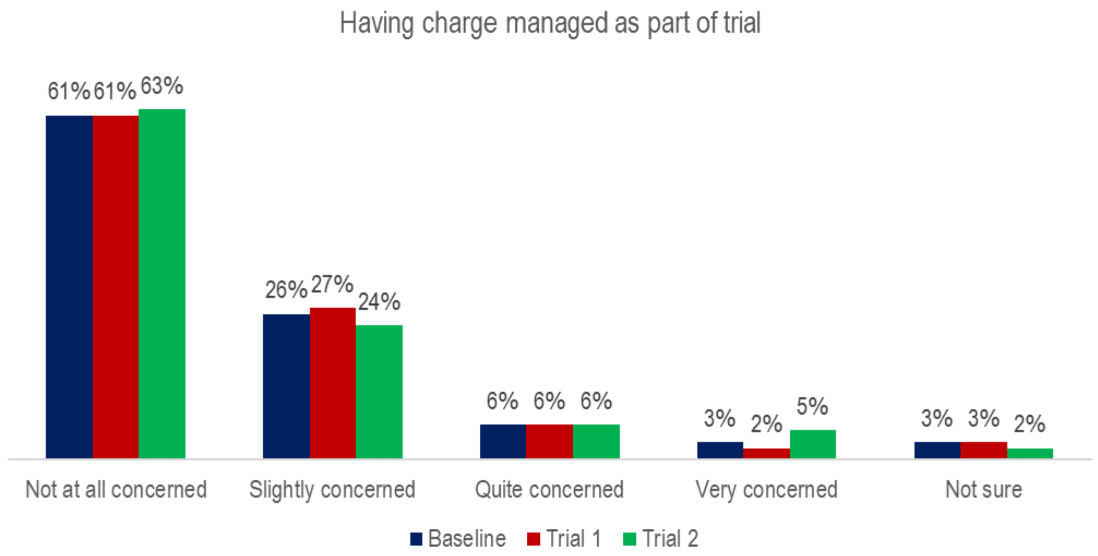

Figure 11-27: CrowdCharge Trial 2 Concerns about management (Base: Baseline 96, Trial 1 96, Trial 2 96)

The results are very similar between the Baseline, Trial 1 and Trial 2 surveys (no statistically significant changes). Levels of concern remained low throughout, with 87% of participants having no or only slight concerns at Trial 2.

The introduction of the app provided a way in which participants could influence the likelihood that they would be managed, giving them back a level of control which was not available in Trial 1. The Trial 2 survey therefore asked participants who were aware of the app to what extent the app helped to alleviate any concerns that they had about managed charging.

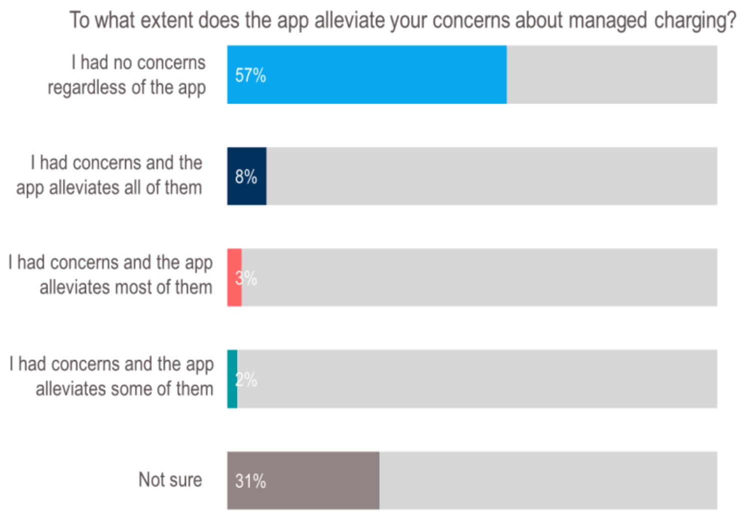

Figure 11-28: To what extent does the app alleviate your concerns about managed charging? (Base: 119 - all those who were aware of the app)

In the results shown above, over a half of participants did not have any concerns about managed charging prior to receiving the app. The app alleviated the concerns of some participants, but many were unsure. This may be due to a lack of awareness of how the information they entered in the app would influence the likelihood that they would be managed.

The results have been further disaggregated based on the app sign-up and usage information shown in Section 11.1.5.

Table 11-7: Relationship between app usage and impact of the app on level of concerns about management

Survey Response	Responded to the Trial 2 Survey (based on those who stated they had used the app in the survey) = 119 participants	Responded to the survey, had an account, but had not entered data = 20 participants	Responded to the survey, had an account, and entered data = 58 participants
I had no concerns regardless of the app	57%	50%	60%
I had concerns and the app alleviates all of them	8%	0%	2%

Survey Response	Responded to the Trial 2 Survey (based on those who stated they had used the app in the survey) = 119 participants	Responded to the survey, had an account, but had not entered data = 20 participants	Responded to the survey, had an account, and entered data = 58 participants
I had concerns and the app alleviates most of them	3%	0%	5%
I had concerns and the app alleviates some of them	2%	25%	5%
Not sure	31%	25%	28%

11.1.6.4 Trial 2 Findings from Focus Groups

CrowdCharge participants in the focus group discussion held at the end of the project shared their views on the app. They were quick to point out that the 'app' was in fact a website (i.e. not a smartphone smartphone app). They found adding their journeys involved too much effort and was "fiddly". For many, the app wasn't useful as they did irregular journeys and therefore couldn't just enter a series of regular journeys (increasing the effort involved further).

It is notable that the vast majority of those in the group that said "I had concerns and the app alleviates some of them" did not actually input any data. This suggests that simply being able to access the app was sufficient to address some concerns.

A selection of quotes supporting these impressions, are shown below:

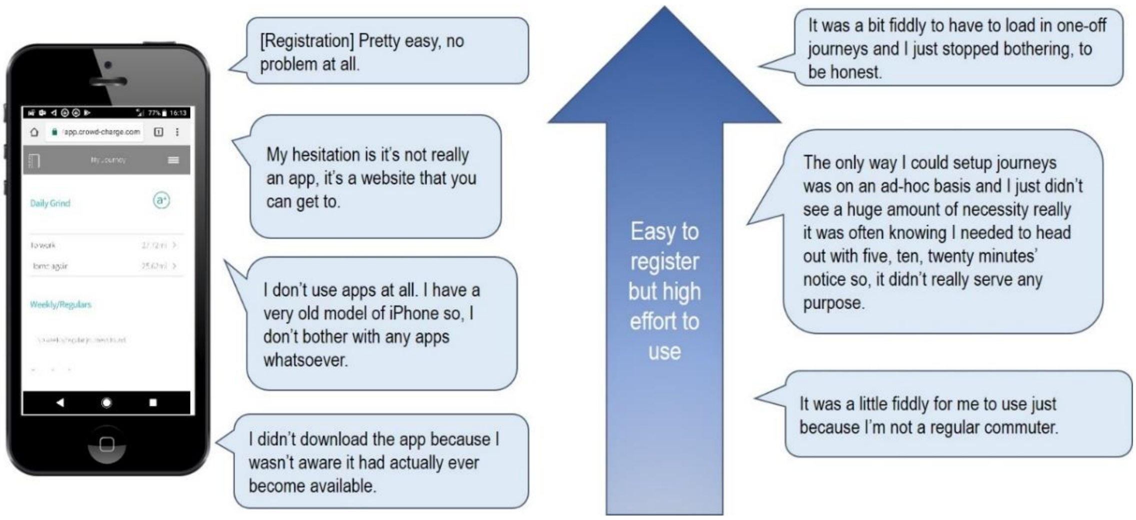

Figure 11-29: CrowdCharge Trial 2 Focus Group Quotes

11.1.6.5 Summary

Satisfaction with Trial 2 charging arrangements (i.e. demand management, with an app) among the CrowdCharge trial participants who completed the survey remained steady compared to the previous stages of the project. Acceptability of the charging arrangements also remained high (no statistically significant changes between Trial 1 and Trial 2) and was consistent with the Baseline and Trial 1 results. Most participants still had few concerns about having their charge managed as part of the project.

The majority of CrowdCharge cohort participants were aware of the app (71%). 119 survey respondents were aware of the app, and 58 of these people stated they had used the app (49% of those aware of the app had used it). Among participants who had used the app, viewing charge point usage was stated to be the most used function.

11.1.7 Key Findings – CrowdCharge Trial 2

- In the evening peak, the 90th Percentile peak demand was approximately 600W per charger (e.g. in a group of 100 chargers the peak demand during the evening would be less than 60kW on 90% of days). This demand was constrained by the use of demand management – unrestricted demand would be higher. This is consistent with winter peak demand during the evening, due to the use of demand management in both cases.
- Overall energy demand (area under the demand curve) was lower in summer. In the winter a second, higher peak in demand occurred at approximately 01:00, with a 90th percentile value of 825W per charger. In the summer the 90th percentile demand at 01:00 was around 480W per charger.
- During Trial 2, management was frequently active during the weekday evening peak, when management was active on 90% of days. No management occurred at the weekend. This management occurred when the total demand from EV chargers (if they were all given their maximum allocation of current) exceeded the amount of current available in the capacity profile.
- The demand management led to individual chargers having their charging rate reduced (e.g. from 32A to 17A). The current limit assigned to each individual charger varied based on a prioritisation algorithm which used journey plans to determine which chargers required a greater current allocation.
- Demand management did not lead to an increase in the proportion of charging events where vehicles were not fully charged when unplugged. In fact, there was a statistically significant decrease in the proportion of hot unplug events amongst Trial 2 participants from 18.1% (outside of management) to 16.5% (during Trial 1) to 15.5% (during Trial 2).
- 4% of charging events during Trial 2 were constrained by demand management (491 charging events).
- 45% of participants experienced some management of their charging events.

- Participants with 32A vehicles experienced more management than those with 16A vehicles. The management they experienced was also more restrictive.
- Management was less restrictive in Trial 2 than Trial 1, with lower values of CrowdCharge Management Factor.
- Table 11-8, below, relates the scores given for participants **satisfaction** with their current charging arrangements in the Trial 2 survey to values of CrowdCharge Management Factor (i.e. 81% of participants who were not managed in Trial 2 gave a satisfaction score of 8 – 10):

Table 11-8: Relationship between Amount of Management in Trial 2 and Satisfaction Scores

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
Not Managed During Trial 2	94	2%	17%	81%
CrowdCharge Management Factor 1st Quartile	20	0%	20%	80%
CrowdCharge Management Factor 2nd Quartile	16	0%	13%	88%
CrowdCharge Management Factor 3rd Quartile	18	6%	17%	78%
CrowdCharge Management Factor 4th Quartile	15	0%	20%	80%

This shows that increasing amounts of management do not lead to higher rates of dissatisfaction.

- Table 11-9 relates the scores given by participants for the **acceptability** of their current charging arrangements in the Trial 2 survey to values of CrowdCharge Management Factor (i.e. 82% of participants who were not managed during Trial 2 gave an acceptability score of 8 – 10).

Table 11-9: Relationship between Amount of Management in Trial 2 and Acceptability Scores

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
Not Managed During Trial 2	92	1%	17%	82%
CrowdCharge Management Factor 1st Quartile	20	0%	15%	85%
CrowdCharge Management Factor 2nd Quartile	16	0%	19%	81%
CrowdCharge Management Factor 3rd Quartile	18	6%	17%	78%
CrowdCharge Management Factor 4th Quartile	15	0%	20%	80%

This shows a similar trend to the satisfaction results, with no clear link between higher amounts of management and the acceptability scores given by participants.

- At the start of Trial 2 participants were invited to register for a CrowdCharge web app account which would allow them to influence the likelihood that they would be managed by entering data (regular and one -off journeys and state of charge).
- 55% of participants chose to sign up for an app account. There were very few groups who were statistically more or less likely to sign up than the population as a whole. Those who used the vehicle for social purposes only, had demonstrated a lack of engagement by not completing the Recruitment survey and those who were "not at all concerned" about management were all less likely to sign up for an app account than the population average. Those who were "slightly concerned" amount management were more likely to sign up than the population average, but this trend did not extend to those who were "quite" or "very concerned".
- Overall the amount of data entered by participants was low:
  - 65% of those with an account made at least one data entry of any type;
  - 41% entered at least one regular journey;
  - 25% entered at least one 'one-off' journey; and
  - 57% provided at least one state of charge value.
- The frequency with which participants entered data was also low. The most frequently entered type of data was state of charge. However, 72% of the population entered this less than once a fortnight. State of charge should have been entered each time a participant plugged their vehicle in. If this had occurred, then a participant's data entry frequency would have been similar to their charging

frequency. In fact, 80% of participants entered their state of charge for fewer than 1 in 5 of their charging sessions.

- Participants who were more concerned about demand management did not enter data more frequently than those who were not concerned.
- The customer research survey shows that participants tended to use the app because it was part of the trial (and often they felt it wasn't useful beyond this), or to monitor the cost of charging. The elements which related to journey planning and providing inputs to influence the likelihood of management were also cited as reasons for using the app by 7% of participants.
- There was no statistically significant change in the proportion of participants willing to continue with their charging arrangements when compared to either the Baseline or Trial 1 surveys, despite the continuation of frequent demand management on weekdays.
- Satisfaction and acceptability can be linked to participants use of the app. The tables below show first the satisfaction, then the acceptability results from participants, based on whether they had an app account, and whether they entered data.

Table 11-10: Link between app usage and satisfaction

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
No app account	62	3%	13%	84%
Had an account, but didn't enter data	33	0%	15%	85%
Had an account and entered data	73	3%	22%	75%

Table 11-11: Link between app usage and acceptability

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
No app account	61	3%	13%	84%
Had an account, but didn't enter data	32	0%	13%	88%
Had an account and entered data	73	1%	22%	77%

There were no statistically significant differences in the proportion of participants who gave either neutral or highly positive scores for either metric between the three groups.

- The focus group responses from CrowdCharge Trial 2 participants indicated that the participants generally found the data input requirements of the web-based app were too great and were not well suited to an irregular journey pattern.

11.2 GreenFlux

11.2.1 Description of Trial

Trial 2 introduced an app (available for Android and iOS phones), which allowed trial participants to view information about their charge sessions and request 'high priority' for individual charge events.

During Trial 1 the GreenFlux algorithm used two priority levels:

- 'Normal' priority – charging sessions where the vehicle is drawing more than 25% of the available current (i.e. in the main part of the charge cycle); and
- 'Low' priority – charging sessions where only a small amount (or no) current is being drawn (i.e. vehicle on a timer and not yet started charging or battery nearly full).

The available current (the capacity limit, equivalent to the amount of 'spare' network capacity for EV charging) was offered to chargers on 'normal' priority first. Any remaining current (once these had received their full allocation) was then allocated to the 'low' priority group. If there was not enough capacity available to give all the 'normal priority' transactions a full allocation, then demand management began.

During Trial 2 a 'high priority' level was introduced – consisting of charge transactions where the user had requested high priority via the GreenFlux app. Current was first offered to 'high priority' transactions, then the remainder to the 'normal priority' group, then any remainder to the 'low priority' group. Therefore, unless a very large number of participants had requested high priority, this effectively acted as an override for demand management for the active transaction.

An example of a test performed on this algorithm is given in Section 4.9.2 of this report, see Figure 4-16.

The first group of participants moved into Trial 2 on 3rd April 2018. Participants were moved over from Trial 1 to Trial 2 in batches, until the last group transferred from Trial 1 on 30th May 2018. Trial 2 continued until 10th October 2018. The 'Spring-Winter' combined capacity profile (which defined the amount of current available) was used for the majority of Trial 2 (23rd May 2018 to end of Trial 2) to ensure that some management was still required.

This section of the report will focus on power demand from the group of chargers during summer (from late July and August, to allow comparison with the winter profiles shown in Trial 1 above). The incidence of management at a group level presented in this section is based on the period from 23rd May to 10th October 2018 when the 'Spring-Winter' combined profile was in place.

The individual participant experience data includes the full duration of Trial 2 for each participant, in order to cover their experience of the whole of Trial 2.

11.2.2 Demand Profiles

As described above, Trial 2 was in operation between April and October 2018. The resulting power demand from groups of chargers will be used for two purposes:

- Comparing winter (Trial 1) and summer (Trial 2) demand (this section); and
- Assessing the impact of the time of use incentive introduced in Trial 3 on group demand (Section 12.2)

The meter value data from individual chargers has been aggregated up to a group level and converted to power (rather than current) in the same way as described in Section 10.2.2.

This section shows demand profiles for the summer period, using data from 26th July to 2nd September 2018 (inclusive). Profiles below are expressed in W per Charger in Group. The graph below shows the maximum, 90th percentile and average demand for weekdays during summer in Trial 2 (26th July – 2nd September 2018).

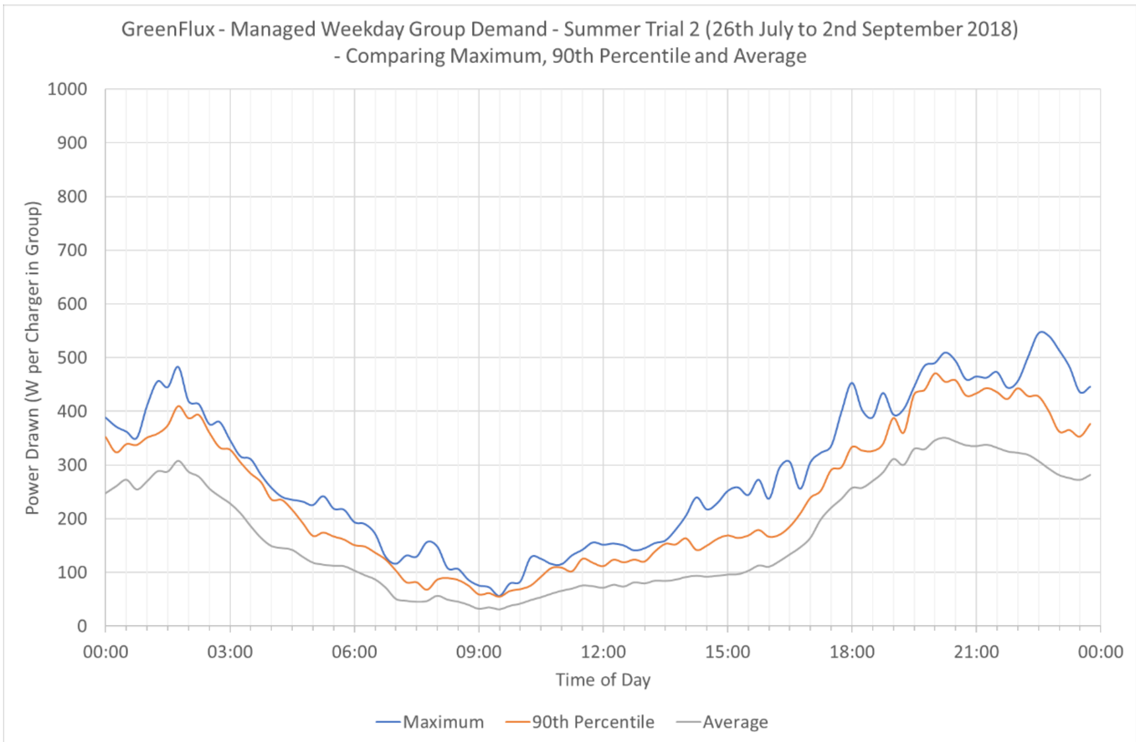

Figure 11-30: GreenFlux Trial 2 Managed Weekday Demand (Summer) - Maximum, 90th Percentile, Average

This graph illustrates the variability in the current drawn at each time of day from day to day, with the 'maximum' curve showing multiple distinct peaks, which are smoothed out in both the '90th percentile' and 'average' curves (e.g. at 22:45). The shape of the graph shows the variation in demand across the day, with the following main features (based on the shape of the average and 90th percentile curves):

- A steady increase in demand from the middle of the afternoon (16:00) until around 20:15;
- In this case, the evening peak demand has been restricted by the use of demand management, so the 'unrestricted' profile would result in a different shape. This is explored in Section 8.10; and
- A 2nd (smaller) peak occurs in the early hours of the morning (01:45) due to participants who charge their car overnight using timers.

The graph below compares the 90th percentile weekday and weekend demand curves.

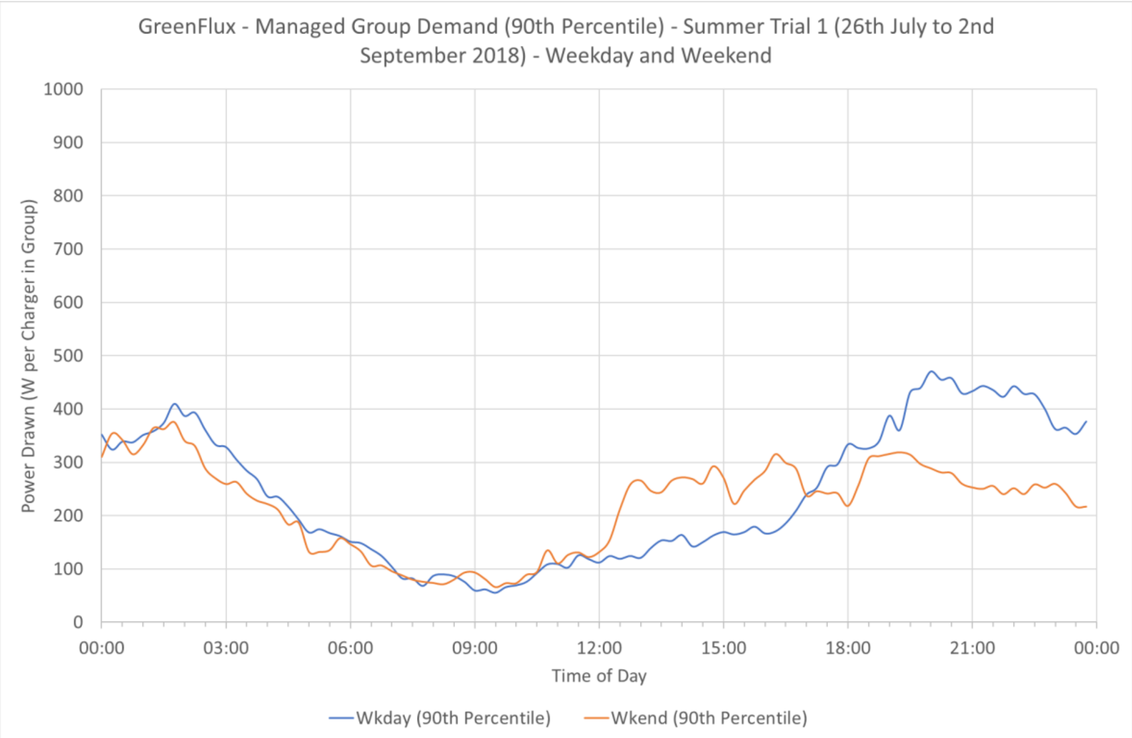

Figure 11-31: GreenFlux Trial 2 Summer Demand - 90th Percentile, comparing Weekday and Weekend

The evening peak on weekend days is considerably lower than the weekday (315W per charger at the weekend, 470W per charger on weekdays). Some participants continue to charge their vehicle overnight using a timer – creating a peak of approximately 370W per charger. This peak is higher than the evening peak on weekends.

At the weekend, demand is higher (than the weekday) during the early part of the afternoon – with a much flatter pattern of demand from 12:00 to around 19:00, compared to the peak observed during the working week.

The profiles shown above have grouped all weekdays (Monday – Friday) and weekend days (Saturday and Sunday) together. There may be trends within the week – for example higher demand on Mondays compared to Fridays. The graph below shows the 90th percentile of group demand (W per charger in the group) from the summer period, shown across all seven days of the week.

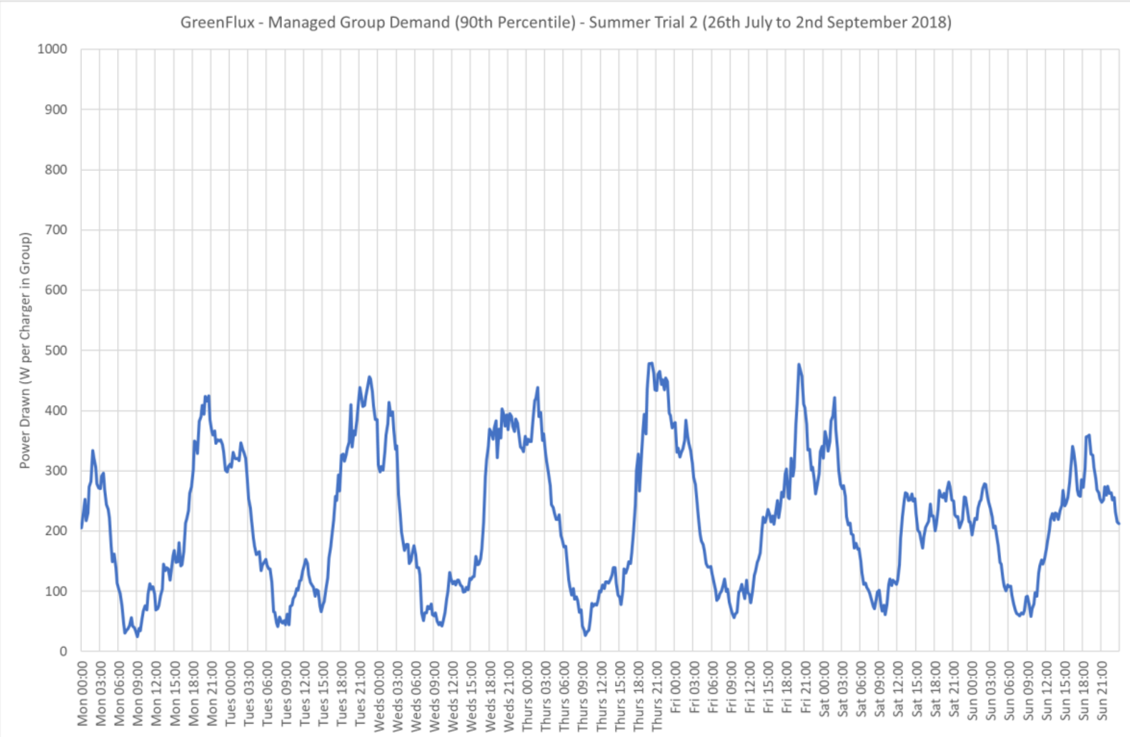

Figure 11-32: GreenFlux Trial 2 Summer - 90th Percentile, 7 day demand

This shows a similar pattern of demand across all weekdays, with two distinct peaks - one in the evening and another smaller one at 01:00. Demand on Saturdays is lower, and more consistent across the day, whereas Sunday has distinct peaks (just after 15:00, just after 18:00 and another in the early hours of Monday morning).

The graphs below compare winter and summer demand for weekdays and the weekend.

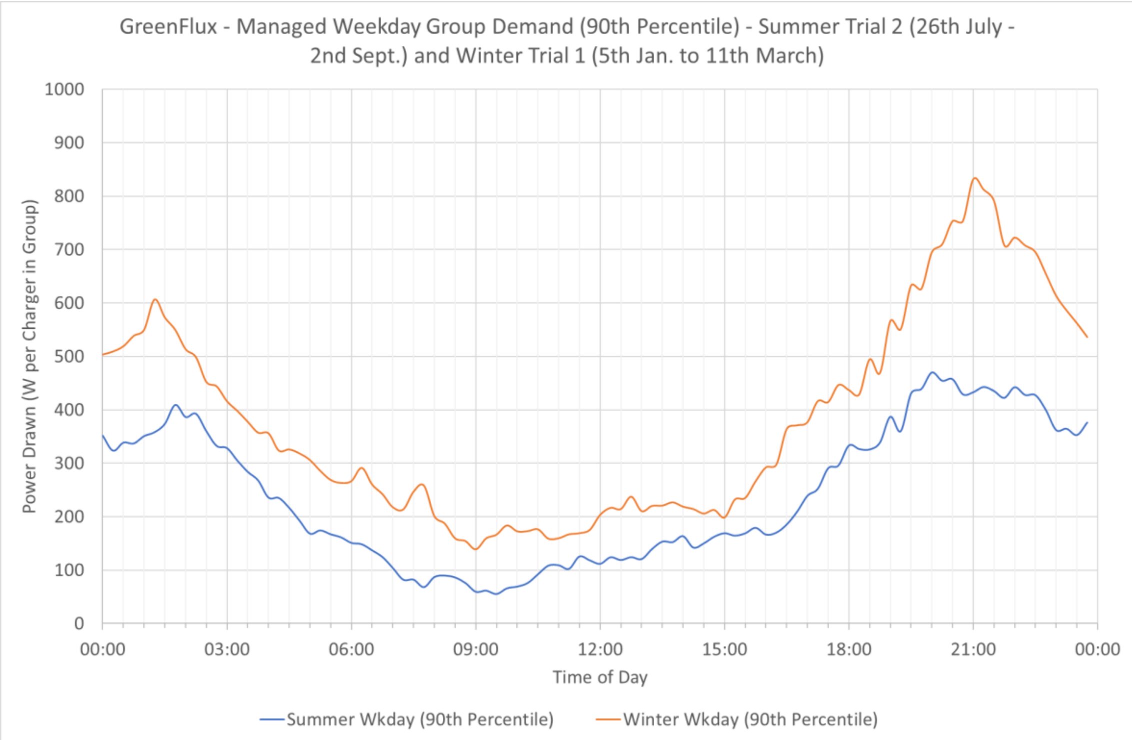

Figure 11-33: Comparing Managed Weekday Demand - Winter vs. Summer

The evening peak demand for the GreenFlux group was much lower in the summer (maximum of 470W per charger in summer, compared to 830W per charger in winter). The shape of the demand is similar, with an increase in demand in the early hours of the morning caused by participants using timers to ensure their vehicle charges overnight.

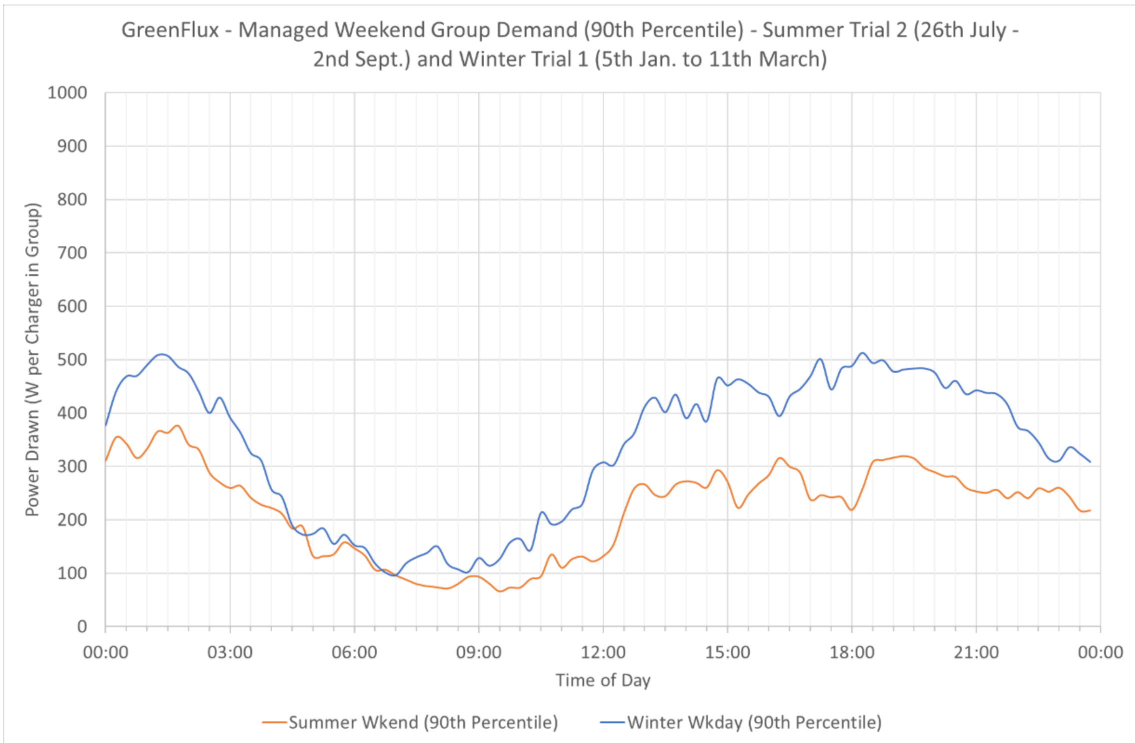

Figure 11-34: Comparing Managed Weekend Demand - Winter vs. Summer

The shape of the demand profile for weekends is similar in both winter and summer, although the total energy demand (area under the curve) is considerably lower in the summer.

11.2.3 Occurrence of Demand Management – Group Level

As described above, during Trial 2, GreenFlux began to constrain charging when it was no longer possible to allocate all active chargers their required 16A or 32A (based on a test of the car's maximum charging rate at the start of each charging event). Management was deemed to be active when the total current allocated to chargers[135] was within 13A of the capacity limit (e.g. if the capacity limit was 500A and 490A were allocated to chargers in the group, then management was active).

Throughout Trial 2, eight different capacity profiles were implemented which varied with season and the number of chargers in the group. The capacity profiles were scaled so that management would occur at the same frequency as the number of chargers in the group was increased (see Section 4.9.2, Figure 4-19). This figure also shows the time periods when different seasonal profiles were applied. The amount of management varied between

[135] Allocations to individual chargers of 13A were excluded from these totals. Once charging was complete a charger moved to a 'low priority' status and allocated either 13A or 0A. Management became active when it was not possible to allocate the maximum rating to all chargers in the 'normal' priority group. Low priority chargers were only allocated current if some remained after all 'normal priority' chargers had received a full allocation.

seasons due to variations in the available network capacity and underlying demand from EV chargers (e.g. lower demand in summer due to warmer temperatures).

The table below summarises the seasonal profiles used, and the resulting amount of management (at a group level).

Table 11-12: GreenFlux Trial 2 - Seasonal Profiles Used and Amount of Management

Seasonal Profile	Number of Minutes Active	Number of Managed Minutes	% of Minutes with Active Management
Winter	20,880	2,175	10.4%
Spring	48,960	15	0.03%
Spring Winter Combined	202,335	7,740	3.8%

Management was most frequent when 'winter' profiles were active. This is a combination of a small group size (20 chargers in the group) and winter capacity profiles being the most restrictive.

Management occurred at a similar frequency to the CrowdCharge groups when the 'Spring Winter Combined' profile was running (for groups with greater than 100 chargers).

This sub-section shows the frequency of management when 'Spring Winter Combined' profiles were active – 24th May to 9th October 2018, as this represents the majority of Trial 2.

The graph below shows the percentage of days, at each time of day, when management was active, separated by weekdays and weekends.

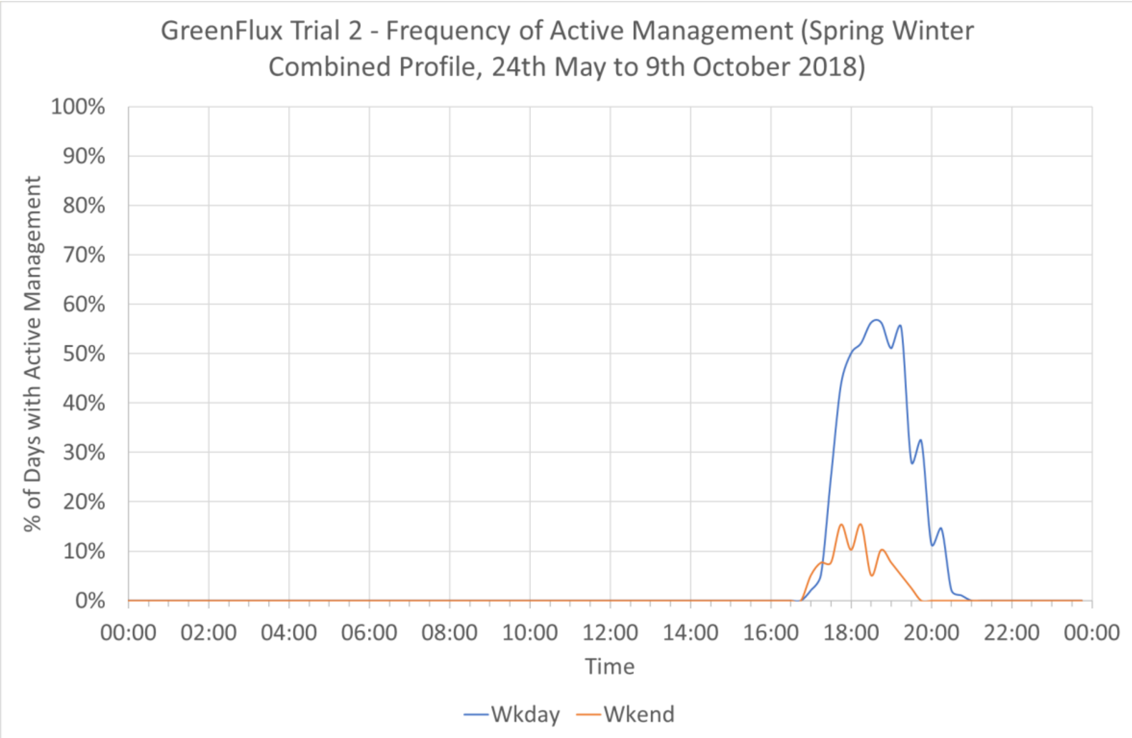

Figure 11-35: % of Days with Active Management - GreenFlux Trial 2

This shows that management only occurred during the evening peak, with management occurring between 17:00 and 20:45 on weekdays (slightly shorter window than weekday in Trial 1) and 17:00 and 19:30 at the weekend. Management occurred on around 56% of weekdays and 15% of weekend days.

The impact this management had on individual participants is explored in detail in the next section.

11.2.4 Participant Experience of Management

Participant's experience of management will vary, as described in previous sections. This section outlines the amount of management which participants experienced during Trial 2, including the level of restriction they experienced (using the 'Management Factor' metric described in Section 10.2.4. The key findings section (see Section 11.2.7) combines this data with the results of the Trial 2 survey to explore any link between the amount of management participants experienced in Trial 2, and their satisfaction with their charging arrangements.

One way in which management could have affected participants is to cause an increase in the proportion of charge events where vehicles are 'hot unplugged' (i.e. unplugged whilst still charging). Management reduces the current available so may have led to vehicles not being fully charged when they were unplugged. The bar graph below shows the proportion of charge events which were 'hot unplugged' outside of management, during Trial 1 and during Trial 2, for participants who took part in Trial 2.

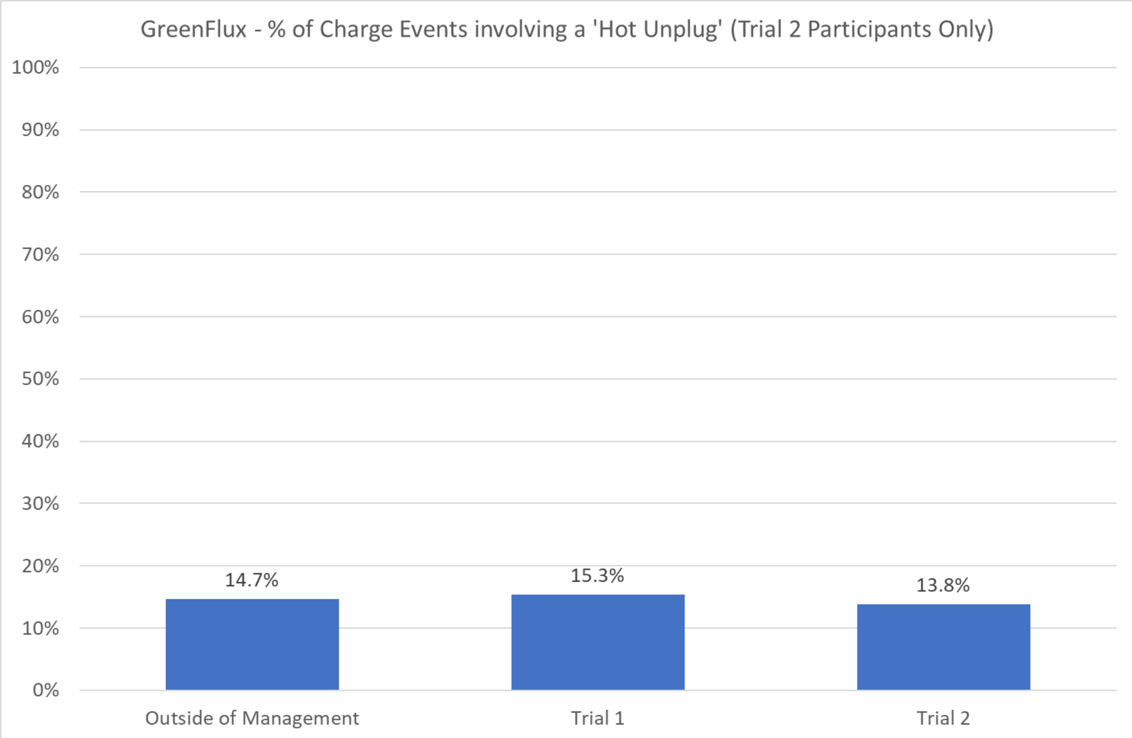

Figure 11-36: GreenFlux Trial 2 - Hot Unplug Rate

This shows very little change in the hot unplug rate throughout the trials. Hot unplugging took place less frequently in Trial 2 than both Trial 1 and 'Outside of Management'. Although these changes are small (13.8% vs. 15.3% for Trial 1 and 13.8% vs. 14.7% for 'Outside of Management') both are statistically significant due to the large sample sizes involved (number of charge events)[136]. The slight decrease between Trial 1 and 2 may be a seasonal effect as Trial 2 took place from April – October, when vehicle range is likely to be slightly higher, so the energy required in each charge event is potentially lower.

Data from the trial (transactions, current meter values and allocation data) has been used to evaluate each transaction during Trial 2 and determine whether or not it was curtailed (managed). For each participant, data from smart chargers has been used to calculate:

- How many times they charged their vehicle (at home) during the time when they were participating in Trial 2;
- How many of these charging sessions were curtailed (where meter values and allocation data are available); and
- To what degree they were curtailed, using the 'GreenFlux Management Factor' metric described in Section 10.2.4 above.

[136] Trial 2 compared to Trial 1 – Z = 4.06 and Trial 2 compared to 'Outside of Management' – Z = 1.98 (value of 1.96 would indicate confidence at the 5% level)

19,732 charging events took place during Trial 2 (where consumed energy was 0.5 to 100kWh). Current meter value and 15 minute allocation data has been used to determine whether individual charging sessions were managed. This data is not available for charge sessions which took place when chargers were offline. This applies to 2,477 of the 19,732 charging events (13%). There are therefore 17,255 charging events where it is possible to show whether these events were managed. Of these, 2,611 events were managed (15%). This represents a statistically significant[137] decrease when compared to Trial 1, when 17% of 19,119 events were managed.

269 participants were part of at least one Trial 2 group and transaction data is available for 249 of these participants (where it is possible to determine if the transaction was managed). The remaining twenty participants may have either lost their communications (and this was not re-established later in the project), not used their charger, had smart charging disabled or left the project. Participants are included in the analysis below where they have more than five transactions during Trial 2, and where it is possible to determine whether their transactions were managed for at least 20% of their charging events. 242 participants meet these criteria.

The spread of the proportion of events that were curtailed is shown below, separated by participants whose registered vehicle was rated at 16 (3.6kW) and 32A (7kW).

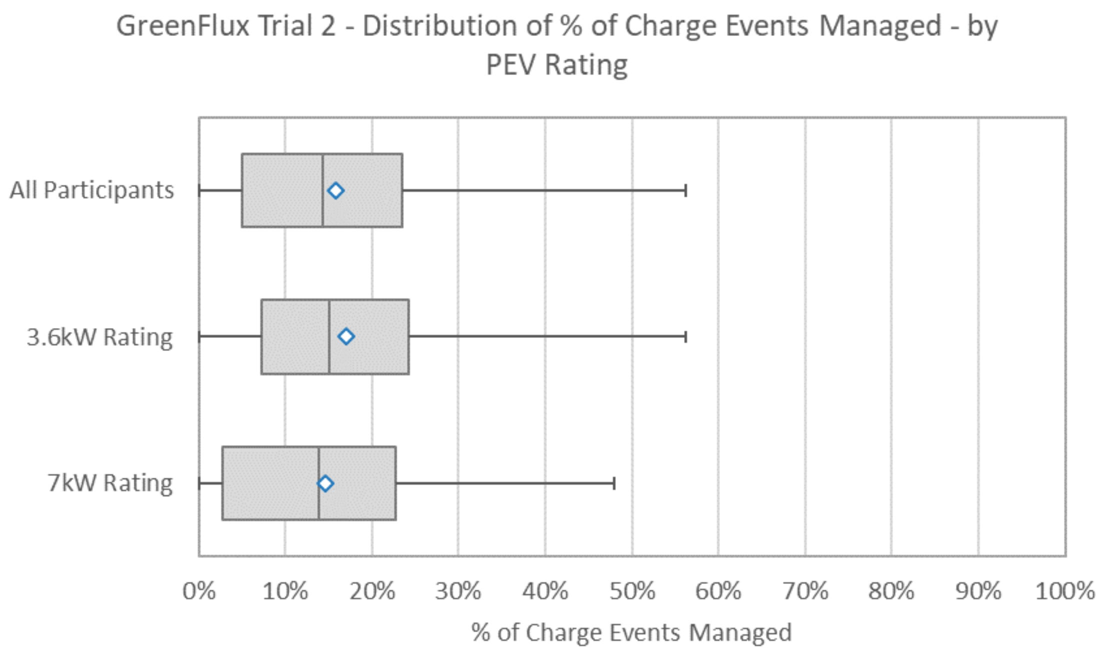

Figure 11-37: GreenFlux Trial 2 - Distribution of % of Charge Events Managed by PEV Rating

[137] Z test. Z = 5.68 (value of 1.96 would indicate 5% confidence level)

14.1% of charge events involving 3.6kW vehicles were managed, compared to 12.7% of those from 7kW vehicles. This difference is statistically significant[138] due to the large sample size (large number of charge events). Although the GreenFlux algorithm ttake vehicle charging rates into account, there may be other differences between the 7kW and 3.6kW groups – e.g. the time of day they were charging. These differences may have led to the increased tendency of charge events involving 3.6kW vehicles to be managed.

The proportion of charge events managed is very similar to Trial 1. The table below compares the median and interquartile range for each category in Trial 1 and Trial 2.

Table 11-13: Comparing % of Charge Events Managed GreenFlux Trial 1 vs. Trial 2

Trial and Group	Median % of Charge Events Managed	Interquartile Range (% of Charge Events Managed)
1 – All Vehicles	15.0%	4.2% to 24.8%
2 – All Vehicles	14.3%	5.0% to 23.5%
1 – 3.6kW Rating	14.8%	1.6% to 22.7%
2 – 3.6kW Rating	15.1%	7.4% to 24.2%
1 – 7kW Rating	15.3%	5.9% to 27.5%
2 – 7kW Rating	13.8%	2.9% to 22.6%

194 participants had enough data available to calculate the proportion of their charge events which were managed in both Trial 1 and Trial 2. Of these 194 participants:

- 4.6% experienced no management in either trial;
- 0.5% were managed for the same proportion of their events in both trials;
- 41.2% were managed for a greater proportion of their charging events in Trial 2 (compared to Trial 1); and
- 53.6% were managed for a smaller proportion of their charging events during Trial 2 (compared to Trial 1).

Figure 11-35 shows the times when management was active during Trial 1 and the frequency of this management. It shows that management was only active between 17:00 and 20:45 on weekdays and 17:00 and 19:30 at the weekend. Management occurred on around 55% of weekdays and 15% of weekend days when the combined ‘Spring-Winter’ profile was active (the majority of the trial). Therefore, participants who mainly charged outside of these time windows will have experienced less management than those who regularly charge in the evening peak.

[138] Z test. Z = 2.83

Each transaction in Trial 2 has been evaluated to show whether or not it began between 16:00 and 19:59 Monday – Friday (‘Began in Weekday Evening Peak’). The graph below shows the relationship between how many charging transactions began in the weekday evening peak, and how many transactions were managed, split by PEV rating (3.6kW and 7kW). Each dot on the graph represents a participant.

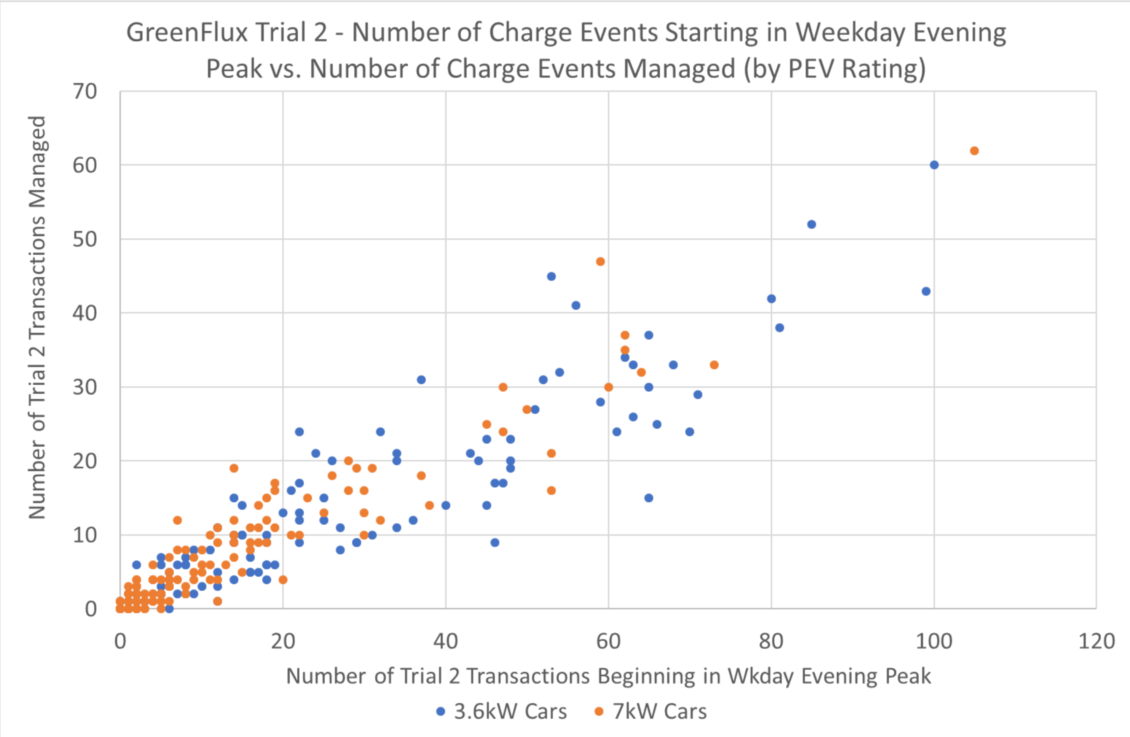

Figure 11-38: GreenFlux Trial 2 Number of Transactions beginning in Weekday Evening Peak vs. Number of Transactions Managed (by PEV Rating)

(N.B. “Beginning in Weekday Evening Peak” is defined as events where charging began between 16:00 and 19:59 Monday – Friday)

This shows some correlation between the number of charge events which began in the weekday evening peak and the amount of management experienced[139]. Some variation between participants is to be expected, for the same reasons as set out in Section 10.2.4 for Trial 1.

The other factor which could influence how often a participant was managed is their use of the high priority feature in the GreenFlux app which was introduced in Trial 2. This is explored in the section below (Section 11.2.5).

The analysis above is based on a binary ‘managed’ or ‘not managed’ flag applied to each charging event. It does not include how restrictive the management was. The ‘GreenFlux

[139] Correlation function used to analyse the degree of correlation between ‘Number of Charge Events Beginning in Weekday Evening Peak’ and ‘Number of Charge Events Managed’. Correlation value of 0.91 for 3.6kW vehicles and 0.95 for 7kW vehicles. Both of these values are statistically significant.

Management Factor' metric has been developed to assess the restrictiveness of the management which each participant experienced. Further details of this metric are given in Section 10.2.4. The management factor for each participant has been calculated for Trial 2, based on the formula below:

$$\text{GreenFlux Management Factor (each participant)} = \%\text{ of Events Managed} \times \text{Median }\%\text{ of Time in Transaction Managed}$$

The distribution of 'GreenFlux Management Factor' across the population of 211 GreenFlux participants who experienced some management during Trial 2 is shown below, split by PEV rating.

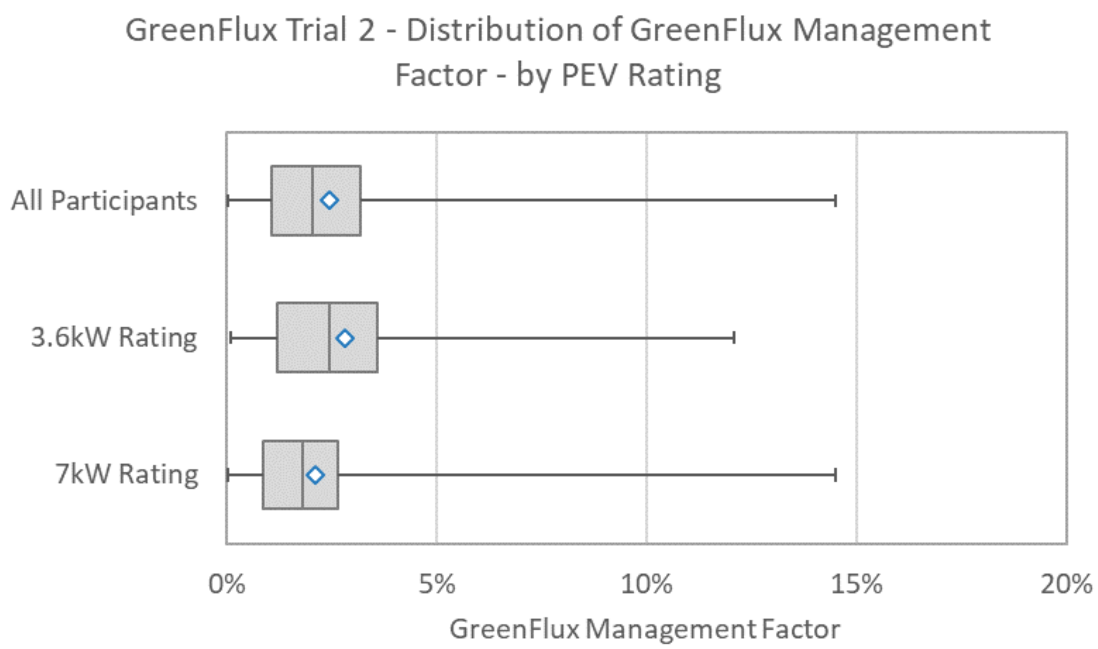

Figure 11-39: GreenFlux Trial 2- Distribution of GreenFlux Management Factor (by PEV Rating)

This shows that management factor varied between 0.05% and 14.5%. The median value was 2.1% (compared to 3% in Trial 1). GreenFlux Management Factor appears to be slightly lower amongst 7kW vehicles than 3.6kW (median of 1.8 vs. 2.6%). The plots below compare GreenFlux Management Factor in Trial 1 and 2.

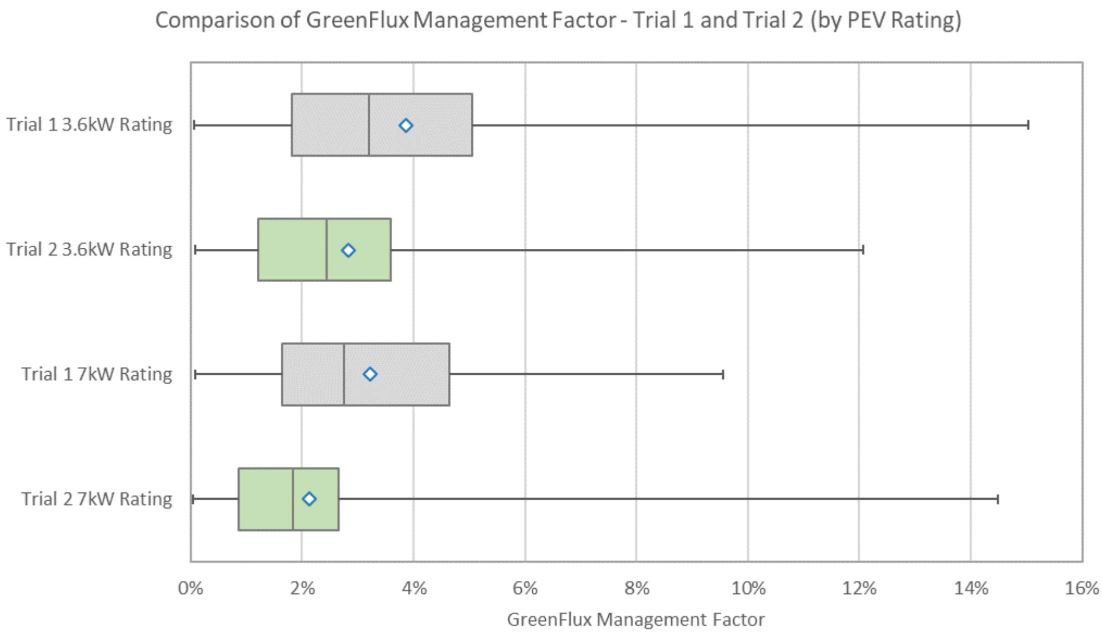

Figure 11-40: GreenFlux Management Factor - comparing Trial 1 and Trial 2 (by PEV rating)

This shows a decrease in GreenFlux Management Factor for the majority of participants between Trial 1 and 2. This is likely to be due to reductions in both the proportion of charging events which were managed, and the restrictiveness of management.

The link between 'GreenFlux Management Factor' and participants satisfaction with their charging arrangements is explored in the key findings section (see Section 11.2.7).

11.2.5 App Usage

Trial 2 introduced a smartphone app which allowed GreenFlux participants to interact with the smart charging system. The first version of the app (used in Trial 2) included the following features (only available during an active charging transaction, when the charger was online):

- Displayed the current being drawn and limit being applied to the charger during active charging transaction; and
- Allowed the user to request high priority for their charging transaction.

The high priority feature effectively acted as an override to demand management. The override only applied to the current charging transaction. Use of the high priority feature was included in the transaction records showing the time at which a high priority request was made for each transaction (or a blank field if the feature wasn't used). Participants were contacted at the start of Trial 2 with login details for the app and instructions to assist them to download and use the app.

The amount of interactions between participants and the app can be assessed using various metrics:

- Number of times the app was downloaded (compared to the number of participants invited to download it) (this section);
- The level of interaction with the app, which participant's reported in the Trial 2 survey, including their reasons for using the high priority feature and, in some cases, the reasons why they chose not to download or use the app (Section 11.2.6); and
- The use of the high priority feature (this section).

11.2.5.1 Downloads of the GreenFlux App

The app was released in April 2018. Participants were invited to download the app in batches, as they were moved from Trial 1 to Trial 2, or when they first went into routine management.

The graph below compares the total number of installed copies of the app throughout Trial 2, compared to the number of participants invited. The data for this analysis has been obtained using data from the relevant app stores (Apple and Google Play), which does not allow downloads to be assigned to participant users.

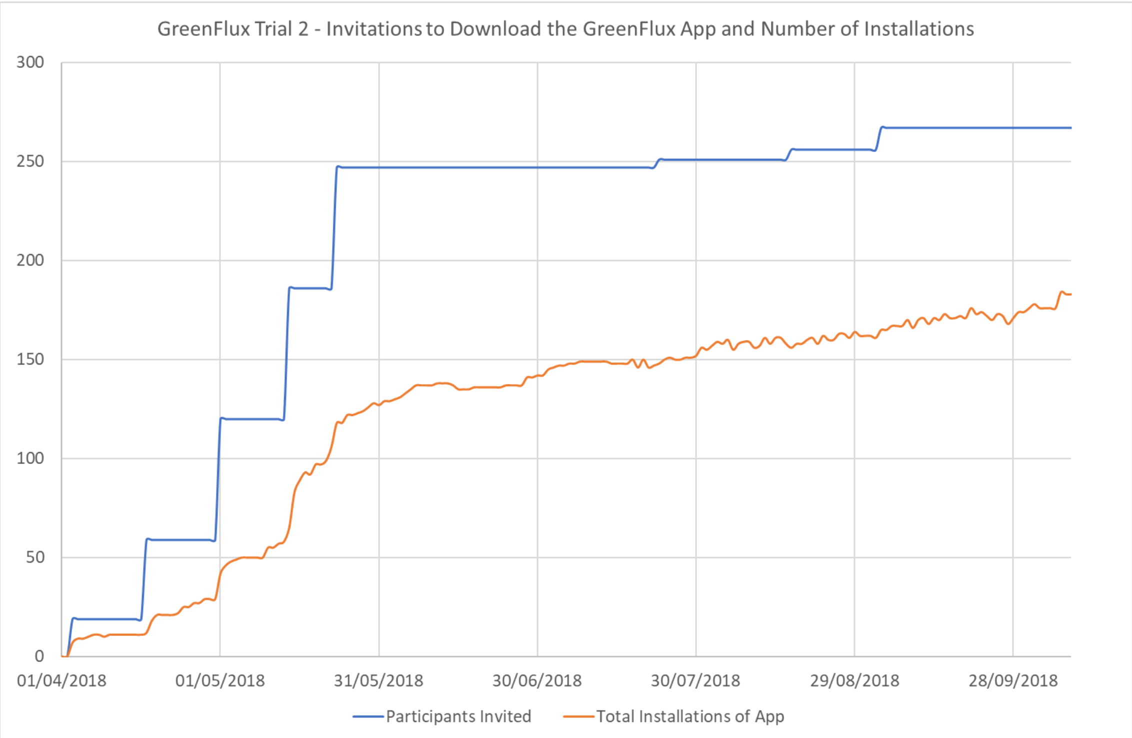

Figure 11-41: GreenFlux Trial 2 - Number of Downloads of App vs. Number of Invites Issued

This shows the number of downloads increasing throughout Trial 2, with each batch of invitees (step increases in the blue line), resulting in an increase in the number of downloads. The two are closely aligned, suggesting that if participants were going to download the app, they tended to do this shortly after receiving the original email. Across Trial 2 the app was downloaded a total of 183 times, compared to 267 invitations being issued (69%).

11.2.5.2 High Priority Requests

Transactions which took place during Trial 2 have been analysed to show the use of the high priority feature. 18,282 transactions took place in Trial 2, of which 782 had an associated high priority request (4.2%).

268 participants were part of at least one Trial 2 group. Transaction records exist for 241 of these participants, and 147 participants made at least one high priority request (61%). The graph below shows the proportion of transactions with a high priority request through the duration of Trial 2.

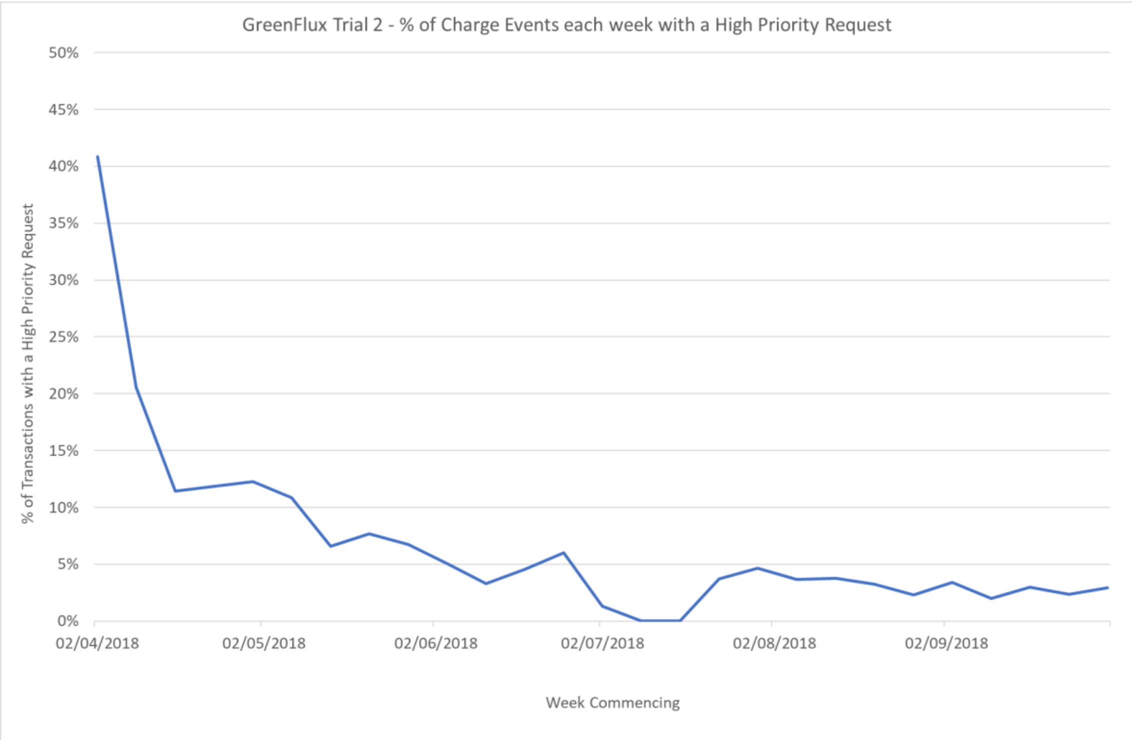

Figure 11-42: GreenFlux Trial 2 - % of Transactions Involving a High Priority Request - over time

The first week is an anomaly, as the first batch of participants were asked to use the app to test it, as a pilot group. The level of high priority requests declined after the first few weeks of the trial and did not exceed 5% of charge events after Week 27 (w/c 2nd July). This suggests that use of a high priority feature is likely to be relatively infrequent.

App use by individual participants may occur occasionally. The analysis below considers the proportion of each participant's charge events which involved a high priority request. The period from 2nd July onwards (Week 27) has been used, as this represents the time when usage had stabilised (thus removing the 'novelty' effect at the start of the trial). Over this period 11,305 charging events took place, with 282 high priority requests (2.5%). 80 of 237 participants used the high priority feature in this period (33%).

The graph (Figure 11-43) below shows the contribution of individual participants to the total number of transactions with high priority requests (from Week 27 onwards).

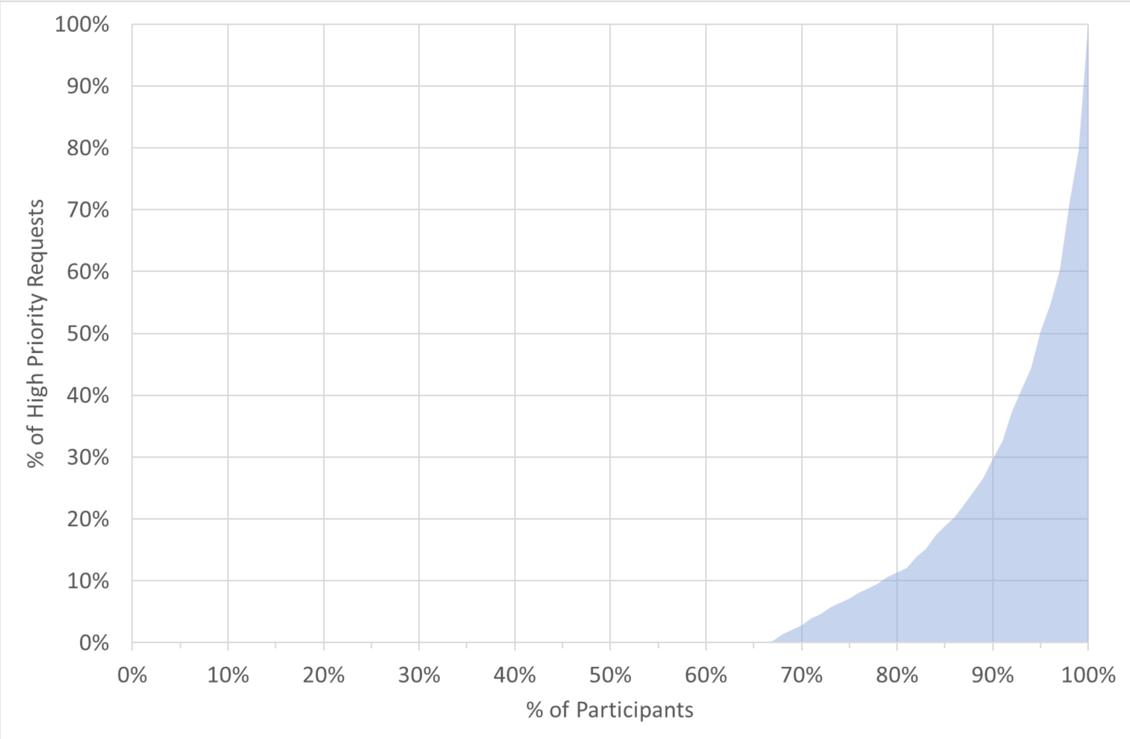

Figure 11-43: % of Participants and % of High Priority Requests - GreenFlux Trial 2

This indicates that approximately 20% of participants were responsible for 90% of high priority requests from Week 27 onwards. In fact, two participants alone contributed 16% of the high priority requests from Week 27 onwards.

The box and whisker plots below show the variation in proportion of transactions involving a high priority request for all participants who charged their vehicle during Trial 2 (from Week 27 onwards), first split by PEV type, then battery capacity.

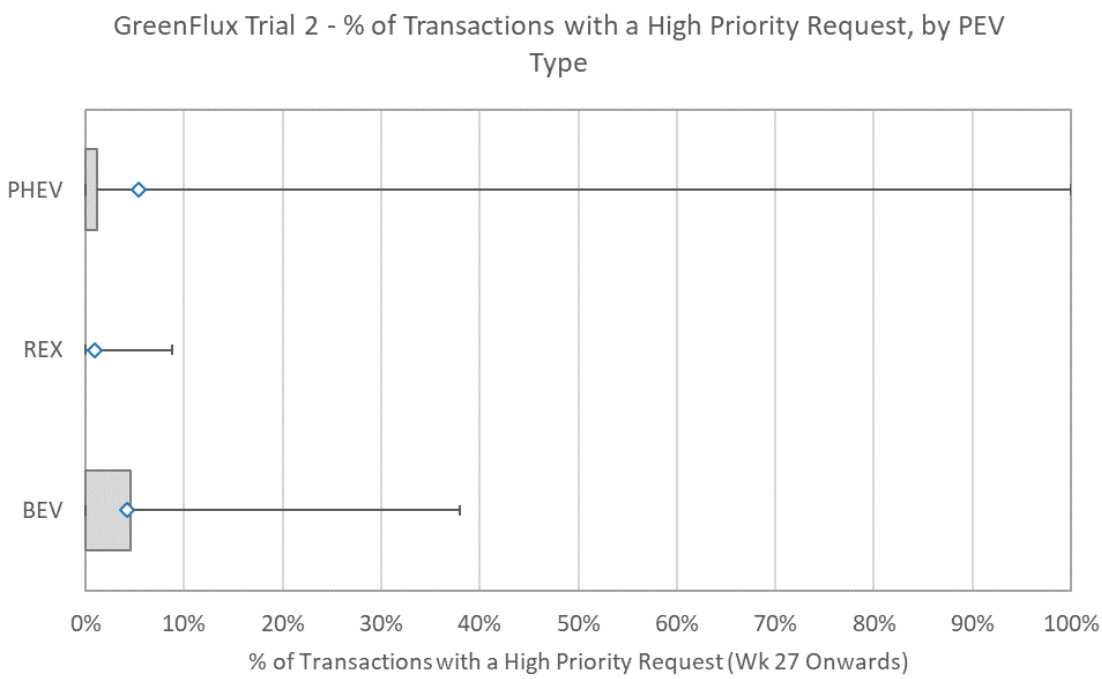

Figure 11-44: % of Charge Events with High Priority Request - by PEV Type

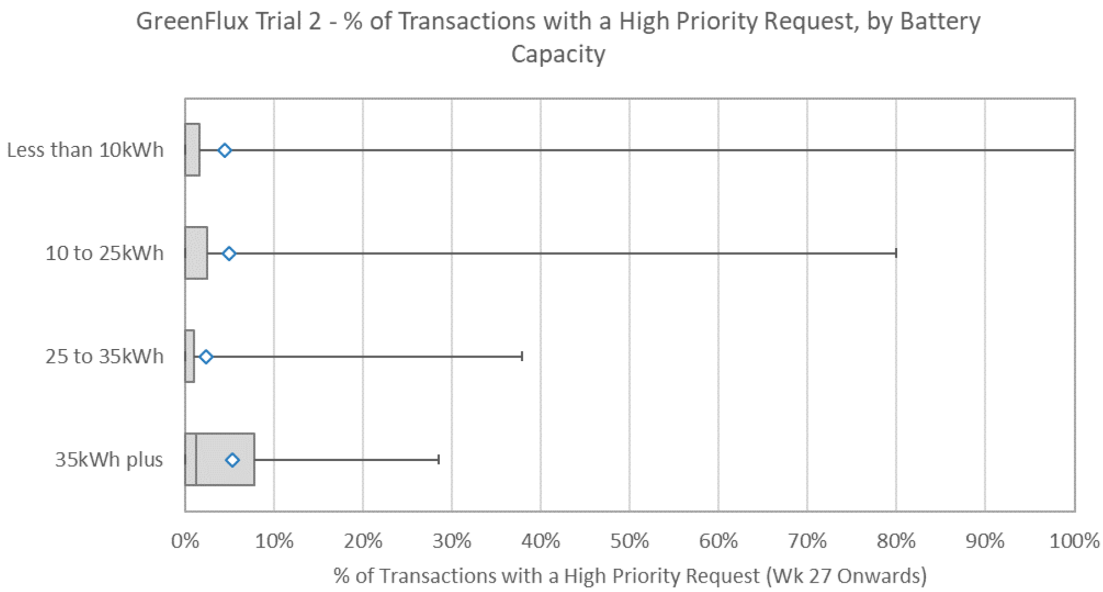

Figure 11-45: % of Charge Events with High Priority Request - by Battery Capacity

These graphs show that the majority of participants rarely used the high priority feature.

Certain groups of participants may have been more or less likely to use the high priority feature. Three metrics have been calculated for several groups of participants to determine if this was the case, and these are shown in the table below. The metrics used are:

- % of Participants with high priority requests from Week 27 onwards;
- Median % of transactions with a high priority request; and
- Upper Quartile % of transactions with a high priority request

Table 11-14: Use of the High Priority Feature (GreenFlux Trial 2) by Different Groups of Participants

	Category	Sample Size	% of Participants with high priority requests from Wk 27 onwards	Median % of charge events with a high priority request	Upper Quartile % of charge events with a high priority request
	All Participants	237	34%	0%	2.6%
PEV Type	PHEV	88	32%	0%	9.9%
	REX	36	22%	0%	3.2%
	BEV	113	39%	0%	16.9%
Battery Capacity	Less than 10kWh	60	28%	0%	1.5%
	10 to 25kWh	62	35%	0%	2.4%
	25 to 35kWh	70	26%	0%	0.8%
	35kWh and above	45	51%	1.3%	7.8%
Age	No response	17	12%	0%	0.0%
	18 to 35	31	39%	0%	5.3%
	36 to 45	69	41	0%	2.7%
	46 to 55	69	30	0%	2.1%
	56 to 64	33	36	0%	4.2%
	65+	18	28	0%	1.6%
Uses of the Vehicle	Social Only	35	29%	0%	2.4%
	Business and Commuting	64	38%	0%	2.7%
	Commuting	77	39%	0%	3.8%
	Business	27	33%	0%	2.2%
Level of Concern re: Management*1	Not sure	15	27%	0%	1.1%
	Not at all concerned	106	34%	0%	2.6%
	Slightly concerned	64	41%	0%	5.4%
	Quite or very concerned	18	39%	0%	2.9%

	Category	Sample Size	% of Participants with high priority requests from Wk 27 onwards	Median % of charge events with a high priority request	Upper Quartile % of charge events with a high priority request
Charging Frequency*2	0 to 0.27 sessions per day (GreenFlux (GF) 1st Quartile)	53	28%	0%	7.7%
	0.27 to 0.51 sessions per day (GF 2nd Quartile)	57	42%	0%	4.5%
	0.51 to 0.81 sessions per day (GF 3rd Quartile)	61	34%	0%	2.5%
	More than 0.81 sessions per day (GF 4th Quartile)	62	31%	0%	1.0%
Trial 1 Management Experience	Not part of Trial 1, or not managed during Trial 1	66	36%	0%	2.9%
	GreenFlux (GF) Management Factor 1st Quartile	38	37%	0%	2.2%
	GF Management Factor 2nd Quartile	40	40%	0%	3.9%
	GF Management Factor 3rd Quartile	43	30%	0%	2.7%
	GF Management Factor 4th Quartile	50	26%	0%	0.8%

**1: This data uses the most recent response from each participant – i.e. the level of concern they reported on the Trial 1 survey if available, otherwise the baseline survey response is used.*
**2: Charging frequency has been calculated as the average value between December 2017 and November 2018, where at least six months data was available.*

The proportion of participants in each sub-group who made a high priority request from Week 27 onwards has been compared against the population as a whole to determine whether any groups were more or less likely to use the high priority feature. The statistically significant results were as follows:

- Participants whose vehicle had a battery capacity of 35kWh and above were **more**[140] likely to make high priority requests (this can also be seen in Figure 11-45: % of Charge Events with High Priority Request - by Battery Capacity);
- Participants whose vehicle had a battery capacity between 25 and 35kWh were also **more** likely to make a high priority request, albeit at a confidence level of 10%[141],

[140] Z test comparing 35kWh plus group to the population as a whole. Z = 2.74 (a value of 1.96 would indicate confidence at the 5% level)
[141] Z test comparing 25 to 35kWh to the population as a whole. Z = 1.69 (a value of 1.64 would indicate confidence at the 10% level).

rather than the 5% used elsewhere in this report (this is partly due to the small sample size);
- Participants who had not completed a Recruitment survey (the "no response" group for age) were **less** likely[142] to have made a high priority request when compared to the population. The Recruitment survey was the first piece of customer research that participants were asked to complete and was part of the 'obligatory' surveys (see Section 6.8.1). This suggests that these participants were generally less engaged in the trial, perhaps explaining their lower tendency to have used the high priority feature which would have required them to download and login to an app.

The reasons for this are not clear. However, 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 proportion making high priority requests has also been compared within sub-groups – for example, to show whether the difference between the REX and BEV groups (22% vs. 39% making a high priority request) was statistically significant. This analysis shows that:

- Participants whose vehicles had a battery capacity of 35kWh plus were **more** likely to have made a high priority request than both those whose vehicle battery capacity was either 'Less than 10kWh' or '25 to 35kWh' (at the 5% confidence level). They were more likely to have made a request than the '10 to 25kWh' group at the 10% confidence level[143];
- Participants who had not completed the Recruitment survey ("no response" for age) were **less** likely to have made a high priority request when compared to both the '18 to 35' and '36 to 45' groups[144]. They were also less likely to have made a request than the 56 to 64 age group, albeit at the 10% level[145]; and
- BEV drivers were **more** likely to have made a high priority request than REX drivers (also at the 10% level)[146].

[142] Z test comparing "no response" group to the population as a whole. Z = 1.99
[143] Z test comparing between battery capacity groups. 35kWh plus vs. Less than 10kWh (51% vs. 28%) Z = 2.42. 35kWh plus vs. 10 to 25kWh (51% vs. 35%) Z = 1.67 and 35kWh plus vs. 25 to 35kWh (51% vs. 26%) Z = 2.75.
[144] Z test comparing between age groups. "no response" vs. 18 to 35 (12% vs. 39%) Z = 1.96, "no response" vs. 35 to 45 (12% vs. 41%) Z = 2.24.
[145] Z test comparing "no response" vs. 56 to 64 (12% vs. 36%) Z = 1.79
[146] Z test comparing BEV vs. REX (39% vs. 22%) Z = 1.86

Perhaps surprisingly, there was no link between the tendency of participants to use the app and either the level of concern they expressed regarding management, or the amount of management they actually experienced during Trial 1.

The app interface during trial 2 showed participants the current that their vehicle was drawing, and the amount available from their charger in real time. Participants may have requested 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 have occurred during the charging transaction, or because they perceived that their charging was less flexible (the impact of demand management would be higher). The timing of the requests can provide some insight to this, particularly when compared to the times of day when management is active (see Figure 11-35) and flexibility of charging sessions (see Section 8.9).

The table below shows the proportion of plug-in events with an associated high priority request for four parts of the day, for both weekdays and weekends.

Table 11-15: Proportion of Plug-In Events with a High Priority Request, by Time of Day and Weekend/Weekend

Time Window	Weekday		Weekend	
	Number of Plug-In Events	% with High Priority Request	% with High Priority Request	% with High Priority Request
Overnight (00:00 to 07:59)	212	9.4%	92	4.3%
Daytime (08:00 to 15:59)	1,958	4.1%	1,226	3.3%
Evening Peak (16:00 to 19:59)	4,024	1.9%	1,023	1.8%
Late Evening (20:00 to 23:59)	2,195	1.4%	575	2.1%

On weekdays, high priority requests were significantly more likely to be made when vehicles were plugged in during the 'overnight' period compared to both 'daytime' and 'evening peak'[147]. High priority requests were also significantly more likely to be made when vehicles were plugged in during the day, compared to the evening peak[148] - this is also true at the weekend[149].

[147] Z Test. Comparing % with High Priority Request. Overnight vs. Daytime (9.4% vs. 4.1%) Z = 3.48. Overnight vs. Evening Peak (9.4% vs. 1.9%) Z = 7.26 (a value of 1.96 would indicate confidence at the 5% level).
[148] Z Test. Comparing % with High Priority Request. Daytime vs. Evening Peak (4.1% vs. 1.9%) Z = 5.18.
[149] Z Test. Daytime (weekend) vs. Evening Peak (weekend) (3.3% vs. 1.8%) Z = 2.34

The timing of requests shown above does not align with the times of day when management was most likely (the evening peak), suggesting that participants did not request high priority when they saw active management within the app.

Requesting high priority may be related to participants perception of flexibility. If they plugged their vehicle in at 18:00 and knew that it would be connected until 7:00 the next morning but would only charge for a small proportion of this time, then the impact of management would be minimal. However, if they connected at another time of day, with less flexibility (charging for a higher proportion of the plug-in duration) then the impact on management may have been greater. This aligns with the findings in relation to the flexibility available for plug-in events at different times of day shown in Section 8.9 and repeated here for reference (Figure 11-46 and Figure 11-47).

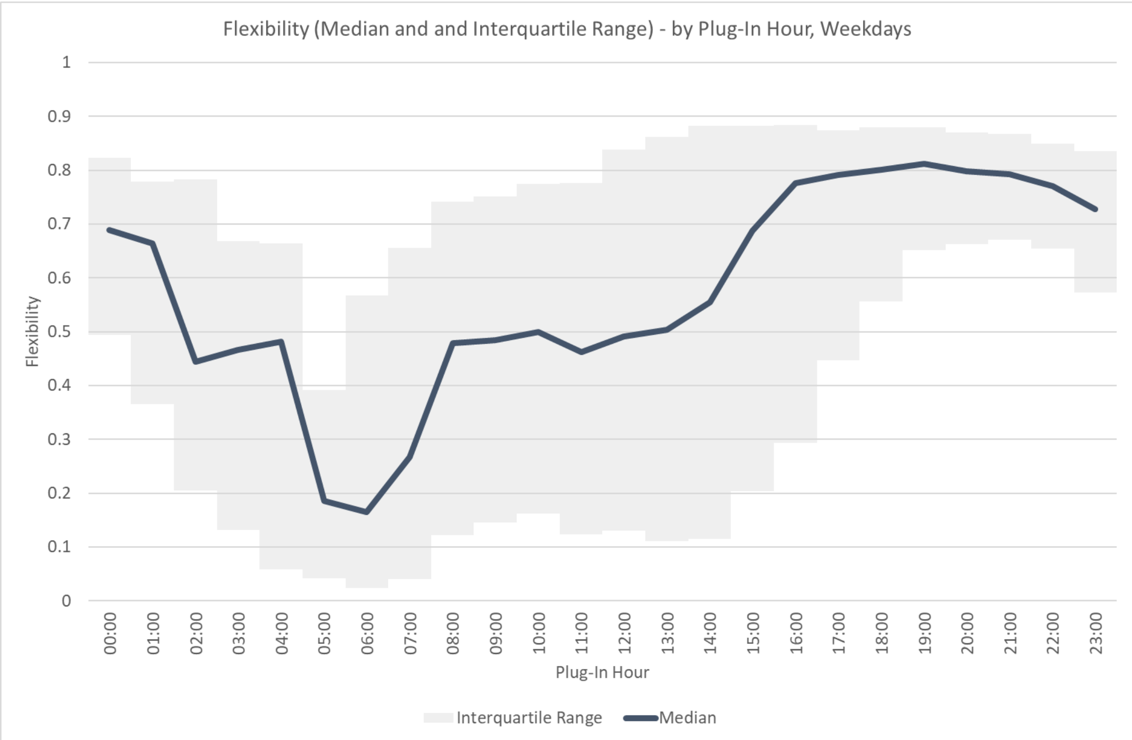

Figure 11-46: Flexibility by Plug-in Hour – Weekday

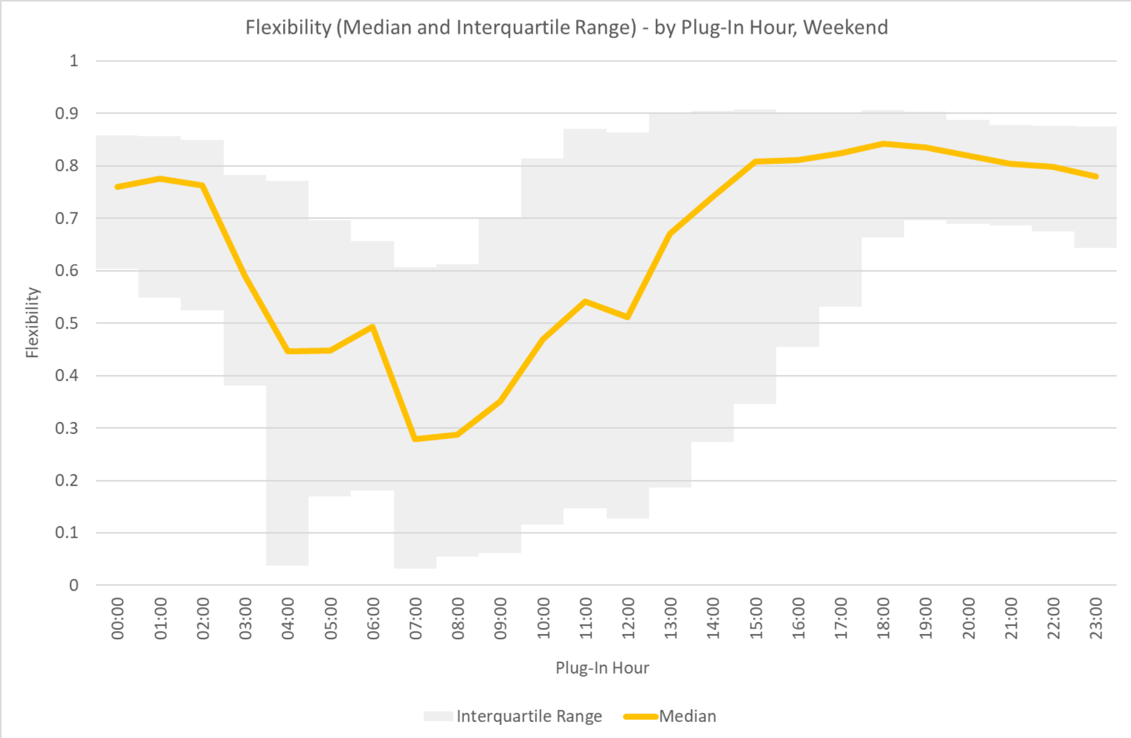

Figure 11-47: Flexibility by Plug-in Hour – Weekend

11.2.6 Customer Research Results

After a participant had been able to access the GreenFlux app for at least four weeks, they were invited to complete a survey by Impact. Those who completed the survey were rewarded with a £10 Amazon voucher (assuming they had also completed the Recruitment and Baseline surveys). All Trial 2 qualifying participants were invited to complete a survey, regardless of whether or not they downloaded the GreenFlux app.

The Trial 2 survey consisted of many of the same quantitative and qualitative questions that appeared in the Baseline and Trial 1 surveys, allowing charging behaviour and attitudes towards charging arrangements to be tracked through the different phases of the project. In addition, the Trial 2 survey collected information about participants use of the app.

The Trial 2 survey was open for responses between 23rd July and 8th November 2018. The full text of the GreenFlux Trial 2 survey can be found in Appendix 8. The response rate is shown below.

Table 11-16: GreenFlux Trial 2 Survey Response Rate

	Surveys Issued	Surveys Completed	Response Rate (%)
GreenFlux Trial 2	265	230	87%

All participants who were invited to complete a Trial 2 survey took part in Trial 2 (i.e. their charger was part of a Trial 2 group), and had been invited to download the app. Due to variations in charging behaviour, and the fact that downloading the app was optional, the 230 respondents contained a mix of management experiences and use of the app. The responses to a selection of relevant questions have been analysed based on participant's management experience and use of the app during Trial 2. These results can be found in Section 11.2.7.

11.2.6.1 Reported change in charging behaviour

Participants were asked about their charging behaviour in Trial 2, and whether this had changed since they last completed a survey (either the Trial 1 or Baseline survey). 88% of participants reported that their charging behaviour had not changed substantially since their previous survey. Some of the reasons behind changes in charging behaviour are shown in Figure 11-48 below. The reasons given did not include the introduction of smart charging or the availability of the app.

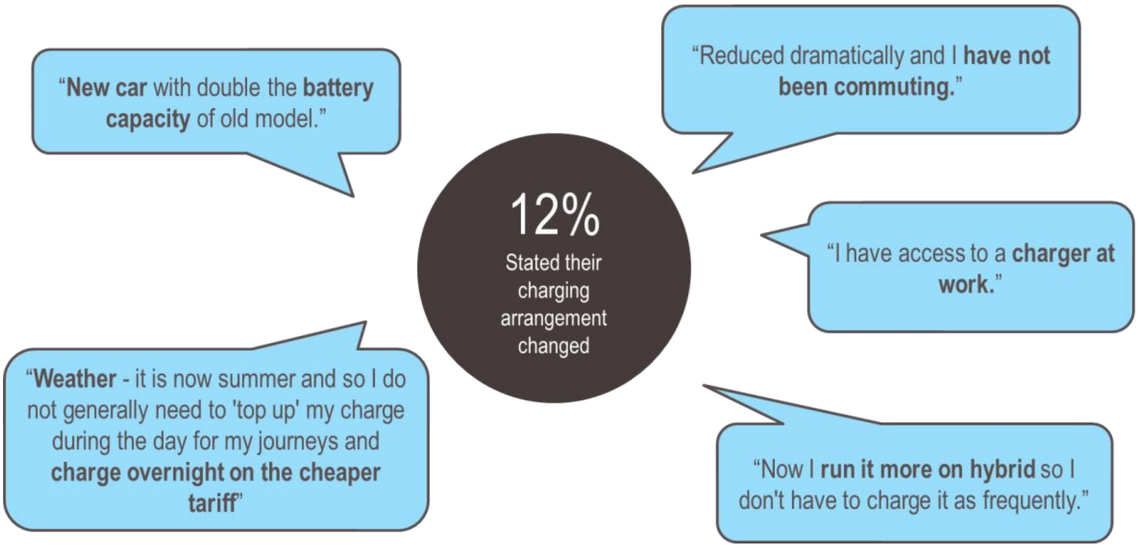

Figure 11-48: Reported charging behaviour by whole cohort and type of vehicle (230 survey responses – all respondents)

Few participants reported any change in their charging behaviour, and a detailed presentation of this behaviour is given in Section 10.2.5.

11.2.6.2 Attitudes to the App

Trial 2 was the first part of the project in which participants could use an app to interact with the smart charging system. For GreenFlux participants the app showed them whether their charging session was being managed and allowed them to request high priority. The high priority feature effectively prevented their charging session from being constrained.

The Trial 2 survey therefore focussed on participants' awareness of the app and its features, their reasons for using (or not using) it and collecting feedback on it (e.g. ease of use, additional features). This sub-section reports the results of these questions. This is linked to participants' attitudes towards their charging arrangements and management in the next sub-section, to show the effect of the app.

The first question sought to measure the level of awareness of the app amongst trial participants, and how many participants had used the app. Each participant had received multiple invitations to download the app from DriveElectric.

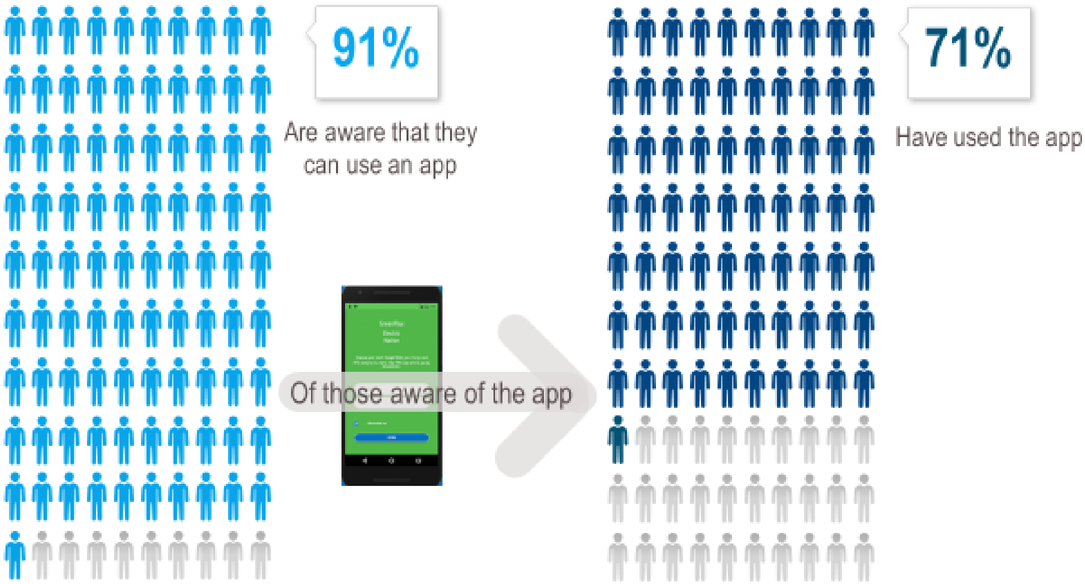

Figure 11-49: Are you aware that you can access an app to interact with your smart charging system? (Base:230 – all respondents), Have you used the app? (Base:209 – those who were aware of the app)

Figure 11-49, above, shows that awareness of the app was high amongst survey respondents (91%). 71% stated that they had used the app, this can be compared to the data presented on app usage above (see Section 11.2.5).

Data from GreenFlux showed that 61% of participants made at least one high priority request. Other participants may have used the app to view their current charging session (without requesting high priority).

Participants who had not used the app were asked for the reasons behind this. Their free text responses have been categorised, and the breakdown is shown in the pie chart below.

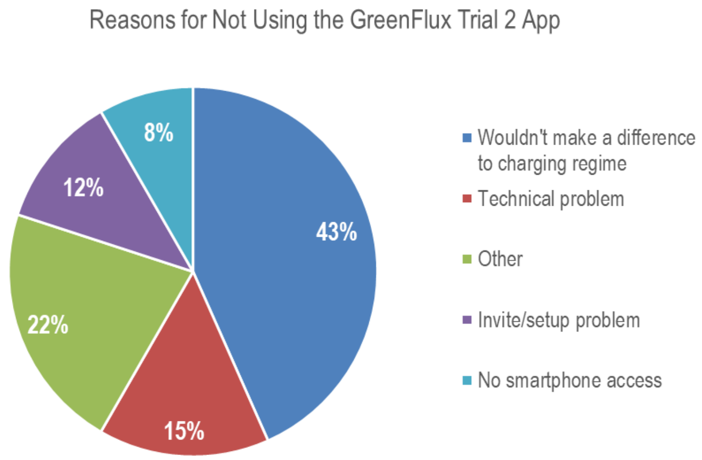

Figure 11-50: Reasons for Not Using the GreenFlux Trial 2 App (Base: 60 – those who hadn't used the app)

The most common reason (43% of responses) for not using the app was a belief that it wouldn't make a difference to the participants charging regime, or that they didn't need high priority. Some participants experienced technical problems. These may have been due to communication faults between the charger and back office, as a communications connection was required to allow the app to display the active charge session.

A selection of quotations from participants is shown in Figure 11-51, matched to the categories given above.

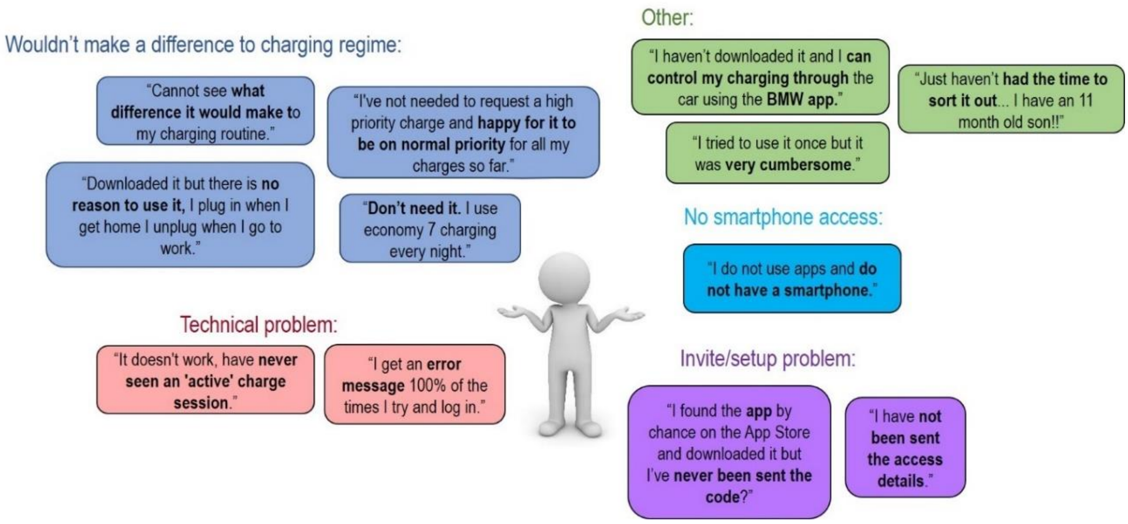

Figure 11-51: Free text responses showing reasons for not using the GreenFlux App

Participants who had stated that they were aware of the app were asked if they knew that they could request high priority charging by using the app (Figure 11-52).

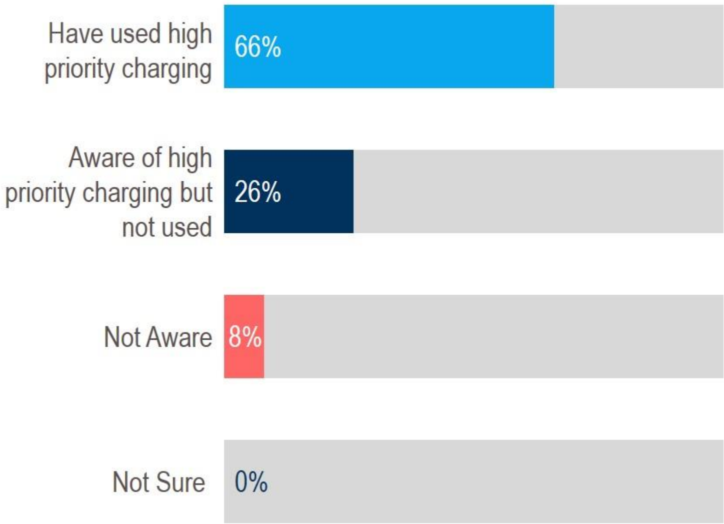

Figure 11-52: Awareness and use of the high priority feature (Base: 209 – all those aware the app was available)

The table below shows the proportion of participants who stated that they had used the high priority feature, split by battery capacity.

Table 11-17: % of survey respondents stating they had used the high priority feature - by battery capacity

Battery Capacity Group	Sample Size	% Stating "Yes, and I have used it"
Less than 10kWh	55	69%
10 to 25kWh	56	66%
25 to 35kWh	60	55%
35kWh plus	39	74%

Participants with an EV battery capacity of more than 35kWh were significantly more likely to have used the high priority feature compared to the '25 to 35kWh' group[150].
This aligns with the analysis of high priority requests from the GreenFlux data shown in Section 11.2.5.

Participants who were aware of the app and had used it to request 'High Priority' were asked why they had chosen to use it. The free text responses were categorised, and the proportion of responses of each type is shown in the pie chart below (Figure 11-53).

[150] Z test. Comparing % stating "Yes, I have used it" for '35kWh plus' and '25 to 35kWh' (74% vs. 55%) Z = 2.01.

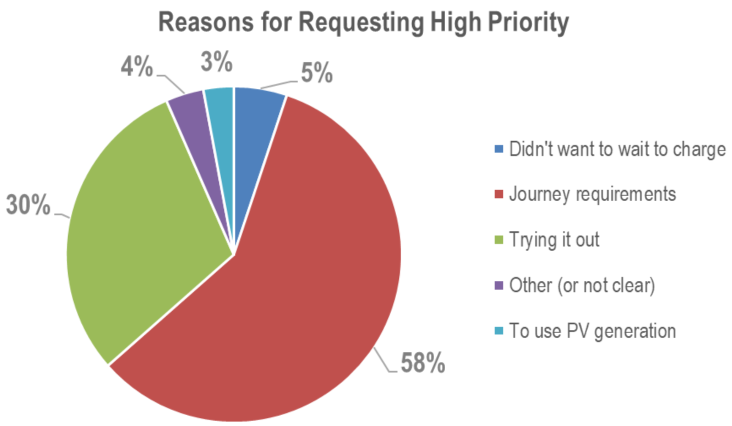

Figure 11-53: Reasons for Requesting High Priority (Base: 137 – respondents who were aware of the app, and stated that they had used it)

The most common reason for requesting high priority was to ensure the vehicle had enough charge for another journey (either later the same day, or a long journey the day after). A third of respondents only used the app to test it out, either because they had been asked to when the app was first launched, or to satisfy themselves that it worked in case they needed it later.

A selection of quotations from participants is shown below for each category of response.

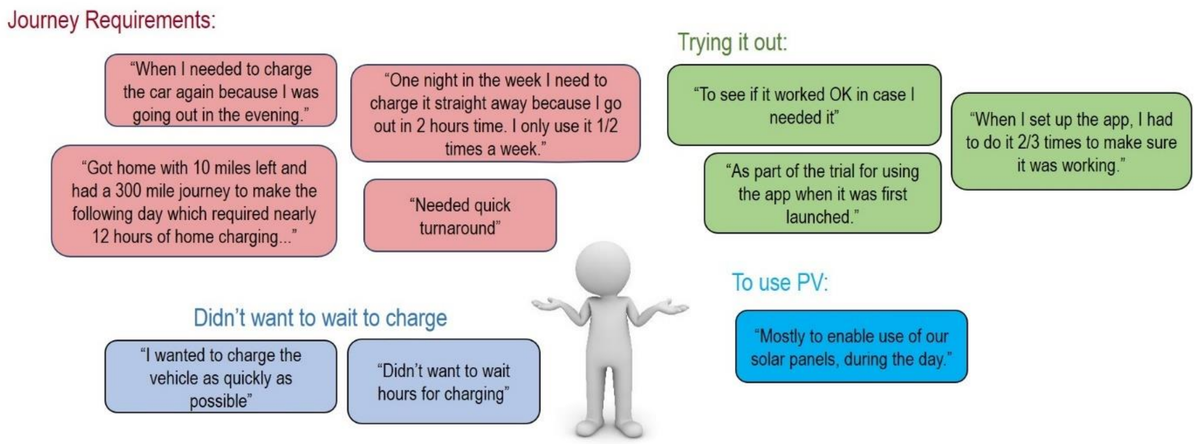

Figure 11-54: Reasons for requesting high priority

GreenFlux trial participants who said they had used the app were asked how easy it was to use (Figure 11-55).

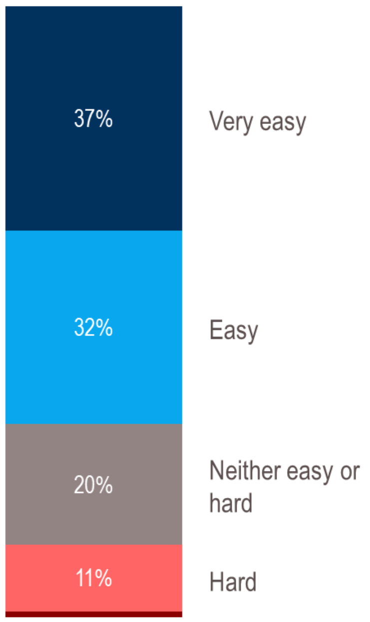

Figure 11-55: How easy do you find using the app? (Base: 150 – all respondents who were aware of the app and stated they had used it)

Overall, most trial participants thought that the app was easy to use – 69% found it either ‘Very easy’ or ‘easy’ to use. Only 11% of respondents found it ‘Hard’ to use.

Survey respondents were then asked if they would continue to use the app (Figure 11-56).

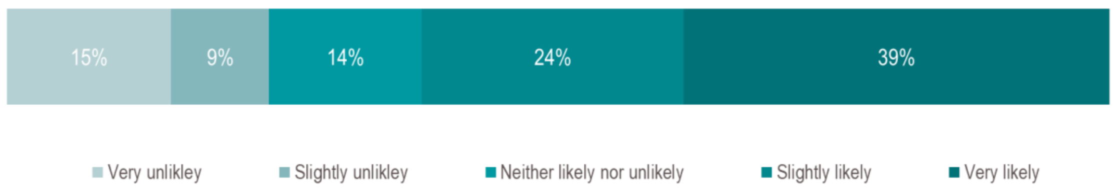

Figure 11-56: How likely are you to use the app going forward? (Base: 230 – all respondents)

63% of GreenFlux participants stated that they were likely (based on ‘Very likely’ and ‘Slightly Likely’ responses) to continue using the app and around two fifths stated that they were very likely to continue to use it. These results have been disaggregated based on whether or not the participant had many any high priority requests from Week 27 onwards (i.e. using the data from GreenFlux) and their vehicles battery capacity.

Table 11-18: Likelihood of using the app in the future - by use of high priority and battery capacity

	Group	Sample Size	Very unlikely	Unlikely	Neither Likely nor Unlikely	Slightly Likely	Very Likely
High Priority Requests Week 27 onwards	Made a High Priority Request from Week 27	75	9%	3%	12%	21%	55%
	Did not make a High Priority Request from Week 27	155	17%	12%	15%	25%	31%
Battery Capacity	Less than 10kWh	61	13%	10%	18%	28%	31%
	10 to 25kWh	59	10%	8%	8%	27%	46%
	25 to 35kWh	69	22%	9%	14%	22%	33%
	35kWh plus	41	12%	10%	15%	15%	49%

Participants who used the high priority feature from Week 27 onwards were **more likely** to indicate that they were "very likely" to use the app in the future, compared to who had not made any high priority requests[151].

Conclusions in relation to battery capacity can only be made at the 10% confidence level but show that the '10 to 25kWh' group were **more likely** to continue to use the app in the future compared to the 'Less than 10kWh' group. The '35kWh plus' group were **more likely** to continue to use the app in the future compared to both the '25 to 35kWh' and 'Less than 10kWh' groups[152].

Participants were asked to identify other functions that they would expect to be part of the app's functionality. 55% of GreenFlux participants who responded to the survey didn't

[151] Z test. Comparing % stating very likely comparing (55% vs. 31%) Z = 3.50.
[152] Z test. Comparing % stating very likely. '10 to 25kWh' vs. 'Less than 10kWh' (46% vs. 31%) Z = 1.69. '35kWh plus' vs. '25 to 35kWh' (49% vs. 33%) Z = 1.72. '35kWh plus' vs. 'Less than 10kWh' (49% vs. 31%) Z = 1.89.

expect to see any other functions. The chart below (Figure 11-57) shows the most commonly suggested features:

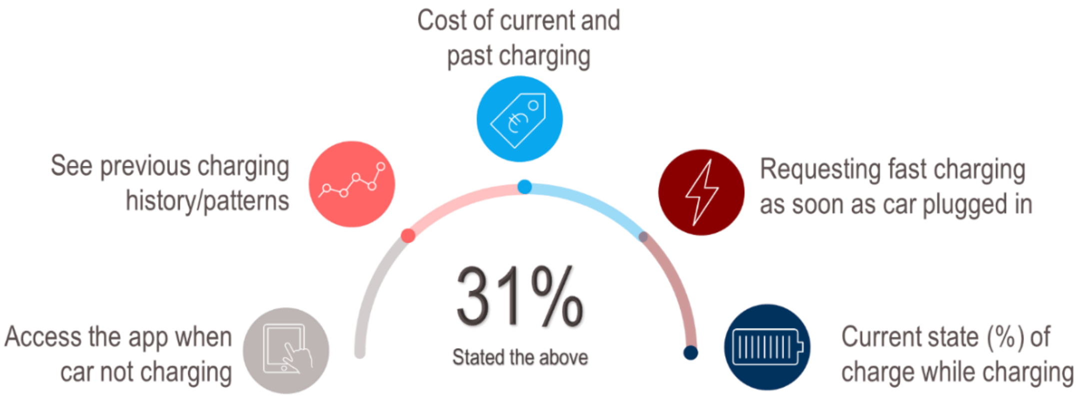

Figure 11-57: Are there any other features that you expected to see on the app? (Base 230 – all respondents)

Some of the functions were already available in the app (requesting fast charging as soon as car plugged in), whilst others are not possible using the existing communications protocol between the car and the charger/back office (current state (%) of charge while charging).

11.2.6.3 Acceptability and satisfaction with charging arrangements

One of the key elements of the Electric Nation trial was to understand the acceptability of smart charging amongst participants, and the factors which affect this. Participants were asked a consistent series of questions at multiple points through the project – before management (the Baseline survey, see Section 9.1), as part of Trial 1 (see Section 10.2.5), Trial 2 (this section) and Trial 3 (Section 12.2.5). This allows participants' attitudes towards their charging arrangements to be compared.

This section shows the results of this part of the survey and compares the responses to those received in the Baseline, Trial 1 and Trial 2 surveys, showing the effect of the availability of an app. All the results presented in this section are based on those participants who responded to all three surveys. Section 11.2.7 relates these scores to the amount of management a participant experienced and their use of the app (based on data received from GreenFlux). The results from all respondents can be found in Appendix 3.

Participants were asked to rate the acceptability of their current charging arrangements on a scale of 1 (completely unacceptable) to 10 (completely acceptable). Figure 11-58, below, shows the proportion of participants who rated their charging arrangements as highly acceptable (a score of 8, 9 or 10) for the Baseline, Trial 1 and Trial 2 surveys.

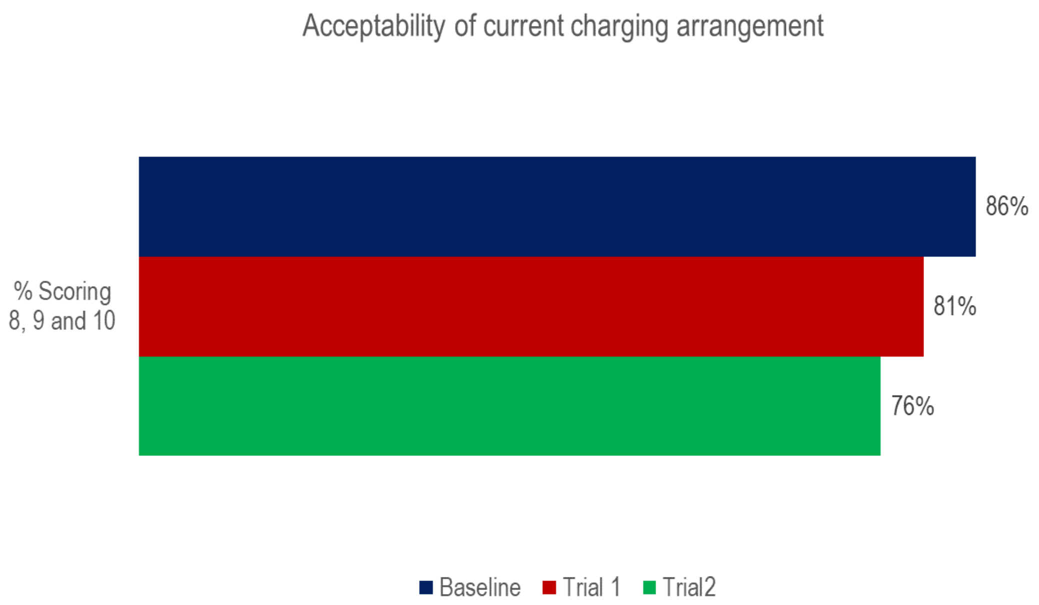

Figure 11-58: Acceptability of Current Charging Arrangements (Base: Baseline 123, Trial 1 – 125, Trial 2 -123 responses; excludes those who answered 'don't know')

There was a slight decrease in acceptability between Trial 1 (demand management, no app) and Trial 2 (demand management, with app) but this is not statistically significant[153]. However, the decrease in the proportion of participants who rated their charging arrangements as 'highly acceptable' between the Baseline survey and the Trial 2 survey is statistically significant[154]. The reasons for this may include the amount of management participants experienced, or other factors relating to their charging experience. Section 11.2.7 links the acceptability scores which participants gave with the amount of management they experienced and their use of the app.

Participants were also asked to score their satisfaction with their charging arrangements on a 1 to 10 scale. Figure 11-59 compares the level of satisfaction for those participants who completed all three surveys (Baseline, Trial 1 and Trial 2).

[153] Z test: Z value = 0.84
[154] Z Test. Z value = 1.96

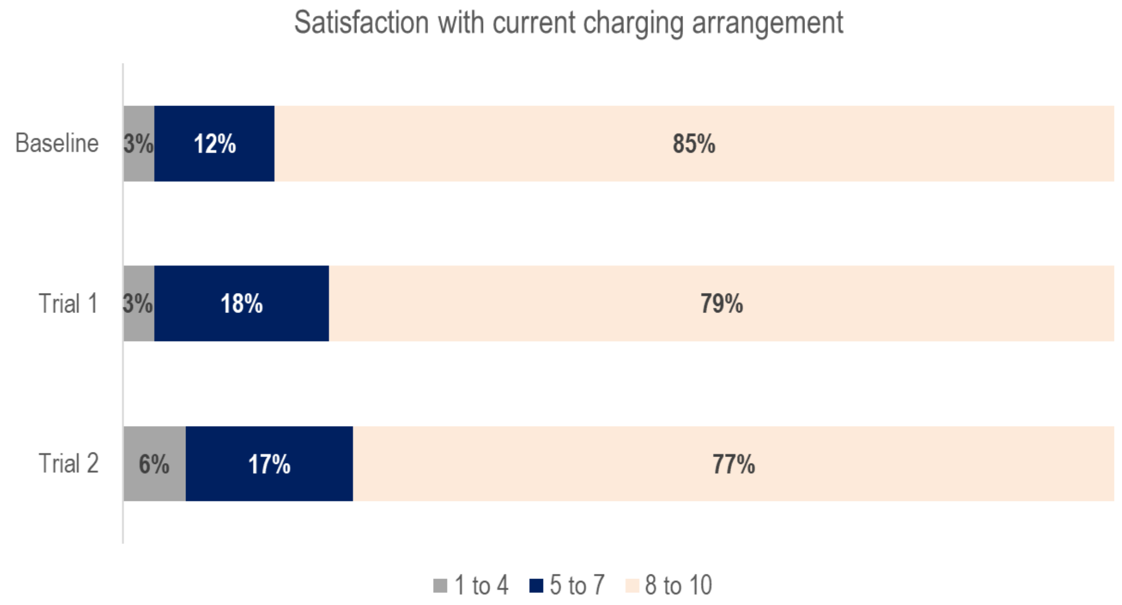

Figure 11-59: Satisfaction with Charging Arrangements (Baseline – 124 responses, Trial 1 – 125 responses, Trial 2 – 125 responses; excludes those who answered 'don't know')

The proportion of participants who were highly satisfied (scores 8 to 10) reduced slightly between the Baseline and Trial 1 surveys and again between Trial 1 and Trial 2. However, these changes are not statistically significant[155]. The increases in the proportion of 'dissatisfied' and 'neutral' scores between the three surveys are also not statistically significant. The link between participants' experience of management, their use of the app and levels of acceptability and satisfaction are explored in Section 11.2.7.

Table 11-19 compares the proportion of participants who were highly satisfied (scores of 8 to 10) for all three surveys, disaggregated by PEV type and battery capacity.

Table 11-19: % of Survey Respondents Highly Satisfied - Baseline, Trial 1 and Trial 2 by PEV Type and Battery Capacity

Group		Sample Size	% of Survey Responses Scoring 8 - 10		
			Baseline	Trial 1	Trial 2
PEV Type	REX	22	77%	68%	73%
	PHEV	47	85%	83%	81%
	BEV	56	88%	80%	75%
Battery Capacity	Less than 10kWh	29	89%	79%	79%
	10 to 25kWh	37	84%	86%	86%
	25 to 35kWh	39	82%	74%	72%
	35kWh+	20	85%	75%	65%

155 Z Test. Baseline to Trial 1 Z = 1.23. Trial 1 to Trial 2 Z = 0.38. Baseline to Trial 2 Z =- 1.61.

Satisfaction levels between Trial 1 and Trial 2 either decreased or stayed at the same levels across all the groups, although none of the changes were statistically significant[156]. Although the proportion of 'highly satisfied' participants varies between the sub-groups in each of the surveys, there are no statistically significant differences[157].

Participants were also asked to state for how long they would be willing to continue with their current charging arrangements. The results are shown below for participants who completed the Baseline, Trial 1 and Trial 2 surveys in Figure 11-60, below.

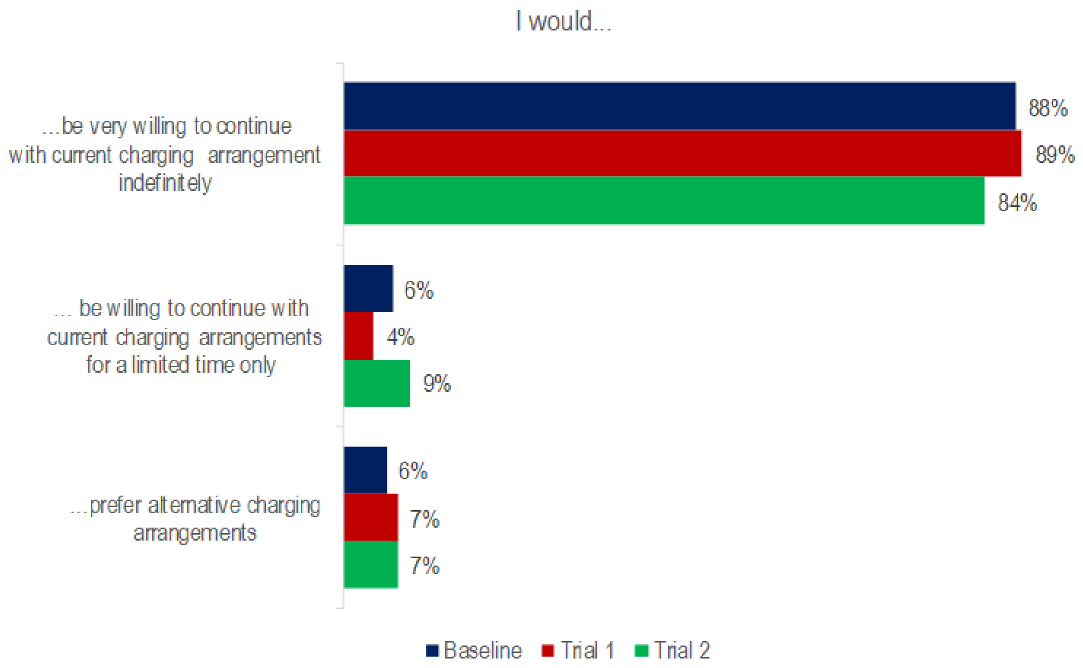

Figure 11-60: Willingness to Continue with Charging Arrangements (Baseline – 124 responses , Trial 1 – 125 responses, Trial 2 – 125 responses)

The proportion of participants that would be willing to continue with their current charging arrangements indefinitely remained high across all three surveys. There was a slight decrease between the Trial 1 and Trial 2 surveys, but the difference was not statistically significant[158]. The number of respondents who would be willing to continue with their current charging arrangements for a limited time only doubled between the Trial 1 and Trial 2 surveys, but this was not statistically significant at either the 5% or 10% level[159].

[156] Z test: Z values range from 0 for battery capacities of 10 to 25kWh and 25 to 35kWh up to 0.69 for participants with vehicles having a battery capacity >35kWh
[157] Z test: for Trial 2, Z values range from 0.18 between 'REX' and 'BEV' up to 1.90 between battery capacities of 10 to 25kWh and >35kWh
[158] Z test: Z value = 1.11
[159] Z test: Z value = 1.55

Table 11-20 disaggregates the Baseline, Trial 1 and Trial 2 surveys by vehicle type and battery capacity and shows the proportion of participants in each sub-group who were willing to continue with their charging arrangements indefinitely.

Table 11-20: Proportion of Participants Willing to Continue with Charging Arrangements Indefinitely - Baseline, Trial 1 and Trial - by PEV Type and Battery Capacity

<table>
<tr><th colspan="2" rowspan="2">Group</th><th rowspan="2">Sample Size</th><th colspan="3">% of Survey Respondents Willing to Continue with Charging Arrangements Indefinitely</th></tr>
<tr><th>Baseline</th><th>Trial 1</th><th>Trial 2</th></tr>
<tr><td rowspan="3">PEV Type</td><td>REX</td><td>22</td><td>86%</td><td>91%</td><td>82%</td></tr>
<tr><td>PHEV</td><td>47</td><td>87%</td><td>85%</td><td>91%</td></tr>
<tr><td>BEV</td><td>56</td><td>89%</td><td>91%</td><td>79%</td></tr>
<tr><td rowspan="4">Battery Capacity</td><td>Less than 10kWh</td><td>29</td><td>90%</td><td>86%</td><td>90%</td></tr>
<tr><td>10 to 25kWh</td><td>37</td><td>86%</td><td>92%</td><td>92%</td></tr>
<tr><td>25 to 35kWh</td><td>29</td><td>90%</td><td>90%</td><td>79%</td></tr>
<tr><td>35kWh plus</td><td>20</td><td>80%</td><td>85%</td><td>70%</td></tr>
</table>

Willingness to continue fell from Trial 1 to Trial 2 for both REX and BEV groups, but increased slightly for the PHEV group. The change in score amongst BEV drivers (91% in Trial 1, 79% in Trial 2) was statistically significant at the 10% level[160].

With respect to battery size, the willingness of the two smaller battery size sub-groups to continue at the end of Trial 2 was slightly increased or unchanged from Trial 1, whereas for the largest two battery sub-groups it was lower. Comparing the battery capacity subgroups to each other (for the Trial 2 survey only), participants with a battery capacity of '35kWh plus' were significantly less likely to be willing to continue with their arrangements indefinitely than either the 'Less than 10kWh' or '10 to 25kWh' groups, at the 10% and 5% confidence level respectively[161].

Participants were asked about their concerns regarding smart charging. The results from the Baseline survey (before management), Trial 1 (no app) and Trial 2 are shown in Figure 11-61, below.

[160] Z test: Z value ranges from 0.87 for 'REX' up to 1.78 for 'BEV'

[161] Z test. 35kWh plus vs. Less than 10kWh (70% vs. 90%) Z = 1.78 (a value of 1.64 would indicate confidence at the 10% level). 35kWh plus vs. 10 to 25kWh (70% vs. 92%) Z = 2.18.

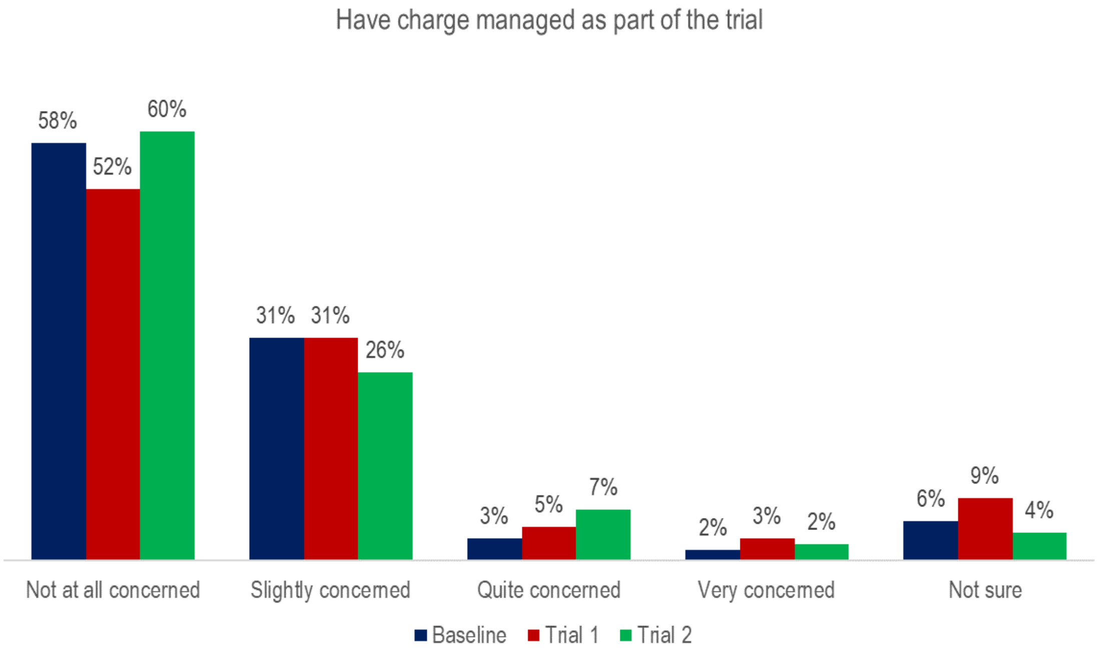

Figure 11-61: Level of concern re: demand management (Base: Baseline 125, Trial 1 125, Trial 2 125)

The proportion of GreenFlux trial participants with no concerns about having their charge managed remained broadly similar and there are no statistically significant differences between the responses in this category in the Trial 1 and Trial 2 surveys[162].

The app appears to have increased the proportion of participants who were either 'quite' or 'very' concerned about demand management, from 8% of respondents at the end of Trial 1 to 10% at the end of Trial 2, although this change is not statistically significant[163].

Table 11-21 below disaggregates the Trial 2 results by battery capacity.

Table 11-21: Level of Concern about Management (Trial 2) - by Battery Capacity

Battery Capacity Group	Sample Size	% of Respondents (Trial 2 Survey)		
		'Not at all concerned'	'Slightly concerned'	'Quite' or 'Very Concerned'
Less than 10kWh	29	69%	24%	7%
10 to 25kWh	37	57%	30%	8%
25 to 35kWh	39	67%	18%	10%
35kWh plus	20	40%	40%	15%

162 Z test: Z value = 1.27
163 Z = 0.28

Participants whose vehicle had a battery capacity of '35kWh plus' were less likely to be not at all concerned about management than those with a battery capacity of either 'Less than 10kWh' or '25 to 35kWh'[164]. The lower proportion of participants with '35kWh plus' vehicles who were 'not at all concerned' was offset by a larger proportion who were 'slightly' concerned – there were no statistically significant differences between the battery capacity groups reporting to be 'quite' or 'very' concerned.

The introduction of the app, and the high priority feature may have decreased participants concerns about demand management. Trial participants who were aware of the app were asked to what extent the app helped to alleviate any concerns that they had about managed charging (Figure 11-62).

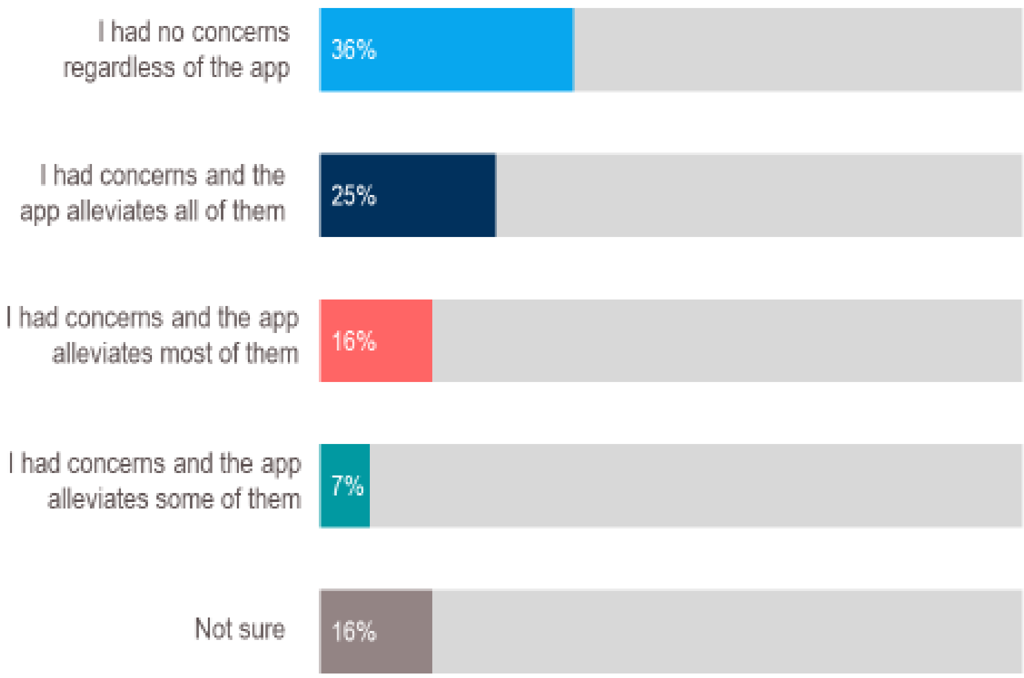

Figure 11-62: To what extent does the app alleviate your concerns about managed charging? (Base: 210)

Over a third of participants did not have any concerns about managed charging. 100 participants stated that they had some concerns prior to the introduction of the app. Of these 100 participants:

- 15 said the app alleviated **all** of their concerns;
- 33 said the app alleviated **most** of their concerns; and
- 52 said the app alleviated **some** of their concerns.

[164] Z Test. 35kWh plus vs. Less than 10kWh (40% vs. 69%) Z = 2.45. 35kWh plus vs. 25 to 35kWh (40% vs. 67%) Z = 2.48.

The survey question did not provide an option for participants to report that the app increased their level of concern. It is likely that participants who felt this way would have used the 'not sure' option – used by only a minority of respondents. The results are disaggregated below, where participants have been divided based on whether or not they had made any high priority requests after Week 27.

Table 11-22: To what extent does the app alleviate your concerns about managed charging? - by use of the high priority feature

Survey Response	Responded to the Trial 2 Survey and made high priority requests from Week 27 onwards	Responded to the survey, did not make any high priority requests from Week 27 onwards
Sample Size	**73**	**137**
I had no concerns regardless of the app	25%	42%
I had concerns and the app alleviates all of them	11%	5%
I had concerns and the app alleviates most of them	22%	12%
I had concerns and the app alleviates some of them	30%	22%
Not sure	12%	18%

Those who used the app to make a high priority request from Week 27 (i.e. after the initial part of the trial was over) were significantly less likely to have had no concerns regardless of the app[165]. However, amongst this group, the proportion who said that the app alleviated "most" or "some" of their concerns was 63%.

11.2.6.4 Trial 2 findings from focus groups

GreenFlux participants in the focus group discussion held at the end of the project shared their views on the app. Overall, they felt that downloading and using the app was easy.

Most participants had used the high priority feature, typically owing to wanting to make a longer journey, or an additional/different journey from their normal routine (mirroring the findings from the trial population as a whole). A series of quotations regarding using the app are shown in Figure 11-63, below.

[165] Z Test. 25% vs. 42% Z = 2.44

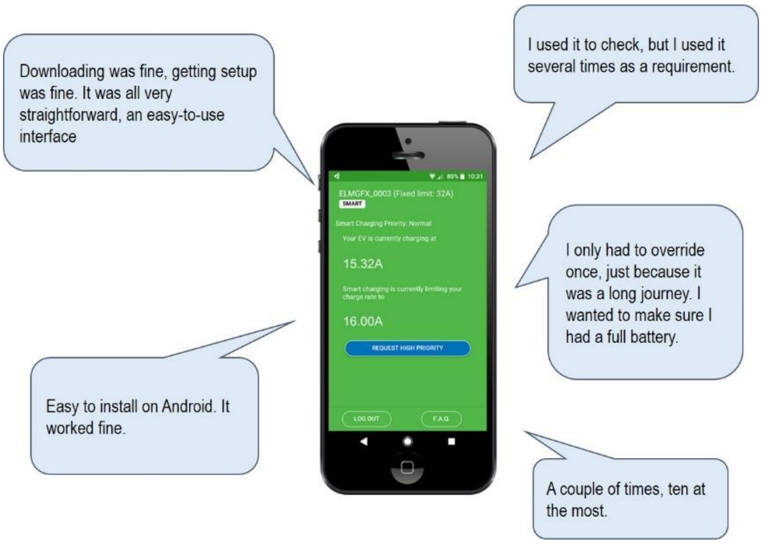

Figure 11-63: Feedback on Using GreenFlux App

The introduction of the 'request high priority' button was welcomed by GreenFlux participants. Those that may have had range/charger anxiety during Trial 1 were placated with the ability to override demand management, Figure 11-64:

Figure 11-64: Reasons for using High Priority

11.2.6.5 Summary

Satisfaction with current charging arrangements among the GreenFlux trial participants remained steady between Trials 1 and 2. There was a slight decline in the proportion of participants giving the highest scores for satisfaction between the Baseline and Trial 2 surveys. However, this was not statistically significant.

The vast majority of GreenFlux participants were aware of the app (91%) and 71% stated they had used it.

Among those who did not engage with the app, many were not concerned about having their charging managed and did not therefore feel the need to intervene by using the app.

Two thirds of participants requested high priority charging, however 30% of these participants only requested this to test the function. Other participants requested priority charging to ensure that they had enough charge for unexpected trips or to plan for long journeys, because they had concerns about the potential impact of restrictions on ‘normal’ charging.

Free text responses from trial participants during Trial 2 suggested that they would have liked the app to give them more information on their charging history and greater interaction between their PEV and their charger.

11.2.7 Key Findings –GreenFlux Trial 2

- The 90th Percentile peak demand was approximately 470W per charger (compared to 830W per charger in winter). This demand was constrained by the use of demand management – unrestricted demand would be higher.
- The total energy requirement per day (area under the demand curve) was lower in summer.
- Management was active on slightly more than 50% of weekdays (during the evening peak only) during most of Trial 2. It was active less frequently at the weekend (fewer than 15% of weekend days). Management led to individual chargers having their charging paused, or the rate reduced, for short periods (15 minutes).
- 15% of charging events during Trial 2 were constrained by demand management (2,611 charging events). This is a slightly lower (but still statistically significant) percentage than in Trial 1 (17%).
- 87% of participants experienced some management of their charging events during Trial 2.
- Curtailing of charging events during demand management did not lead to an increase in the proportion of Trial 2 participants’ charging events where the vehicle was hot unplugged before the battery was fully charged. In fact, there was a statistically significant decrease between the ‘outside of management’ period and Trial 2 (14.7% vs. 13.8%) and between Trial 1 and Trial 2 (15.3% vs. 13.8%).
- Charging constraints were shared equally amongst participants who vehicles were rated at 16A or 32A, with similar proportions of events being curtailed in each group, and similar values for GreenFlux Management Factor.

- Participants who charge more often in the evening peak experienced more management who charge outside of this time window.
- Table 11-23 below, relates the scores given for participants **satisfaction** with their current charging arrangements in the Trial 2 survey to values of GreenFlux Management Factor:

Table 11-23: Relationship between GreenFlux Trial 2 Management Experience and Satisfaction

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
Not Managed During Trial 2	29	3%	21%	76%
GreenFlux Management Factor 1st Quartile	42	7%	19%	74%
GreenFlux Management Factor 2nd Quartile	45	4%	20%	76%
GreenFlux Management Factor 3rd Quartile	41	15%	20%	66%
GreenFlux Management Factor 4th Quartile	52	4%	17%	79%

This shows that increasing amounts of management do not lead to higher rates of dissatisfaction. There is no consistent trend between the amount of management experienced and proportion of participants who were either “highly satisfied” or “neutral”, and none of the difference shown above are statistically significant at the 5% level.

- Table 11-24 below, relates the scores given by participants for the **acceptability** of their current charging arrangements in the Trial 2 survey to values of GreenFlux Management Factor.

Table 11-24: Relationship between GreenFlux Trial 2 Management Experience and Acceptability

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
Not Managed During Trial 2	29	3%	17%	79%
GreenFlux Management Factor 1st Quartile	42	10%	14%	76%
GreenFlux Management Factor 2nd Quartile	44	11%	16%	73%
GreenFlux Management Factor 3rd Quartile	41	12%	20%	68%
GreenFlux Management Factor 4th Quartile	51	4%	20%	76%

This shows no relationship between the amount of management participants experienced and the acceptability of their charging arrangements, and none of the differences are statistically significant.

- As part of Trial 2 GreenFlux participants were invited to download an iOS or Android smart phone app which would allow them to select 'high priority' for individual charging events, and so prevent their charging session from begin managed. Over the course of Trial 2 there were 183 downloads of the app, compared to 267 invitations (69%).
- Over the full duration of Trial 2, 4.2% of charging events included a high priority request. Use of the high priority feature declined from much higher levels in the first few weeks of Trial 2 to a relatively stable 3% of charging events in each week in the second half of the trial.
- Once use of the feature had stabilised, only 33% of participants made high priority requests. 20% of participants were responsible for 90% of requests – suggesting that a small group of participants use the feature very frequently. Certain groups had differing tendencies to use the high priority feature:
  - **More likely** to use high priority: owners of vehicles with a battery capacity of greater than 35kWh (5% confidence level), owners of vehicles with battery capacities between 25 and 35kWh (10% confidence level);

  - **Less likely** to use high priority: participants who showed a low level of engagement with the trial (they did not complete a Recruitment survey); and
  - There was no link between the level of concern that participants expressed about demand management and their tendency to use the high priority feature.

- Participants most often used the app because of particular journey requirements (e.g. making a longer trip than usual, or another trip later the same day). The second most frequent reasons for using the app was to try it out - in some cases because the participant wanted to understand the feature in case they needed it at a later date.
- Amongst those who did not use the app, this was most often because it would not make a difference to their charging regime (e.g. because they charge overnight).
- The proportion of participants who were willing to continue with the current charging arrangements indefinitely remained high at the end of Trial 2 (84%), and there had been no statistically significant decline from Trial 1
- The amount a participant used the app may be linked to the satisfaction and acceptability scores they gave in the Trial 2 survey. Participants have been divided into three groups; those who made no high priority requests (once usage had stabilised partway through Trial 2), those in the lower two quartiles for use of high priority, and those in the upper two quartiles.

Table 11-25: Link between App Usage and Satisfaction

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		1 – 4	5 – 7	8 – 10
No high priority requests	135	7%	16%	77%
Lower two quartiles (high priority used for less than 5.85 of their charging events)	36	0%	22%	78%
Upper two quartiles (high priority used for less than 5.85 of their charging events)	39	10%	26%	64%

Table 11-26: Link between App Usage and Acceptability

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
No high priority requests	133	9%	14%	77%
Lower two quartiles (high priority used for less than 5.85 of their charging events)	36	3%	22%	75%
Upper two quartiles (high priority used for less than 5.85 of their charging events)	39	10%	21%	69%

Although these tables appear to show that the participants who made the most high priority requests (they were in the upper two quartiles) tended to be less satisfied with their charging arrangements and find them less acceptable, neither difference was statistically significant at either the 5% or 10% level.

- Participants in the focus groups found the process of downloading and using the high priority app easy and felt it offered reassurance that they could influence the likelihood that they would be managed when this was necessary.

12 Trial 3 Findings

Trial 3 introduced elements of time of use pricing for both CrowdCharge and GreenFlux participants. The project had already observed that trial participants with dual rate meters, were more likely to use vehicle timers to delay charging to the overnight period.

Beyond Economy7/10 tariffs, which have existed since the 1970s, alternative time of use pricing may be introduced by energy suppliers in the future, with energy customers opting into tariffs by changing tariff or supplier. Sophisticated time of use tariffs, where prices vary beyond the day/night rate used in Economy7 require the energy customer to have a smart meter installed to allow half hourly consumption to be accurately metered. The Octopus Agile[166] tariff is one example of such a Time of Use tariff.

The project team also noticed a small number of energy suppliers launching special “EV Tariffs”, e.g. Good Energy’s Electric Vehicle tariff, aimed specifically at EV owners, offering savings through off-peak electricity cost savings.

The purpose of this part of the trial was to test whether savings on electricity costs for charging EVs (with smart charging enabling the process) would act as an incentive to change EV drivers’ charging behaviours. The process of changing trial participants’ household tariffs would have been time consuming and expensive within the scope of the project; it was therefore decided to use a “virtual” tariff instead. This has the disadvantage that other household electricity costs, other than EV charging, were not subject to the same virtual tariff, which may affect customer acceptance of time of use tariffs. It also meant that the ‘savings’/rewards which participants earned by changing their behaviour could not form part of their electricity bill. These were instead passed to the participants in the form of an Amazon voucher (more details below).

The way in which the Time of Use system was implemented differed between the Electric Nation trial’s two demand management providers and these are described in more detail in the following sections. A common tariff structure was implemented by both providers, shown below.

[166] https://octopus.energy/agile/

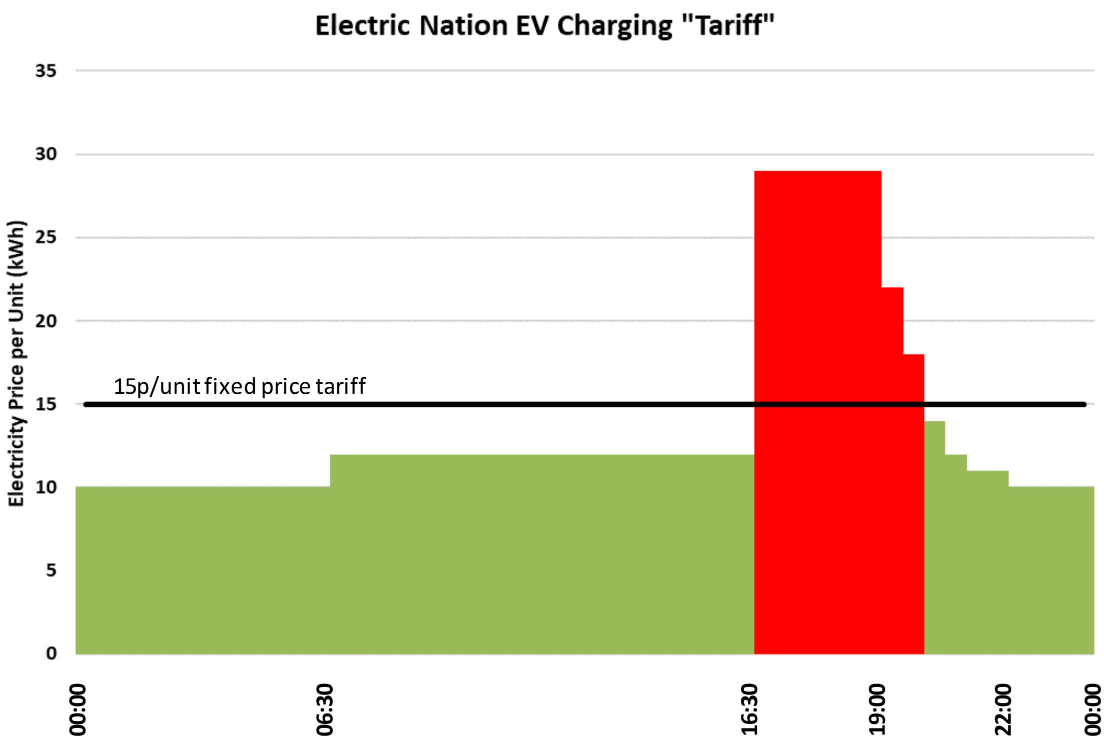

Figure 12-1: Trial 3 ToU Reward Tariff Structure (CrowdCharge and GreenFlux)

All Trial 3 participants began the trial with a £10 reward (Amazon voucher). Each charge session was analysed to calculate a 'cost' associated with the energy (based on meter values from the smart charger). Each unit of energy consumed during times when the price was more than 15p/kWh (the horizontal line above) decreased the reward value by the difference between the tariff price and 15p/kWh. For example, a kilowatt hour of energy consumed during the peak period would decrease the reward value by 13 pence (28p/kWh – 15 p/kWh). Each unit consumed when the price was less than the flat rate increased the reward value by the difference between the tariff price and 15p/kWh. At the end of the trial all participants who took part in Trial 3 received an Amazon voucher equal to their reward value.

12.1 CrowdCharge

12.1.1 Description of Trial

In Trial 3, CrowdCharge continued to use the same journey planning approach that was deployed in their Trial 2 app. The only modification to the app interface was a display of the participant's current reward value.

The main change CrowdCharge made in Trial 3 was an alteration to the algorithm which now aimed to move charging away from peak price periods (16:30 – 19:30). Charging was scheduled based on the information entered in the journey planning app, or a default assumption that the participant required enough energy to complete a 50-mile journey[167] (either using a known SoC value from the app, a historical estimate based on previous charging sessions, or an assumed value of 10% in the absence of a prediction based on historical data), four hours after plugging in. Example scenarios are outlined below:

- The default scenario (when no journey plan had been entered): A participant connects their vehicle when they arrive home in the evening (e.g. 18:00), but no journey plans have been entered. The CrowdCharge system assumed the vehicle was required four hours later (default assumption) and would be travelling 50 miles. Peak time energy would be used to ensure there was 25kWh in the battery (or it was fully charged) by 22:00. Charging would occur between 18:00 and 22:00;
- With journey plans – Example 1: A participant connects their vehicle when they arrive home in the evening peak (e.g. 18:00). They enter a journey plan with a time of departure of 7:30 the next morning. The system would therefore move some of the charging to the overnight (off-peak) period, as the energy is not required until the following morning.
- With journey plans – Example 2: A participant connects their vehicle when they arrive home in the evening peak (e.g. 18:00). They enter a journey plan with a departure time of later that evening (e.g. 21:00). In this case the CrowdCharge system would use peak time energy (charging between 18:00 and 21:00) to ensure that the energy requirement was met. By entering a journey plan, the system would prioritise charging this vehicle if demand management was required.

During Trial 3, CrowdCharge tailored the current allocated to each active charger based on the energy price and journey plans (or the default assumption). The minimum current allocated to any charger was 6A (i.e. charging was never paused). For example, in the second scenario above the charger would be allocated 6A throughout the time when the energy price was high. The impact this had on reward values is described in Section 12.1.4 below. Because of this limitation, all CrowdCharge transactions during Trial 3 were 'managed' as the current made available by the charger was a function of the tariff price. For this reason, this section does not present the degree to which individual participants charging was 'managed' during Trial 3.

[167] Using a conservative efficiency figure of 2 miles/kWh

Management continued to be active if the total current required by all the active chargers was greater than the capacity limit. When this occurred, vehicles were prioritised using journey plans, in a similar manner to Trial 2. Examples of the testing of the updated algorithm for Trial 3 are given in Section 4.10.1 (see Figure 4-21 and Figure 4-22).

245 participants took part in CrowdCharge Trial 3. They were transferred into Trial 3 in two batches during November 2018; one group of 20 participants as a 'pilot' group which operated for one week (using the 'Spring-Winter' combined profile), followed by the remaining 225 participants (using a Winter profile). Trial 3 ended on 17th December 2018 (the end of the Electric Nation smart charging trial).

This section of the report presents:

- How the ToU tariff, combined with the CrowdCharge app and updated algorithm changed the power demand from the group of chargers (compared to the end of Trial 2, and Winter during Trial 1);
- The incidence of management at a group level based on the period from 14th November to 16th December 2018;
- The degree to which participant's interacted with the journey planning app, and how this compares to Trial 2, and the level of rewards they earned;
- Findings from the customer research survey completed by participants at the end of Trial 3;
- The interactions between participants and the support line during CrowdCharge Trial 3; and
- Key findings from Trial 3, including the relationship between both app usage and reward values with satisfaction rates.

12.1.2 Demand Profiles

As described above, Trial 3 was in operation during November and December 2018. The resulting power demand from groups of chargers can be compared to other periods during the trial in order to show the potential impact of a combination of a ToU tariff, journey planning app and changes to the CrowdCharge algorithm on the demand profile from EV chargers.

The current meter value data from individual chargers has been aggregated up to a group level and converted to power (rather than current) in the same way as described in Section 10.1.2.

This section shows demand profiles for the period between 14th November and 16th December 2018 (inclusive). Profiles below are expressed in W per Charger in Group. The graph below shows the maximum, 90th percentile and average demand for weekdays Trial 3 (14th November – 16th December.

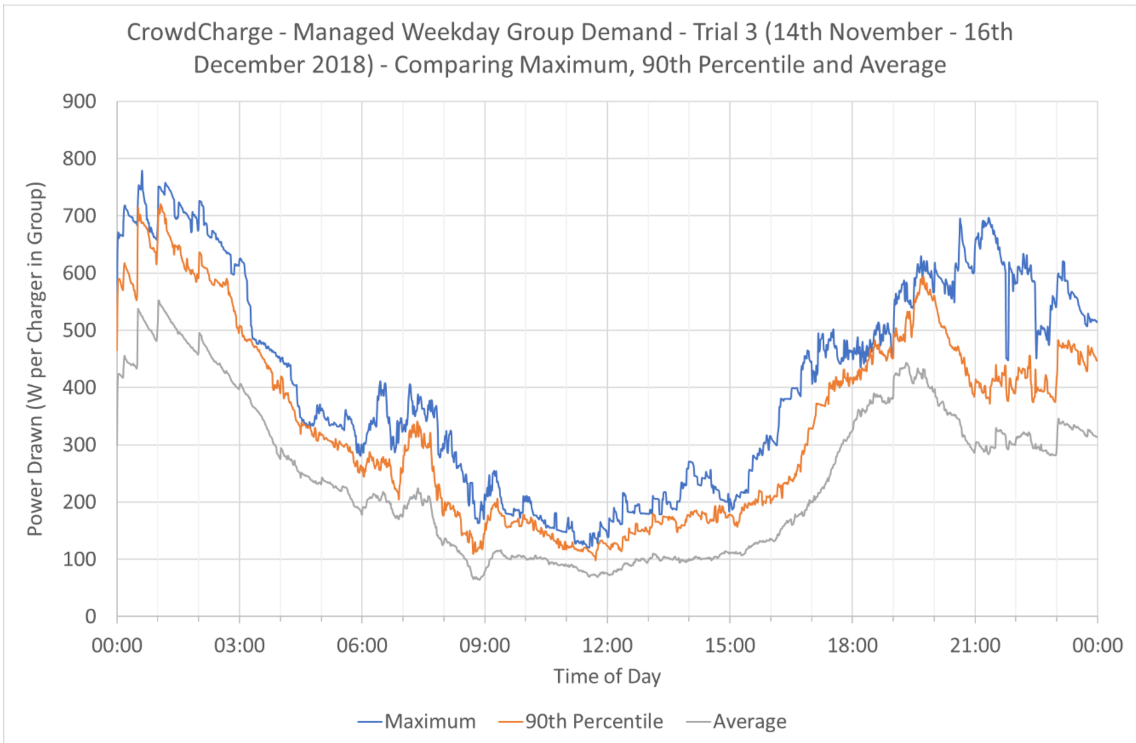

Figure 12-2: CrowdCharge Trial 3 Managed Weekday Group Demand - Maximum, 90th Percentile and Average

This graph illustrates the variability in the current drawn at each time of day from day to day. The greatest variation between the three curves occurs in the evening peak – with the maximum curve showing an earlier increase in demand and higher demand later in the evening (e.g. 21:00). The shape of the maximum curve could be as a result of the updated algorithm, with load increasing as the price decreased between 19:30 and 22:00 (where participants had entered journey plans with departure set for the following morning). The shape of the curve is broadly similar to previous parts of the CrowdCharge trial.

The graph below compares the 90th percentile weekday and weekend demand curves.

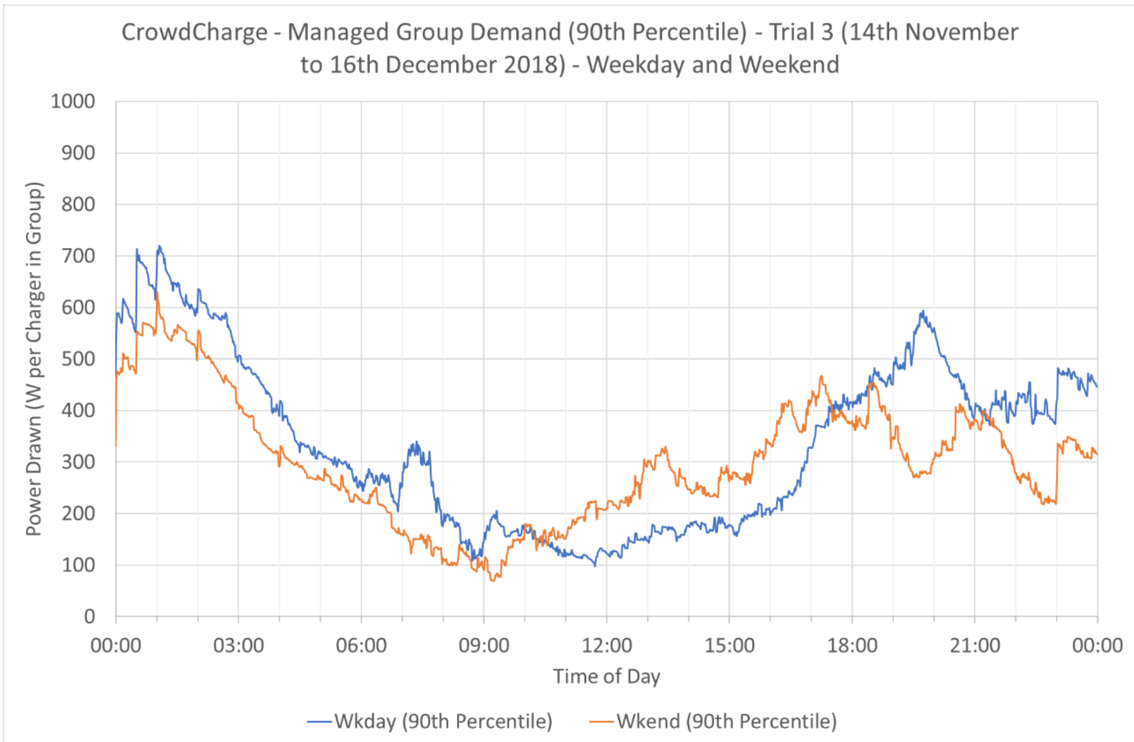

Figure 12-3: CrowdCharge Trial 3 Managed Group Demand - Weekday and Weekend (90th Percentile)

There are similar differences between weekdays and the weekend to other parts of the CrowdCharge trial. Demand during weekend daytime was higher than weekdays', and the traditional evening peak was absent. The slight increase in demand at 20:30 could be as a result of the decreasing tariff price. Demand overnight was similar (although slightly lower at the weekend), and the increase in demand between 07:00 and 08:00 during the week was absent. Participants continued to use timers, resulting in the 01:00 peak observed throughout the trial.

The profiles shown above have grouped all weekdays (Monday – Friday) and weekend days (Saturday and Sunday) together. There may be trends within the week – for example higher demand on Mondays compared to Fridays. The graph below shows the 90th percentile of group demand (W per charger in the group) during Trial 3, shown across the seven days of the week.

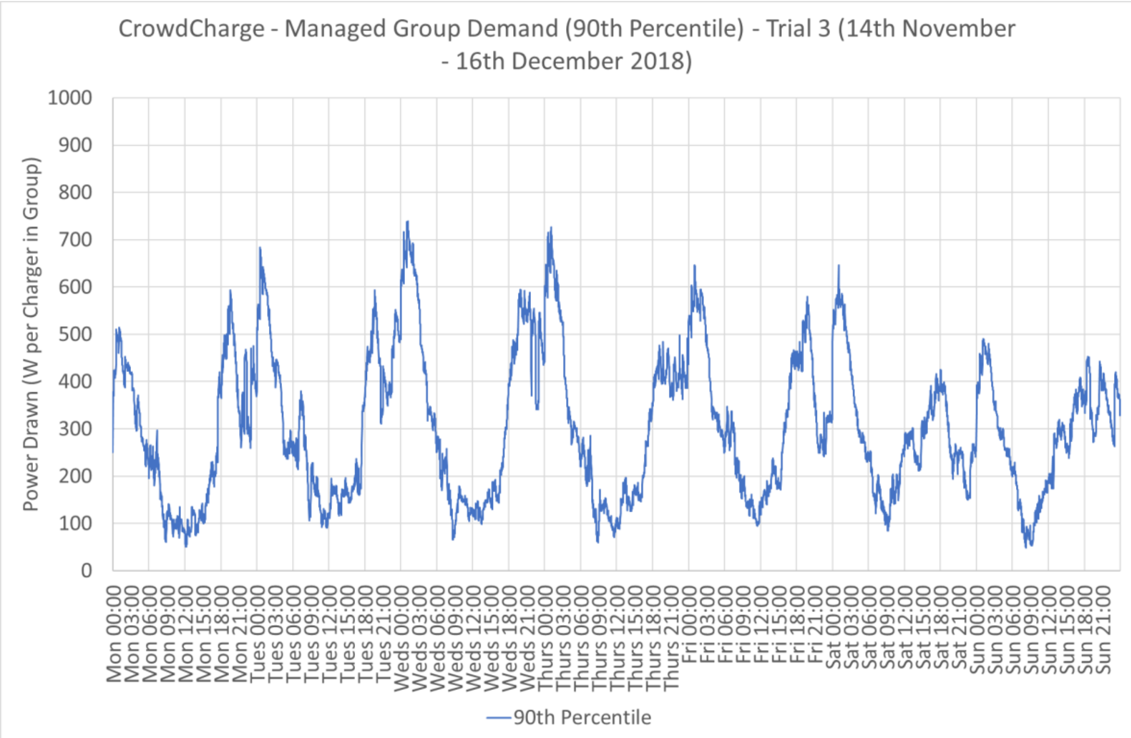

Figure 12-4: CrowdCharge Trial 3 Managed Group Demand - 7 Day Curve (90th Percentile)

This shows a similar pattern of demand on Monday – Wednesday, with slightly lower demand on Thursday and Friday. Monday – Wednesday and Friday evenings show a similar pattern, with one peak in demand just after 18:00 and another, higher peak at just after midnight (caused by participants using timers). This was similar to the demand during Winter in Trial 1, and not as a result of the ToU incentive introduced in Trial 3.

One of the main aims of Trial 3 was to determine the extent to which a system such as that deployed by CrowdCharge could change the shape of the demand profile. The 'Trial 3' (14th November to 16th December) demand profile has been compared to two sets of data (neither of which include ToU elements):

- The final part of Trial 2 – 15th October to 12th November (inclusive). Previous analysis has shown that demand was seasonal, therefore only the last month of Trial 2 has been used, as demand from earlier was likely to be less comparable with Trial 3 due to seasonal affects; and
- 'Winter' in Trial 1 – 11th January to 7th March 2018. This demand was likely to be slightly higher than for Trial 3 as January – March was likely to be colder than November – December (increasing the energy required by EVs). Although Trial 1 data was available for November and December 2017 the number of chargers in the group was lower and this could affect the comparability of the results.

The graphs (Figure 12-5 – weekday and Figure 12-6 - weekend) below compare the Trial 3 data to both periods above, for weekdays and weekends.

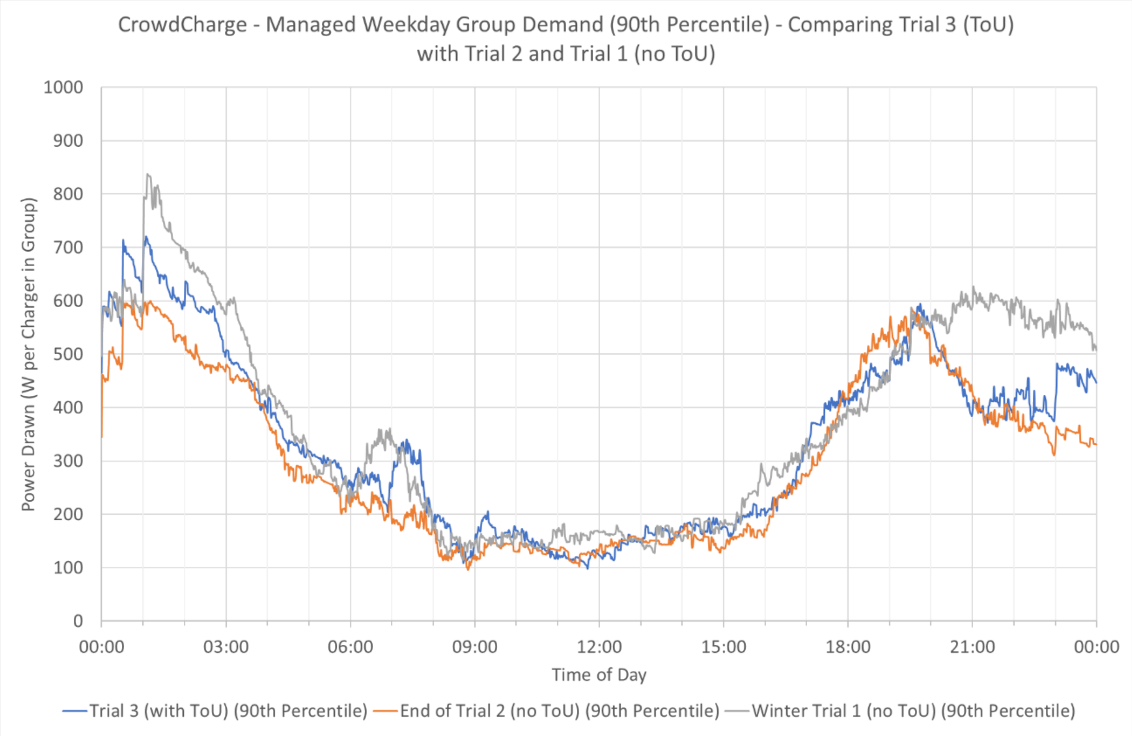

Figure 12-5: Comparing Managed Weekday Demand (90th Percentile) - Trial 3 (ToU incentive) to Trial 2 and Trial 1 (no ToU incentive)

Although efforts were taken to use comparable data sets (in terms of seasons), the main differences between the curves are likely to be seasonal, and not as a result of the time of use system:

- Trial 3 includes a small increase in demand around 7:00, likely due to participants pre-heating their vehicles (observed in Winter, but not at the end of Trial 2 in late October/early November);
- Evening peak demand was very similar across all three trials, and this has been limited to the amount available in the capacity limits;
- Levels of overnight demand during Trial 3 was between that which was observed at the end of Trial 2 (late October/early November) and Winter (January – March);
- The combination of the app, ToU pricing and updated algorithm may be responsible for the step increase in demand between 22:00 and 00:00, as vehicles that had entered a journey plan and a recent state of charge value would begin to charge at full rate during this time; and
- Demand at other times of day are very similar in all three cases.

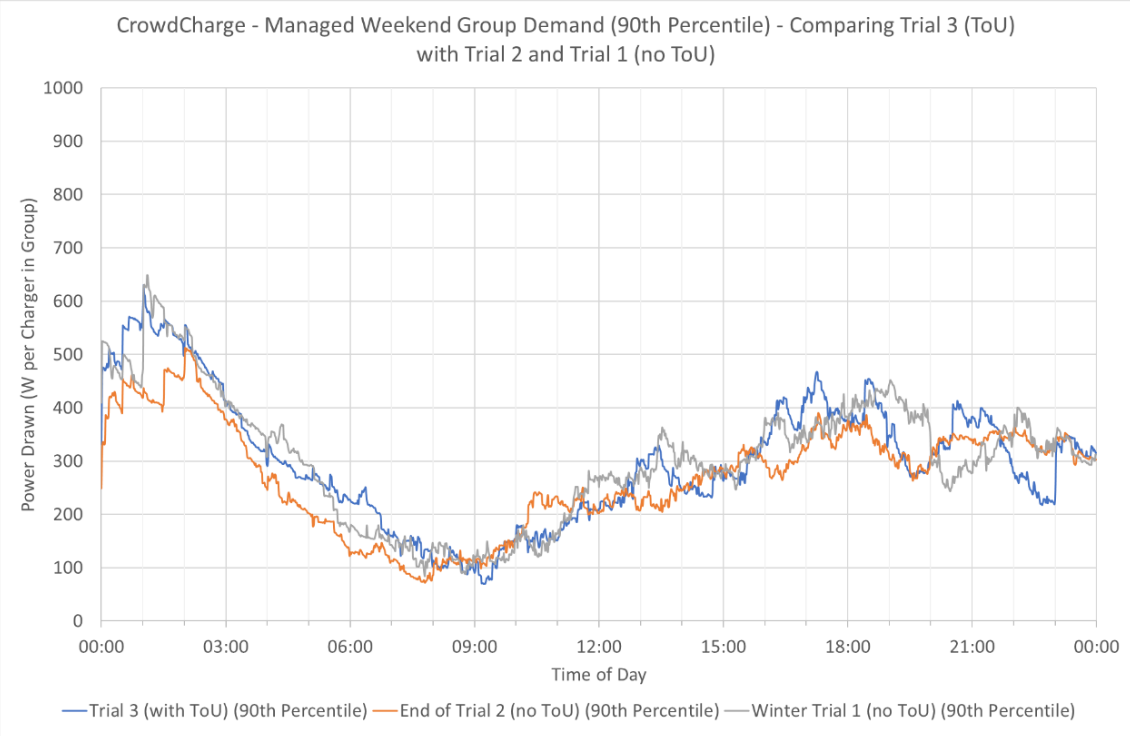

Figure 12-6: Comparing Managed Weekend Demand (90th Percentile) - Trial 3 (ToU incentive) to Trial 2 and Trial 1 (no ToU incentive)

The Trial 3 profile was very similar to both the end of Trial 2 and Winter during Trial 1. The CrowdCharge system relied on journey plans and recent State of Charge values to enable charging to be scheduled for the off-peak period. In the absence of either of these pieces of information, the system assumed that the driver required enough additional energy to make a 50-mile journey 4 hours after plugging the vehicle in. For plug-in events during the evening peak, this assumption would result in the charger being allocated current during the peak period, despite the price. Use of the app during Trial 3 is explored more in Section 12.1.4.

12.1.3 Occurrence of Demand Management – Group Level

As described above, during Trial 3 the CrowdCharge system used journey plans and state of charge information alongside the tariff to maximise the charging which occurred off-peak. Example scenarios are given below:

1. The default scenario, when no information has been entered into the app: A driver plugs in at 18:00 and no information had been entered in the app (no journey, no state of charge). The system assumed that the driver needed enough energy to travel another 50 miles[168], leaving in 4 hours' time (22:00). In this case, despite the

[168] This energy was calculated based on an estimate of the vehicle state of charge at plug-in. The CrowdCharge system used the value of state of charge entered into the app (if available), or an estimate based on previous charging sessions (this estimation process if part of the proprietary CrowdCharge system) or a default value of 10%. If the vehicle range was less than 50 miles then it would receive a full charge.

peak price the charger would be allocated as much current as possible in order to meet the journey requirement.

2. A driver plugs in at 18:00. They enter their state of charge into the app and their next journey was planned with a departure time of 7:30 the next morning. The energy needed for this journey could be supplied within the off-peak period. In this case the charger would be allocated 6A during the peak period (the lowest amount possible). The current allocation would increase during the off-peak period.

If the majority of participants who were plugging in during the evening peak were in 'Scenario 2' (i.e. they had entered information into the app, including state of charge), then the total demand during this period would have been reduced compared to other periods of the trial. The analysis presented in the previous section shows that this was not the case, and evening peak demand was very similar to both Trial 2 and Winter during Trial 1.

The CrowdCharge system continued to manage demand against the capacity limit, so that if it was not possible to allocate the maximum current required to all active chargers then demand management would begin. Demand management has been assumed to be active at a group level when the total current allocated to active charge by the CrowdCharge system was greater than or equal to 95% of the capacity limit.

Two groups were used during Trial 3, a small pilot group of 20 participants for one week (using a 'Spring-Winter' combined profile), followed by all Trial 3 participants operating under a Winter profile for the remainder of the trial.

The table below summarises the groups, the number of participants in each, and the resulting amount of management (at a group level).

Table 12-1: Summary of Group Level Management in CrowdCharge Trial 3

Group	Dates Actives	Number of Chargers in Group	Number of Minutes Active	Number of Managed Minutes	% of Minutes with Active Management
CCToUPilot01	7th – 13th Nov. 2018	20	9,900	247	2.5%
CCToUPilot02	13th Nov. – 16th Dec. 2018	245	47,700	1,778	3.7%

This sub-section shows the frequency of management at a group level from 14th November to 16th December, inclusive.

The graph below shows the percentage of days, at each time of day, when management was active, separated by weekdays and weekends.

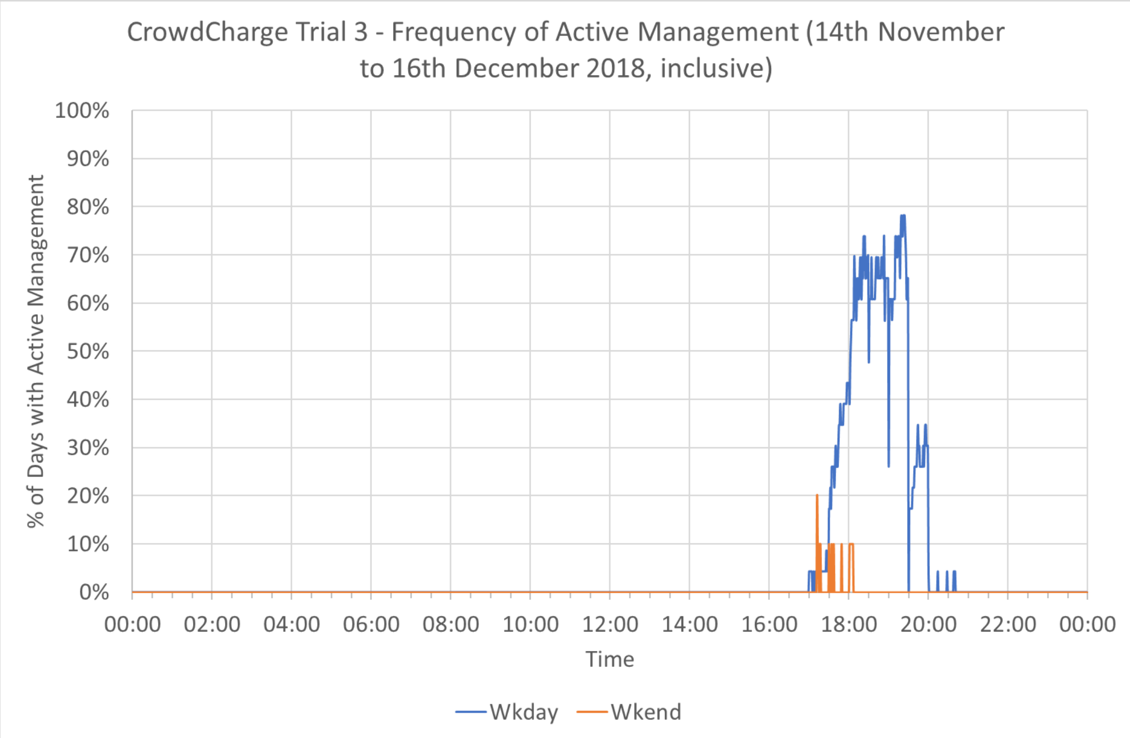

Figure 12-7: CrowdCharge Trial 3 - % of Days with Active Management (Group Level) - Weekday and Weekend

This shows minimal change from Trial 2 (Figure 11-6 shows the equivalent data for Trial 2). Management was slightly less frequent on weekdays but occurs over a very similar time period (17:00 to 20:40 in Trial 3, 17:30 to 20:42 in Trial 2). In the absence of the Time of Use system and no other changes, then demand management may have been slightly more frequent as the capacity limit on the 'Winter' profile (used in Trial 3) was lower than the limit on the 'Spring-Winter' combined profile (used in Trial 2). Management occurred occasionally at the weekend during Trial 3 due to the introduction of more restrictive 'Winter' profiles.

All charging events during Trial 3 were 'managed' by the CrowdCharge system, as it aimed to manage the current allocated to each charger based on the tariff. Therefore, no analysis of individual level management has been completed for Trial 3.

The graph below compares the 'hot unplug' rate (i.e. the proportion of charging events where the vehicle was not fully charged when it was unplugged), outside of management, and during each of the three trials, for only those participants who took part in Trial 3.

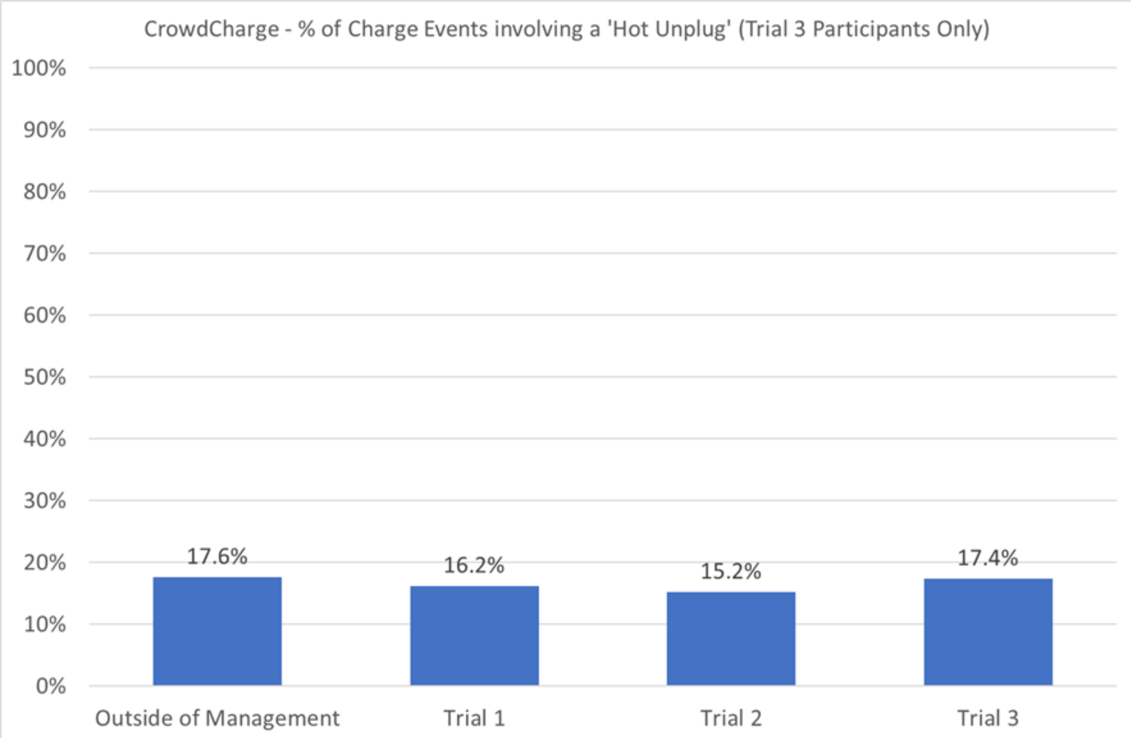

Figure 12-8: % of Charge Events Hot Unplugged - for Trial 3 Participants only

The differences in hot unplug rate between Trial 3 and the first two stages of the trial (Trial 1 and 'Outside of Management') are not statistically significant[169]. The increase in the hot unplug rate from Trial 2 to Trial 3 was statistically significant[170]. This may be due to changes in the algorithm, as vehicles were only allocated 6A once the energy required for planned journeys (or the default assumption) had been met. It may also be a seasonal effect.

The main part of Trial 3 (when all participants had been moved into the trial) took place between 13th November and 16th December 2018. During this time the participants charged 4,303 times (where current meter values were available to determine whether the vehicle was hot unplugged). Of these 4,303 events 747 were 'hot unplugs' (17.4%, as shown in Figure 12-8). The same group of participants charged 2,094 times (where current meter values were available) between the 13th November and 16th December 2017 (some were outside of management and some in Trial 1 in this period). Of these 2,094 events 313 were 'hot unplugs' (14.9%). The increase in hot unplugs between the two seasonally equivalent periods was statistically significant[171], suggesting that the change in algorithm resulted in a slight increase in the hot unplug rate.

[169] Trial 3 compared to Trial 1 – Z = 1.89 and Trial 3 compared to 'Outside of Management' – Z = 0.34 (value of 1.96 would indicate confidence at the 5% level).
[170] Trial 3 compared to Trial 2 – Z = 3.30
[171] Trial 3 compared to equivalent period in 2017 – Z = 2.44

12.1.4 App Usage and Reward Values

Only minor changes were made to the CrowdCharge app interface for Trial 3 – it now displayed the participant's current reward value. The interface for inputting journey plans and state of charge values was unchanged. As described above, the main changes were to the algorithm, so that the system would attempt to provide the energy required (based on journey plans and state of charge values) at the lowest possible cost. The updated app interface is shown below.

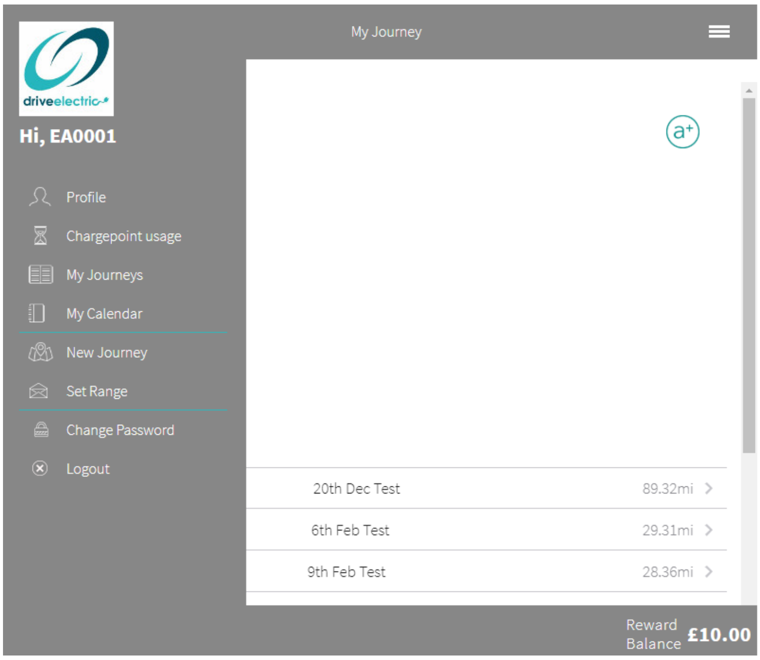

Figure 12-9: Updated CrowdCharge 'App' Interface for Trial 3

The amount of interaction between participants and the CrowdCharge system can be assessed using various metrics:

- Additional participants who registered for an app account to take part in Trial 3 (this section);
- Data entry (regular journeys, one-off journeys and state of charge) (this section); and
- The level of interaction which participant's reported in the Trial 3 survey and other attitudes to the app (Section 12.1.6).

The way in which app data was used to determine the current allocated to chargers was described in detail above. In summary, if no journey plan was entered then a default assumption was made – that the vehicle was required four hours later to travel 50 miles. Current would be allocated to meet the energy required for this journey regardless of the price. Therefore, in the default scenario (no data entered), vehicles plugged in during the evening peak (e.g. 18:00) would charge during the peak period at their maximum rate (unless management was active). If journey plans were available, and the required energy could be supplied using 'off-peak' energy, then the current allocated during the peak price period would be reduced to 6A.

The CrowdCharge system was conservative in the extent to which charging could be minimised in the peak period – i.e. charging was only restricted in the peak when there was substantial evidence via journey plans that this was possible.

The CrowdCharge system calculated the impact of each charging event on the participant's total reward value.

The CrowdCharge system calculated a reward value for each charging event based on the reward which would have been earned if all the energy had been delivered at the lowest price possible. It should be noted that this is different to the actual energy delivery profile. This method was chosen to most accurately reward customer charging behaviour (as opposed to inputting data in the app).

Participants were not aware of this and were instructed that entering journey plans and state of charge value regularly would maximise their reward values. The way in which rewards were calculated are illustrated in the three examples below:

- Participant A: plugs in their vehicle at 18:00, unplugs at 7:30 the next morning and consumes 20kWh. This participant did not enter a journey plan or state of charge value, so they charged at the maximum rate during the evening peak (because the system assumed they needed 50 miles worth of charge in 4 hours' time). However, all the energy could have been delivered at the off-peak price of 10p/kWh because the vehicle was plugged in overnight. The reward value would increase by 5 pence for each kWh (difference between tariff price and flat rate of 15p/kWh). This session would result in the reward balance increasing by £1 (20kWh x 5p/kWh).
- Participant B: plugs in their vehicle at 18:00, has a regular journey set up with a time of departure of 7:30 the next morning. A state of charge value was entered. CrowdCharge would use this data to reduce the charging rate to the minimum possible. The participant unplugs their vehicle at 7:30 the next morning, after consuming 20kWh of electricity. The reward value would be based on charging taking place entirely in the off-peak period, so the participant's reward value would also increase by £1; and
- Participant C: also plugs in at 18:00 and consumes 20kWh of electricity. However, this participant unplugged their vehicle at 21:00. In this case it would not be possible (even if data had been entered) for this charging to take place during the off-peak period, so the charging session would decrease the participant's reward value by £1.15.

The example above shows that the reward value earned by participants was not linked to their use of the app. It was only influenced by the amount of time that their vehicle was plugged in, and the flexibility that offered. For this reason, the reward values are not analysed alongside app usage in the sections which follow.

The average reward received by CrowdCharge participants was £20 (including the £10 starting value). 90% of participants increased their reward value, 3% decreased it and 7% ended the trial with £10 (likely that they didn't use the charger during Trial 3, or it was offline). As described in the bullet points above, participants who regularly plugged in during the evening peak with high flexibility (i.e. charging could have occurred overnight) would have increased their reward value. The resulting reward values align with the findings in relation to flexibility shown in Section 8.9. The reward earned by participants and the level of satisfaction/acceptability they reported in the Trial 3 survey is shown in Section 12.1.7.

12.1.4.1 Account Registrations

During Trial 2, 55% of participants registered for a CrowdCharge account. Prior to the start of Trial 3, all participants were contacted again with details of Trial 3, including the fact that those with a CrowdCharge account would be eligible for a financial reward, depending on their charging behaviour. This incentivised a further 17 participants to register, as shown below. The additional registrations increased the sign-up rate to 64%.

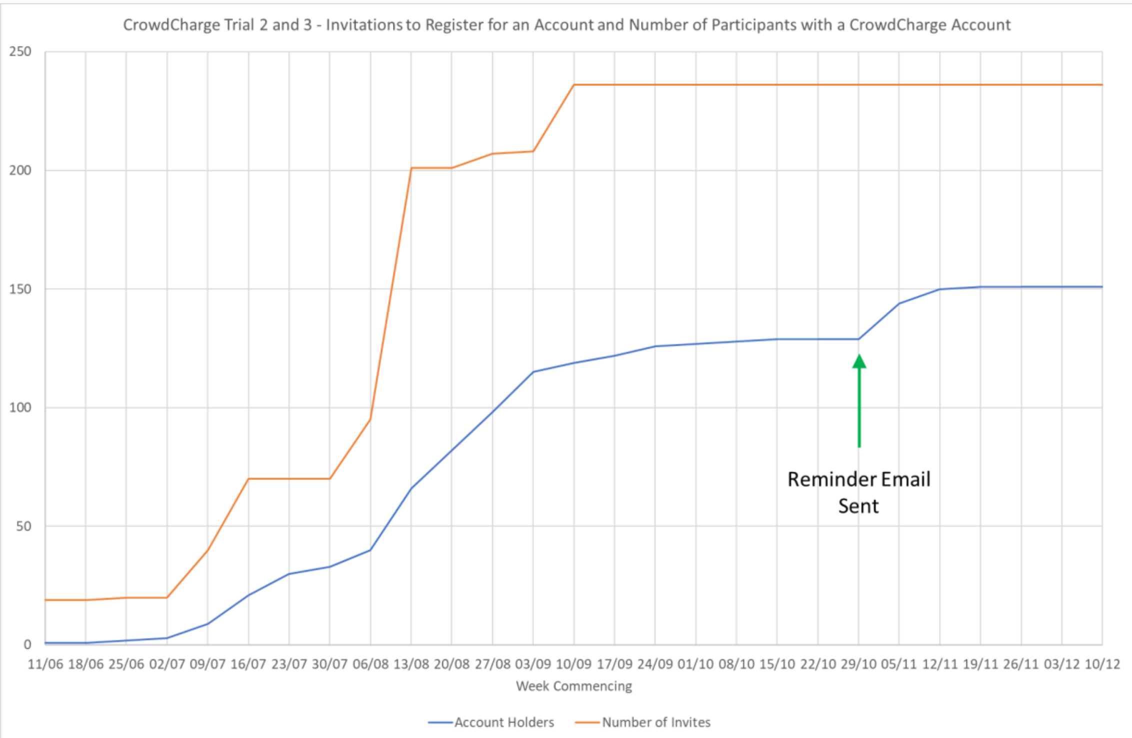

Figure 12-10: CrowdCharge App Invites and Registrations - Trial 2 and Trial 3

12.1.4.2 Data Entry

The CrowdCharge algorithm required journey plans and state of charge values to be entered to enable it to schedule charging (i.e. avoiding charging during the peak price window). In the absence of this information, the algorithm assumed the vehicle required enough energy to travel 50 miles, leaving 4 hours after plug-in (the amount required was calculated based on an estimated SoC of the vehicle, explained in more detail above, and a conservative assumption for vehicle efficiency (miles/kWh)). Therefore, vehicles plugged in during the evening peak, without a journey plan, would be charged during the peak (e.g. plug-in at 17:00 with no journey plan requires energy for 50 miles of travel, delivered before 21:00).

The demand profiles presented in Section 12.1.2 show minimal changes to the demand profile during Trial 3. Vehicles were still charging during the evening peak and management was still frequent (see Figure 12-7).

The information issued to participants when Trial 3 began encouraged them to enter data into the app to maximise their reward value (i.e. because it would allow charging to be scheduled overnight). This section explores the frequency with which data was entered during Trial 3, and so the response of participants to this instruction.

CrowdCharge provided two 'snapshots' of the number of data entries each participant had made into the app (i.e. between registration and the date of the snapshot). These snapshots were taken on 11th October 2018 and 7th January 2019. No snapshot was provided which coincided with the launch of Trial 3 on 13th November 2018. They have therefore been treated as follows:

- Entries between a participant's registration and 11th October: Trial 2 Data Entry (see Section 11.1.5.2); and
- Entries between 11th October and 7th January: Trial 3 finished on 16th December 2018 and participants were informed that the trial was over. Therefore, it has been assumed that all the data entries were made by 16th December. Data entries from either 11th October or the participant's registration (whichever was later) to 7th January have been assigned to Trial 3. This will slightly overestimate the data entries related to Trial 3 as it covers part of Trial 2, and it is possible that some data entries were made after the end of the Trial.

151 participants had an operational CrowdCharge account by the end of Trial 3. Of these 151 participants, 67 had made at least one data entry during Trial 3 (44%, compared to 65% in Trial 2). A statistically significant decrease[172]. Amongst the group of 17 participants who only signed up for an account in Trial 3, 41% had entered some data.

This can be further broken down by information type:

[172] Trial 2 65% of 128 participants. Trial 3 44% of 151. Z = 3.51 (a value of 1.96 would indicate a 5% confidence interval)

- 19% (of the 151 participants with an account) entered at least one regular journey. This compares to 41% in Trial 2 – however, some participants may have entered their regular journeys as part of Trial 2 and so had nothing further to add. Of the 17 participants who only had an account in Trial 3, none entered any regular journeys;
- 19% had entered at least one 'one-off' journey (compared to 25% in Trial 2); and
- 42% had entered their vehicle state of charge at least once (compared to 57% in Trial 2).

These figures provide an indication that data entry rates fell during Trial 3. This is further explored below.

For each participant, the number of days for which they had had a CrowdCharge account between 11th October (or the date they got an account, if this was later) and 16th December (the assumed end of data entries) has been calculated. The frequency with which they entered each piece of data has been calculated and converted to entries per week. This calculation has been made for the 151 participants who had had an account during Trial 3. The box and whisker diagram below shows the distribution of data entry frequency for the three data types, for Trial 2 and 3 to allow comparison. The 'all data types' figure considers the total data entries made for each participant (regular journeys + one offs + state of charge).

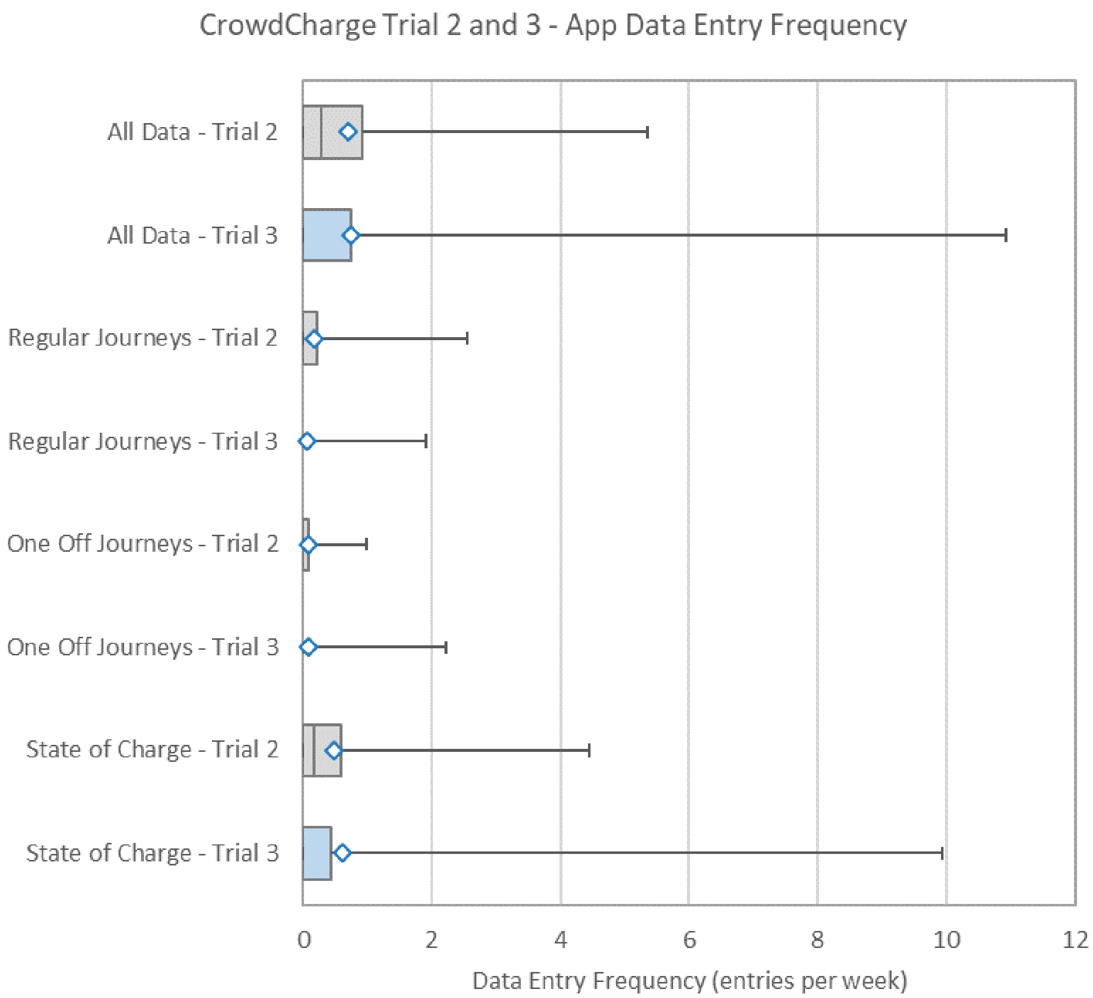

Figure 12-11: CrowdCharge App Data Entry Frequency - by Data Type, Trial 2 and Trial 3

This shows that across data types, data entry frequencies dropped for the majority of participants. In all cases, the 75th percentile data entry frequency (i.e. the right hand side of the box) has decreased from Trial 2 to Trial 3. The decrease in data rates for 'regular journeys' was statistically significant[173]. For 'one off' journeys and state of charge a small number of participants increased their data entry frequency, as the maximum line for both these categories has increased in Trial 3.

For the 132 participants who had an account in both Trial 2 (for at least a week) and 3, their data entry frequencies have been compared for the two trials in the table below.

[173] Significance test for independent means. Trial 2 regular journey data entry rate vs. Trial 3. Z = 3.10 (a value of 1.96 would indicate confidence at the 5% level).

Table 12-2: Comparing Data Entry Rates CrowdCharge Trial 2 vs. Trial 3

Data Type	**No** entries in Trial 2 or Trial 3	Data Entry Frequency **Lower** in Trial 3 than in Trial 2	Data Entry Frequency **Higher** in Trial 3 than in Trial 2
Regular Journeys	45% (59)	41% (54)	14% (19)
One Off Journeys	58% (76)	23% (30)	20% (26)
State of Charge	32% (42)	43% (57)	25% (33)

This shows that across all data types, fewer than 25% of participants followed the guidance and increased their data entry frequency during Trial 3. The lower level of data entries by participants explains the continued charging of vehicles at their maximum rate during the evening peak, and so the lack of change in the demand profile. The reasons why participants used (or did not use) the app are explored in more detail in Section 12.1.6.

12.1.5 Charging Behaviour During Trial 3

The data presented above shows that the majority of participants did not respond to the instructions provided alongside the launch of the incentive scheme and ToU tariff by increasing the frequency with which they entered data into the app. It is possible that participants changed their charging behaviour in other ways to try and increase their reward, for example setting a timer to avoid charging at the peak. The demand profiles above appear to indicate that this behaviour was not widespread, however this is explored below.

One way in which participants could avoid charging at the peak would be to change the time at which they plug-in their vehicle. The charts below compare the proportion of plug-in events in each hour outside of Trial 3 (without the ToU incentive – for those who participated in Trial 3 only) and during Trial 3. The line on each graph shows the change between the two periods. Separate graphs are shown for weekdays and weekends. Outside of the ToU trial this is based on 38,045 weekday and 13,460 weekend charging events. During Trial 3 it is based on 4,338 weekday and 1,653 weekend charging events.

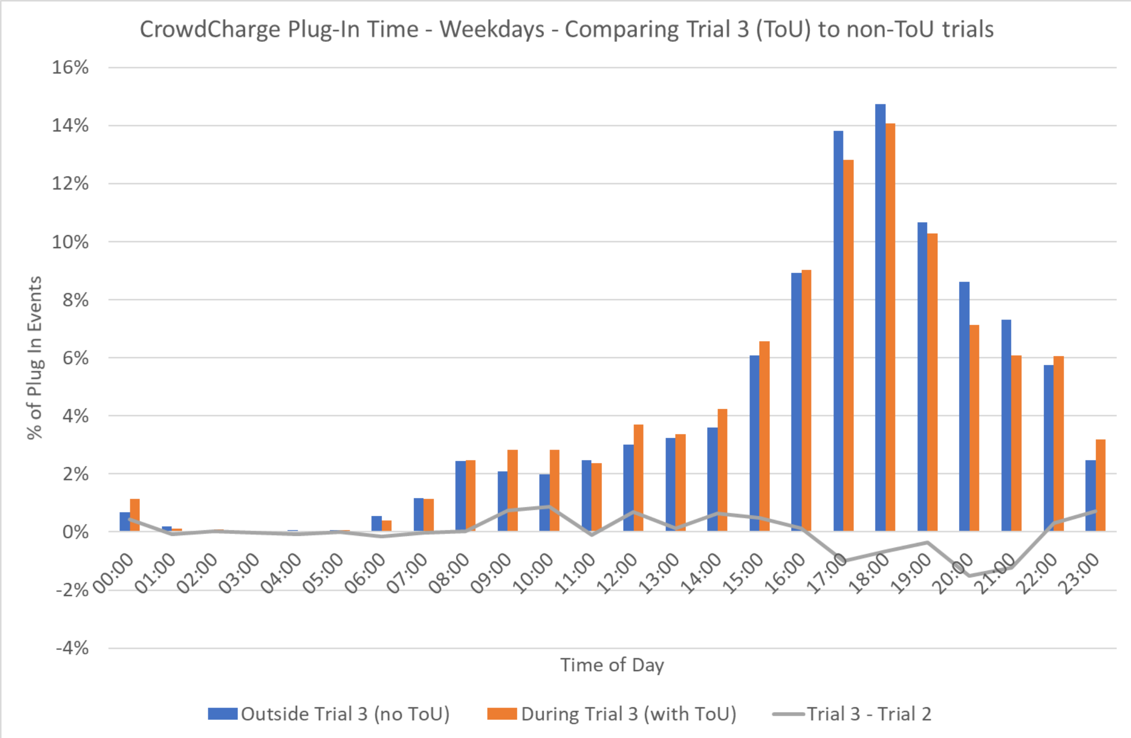

Figure 12-12: Proportion of Plug-In Events in Each Hour - Outside Trial 3 (no ToU) and during Trial 3 (ToU) – Weekdays

The table below compares the percentage of plug-in events which occurred during four time windows, before Trial 3 (no ToU) and during Trial 3 (with ToU).

Table 12-3: Proportion of Plug-In Events at Different Times of Day - Weekdays

Time Window	Before Trial 3 (no ToU) % of Plug-In Events	During Trial 3 (with ToU) % of Plug-In Events
Overnight (00:00 to 07:59)	3%	3%
Daytime (08:00 to 15:59)	25%	28%
Evening Peak (16:00 to 19:59)	48%	46%
Late Evening (20:00 to 23:59)	24%	22%
Total Number of Plug-In Events	**38,045**	**4,338**

Statistical analysis shows the following statistically significant differences between the period without the ToU incentive and Trial 3:

- A slight **increase** in the proportion of plug-in events occurring in the daytime (from 25% to 28%)[174];
- A slight **decrease** in the proportion of plug-in events occurring during the evening peak (from 48% to 46%)[175]; and
- A slight **decrease** in the proportion of plug-in events occurring in the late evening (from 24% to 22%)[176].

However, as shown above these small changes did not result in a significant change in the weekday demand profiles.

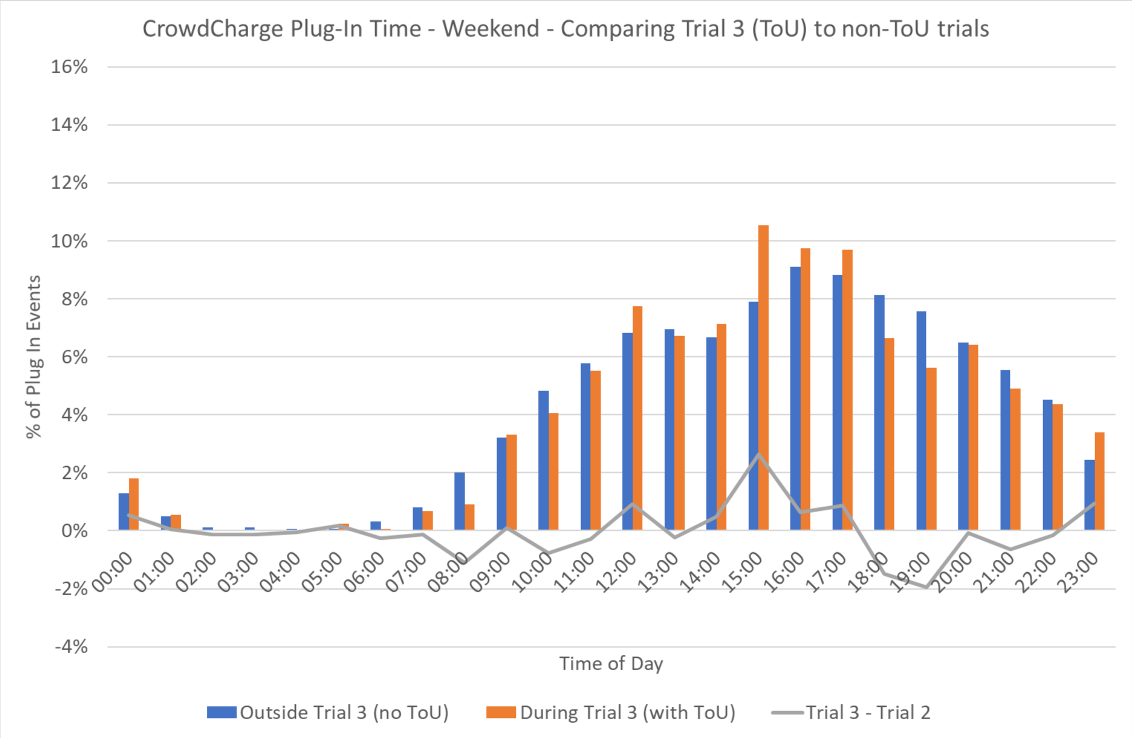

Figure 12-13: Proportion of Plug-In Events in Each Hour - Outside Trial 3 (no ToU) and during Trial 3 (ToU) – Weekend

Plug-in behaviour has been compared for weekends using the same time windows:

Table 12-4: Proportion of Plug-In Events at Different Times of Day - Weekend

Time Window	Before Trial 3 (no ToU) % of Plug-In Events	During Trial 3 (with ToU) % of Plug-In Events
Overnight (00:00 to 07:59)	3%	3%
Daytime (08:00 to 15:59)	44%	46%

174 25% of 38,045 plug-in events vs. 28% of 4,338 plug-in events. Z = 5.00
175 48% of 38,045 plug-in events vs. 46% of 4,338 plug-in events. Z = 2.40
176 24% of 38,045 plug-in events vs. 22% of 4,338 plug-in events. Z = 2.50

Time Window	Before Trial 3 (no ToU) % of Plug-In Events	During Trial 3 (with ToU) % of Plug-In Events
Evening Peak (16:00 to 19:59)	34%	32%
Late Evening (20:00 to 23:59)	19%	19%
Total Number of Plug-In Events	**13,460**	**1,653**

None of the changes shown above were statistically significant at either a 5% or 10% level. This shows that there was no change in plug-in behaviour on weekends during Trial 3.

The CrowdCharge guidelines issued to participants were less explicit about the times at which peak pricing applied than those provided to GreenFlux participants, but on weekdays it appears that a small number of participants plugged in the vehicles earlier during Trial 3.

Participants may have continued to plug-in their vehicle at the same time during Trial 3, but used a timer to schedule charging to begin outside of the peak. The charts below compare the proportion of charging events which began charging in each hour outside of Trial 3 (without the ToU incentive) and during Trial 3. The line on each graph shows the change between the two periods. Separate graphs are shown for weekdays and weekends. Separate graphs are shown for weekdays and weekends. Outside of the ToU trial, this is based on 31.679 weekday and 11,093 weekend charging events (where the start of charging was known). During Trial 3, it is based on 3,109 weekday and 1,194 weekend charging events.

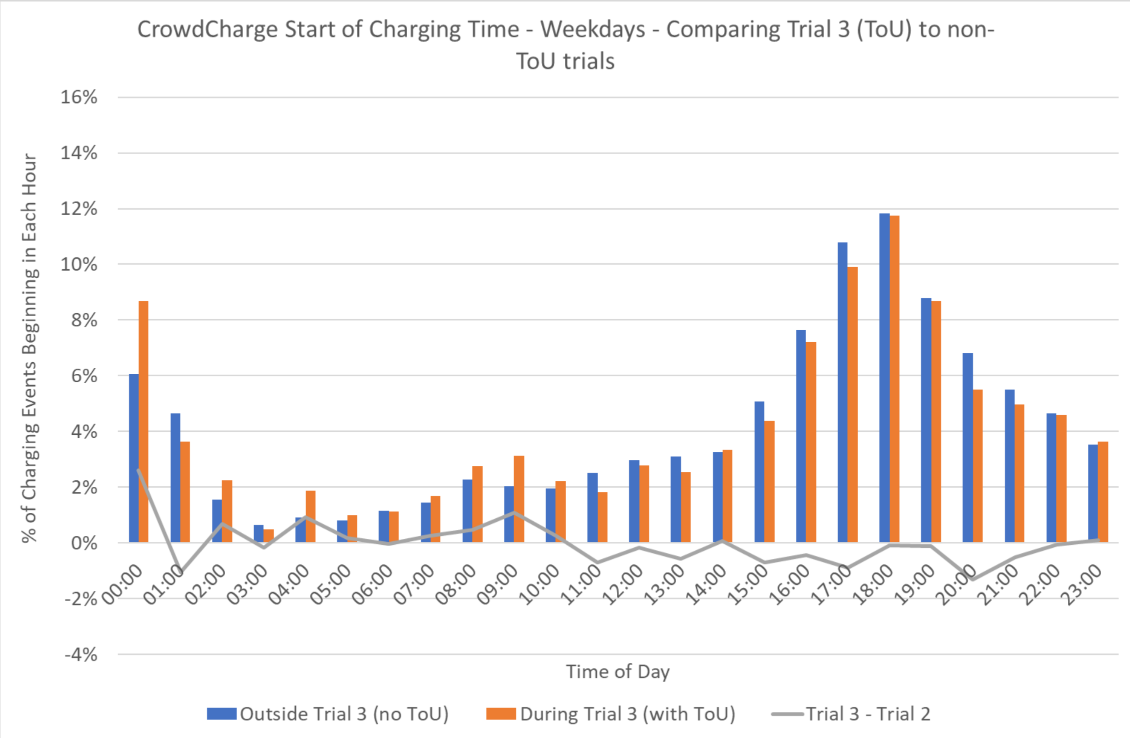

Figure 12-14: Proportion of Start Charge Events in Each Hour - Outside Trial 3 (no ToU) and during Trial 3 (ToU) – Weekdays

The same approach has been taken to analyse any changes in the time when charging began as was shown for plug-in behaviour, above.

Table 12-5: Proportion of Start of Charging Events at Different Times of Day - Weekdays

Time Window	Before Trial 3 (no ToU) % of Start of Charging Events	During Trial 3 (with ToU) % of Start of Charging Events
Overnight (00:00 to 07:59)	17%	21%
Daytime (08:00 to 15:59)	23%	23%
Evening Peak (16:00 to 19:59)	39%	38%
Late Evening (20:00 to 23:59)	20%	19%
Total Number of Charge Events (where start charge was known)	**31,679**	**3,109**

The **increase** in the proportion of charging events occurring in the overnight period (17% to 21%) was statistically significant[177]. There was no statistically significant change in the number of charging events which began in the evening peak[178]. The **decrease** in the proportion of charging events which began in the late evening, although small, was statistically significant[179].

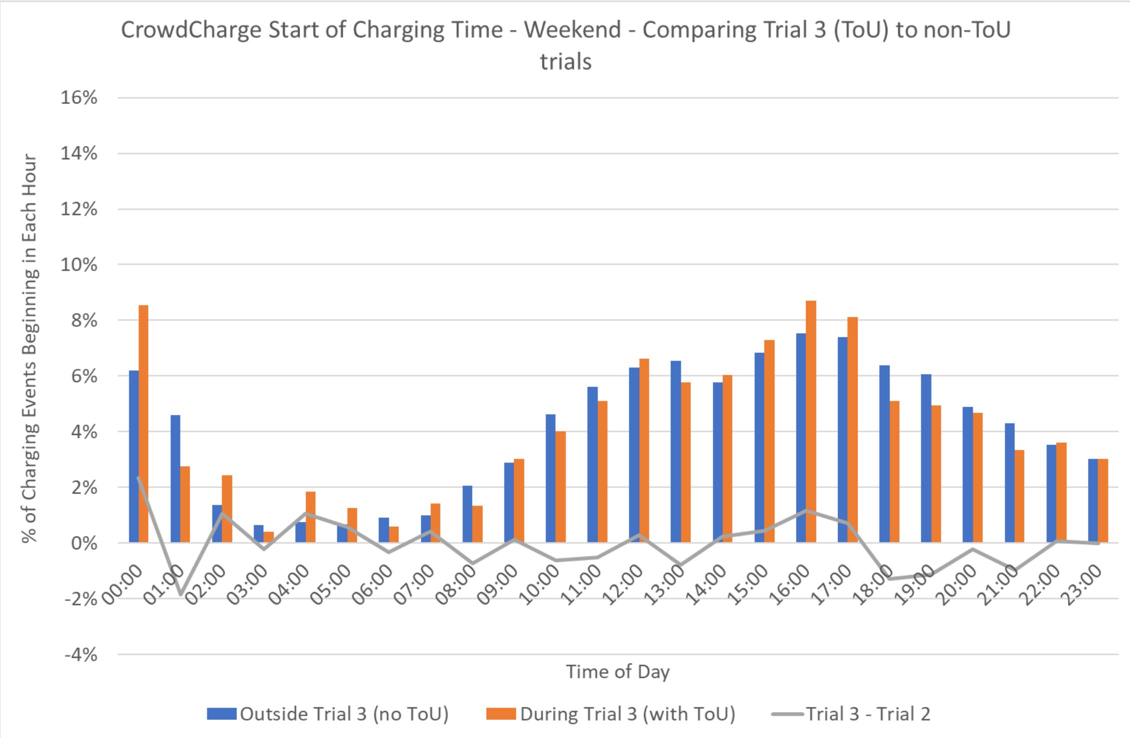

Figure 12-15: Proportion of Start Charge Events in Each Hour - Outside Trial 3 (no ToU) and during Trial 3 (ToU) – Weekend

Table 12-6: Proportion of Start of Charging Events at Different Times of Day - Weekend

Time Window	Before Trial 3 (no ToU) % of Start of Charging Events	During Trial 3 (with ToU) % of Start of Charging Events
Overnight (00:00 to 07:59)	16%	19%
Daytime (08:00 to 15:59)	41%	39%
Evening Peak (16:00 to 19:59)	27%	27%
Late Evening (20:00 to 23:59)	16%	15%

[177] 17% of 31,679 charging events vs. 21% of 3,109 charging events. Z = 4.84
[178] 39.0% of 31,679 charging events vs.37.5% of 3,109 charging events. Z = 1.61
[179] 20.4% of 31,679 charging events vs. 18.7% of 3,109 charging events. Z = 2.35

Time Window	Before Trial 3 (no ToU) % of Start of Charging Events	During Trial 3 (with ToU) % of Start of Charging Events
Total Number of Charge Events (where start charge was known)	**11,093**	**1,194**

The only statistically significant change in the time at which charging began on weekends was an **increase** (from 16% to 19%) in the proportion which began in the overnight period[180].

205 participants used their charger during Trial 3 (where time at which charging began is known). For each of these participants, the percentage of their charging events which began during the weekday evening peak (defined as Monday to Friday between 16:00 and 19:59) has been calculated for Trial 3 and the rest of the trial (without the ToU) incentive. Each participant is represented by a marker on the graph below, with the % of their charging which began in the weekday evening peak outside of Trial 3 plotted against the same metric for Trial 3. The dashed line represents a 1:1 relationship – i.e. no change in charging behaviour in relation to the evening peak.

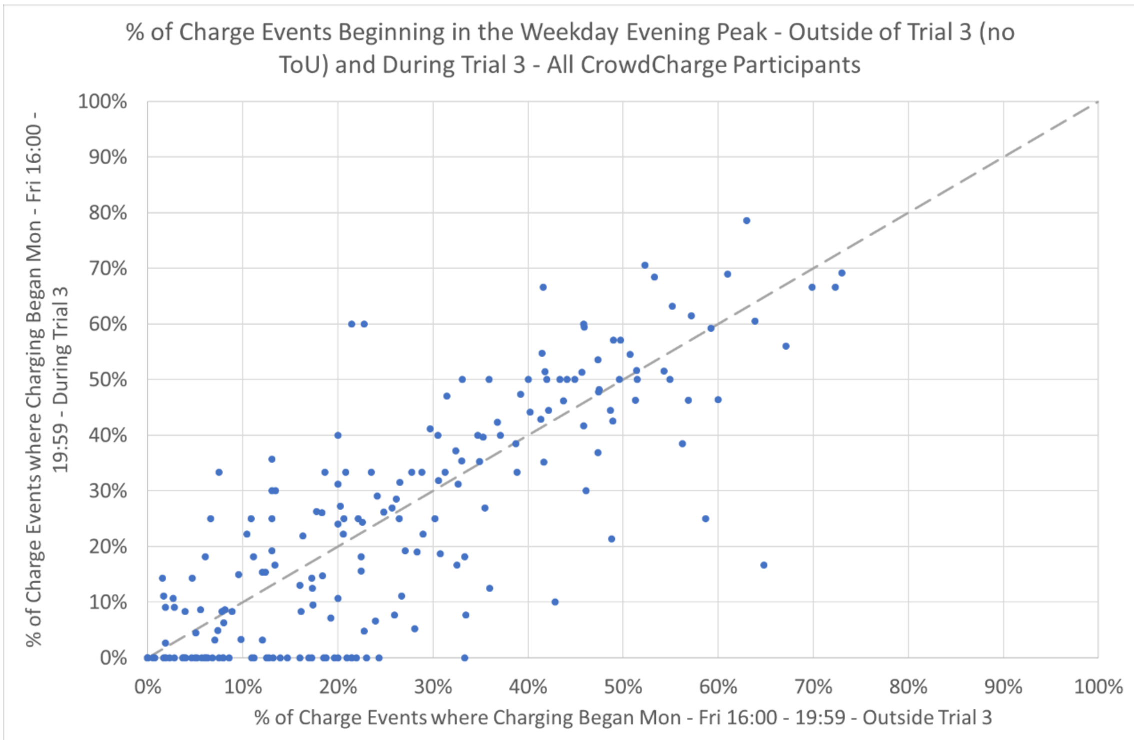

Figure 12-16: Comparing % of Charge Events Beginning in Weekday Evening Peak Before and During Trial 3 - Each Participant

[180] 16.1% of 11,093 charging events vs.19.3% of 1,194 charging events. Z = 2.77

This data is also summarised in the table below.

Table 12-7: Increase or Decrease in Proportion of Charge Events Starting in Weekday Evening Peak

Category	Trial 3 vs. Outside of Trial 3		
	Lower % of Transactions Beginning in the Weekday Evening Peak	**Equal %** of Transactions Beginning in the Weekday Evening Peak	**Higher %** of Transactions Beginning in the Weekday Evening Peak
All Participants	51% (105)	3% (6)	46% (94)

This shows a roughly even split between those participants who have begun charging in the weekday evening peak more and less often in Trial 3. The size of the changes made by participants have generally been relatively small, as the majority of points fit reasonably closely the 1:1 relationship line on Figure 12-16 above.

The data presented above indicates that there were only minimal changes in charging behaviour made by CrowdCharge participants in response to the time of use tariff.

12.1.6 Customer Research Results

Trial 3 participants were asked to complete a survey by Impact between 14th December 2018 and 11th January 2019. Those who completed the survey were rewarded with a £10 Amazon voucher (on condition that they had also completed the Recruitment and Baseline surveys). All qualifying Trial 3 participants were invited to complete a survey, regardless of whether they signed up for a CrowdCharge account. This reward was in addition to any reward they received linked to their charging behaviour and the time of use tariff.

The Trial 3 survey consisted of many of the same quantitative and qualitative questions that appeared in the Baseline and Trial 1 and 2 surveys, allowing charging behaviour and attitudes towards charging arrangements to be tracked through the different phases of the project. In addition, the Trial 3 survey collected information about participants attitudes towards the time of use tariff.

The full text of the CrowdCharge Trial 3 survey can be found in Appendix 9. The response rate for this survey is shown below.

Table 12-8: CrowdCharge Trial 3 Survey Response Rate

	Surveys Issued	Surveys Completed	Response Rate (%)
CrowdCharge Trial 3	245	194	79%

All participants who were invited to complete a Trial 3 survey took part in Trial 3 (i.e. their charger was managed as part of a Trial 3 group) and they had been invited to sign-up to the app. Due to variations in charging behaviour, and the fact that signing up to, and using , the app was optional, the 194 respondents used the app to varying extents and earned differing reward values. Links between satisfaction and acceptability and the reward value earned are explored in Section 12.1.7.

12.1.6.1 Reported change in charging behaviour

Participants were asked whether they have changed their charging behaviour since they last completed a survey. Most (89%) reported that their charging behaviour had not changed substantially. More detail of the responses given by participants in relation to their charging behaviour can be found in Section 10.1.5. The free text responses to this part of the survey detailed the reason for any change in charging behaviour and some examples are shown in Figure 12-17 below.

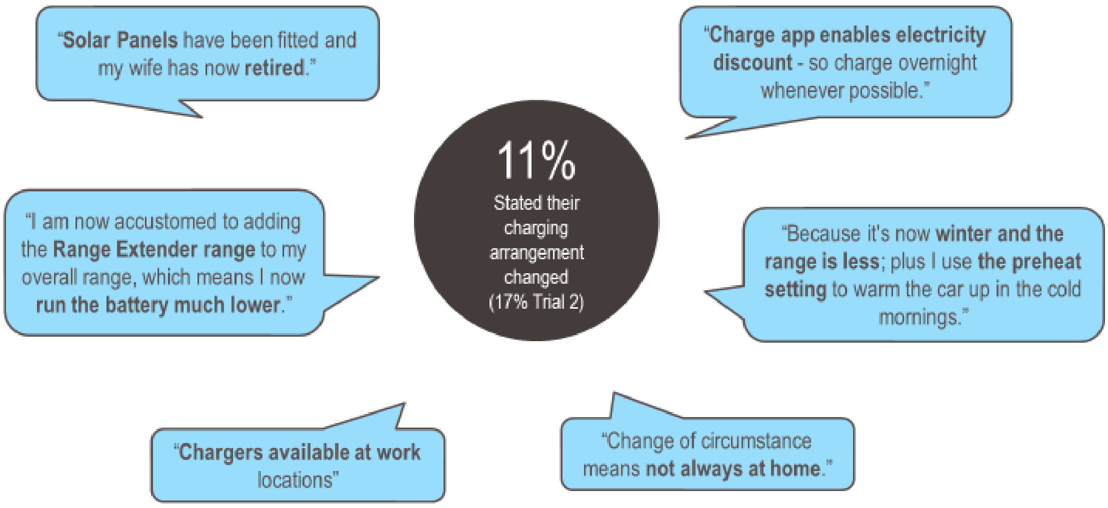

Figure 12-17: Have your charging arrangements changed recently? (since you last completed a survey (Base 194 – all respondents) If so, how? (Base 21)

Only one in ten participants had changed their behaviour (21 respondents). There were a variety of reasons for this behaviour change including the weather getting colder, a change in charge point availability (e.g. charging now available at work) and changes in circumstances. Only one participant mentioned a change to overnight charging due to the app in response to this question. Further participant responses in relation to the time of use tariff are shown below.

12.1.6.2 Attitudes to the App and Time of Use Tariff

In Trial 3 participants continued to have access to the CrowdCharge app which they could use to influence the likelihood that they would be managed, and the time at which charging would take place. Participants were informed that they could maximise their financial reward by entering data into the app regularly. Trial 3 also introduced a time of use tariff for the first time in Electric Nation.

The Trial 3 survey asked similar questions regarding participants awareness of the app and its features, their reasons for using (or not using) it and collecting feedback on it (e.g. ease of use, additional features) as Trial 2. In addition, participants were asked about the time of use reward system and what impact this had on their charging behaviour.

The first question sought to establish the level of awareness of the CrowdCharge app. Each participant had been contacted multiple times during Trial 2 and at the beginning of Trial 3 to invite them to sign-up.

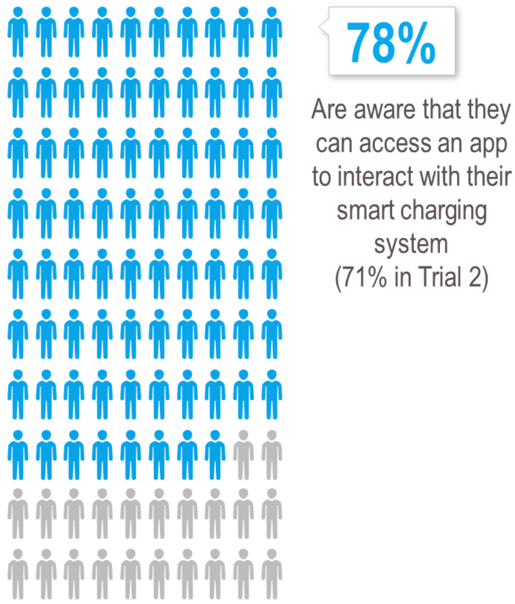

Figure 12-18: Awareness of the CrowdCharge App (Base: 194 – all respondents)

Awareness of the app had increased slightly from Trial 2, although this change was not statistically significant[181]. All the Trial 3 participants had also taken part in Trial 2 (none went straight into Trial 3), so awareness grew within the same group of trial participants, likely due to the additional reminders sent out by DriveElectric prior to the launch of Trial 3. Section 12.1.4.1 shows that these reminders (and the introduction of a financial incentive) also resulted in additional participants registering for an app account.

Participants who were aware that the app was available were then asked whether they had registered for an account at any point during 2018.

[181] Z = 1.53

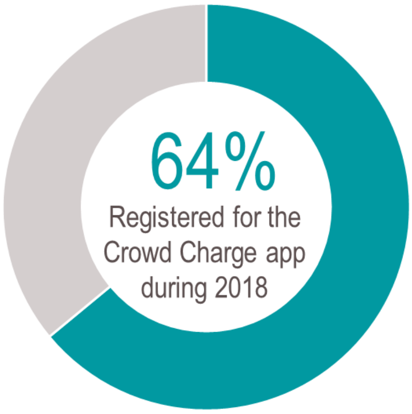

Figure 12-19: During 2018, did you register for the CrowdCharge app? (Base 152 – all those aware of the app)

64% of respondents (of those who were aware of the app) had registered. Those who hadn't registered were invited to give free text responses to explain the reasons for not registering, and a selection of quotes are shown below.

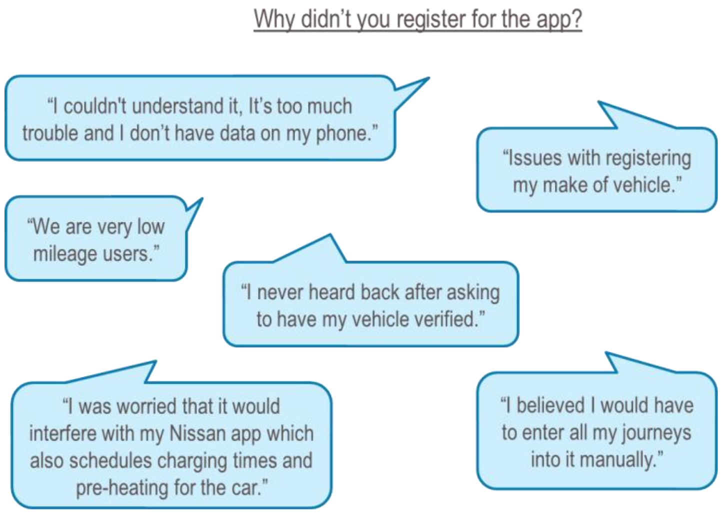

Figure 12-20: Reasons for not registering for a CrowdCharge account (Base:55 – those who were aware of the app, but had not registered)

Reasons for not registering for the app were mainly due to technical issues and a lack of understanding of the benefits of the app and how it interacted with smart charging and the ToU tariff.

The app was updated to show the reward balance, and the algorithm was updated so that data from the app would be used to schedule charging in line with the ToU tariff. At the start of Trial 3 participants were contacted to explain that the app would now support them in earning a financial reward. In the Trial 3 survey participants who were aware of the app (regardless of whether they had an account) were asked if they knew it had recently been updated. 43% of participants (65 of 152 respondents) were aware of the change. This relatively low level of awareness may partly explain why the majority of participants did not increase their data entry frequency (as per the instructions - see Section 12.1.4.2).

Participants who were aware that the app had been updated were asked which of six features of the app they had used and also given a 'none of the above' option. 65 participants were asked this question. 53 of these participants indicated that they had registered for an account, and of these 53, 81% (43 participants) had used at least one of the features listed. The remaining 10 participants selected 'none of the above'. The graphic below shows which features participants selected.

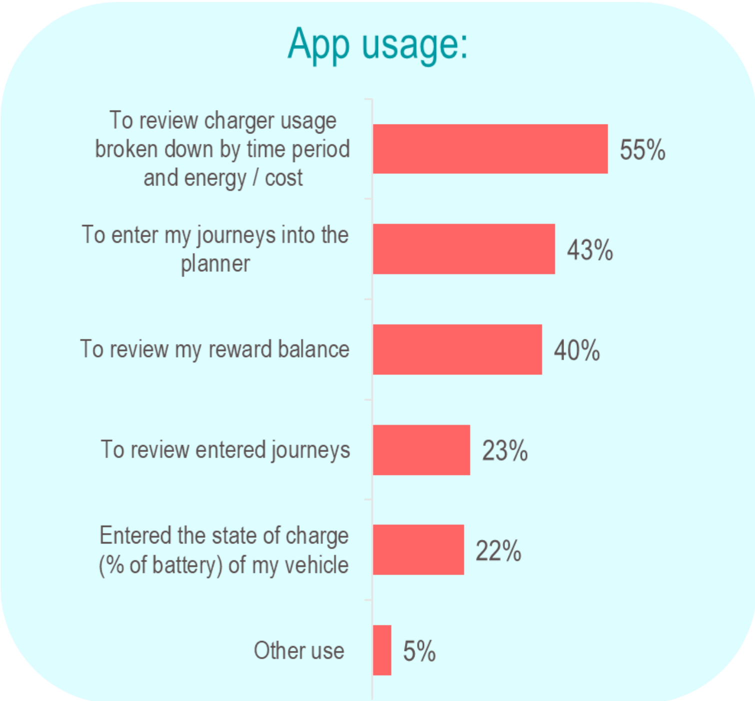

Figure 12-21: Features of the app used by Trial 3 Participants (Base: 65 – those aware that the app had been updated). Participants could select multiple options for this question.

Viewing the energy they had used remained the most used feature (in line with the Trial 2 findings), although this was used by a smaller proportion of the respondents in Trial 3. Entering journeys was used by 43% of participants, although as shown above the level of data entry (both journeys and state of charge) was not sufficient to allow the algorithm to move charging to the overnight period.

Participants who had not used the app were asked to explain the reasons why they had not. The answers tended to fall into one of three themes, with some example quotations shown in Figure 12-22 below.

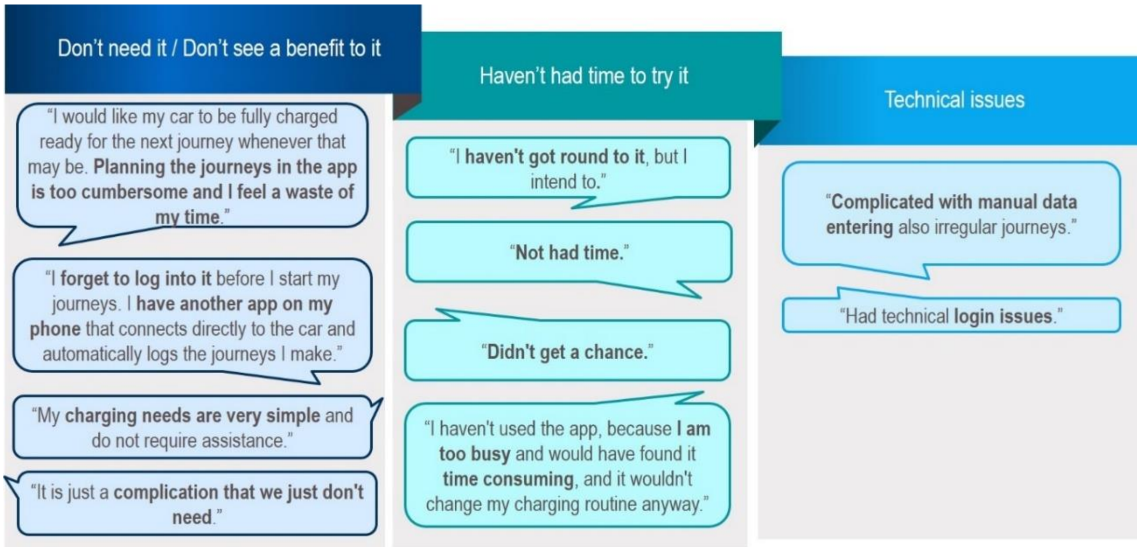

Figure 12-22: Reasons for not using the updated CrowdCharge App

The barriers mentioned are similar those raised by participants in the Trial 2 survey, focusing on the amount of effort required to enter information and a lack of understanding of the benefits of using the app.

Participants were asked to suggest improvements that they would like to see to the Trial 3 app.

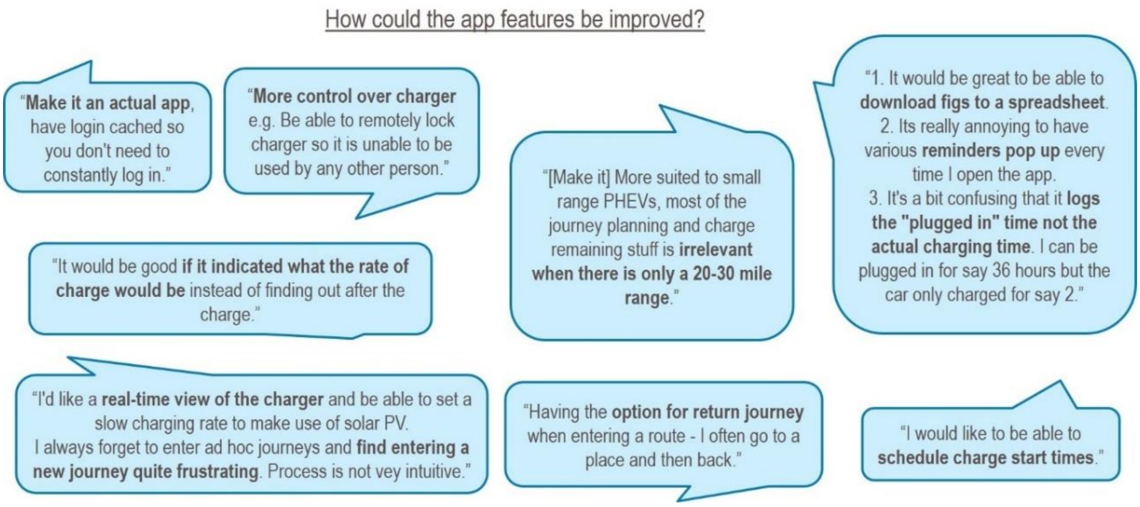

Figure 12-23: How can the feature(s) be improved

Users gave a number of detailed suggestions for improvements which could be made to the app focused on making it easier to enter information and having more control over charging rates and timings of their EV. Some of these are similar to those raised in the Trial 2 survey (e.g. move to a smartphone app, make the process for entering data less demanding).

Trial 3 introduced a time of use tariff to participants. The algorithm used to schedule charging was designed to manage this on behalf of participants (so long as they entered journeys and state of charge values), so the exact structure of the tariff may not have been clear to participants. The Trial 3 survey asked several questions focusing on their response to, and understanding of, the Time of Use reward structure.

Those participants who had used the new version of the app were asked if their behaviour had changed as a result of the Time of Use tariff, and if so, how. Results from this question are shown in Figure 12-24 below.

Figure 12-24: Change in Behaviour in Response to ToU (Base: 43 – those who indicated they had used at least one feature of the updated app)

Only ten participants stated that they had changed their behaviour. The graphic above shows examples of the free text responses. All the responses given (including those not pictured) focussed on changes in plug-in behaviour, or use of timers, rather than changing behaviour in relation to use of the app. Section 12.1.5 above shows that the changes made to charging behaviour by the population, as a whole, were minimal.

Participants who were aware that the app had been updated were asked how easy they found it to understand the reward structure based on the time of use tariff. The results are shown below.

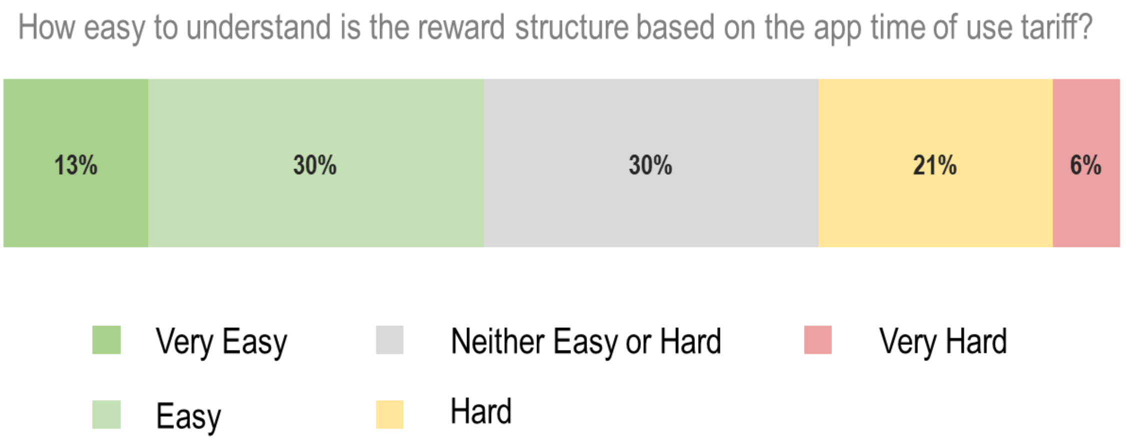

Figure 12-25: Ease of Understanding the ToU Tariff (Base: 65 – those who were aware the app had been updated)

43% of respondents found the tariff/reward structure easy or very easy to understand, compared to 27% who either found it hard or very hard.

Participants who had used the app to either enter journeys, review charge point usage, or enter state of charge, were asked whether they thought that the ToU tariff incorporated into the app would encourage drivers to change their charging behaviour in the future. The results are shown in Figure 12-26 below.

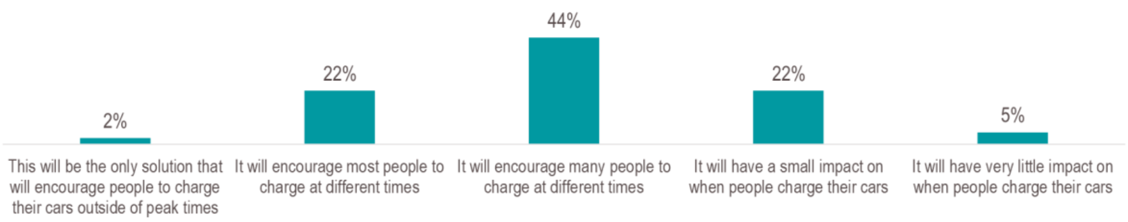

Figure 12-26: To what extent do you think the Time of Use tariff incorporated in the app (i.e. where you can be rewarded for charging outside of peak hours) will encourage EV drivers to charge their cars outside of peak times? (Base those that have used the app to either enter journeys, review charge point usage or entered state of charge = 41)

Most participants who had used the app believe that it could encourage some behaviour change in the future, with 66% of respondents thinking it would encourage "most" or "many" people to change behaviour. However, these responses come from the most engaged group of participants, who had used the app, who may believe that other drivers would behave in a similar manner. The results presented at the beginning of this section show that many participants did not register for the app, or weren't aware that it had been updated. Their views on the extent to which similar reward structures would change other drivers' behaviour may differ from those presented above.

All respondents were asked whether they would use a similar app if it was available in the future.

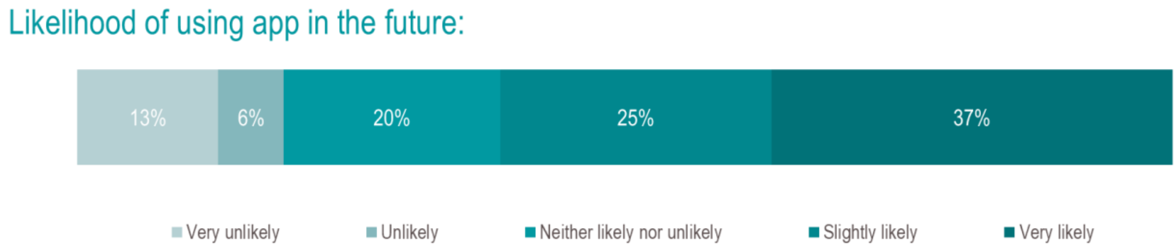

Figure 12-27: If there was a similar scheme/app available to you in the future how likely would you be to use it (Base: 194 – all respondents)

62% of participants stated that they were likely to use a similar app if it was available in the future. However, this was slightly higher than the proportion of participants who had registered for the CrowdCharge app (with only a proportion of this group going on to use the app).

Participants who were aware of the updated app (41 responses) were asked to suggest any improvements that they would like to see to it. 85% of participants didn't expect to see any additional functions (or hadn't used the app and so were unable to comment). The features cited by the remaining 15% of respondents are shown below.

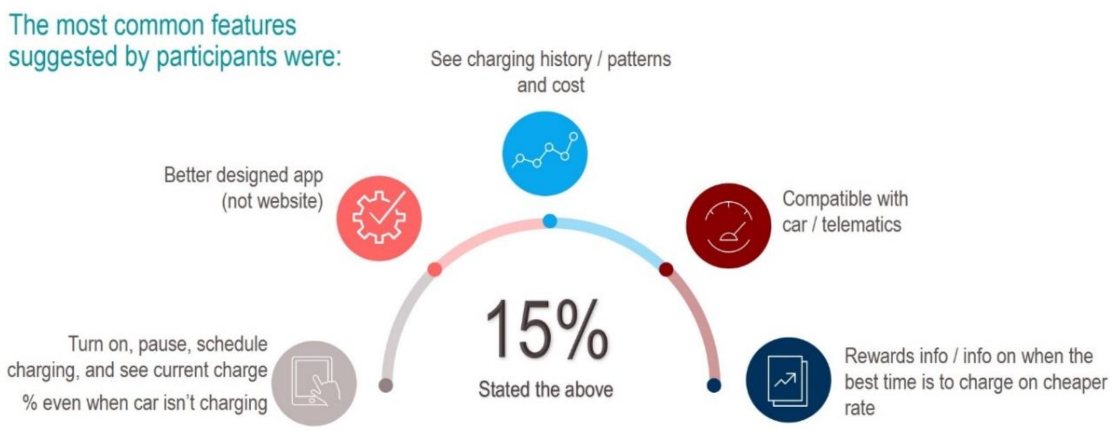

Figure 12-28: Additional Features Suggested by Participants (Base: 41)

Although a lower proportion of participants suggested additional features in this survey compared to Trial 2 (15% of responses vs. 37% of responses) the additional features they requested were very similar. The only 'new' feature requested was further information on the rewards, or when is the cheapest time to charge their vehicle.

12.1.6.3 Acceptability and satisfaction with charging arrangements

One of the key elements of the Electric Nation trial was to understand the acceptability of smart charging amongst participants, and the factors which affect this. Participants were asked a consistent series of questions at multiple points through the project – before management (the Baseline survey, see Section 9.1), as part of Trial 1 (see Section 10.1.5), Trial 2 (Section 11.1.6) and Trial 3 (this section). This allows participants' attitudes towards their charging arrangements to be compared through the trial as they experienced different aspects of smart charging.

This section shows the results of this part of the survey and compares the responses to those received in the Baseline, Trial 1 and Trial 2 surveys, showing the effect that the time of use reward system (alongside an app) has. Section 12.1.7 relates these scores to the reward which participants earnt during Trial 3. This section only uses the results from participants who had completed all four surveys (Baseline, Trial 1, Trial 2 and Trial 3) so that changes in attitudes can be studied. The results for all participants who completed a Trial 3 survey can be found in Appendix 2.

Participants were asked to rate the acceptability of their current charging arrangements on a scale of 1 (completely unacceptable) to 10 (completely acceptable). Figure 12-29 shows the proportion of participants who gave a score of 8, 9 or 10 for the Baseline, Trial 1, Trial 2 and Trial 3 surveys. The results are for the participants who responded to all three surveys.

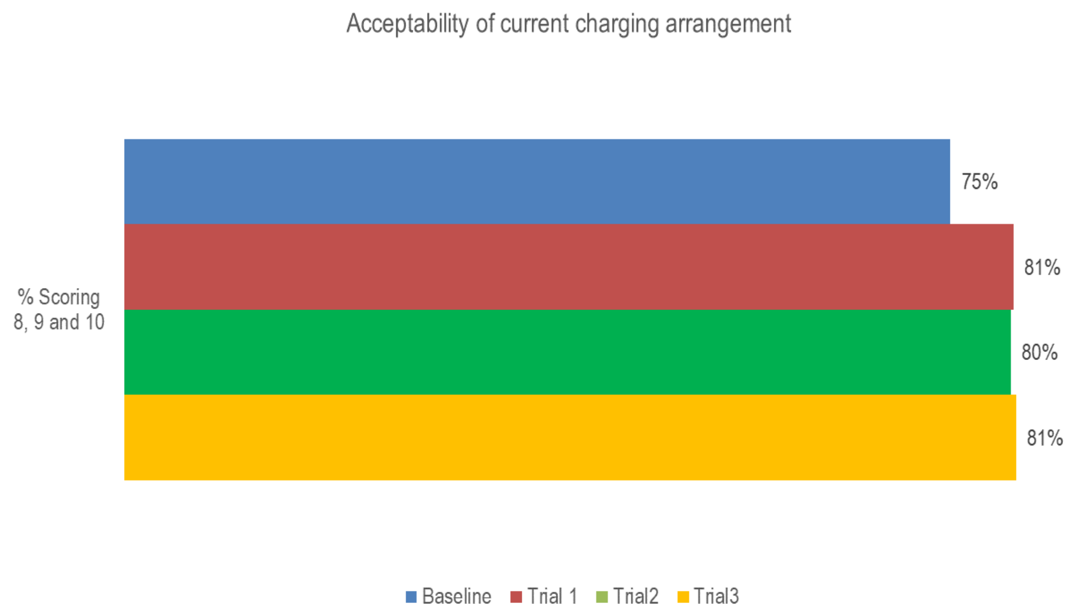

Figure 12-29: Acceptability of current charging arrangements (Base: Baseline 84, Trial 1 83, Trial 2 82, Trial 3 84) - excludes those who answered 'don't know'

The introduction of the time of use reward system has not significantly altered the proportion of participants who rate their charging arrangements as highly acceptable, compared to demand management with an app (but no reward system, Trial 2)[182].

[182] Z test. Z value = 0.16

Participants were also asked to the score their satisfaction with their charging arrangements on a 1 to 10 scale. Figure 12-30 compares the level of satisfaction for the whole population in the Baseline, Trial 1, Trial 2 and Trial 3 surveys.

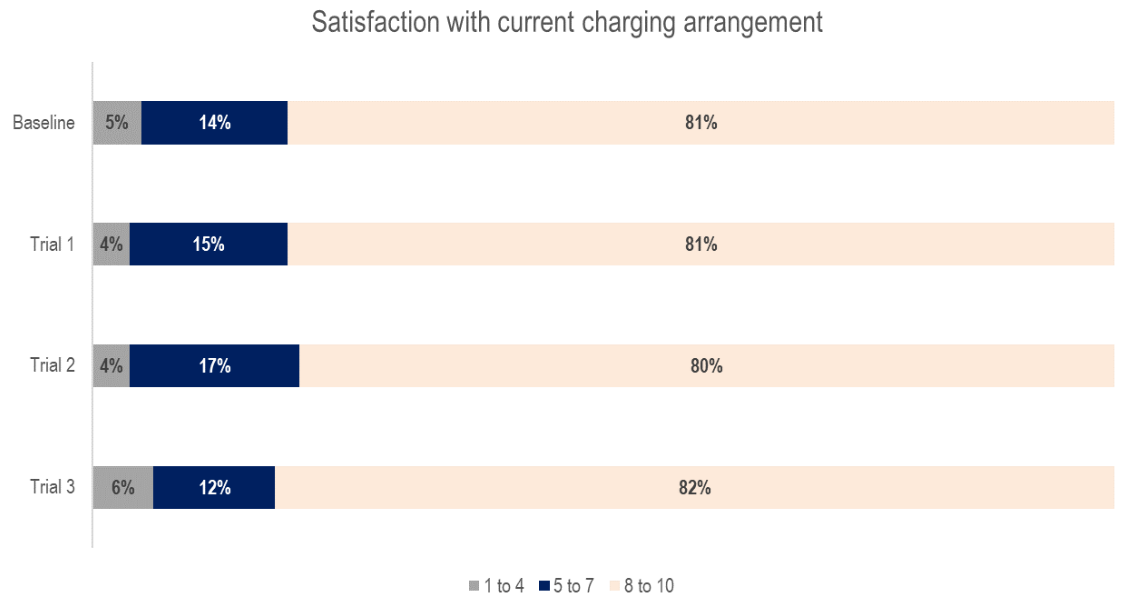

Figure 12-30: CrowdCharge Satisfaction with Current Charging Arrangements (Number of responses = 84 for all four surveys)

The level of satisfaction with current charging arrangements remained very similar between the four surveys. Between the Trial 2 and Trial 3 surveys there was a small decrease between the proportion of participants who were 'neutral' (scores of 5 to 7) but the change is not statistically significant[183]. There is also a slight increase in the proportion of participants who were 'highly satisfied' (scores of 8 to 10) and those who were 'highly dissatisfied' (scores of 1 to 4) between Trial 2 (app, no reward) and Trial 3 (app with ToU reward) but the changes are not statistically significant[184].

[183] Z test. Z value = 0.88.

[184] Z test. Z value = 0.33 and 0.72 for 'highly satisfied' and 'highly dissatisfied' respectively (changes between Trial 2 and Trial 3).

Table 12-9 compares the proportion of participants who were 'highly satisfied' (score of 8 to 10) for all four surveys disaggregated by PEV type and battery capacity.

Table 12-9: Proportion of Participants Highly Satisfied (Baseline, Trial 1, Trial 2, Trial 3) - by PEV Type and Battery Capacity

Group		Sample Size	% of Survey Responses Scoring 8 - 10			
			Baseline	Trial 1	Trial 2	Trial 3
PEV Type	REX	11	91%	73%	82%	82%
	PHEV	34	71%	74%	68%	76%
	BEV	39	87%	90%	90%	87%
Battery Capacity	Less than 10kWh	23	65%	74%	61%	74%
	10 to 25kWh	23	83%	74%	87%	83%
	25 to 35kWh	28	89%	89%	86%	86%
	35kWh+	10	90%	90%	90%	90%

Satisfaction levels between Trial 2 and Trial 3 stayed at similar levels across all the groups, with none of the changes being statistically significant[185]. Although the proportion of 'highly satisfied' participants varies between the sub-groups in each of the surveys, there are no statistically significant differences[186].

The key findings section compares satisfaction and acceptability based on the reward which drivers earned during Trial 3 (see Section 12.1.7).

Participants were also asked to state for how long they would be willing to continue with their current charging arrangements. Figure 12-31 shows the breakdown of results for all respondents who completed a Baseline, Trial 1, Trial 2 and Trial 3 survey.

[185] Z test: Z values range from 0 ('REX' and battery capacities of 25 to 35kWh and >35kWh) up to 0.94 for participants with vehicles having a battery capacity <10kWh.

[186] Z test: for Trial 3, Z values range from 0.30 between battery capacities of 10 to 25kWh and 25 to 35kWh up to 1.19 between 'PHEV' and 'BEV'.

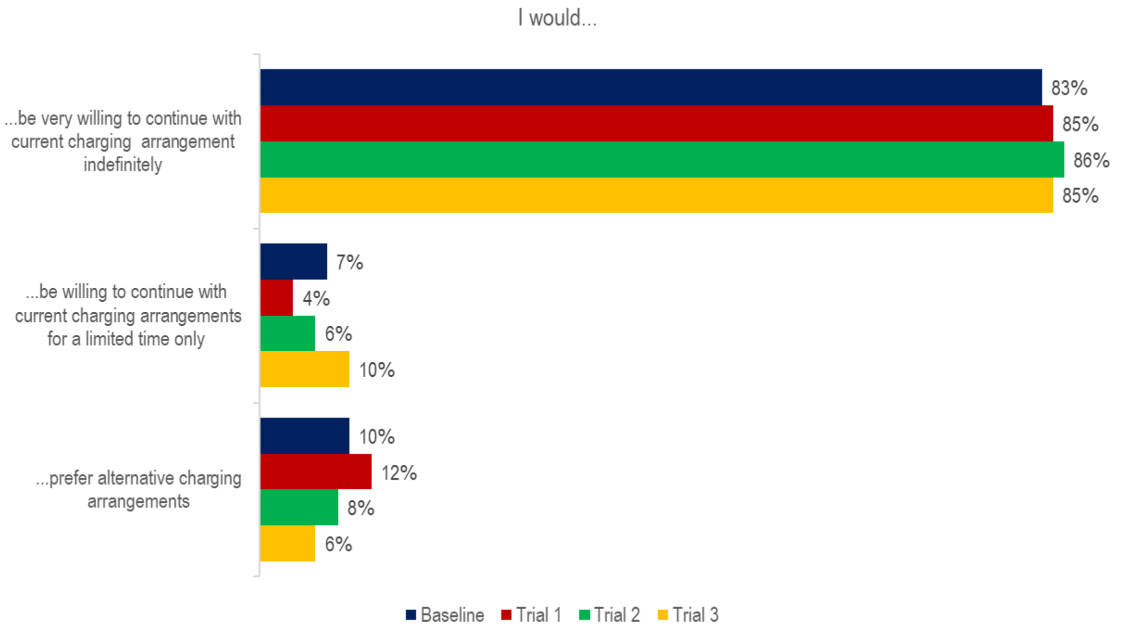

Figure 12-31: CrowdCharge Willingness to Continue with Charging Arrangements (Number of responses = 84 in all four surveys)

The proportion of participants that would be willing to continue with their current charging arrangements remained high across all four surveys. There was a slight decrease between the Trial 2 and Trial 3 surveys, but the difference is not statistically significant[187]. The number of respondents who would be willing to continue with their current charging arrangements for a limited time only increased between the Trial 2 and Trial 2 surveys but again this difference is not statistically significant[188].

Table 12-10 disaggregates the Baseline, Trial 1, Trial 2 and Trial 3 surveys by vehicle type and show the proportion of participants who would be willing to continue with their charging arrangements indefinitely.

Table 12-10: Proportion of Respondents Willing to Continue with Charging Arrangement Indefinitely - by PEV Type

Group		Sample Size	% of Survey Respondents Willing to Continue with Charging Arrangements Indefinitely			
			Baseline	Trial 1	Trial 2	Trial 3
PEV Type	REX	11	100%	73%	82%	91%
	PHEV	34	76%	79%	85%	85%
	BEV	39	85%	92%	87%	82%

[187] Z test: Z value = 0.22.
[188] Z test: Z value = 0.87.

The proportion of participants willing to continue with their charging arrangements indefinitely fell from Trial 2 to Trial 3 for 'BEV' but increased slightly for the PHEV group. However, these changes are not statistically significant[189].

Participants were asked about their concerns regarding smart charging. The results from the Baseline survey (before management), Trial 1 (management, but no app), Trial 2 (management with app) and Trial 3 (management, app and ToU reward) surveys are shown in Figure 12-32 below.

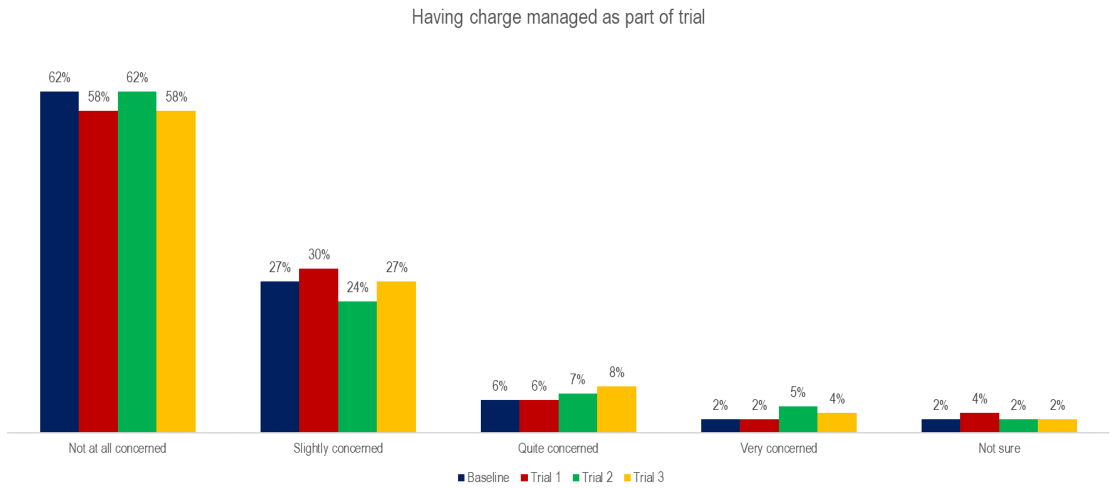

Figure 12-32: Level of Concern regarding Demand Management (Base: 84 across for all four surveys)

The proportion of CrowdCharge trial participants with no concerns about having their charge managed remained broadly similar and there are no statistically significant differences between the responses in this category in the Trial 2 and Trial 3 surveys[190]. There were very few changes throughout the duration of the project, despite the level of management which participants experienced, with the majority remaining either “not at all” or only “slightly” concerned.

The results show a slight increase in the proportion of participants who were 'quite concerned' between Trials 2 and 3 but there was a corresponding decrease in the number of participants who were 'very concerned’ – this was as a result of the movement of a single participant between categories.

12.1.6.4 Trial 3 Findings from Focus Groups

At the end of the project a small number of participants gave additional qualitative information about their experience of taking part in Electric Nation (five in the focus group, one additional participant took part in an in-depth telephone interview).

[189] Z test: Z value = 0.62 for 'REX' and 0.63 for 'BEV'.
[190] Z test: Z value = 0.47.

Focus group participants generally viewed Trial 3 very positively, with most being happy with the rewards concept and the app functionality. Levels of engagement with the app, and the extent to which participants changed their behaviour during Trial 3 varied between focus group participants. A selection of quotes is shown below.

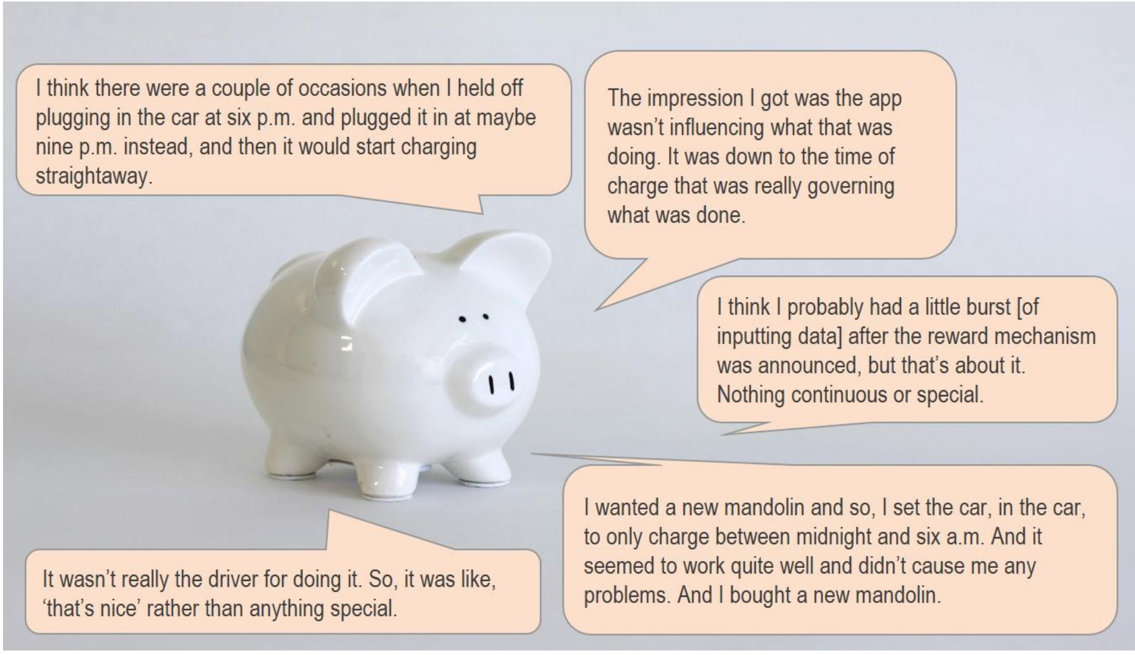

Figure 12-33: Quotations from Focus Group Participants about Trial 3

Focus group participants were asked to suggest potential improvements to the ToU incentive scheme, one participant responded as follows:

> *"I think just an occasional Amazon discount voucher, or something is nice but it's not a general motivator and it's just an extra complication really. Whereas if you're looking at the electricity bill and you can see you paid this much and we got this much discount because it's demand-managed, that's where I'd notice it."*

12.1.6.5 Summary

CrowdCharge participants who responded to the Trial 3 survey showed a greater awareness and higher usage rate of the app in Trial 3 than those who responded to the Trial 2 survey (despite lower data entry rates in the population as a whole). Participants who had used the app during Trial 3 were most likely to have used the functions that allowed them to check their charge point usage or check their reward balance. Only a minority (43%) found the reward structure easy to understand.

Acceptability and satisfaction rates among CrowdCharge participants remained high through Trial 3, and there were no statistically significant changes compared to Trial 2.

The introduction of time of use tariffs did not change the charging or journey patterns for most CrowdCharge participants, and this is also visible in the analysis of charging behaviour shown in Section 12.1.5. The 23% of CrowdCharge participants that reported that they changed their charging behaviour stated that they were waiting until off-peak times to charge their car although participants demonstrated some confusion over the time period that constituted off-peak.

12.1.7 Key Findings – CrowdCharge Trial 3

- The algorithm changes implemented by CrowdCharge, alongside the ToU tariff and journey planning app made minimal difference to the demand profile. In the evening peak, the 90th Percentile peak demand was approximately 600W per charger. This demand was constrained by the use of demand management – unrestricted demand would be higher. This was consistent with winter peak demand during the evening observed in Trial 1. This is to be expected as the capacity profiles used were similar in both cases.
- Due to the lack of reduction in peak demand as a result of the algorithm/ToU/app combination, management was frequently active during the weekday evening peak – it occurred on 70% of weekdays in Trial 3. This management occurred when the total demand from EV chargers (if they were all given their maximum allocation of current) exceeded the amount of current available in the capacity profile.
- There was a small, but statistically significant increase in the proportion of charge events which were hot unplugged in Trial 3 compared to Trial 2 (17.4% vs. 15.2%). There was also small increase when Trial 3 was compared to the same period of time in 2017 (17.4% vs. 14.9%).
- At the start of Trial 3 participants were again invited to register for a CrowdCharge web app account. Participants were informed that by registering for an account they would be eligible for the rewards system. This increased the proportion of participants who registered from 55% (end of Trial 2) to 64% (17 additional registrations).
- Overall the amount of data entered into the app by participants was low, and in general lower than during Trial 2 (though this may be partially explained in that Trial 2 users may have entered regular journeys already and felt no need to add more journeys in Trial 3):
    - 44% of those with an account made at least one data entry of any type (65% in Trial 2) – a statistically significant decrease;
    - 19% entered at least one regular journey (41% in Trial 2);
    - 19% entered at least one ‘one-off’ journey (25% in Trial 2); and
    - 42% provided at least one state of charge value (57% in Trial 2).
- The frequency with which participants entered data was generally lower in Trial 3, compared to Trial 2 (despite instructions to participants encouraging them to enter data to maximise their reward). Fewer than 25% of participants increased their data entry frequency in Trial 3.

- There is little evidence that participants changed their charging behaviour to any great degree during Trial 3. Comparing the time when charging began for Trial 3 participants before and during Trial 3 shows the following small but statistically significant changes:
    - A slight **increase** in the proportion of charge events starting in the overnight period on weekdays from 17% to 21%. There was also an increase at the weekend (from 16% to 19%).
    - A slight **decrease** in the proportion of charge events starting in the late evening (20:00 to 23:59) on weekdays from 20% to 19%.
- Table 12-11 below, relates the scores given for participants **satisfaction** with their current charging arrangements in the Trial 3 survey to the financial reward they earned at the end of Trial 3 (i.e. 83% of participants who were not eligible for a reward gave a satisfaction score of 8 – 10):

Table 12-11: Relationship between satisfaction scores and reward values

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
No account – No reward	102	3%	14%	83%
Reward value £8.05 - £13.44 (1st Quartile)	36	7%	10%	83%
Reward value £13.45 - £17.40 (2nd Quartile)	36	35%	26%	71%
Reward value £17.41 - £23.11 (3rd Quartile)	35	12%	15%	73%
Reward value £23.12 - £57.84 (4th Quartile)	36	0%	10%	90%

There is not a linear relationship which suggests that a higher reward is always associated with a higher proportion of participants being highly satisfied. Although the 4th quartile gave the highest scores (90% 8 to 10) those who were either not eligible for a reward, or received the lowest amounts (1st Quartile) were more satisfied than the 2nd or 3rd quartiles. Participants in the 4th quartile were statistically significantly more likely to give a score of 8 to 10 than those in the 2nd quartile[191] (5% confidence level) and 3rd quartile[192] (10% confidence level).

A higher proportion of participants in the 2nd quartile were dissatisfied (scores 1 to 4). This does not appear to be linked reward value, as they were statistically

[191] 71% of 36 in 2nd Quartile vs. 90% of 36 in the 4th Quartile. Z = 2.03
[192] 73% of 36 in 3rd Quartile vs. 90% of 34 in the 4th Quartile. Z = 1.85

significantly more likely to have given a low score when compared to 1st quartile and those who received no reward[193].

- Table 12-12 relates the scores given by participants for the **acceptability** of their current charging arrangements in the Trial 3 survey to the financial reward they earnt at the end of Trial 3 (i.e. 86% of participants who were not eligible for reward gave an acceptability score of 8 – 10).

Table 12-12: Relationship between acceptability scores and reward values

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
No account – No reward	102	3%	11%	86%
Reward value £8.05 - £13.44 (1st Quartile)	36	3%	24%	72%
Reward value £13.45 - £17.40 (2nd Quartile)	36	6%	19%	74%
Reward value £17.41 - £23.11 (3rd Quartile)	35	9%	15%	76%
Reward value £23.12 - £57.84 (4th Quartile)	36	0%	10%	90%

There is not a clear relationship between reward values and acceptability scores. A statistically significant higher proportion of those who received no reward gave a high (8 to 10) score than those in the 1st quartile[194] (at the 10% level). It may be that these participants were accepting of the fact that they would not earn a reward (they had chosen not to sign-up for an account). Amongst participants who were eligible for a reward those who earned the highest amount (the 4th quartile group) were significantly more likely to give a high score than those who earned the least (the 1st quartile group)[195] (at the 10% level).

- Awareness of the app had increased slightly compared to Trial 3. The reasons given by participants for not registering for the app include technical issues and a lack of understanding of the benefits it offered and how it would interact with smart charging.
- Viewing the energy they had used was the most commonly used feature (in line with the Trial 2 findings). Amongst those who had not used the app, the reasons given were generally a lack of awareness of the benefit, not having enough time, or technical issues.

[193] 3% of 102 vs. 35% of 36. Z = 5.2. 7% of 36 vs. 35% of 36 Z = 2.92.
[194] Z = 1.89.
[195] Z = 1.95

- Participants who were aware of the updated app were asked how easy they found it to understand; 43% found it either “easy” or “very easy” compared to 27% who found it either “hard” or “very hard” to understand.
- The metrics which show participants’ satisfaction with their charging arrangements and concerns about management in Trial 3 were broadly stable compared to Trial 2 as follows with no statistically significant differences in acceptability, satisfaction, willingness to continue or concerns about management compared to Trial 2.
- Participants in the focus group were generally positive about Trial 3. One participant suggested that the format of the reward could be improved if it was included a separately itemised rebate as part of the electricity bill.

12.2 GreenFlux

12.2.1 Description of Trial

Trial 3 used an updated version of the smartphone app which was first launched to participants in Trial 2. The app was developed so that users could set a charging preference, which dictated what time of day their charger would allow charging. This preference would be used for all charging events until the user changed it (as opposed to a high priority request which only applied for a given charging session). The three preferences available were:

- "Minimise cost": the system paused charging during peak and taper tariff period (i.e. it only charged between 22:00 and 16:30);
- "Optimise time and cost": the system only paused during the peak tariff period but would bring a charger on to charge during taper tariff (charging from 19:00 to 16:30); and
- "Optimise time": this was the default option and allowed charging at any time, regardless of cost, and chargers would only be curtailed if demand management was necessary.

The updated app also showed users their reward balance, past charging sessions and the impact these had on the reward balance, and information on the current charging session. The high priority request feature was retained from Trial 2.

The total power drawn for the group of chargers continued to be managed against the capacity limit, so that if the total power required by the group of chargers was greater than the available capacity then demand management would be activated. The capacity limit profile applied at all times of day, so that if an increase in demand occurred at the start of the 'minimise cost' window (22:00) that was larger than the available capacity, then demand management would occur.

A staged approach was used to launch Trial 3 to participants:

- w/c 8th October: all Trial 3 participants were sent details of the tariff/reward structure, and how the new app could be used. The number of installations of the app which would automatically update was limited. Participants could choose to manually update the app. However, GreenFlux could not know which participant had access to the updated app. Reward balances began to be calculated for all the Trial 3 participants, regardless of whether they had access to the update; and
- w/c 15th October: the limits on the number of installations which would update were removed, allowing all participants to access the updated app. All participants whose reward balance had decreased were reset to £10, as they may not have had access to the app. Reward balances which had increased were not reset.

This section of the report presents:

- How the charging preferences available via the app and the ToU tariff changed the power demand from the group of chargers (compared to the end of Trial 2, and Winter during Trial 1);
- The incidence of management at a group level based on the period from 18th October to 16th December 2018;
- The degree to which participant's interacted with the GreenFlux app, and the charging preferences used, and the level of rewards they earned;
- Findings from the customer research survey completed by participants at the end of Trial 3;
- The interactions between participants and the support line during GreenFlux Trial 3; and
- Key findings from Trial 3, including the relationship between both app usage and reward values with satisfaction rates.

12.2.2 Demand Profiles

As described above, Trial 3 was in operation between October and December 2018. The resulting power demand from groups of chargers can be compared to other periods during the trial in order to show the potential impact of a combination of a ToU tariff, app and smart charging on the demand profile from EV chargers.

The current meter value data from individual chargers has been aggregated up to a group level and converted to power (rather than current) in the same way as described in Section 10.2.2.

This section shows demand profiles for period between 18th October and 16th December (inclusive). Profiles below are expressed in W per Charger in Group. The graph below shows the maximum, 90th percentile and average demand for weekdays Trial 3 (18th October – 16th December.

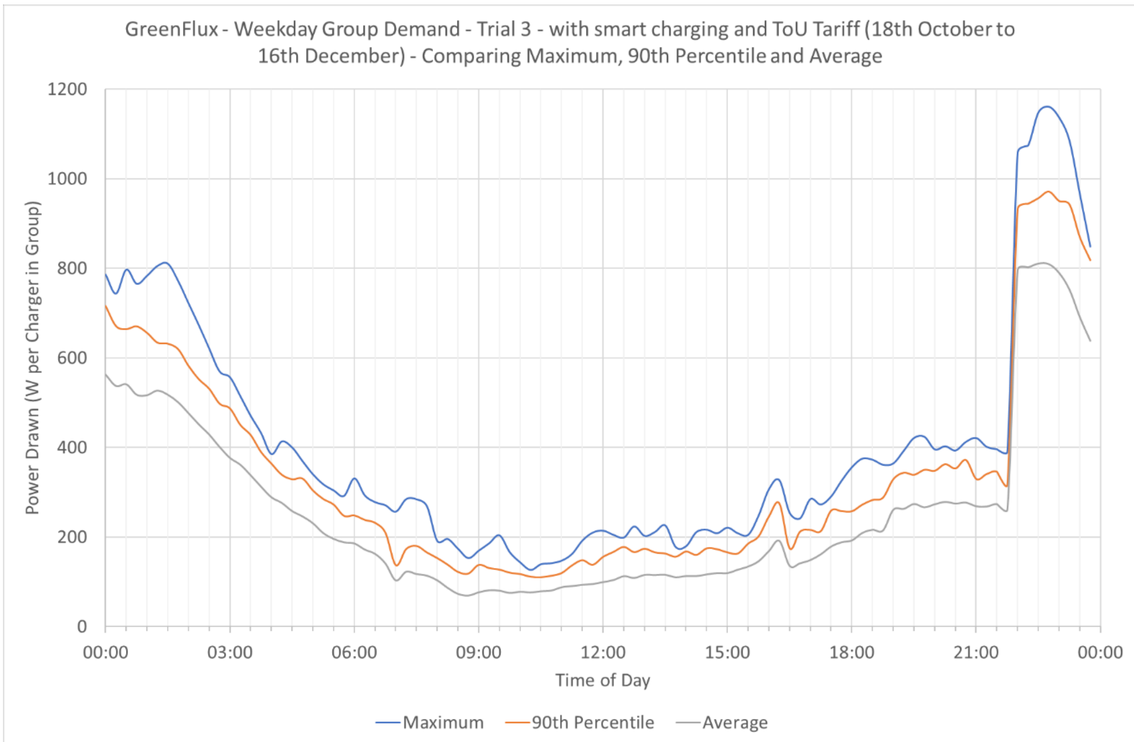

Figure 12-34: GreenFlux Trial 3 - Weekday Group Demand - Maximum, 90th Percentile and Average

This graph illustrates the variability in the current drawn at each time of day from day to day, although all three curves follow a similar pattern. The shape of the graph shows the variation in demand across the day, showing clear differences with the demand profile from previous parts of the trial. The following points are evident:

- A sudden spike in demand at 22:00, when all chargers that were set to ‘minimise cost’ began charging;
- A brief spike in demand between 15:45 and 16:30. This may be a small number of chargers beginning to charge at the very beginning of the evening peak, then stopping again once the peak rate price begins at 16:30; and
- Demand in the traditional evening peak was higher than day-time demand, but considerably lower than during previous trials. This is shown in more detail below.

The graph below compares the 90th percentile weekday and weekend demand curves.

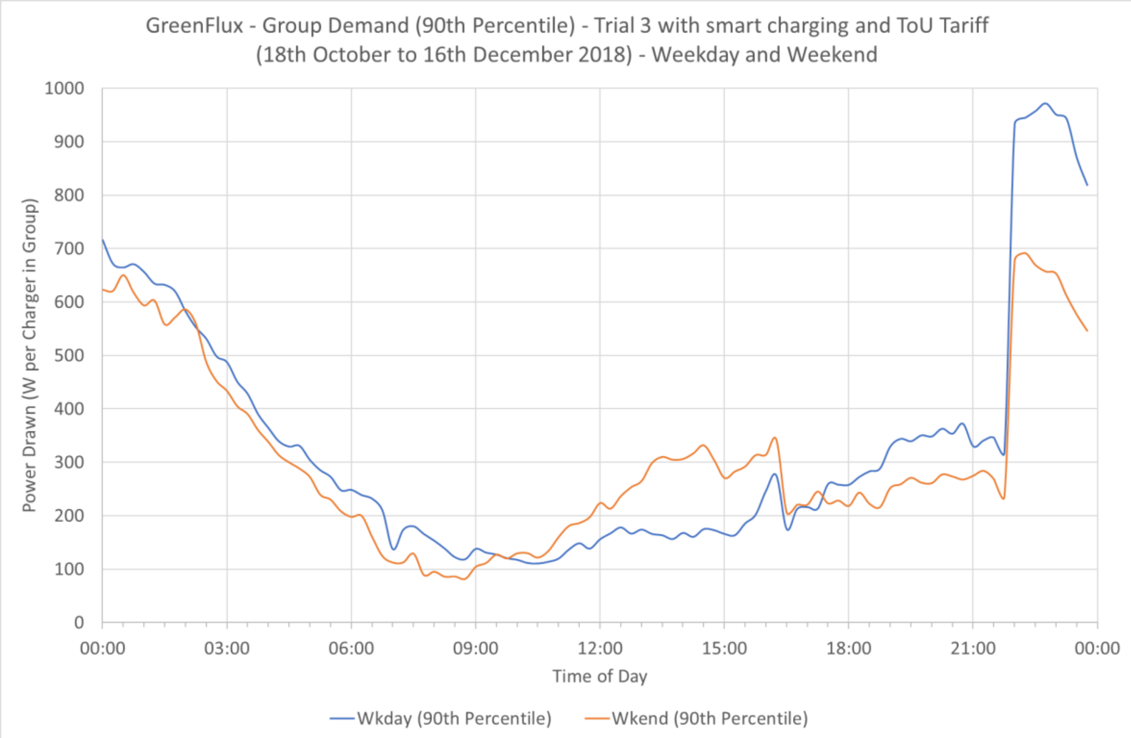

Figure 12-35: GreenFlux Trial 3 Group Demand – Comparing Weekday and Weekend (90th Percentile)

Participants also used the ‘minimise cost’ option extensively at the weekend – seen in the sudden increase in demand at 22:00. The energy demand overall (area under the curve) was lower at the weekend. Daytime demand in higher, with the sudden decrease at 16:30 being due to the start of the peak price, as any active chargers subject to the ‘minimise cost’ option would stop charging at 16:30. Overnight demand was very similar on weekdays and at the weekend.

The profiles shown above have grouped all weekdays (Monday – Friday) and weekend days (Saturday and Sunday) together. There may be trends within the week – for example higher demand on Mondays compared to Fridays. The graph below shows the 90th percentile of group demand (W per charger in the group) during Trial 3, shown across all seven days of the week.

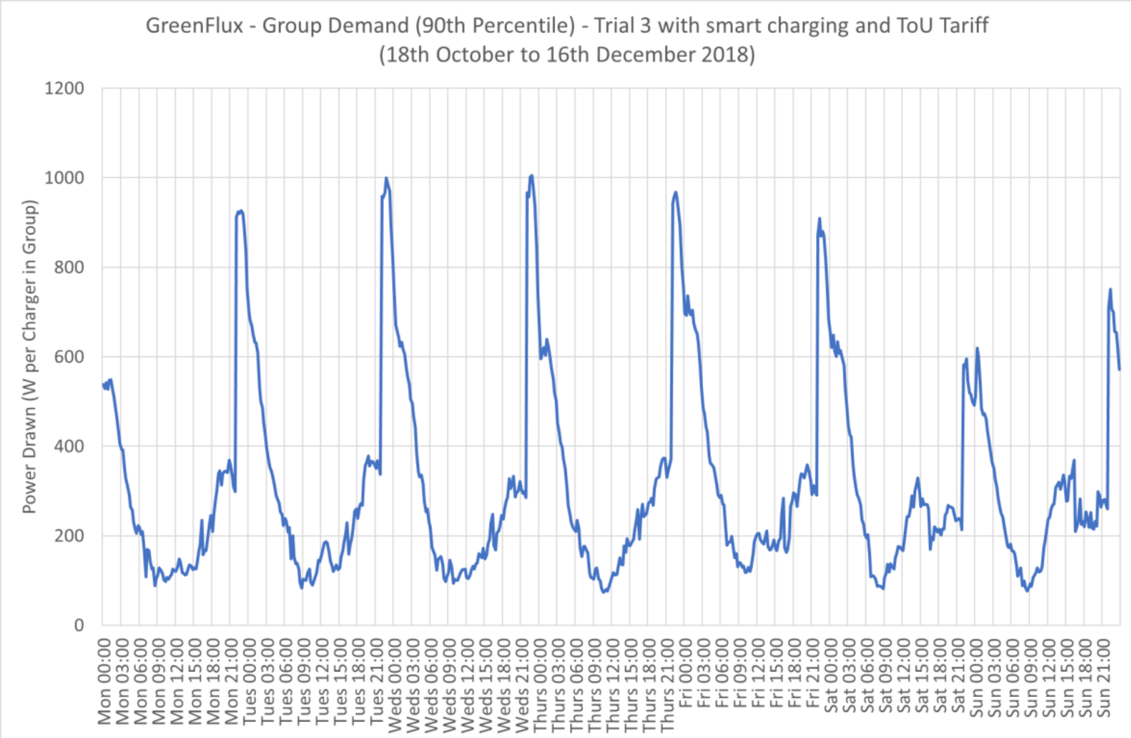

Figure 12-36: GreenFlux Trial 3 Group Demand - 7 Day (90th Percentile)

This shows a similar pattern of demand across all days of the week, with the main peak occurring at 22:00 each day, when the off-peak rate began and chargers on 'minimise cost' started charging. The peak demand was lowest on Saturday. Demand on Sunday was lower than a typical weekday, but higher than Saturday: 750W per charger in the group on Sunday at 22:00, compared to 600W per charger on Saturday.

One of the main aims of Trial 3 was to determine the extent to which a system such as that deployed by GreenFlux could change the shape of the demand profile. The 'Trial 3' (18th October to 16th December) demand profile has been compared to two sets of data, neither of which include ToU elements:

- The final part of Trial 2 – 7th September to 10th October. Previous analysis has shown that demand was seasonal, therefore only the last month of Trial 2 has been used, as demand from earlier was likely to be less comparable with Trial 3 due to seasonal affects; and
- 'Winter' in Trial 1 - 4th January to 7th March 2018. This demand was likely to be slightly higher than for Trial 3 as January – March was likely to be colder than October – December (increasing the energy required by EVs).

The graphs below compare the Trial 3 data to both periods above, for weekdays (Figure 12-37) and weekends (Figure 12-38).

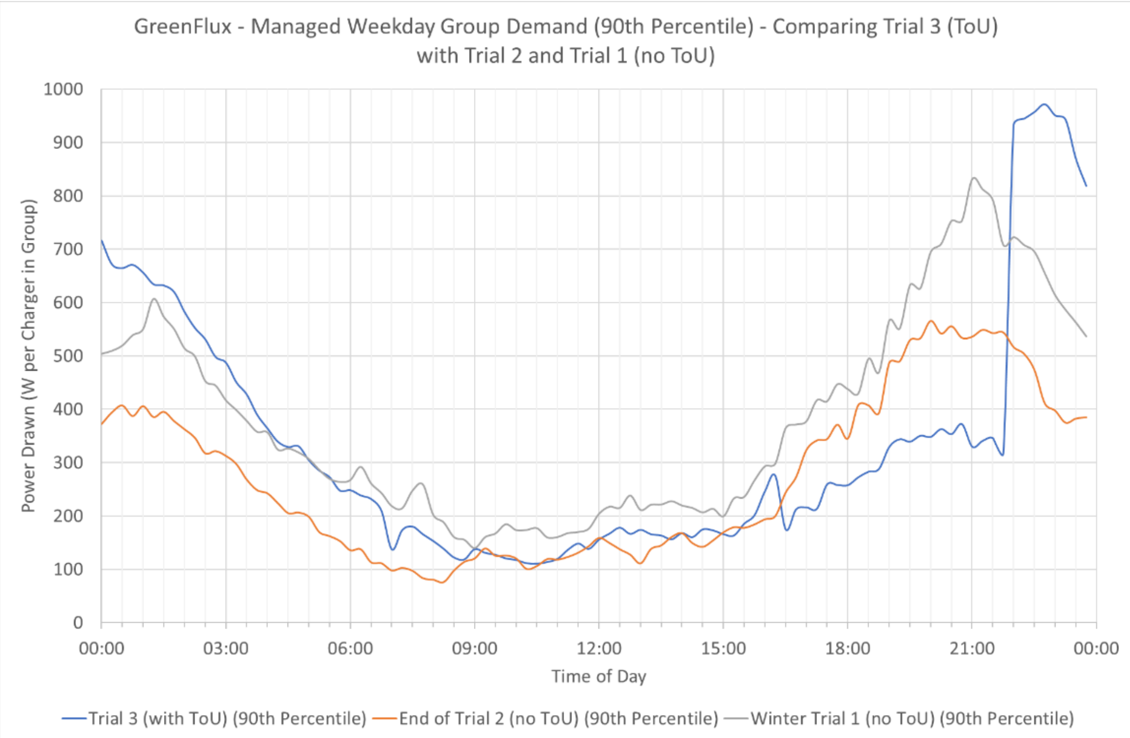

Figure 12-37: Comparing Group Demand in Trial 3 (ToU) to other non-ToU Periods (Weekday, 90th Percentile)

The difference in the profile between Trial 3 and both Trial 1 and 2 is clear, particularly during the traditional evening peak period. Demand in the early hours of the morning (00:00 – 01:30) was higher during Trial 3, but then returns to similar levels to the 'winter' curve, suggesting that the demand which was displaced from the evening peak has been supplied by the early hours of the morning.

Daytime demand was similar in all cases. Trial 3 corresponds most closely to the end of Trial 2, suggesting that demand during October – December (Trial 3) was more similar to September than the winter period chosen. The peak created at 22:00 was higher than the previous peak observed in either winter or the end of Trial 2. However, the available network capacity at 22:00 was much higher than that available at the previous time of peak demand (i.e. at 19:00).

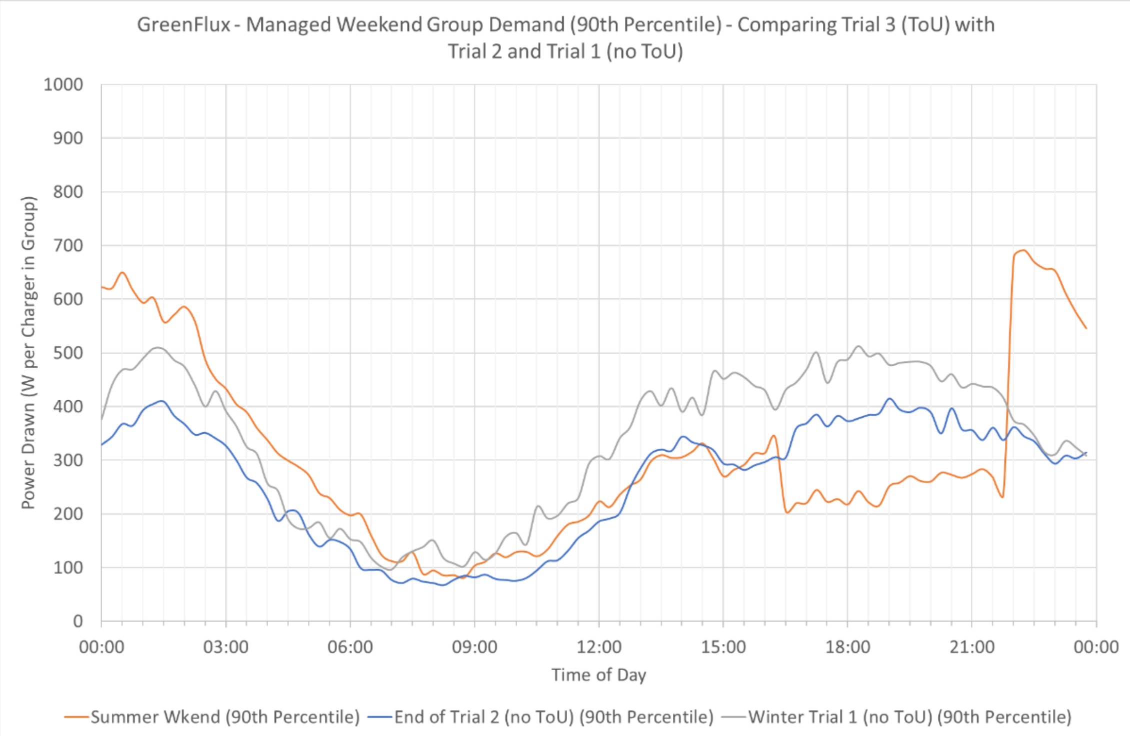

Figure 12-38: Comparing Group Demand in Trial 3 (ToU) to other non-ToU Periods (Weekend, 90th Percentile)

The weekend ToU (Trial 3) profile follows the demand curve from the end of Trial 2 closely during the day, until 16:30 when demand decreases due to the peak pricing. Demand increased sharply at 22:00 as observed elsewhere, due to the start of the off-peak tariff. Demand remains slightly higher throughout the overnight period compared to both the end of Trial 2 (blue curve) and winter in Trial 1 (grey curve).

12.2.3 Occurrence of Demand Management – Group Level

The GreenFlux system continued to manage demand from the trial group throughout Trial 3. If the current required to provide the maximum allocation (either 16A or 32A) was greater than the capacity limit, then chargers would have been curtailed. During Trial 3, two different seasonal profiles were used – the 'Spring-Winter' combined profile (10th October – 15th November) and a winter profile (15th November – 17th December). The table below shows the number of managed minutes associated with each.

Table 12-13: Seasonal Profiles and Occurrence of Management at a Group Level - GreenFlux Trial 3

Seasonal Profile	Number of Minutes Active	Number of Managed Minutes	% of Minutes with Active Management
Spring Winter Combined	51,869	210	0.40%
Winter	46,049	0	0%

Management only occurred when the 'Spring-Winter' combined profile was active. The latest date on which management occurred was 17/10/2018 (at 18:45).

Trial 3 was launched on 10th October, with an email to all participants advising them of the ToU reward scheme and the updates to the app. However, the number of installations of the app which would automatically update was constrained between 10th and 18th October to ensure that any increase in calls to the participant support line could be managed. The default charging profile (i.e. until the participant changed it via the app) was 'Optimise time', allowing charging at all times of day regardless of price. Therefore, during the first week (10th – 18th October) most participants would still be using the default profile. Once all participants had access to the app (after 18th October), no management was required because the total demand was always less than the capacity limit.

The demand profiles shown in Section 12.2.2 above show large increases in demand at 22:00 caused by chargers starting to charge at the beginning of the off-peak rate. The graph below compares the maximum total allocation of current to chargers to the applicable capacity limit for the winter period (when the capacity profile was most restrictive), for both weekdays and the weekend.

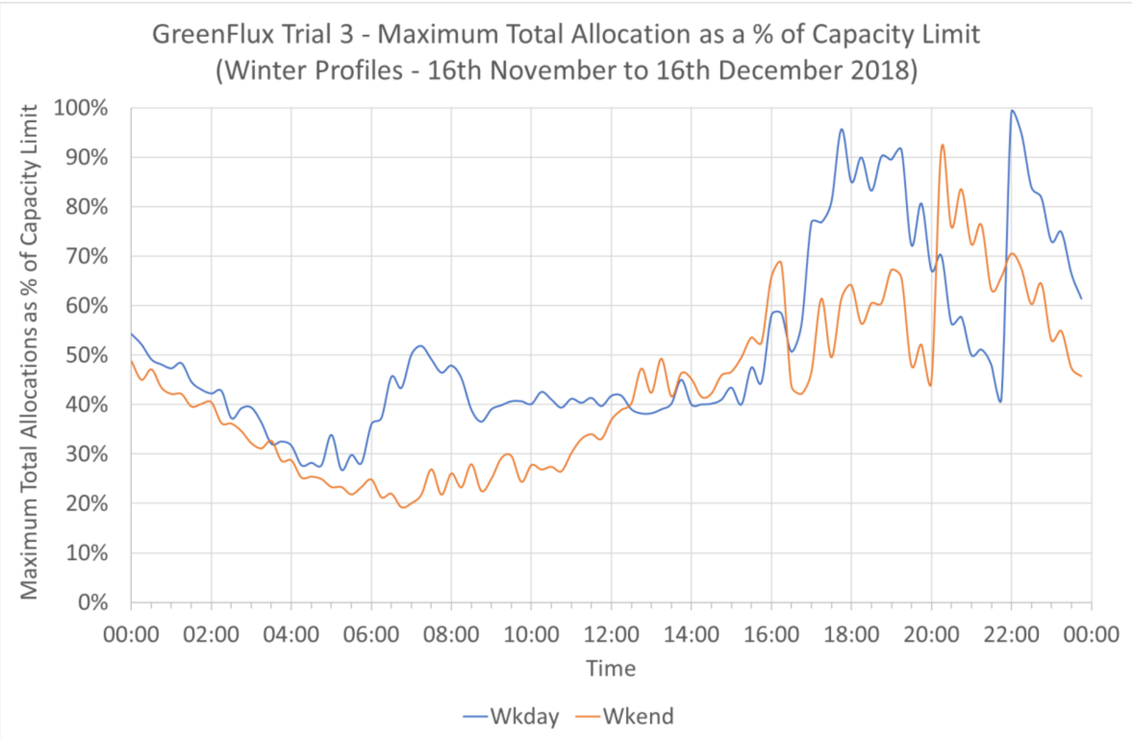

Figure 12-39: Maximum Total Allocation as a % of Capacity Limit - GreenFlux Trial 3 (Winter Profiles)

This shows that management was almost required on at least one weekday at 22:00 (point very close to 100%). During the traditional evening peak, the total current allocated was always less than 96% of the capacity limit.

The analysis above shows that sufficient network capacity was available to support the peak in demand created by the combination of the time of use incentive and smart charging/the GreenFlux app. However, there are other potential impacts of such a large spike in demand including changes in voltage (created by the sudden change in demand), and the availability of electricity generation. Creating this kind of sudden spike in demand is unlikely to be beneficial to the energy system as a whole.

A tariff alone could potentially create such a spike but offer no means by which it could be managed. Smart charging could be used to mitigate this spike, for example by randomising the start times of chargers which were set to 'minimise cost' so that the time they began to charge was more evenly distributed (e.g. between 22:00 and 02:00). This would still allow vehicles to obtain a full charge overnight but would avoid the sudden spike in demand shown above. This was explored within Section 8.10.6.

No group level management occurred during Trial 3 and therefore no analysis of the level of management experienced by individual GreenFlux participants is necessary. The impact of the time of use and charging preferences system on the 'hot unplug' rate is shown in the graph below, for those participants who took part in Trial 3.

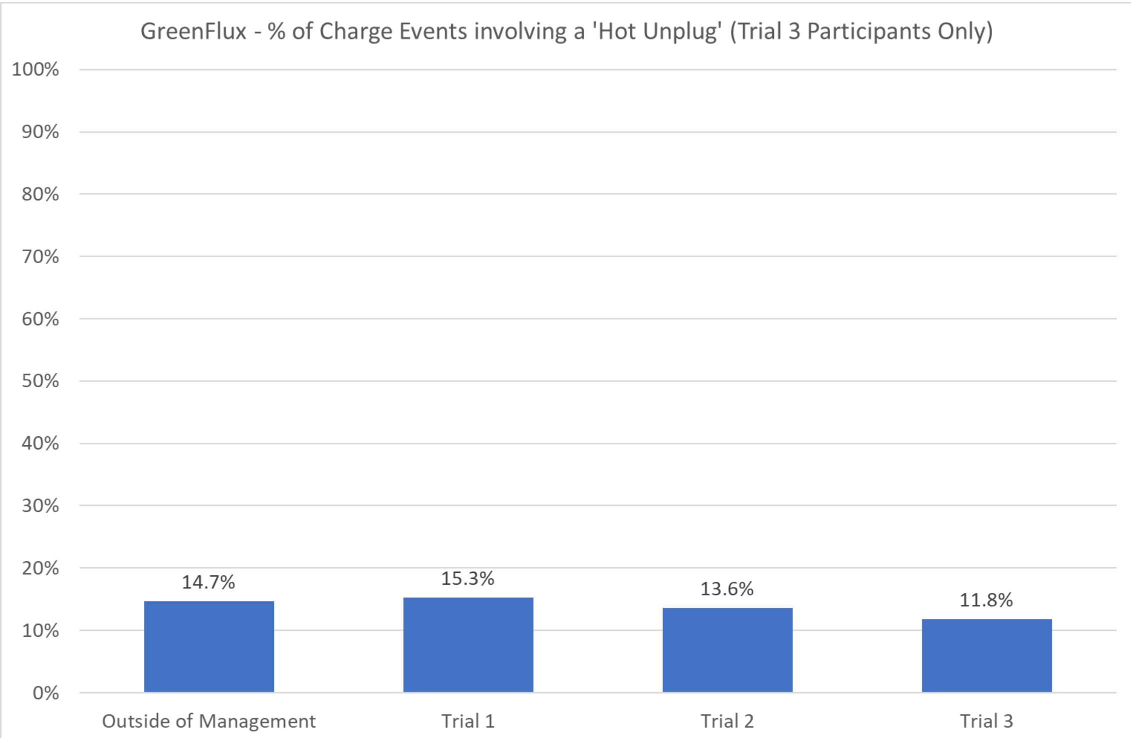

Figure 12-40: % of Charge Events Hot Unplugged - for Trial 3 Participants Only

This shows that despite the change in demand profiles achieved by GreenFlux participants (i.e. suggesting that charging did not begin until 22:00), the number of vehicles which were not fully charged when they unplugged was at the lowest point of the trial. The differences between Trial 3 and all other periods of the project shown above are statistically significant[196].

The next section focuses on the use of the app by GreenFlux participants.

12.2.4 App Usage and Reward Values

For Trial 3 the GreenFlux app was updated to allow participants to select a charging preference. The charging preference was linked to the time of use tariff to assist participants with managing their charging in response to the tariff. Participants could select one of three options, which would remain in place for all charge events until it was updated (i.e. "set and forget"). The charging preferences available were:

- Optimise Time (default option): the charger would operate as normal at all times of the day, regardless of the price. This option was set as the default, so that participants who didn't use the app were not inconvenienced;
- Minimise Cost: charging would be paused between 16:30 and 22:00, so the vehicle would only charge when the reward values were greatest (off-peak charging only); and
- Optimise Time and Cost: the system would pause charging between 16:30 and 19:00, avoiding the highest part of the peak.

The updated app also displayed information about previous charging events, including the impact they had on the participant's reward balance and the current reward balance. The high priority feature from Trial 2 was also still available. GreenFlux provided additional data for each charging event during Trial 3, showing which charging preference had been used and the time of any high priority requests made.

The amount of interactions between participants and the app can be assessed using various metrics:

- Number of times the app was downloaded (compared to the number of participants invited to download it) (this section);
- Use of the high priority feature (this section);
- The level of interaction which participant's reported in the Trial 3 survey, including their reasons for using the high priority feature and/or charging preferences, and in some cases, the reasons why they chose not to download or use the app (Section 12.2.5);
- Charging preferences used by participants (this section); and
- Reward values obtained.

[196] Z test. Trial 3 vs. Outside of Management (11.8% vs. 14.7%) Z = 5.66. Trial 3 vs. Trial 1 (11.8% vs.15.3%) Z = 7.73. Trial 3 vs. Trial 2 (11.8% vs. 13.6%) Z = 4.11.

12.2.4.1 Downloads of the GreenFlux App

The app automatically updated for those participants who had already downloaded it as part of Trial 2. All participants in Trial 3 (including 13 who did not take part in Trial 2) were invited to download the app again and provided with details of the reward system. This may have incentivised some additional participants to download the app, as it would help them to maximise their reward value. The graph below shows the number of downloads of app compared to the number of participants invited for Trials 2 and 3.

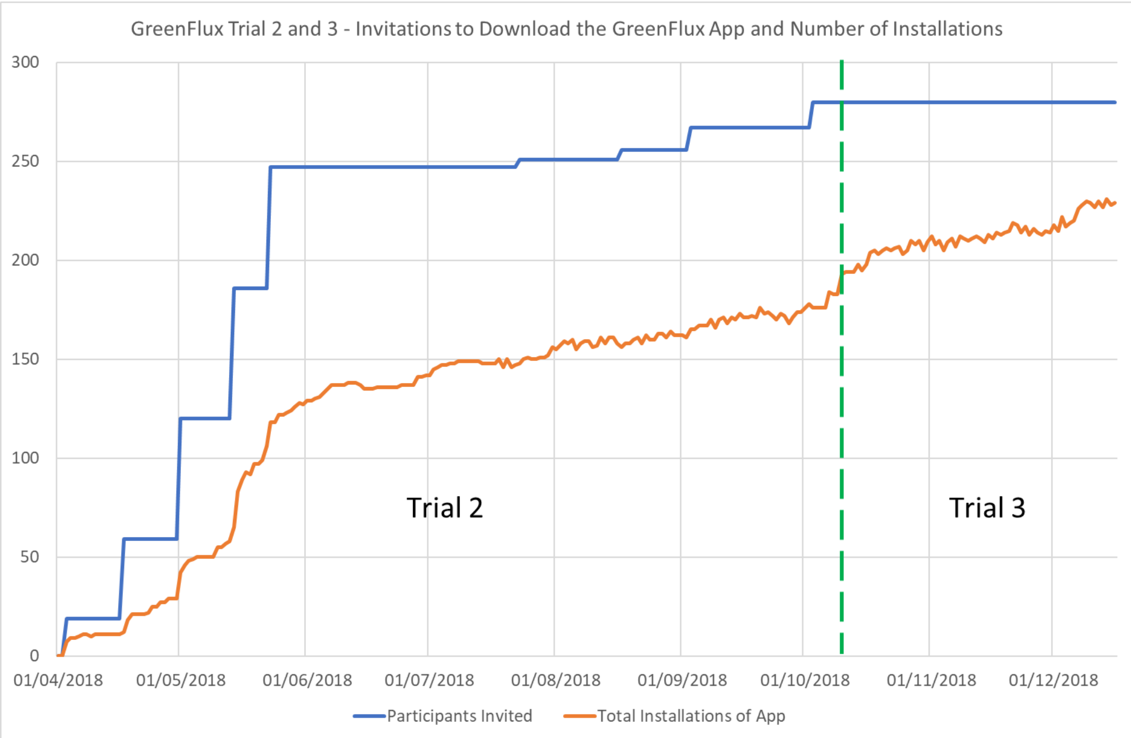

Figure 12-41: Number of Downloads of the GreenFlux App - Trial 2 and Trial 3

This shows an increase in downloads following the launch of Trial 3, and the ToU reward system. The extra downloads during Trial 3 were greater than the number of participants who were only invited to download the app at the start of the ToU trial. This suggests that the new features and the reward system encouraged some additional participants who did not download the app during Trial 2 to do so.

By the end of Trial 3 the app had been downloaded 229 times, compared to 280 invitations (82%), compared to 69% at the end of Trial 2 – a statistically significant increase[197].

12.2.4.2 High Priority Requests

The high priority feature remained available to participants during Trial 3. Transactions which took place during Trial 3 have been analysed to show the use of the high priority

[197] Z test. Trial 3 % Downloaded vs. Trial 2 (82% vs. 69%) Z = 3.54

feature. 9,895 transactions took place in Trial 3, of which 272 had an associated high priority request (2.7%).

274 participants were part of Trial 3. Transaction records exist for 246 of these participants, and 111 participants made at least one high priority request (45%). This compares to 4.2% of transactions involving a high priority request during Trial 2, and 61% of participants making requests.

The graph below shows the proportion of transactions with a high priority request through the duration of Trial 2 and 3.

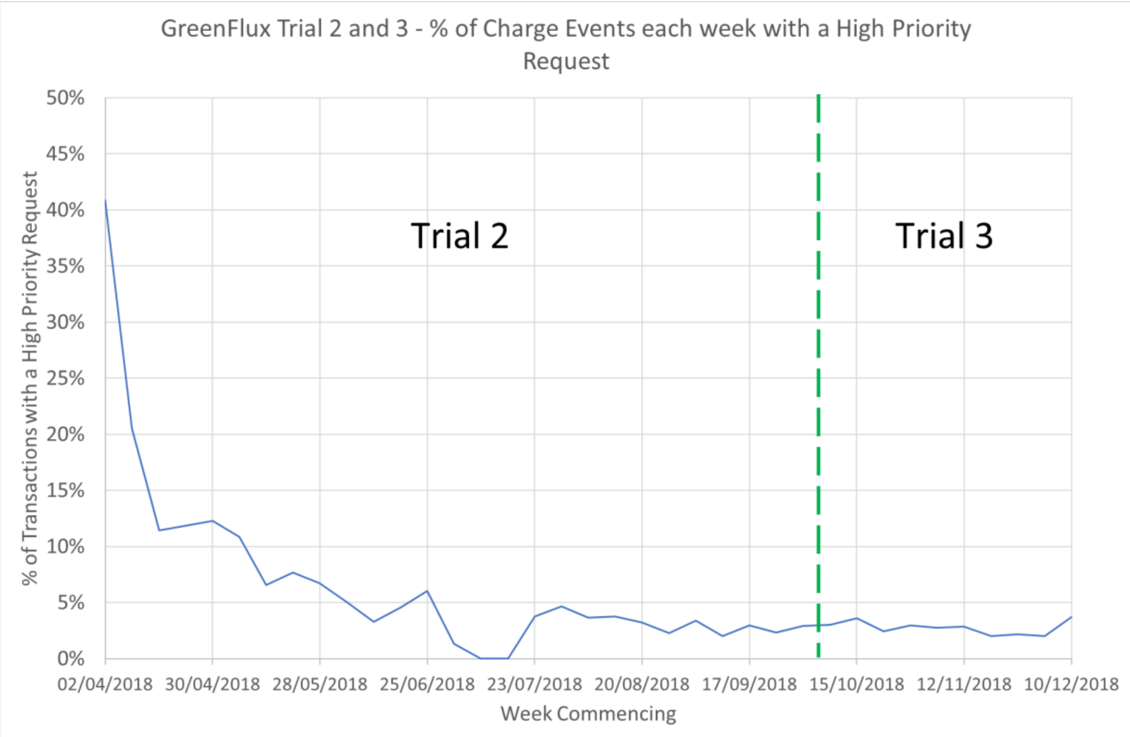

Figure 12-42: Proportion of Charging Events with a High Priority Request - by Week, Trial 2 and Trial 3

This shows that high priority requests continued at a similar rate to the end of Trial 2, even though no management was occurring during Trial 3 (see Section 12.2.3).

219 participants used their charger in both Trial 2 (after Week 27, when high priority use had stabilised) and Trial 3. The use of high priority by individual participants has been compared for the two periods, as follows:

- Those who did not use the feature in either period – 98 participants (45%);
- Those who used the high priority option during Trial 2 (Week 27 onwards) but not during Trial 3 – 22 participants (10%);
- Those who used the high priority option during Trial 3, but not Trial 2 – 45 participants (21%); and

- For participants who used the feature in both periods their use of the feature has been compared by dividing the percentage of transactions with a request during Trial 3 by the percentage with a request during Trial 2 – so, any number more than 1 indicates an increase in use of high priority during Trial 3.

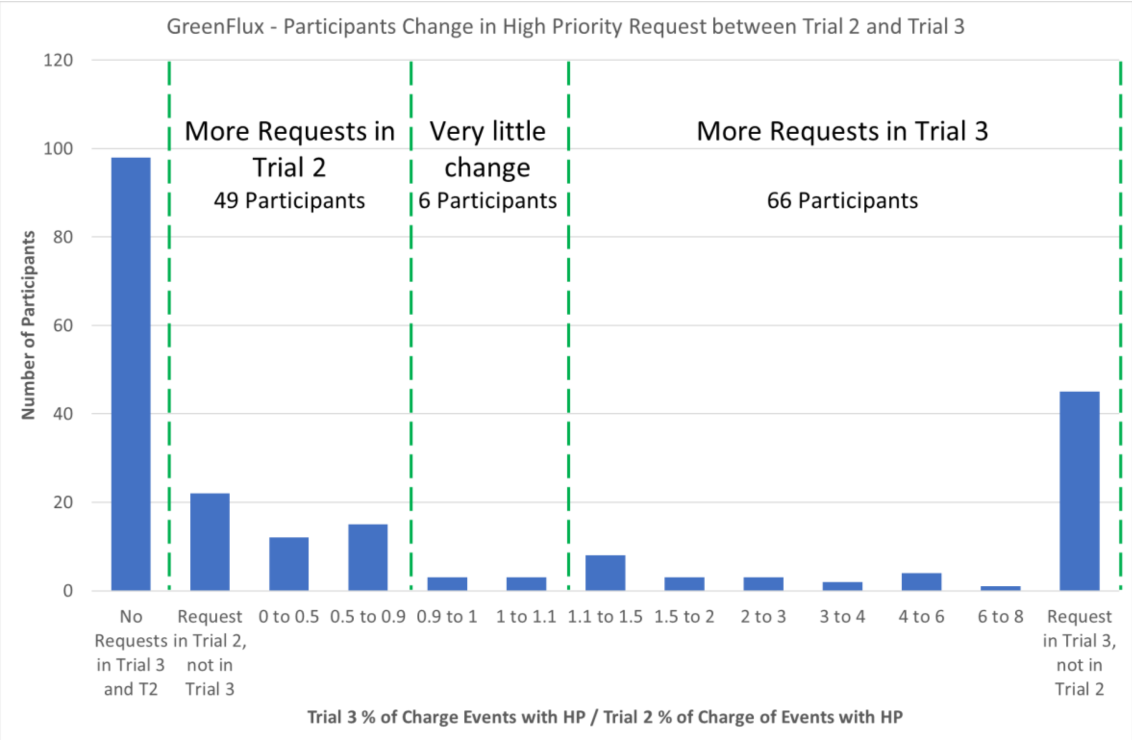

Figure 12-43: Comparing High Priority Requests by Participants - Trial 2 vs. Trial 3

The largest group of participants (98 of 219 = 45%) made no high priority requests in either trial. More participants have increased their use of the high priority feature during Trial 3 than decreased it (30% vs. 22%). As shown above, overall, use of the feature remained low, as only 2.7% of charge events included a high priority request.

The box and whisker plots below show the variation in proportion of transactions involving a high priority request, split by battery capacity and trial period (Trial 2 is based on Week 27 onwards).

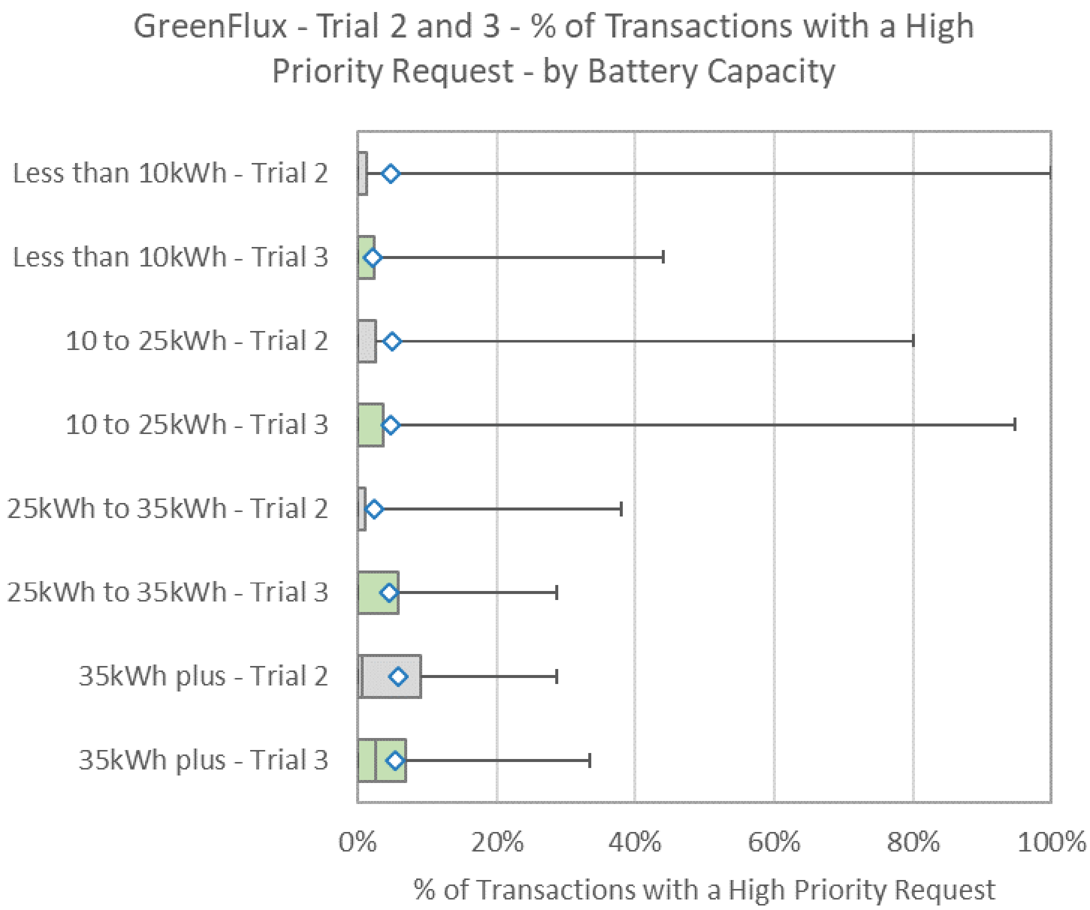

Figure 12-44: Comparing use of the high priority feature - Trial 2 vs. Trial 3 - by Battery Capacity

This shows that the majority of participants continued to use the high priority feature infrequently (75% of participants using it for less than 9% of charge events in all cases).

The proportion of transactions involving a high priority request has been calculated for each participant and analysed to compare the usage between Trial 2 and Trial 3. The only statistically significant difference was a reduction in the use of the feature by those in the '25 to 35kWh' group (at the 10% level)[198].

Comparing use of the high priority feature between battery capacity groups in Trial 3 shows that the 'Less than 10kWh' were significantly **less** likely (at the 5% confidence level) to use it than the rest of the population[199].

[198] Significance Test – Independent Means. 'Less than 10kWh' Trial 2 vs. Trial 3 Z = 1.2. '10 to 25kWh' Trial 2 vs. Trial 3 Z = 0.08. '25 to 35kWh' Trial 2 vs. Trial 3 Z =- 1.84. '35kWh plus' Trial 2 vs. Trial 3 Z = 0.07.
[199] Significance Test – Independent Means. 'Less than 10kWh' Trial 3 vs. 'All other participants' Trial 3 Z = 2.09.

Very little demand management occurred during Trial 3, as detailed in Section 12.2.3 above. However, participants continued to use the high priority feature, despite the fact that their charging was not being constrained.

Within the Trial 2 section above (see Section 11.2.5.2, Table 11-15) the proportion of transactions involving a high priority during different times of day was calculated. The same approach has been taken to show the times at which high priority requests were made in Trial 3.

Table 12-14: Proportion of Charge Events with a High Priority Request - by time of day, weekdays Trial 2 vs. Trial 3

Time Window	Weekday – Trial 2		Weekday - Trial 3	
	Number of Plug-In Events	% with High Priority Request	% with High Priority Request	% with High Priority Request
Overnight (00:00 to 07:59)	212	9.4%	261	12.6%
Daytime (08:00 to 15:59)	1,958	4.1%	1,690	6.1%
Evening Peak (16:00 to 19:59)	4,024	1.9%	3,381	1.2%
Late Evening (20:00 to 23:59)	2,195	1.4%	1,848	1.6%

In total during Trial 2 (after Week 27) there were 8,389 transactions on weekdays, of which 2.5% had an associated high priority request. In Trial 3 there were 7,180 transactions and 2.9% had a high priority request. Despite the large number of charging events involved this increase was not statistically significant[200].

Analysis of the time windows above shows that the change in proportion of charge events with a high priority in the 'daytime' and 'evening peak' periods were statistically significant[201].

[200] Z Test. 2.5% Trial 2 vs. 2.9% Trial 3. Z = 1.54.
[201] Z Test. Daytime increase from 4.1% to 6.1% Z = 2.76. Evening Peak decrease from 1.9% to 1.2% Z = 2.41.

Table 12-15: Proportion of Charge Events with a High Priority Request - by time of day, weekend Trial 2 vs. Trial 3

Time Window	Weekend – Trial 2		Weekend – Trial 3	
	% with High Priority Request	% with High Priority Request	% with High Priority Request	% with High Priority Request
Overnight (00:00 to 07:59)	92	4.3%	86	5.8%
Daytime (08:00 to 15:59)	1,226	3.3%	1,191	3.9%
Evening Peak (16:00 to 19:59)	1,023	1.8%	936	0.7%
Late Evening (20:00 to 23:59)	575	2.1%	502	1.4%

In total, during Trial 2 (after Week 27) there were 2,916 transactions at the weekend, of which 2.6% had an associated high priority request. In Trial 3 there were 2,715 transactions and 2.4% had a high priority request. Despite the large number of charging events involved this increase was not statistically significant[202].

Analysis of the time windows above shows that the decrease in the proportion of charge events with a high priority request in the 'evening peak' period was statistically significant[203].

The decrease in use of the high priority feature during the evening peak is likely to be due to participants choosing not to charge in this window because of the reward system.

12.2.4.3 Charging Preferences

The updated GreenFlux app used in Trial 3 allowed participants to select from one of three 'charging preferences'. The preferences were linked to the ToU tariff and set the times at which their charger would allow their vehicle to charge, as follows:

- Minimise cost: charger would pause charging between 16:30 and 22:00, so the vehicle only charged during the 'off-peak' period. A participant who always charged using this option would increase their reward value;
- Optimise Time (the default option, to prevent unexpected changes to charging as participants used the app for the first time): the charger would allow charging at all times, regardless of the ToU tariff. A participant who used this option and was regularly charging in the evening peak would reduce their reward value; and
- Optimise Time and Cost: an intermediate option. Charging would be paused between 16:00 and 19:30, avoiding the highest prices.

[202] Z Test. 2.6% Trial 2 vs. 2.4% Trial 3. Z = 0.48.
[203] Z Test. Evening Peak decrease from 1.8% to 0.7% Z = 2.17.

GreenFlux provided data for each transaction showing the charging preference used and this has been analysed to show the use of the three options by Electric Nation participants during Trial 3. This data consisted of 9,895 charging events – 40% on 'Minimise Cost', 6% 'Optimise Time and Cost' and 54% 'Optimise Time' (the default option). The low usage of the 'Optimise Time and Cost' option (only 6% of charge events) may indicate that participants preferred the more simple options (two extremes), or that if participants were willing to delay charging then they were happy for it to be delayed until 22:00, rather than 19:30.

This section first examines changes in charging behaviour to show how people responded to the tariff, then compares the behaviour of 'app users' to 'non-app users' before looking at what factors may affect a participant's likelihood to use the app.

Changes in Charging Behaviour

If participants wanted to maximise their reward value by avoiding charging during the peak time, they could have achieved this in several different ways:

1. Plug in their vehicle to charge at different times of day (to their 'normal' time before Trial 3), without using the app to delay charging or a timer on their car. If this method was used widely by participants, then the time at which vehicles were plugged in would differ between Trial 3 and the rest of the data;
2. Continue to plug-in at the same time, but use the app and either 'minimise cost' or 'optimise time and cost' to prevent charging during the peak; or
3. Continue to plug-in at the same time, and instead of using the app, set a timer on their vehicle to avoid charging during the peak.

Behaviour as described in point 1 would be visible by comparing the plug-in times during Trial 3 with the rest of the project. This is shown in the graphs below for weekdays and weekends.

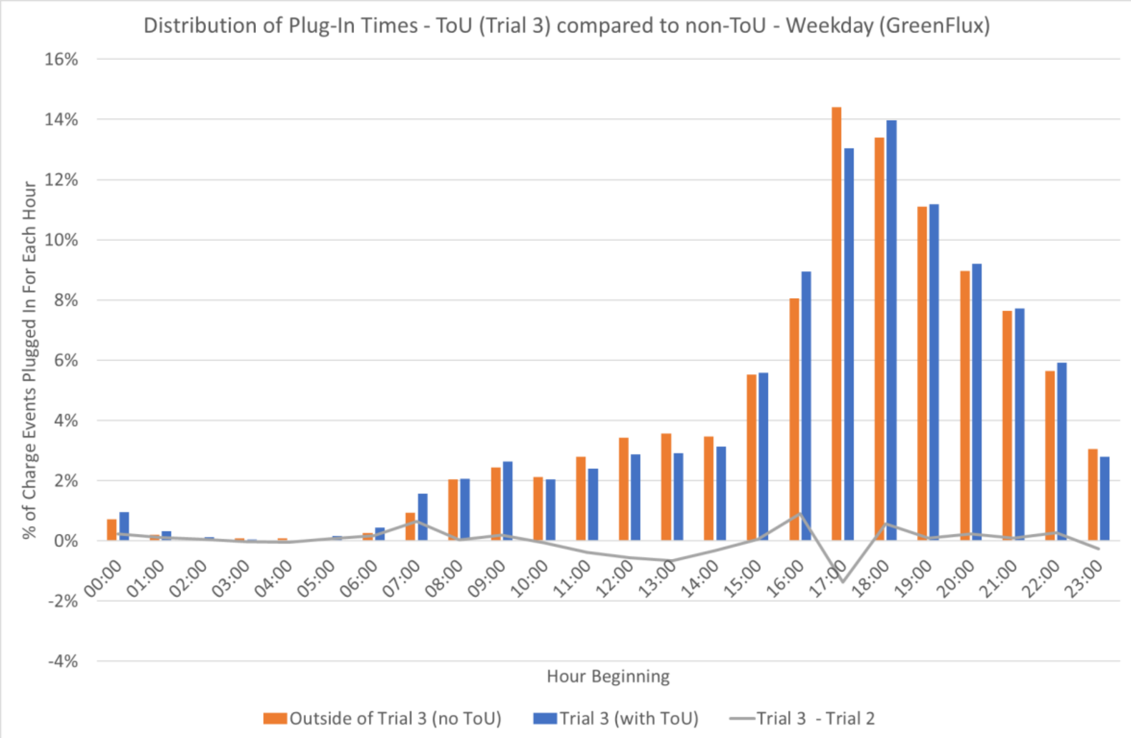

Figure 12-45: % of Plug-ins in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) - Weekdays

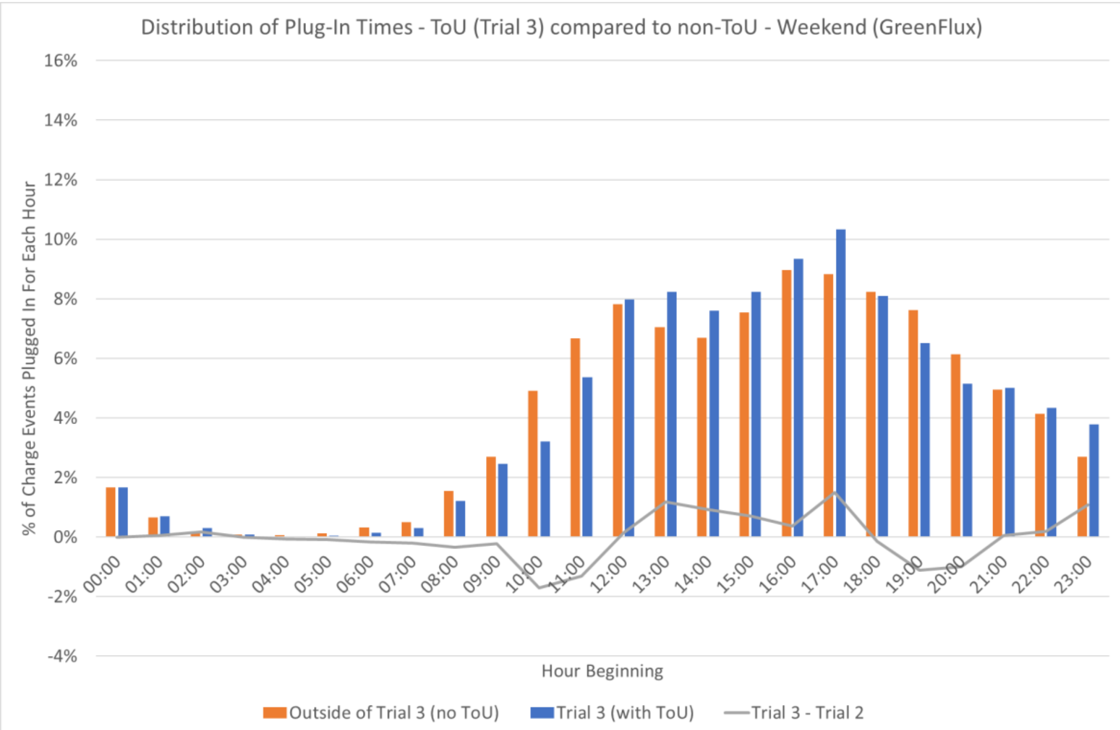

Figure 12-46: % of Plug-ins in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) – Weekend

The proportion of plug-in events which occurred during the evening peak (16:00 – 19:59) has been compared:

Table 12-16: % of Plug-In Events in Evening Peak (16:00 to 19:59) Weekday and Weekdays

	% of Plug-In Events which occurred between 16:00 and 19:59	
	Outside of Trial 3 (no ToU)	Trial 3 (ToU)
Weekday	47.0% of 49,069 events	47.1% of 7,196 events
Weekend	33.6% of 17,671 events	34.3% of 2,721 events

There was no statistically significant difference in plug-in behaviour with respect to the evening peak on either weekdays or weekends[204].

A change in behaviour using either of the methods described in Points 2 and 3 (avoiding the peak price using the app or vehicle timer) would be visible when comparing the time when charging began in Trial 3 with the rest of the project. This is shown below for weekdays and the weekend.

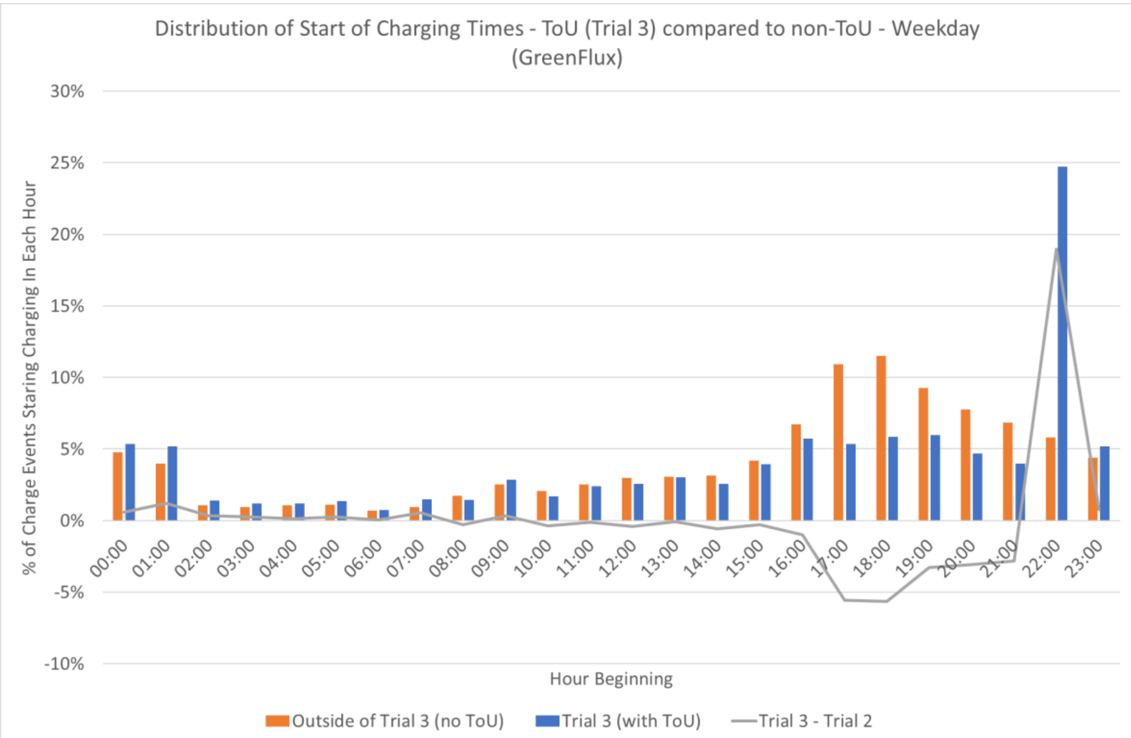

Figure 12-47: % of charge events starting in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) – Weekday

[204] Z test. Weekday 47.0% vs. 47.1% Z = 0.16. Weekend 33.6% vs. 34.3% Z = 0.72.

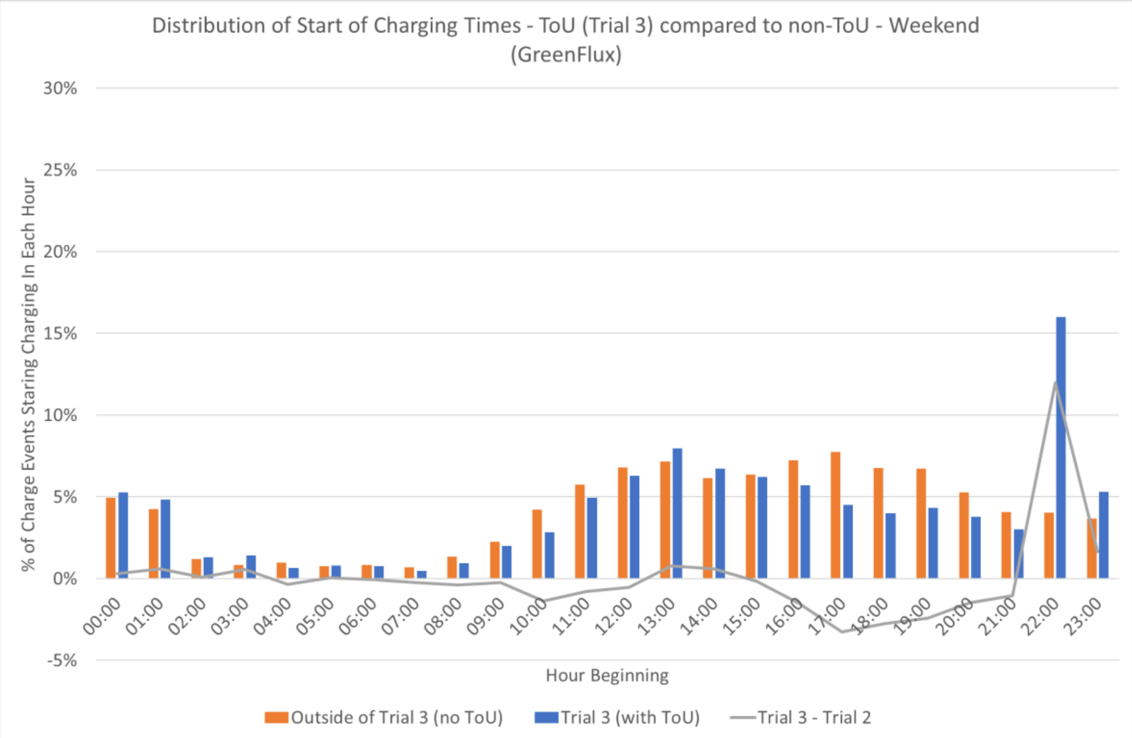

Figure 12-48: % of charge events starting in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) – Weekend

Two different time periods are compared below – the proportion of charge events beginning in the evening peak (16:00 to 19:59) and the proportion beginning between 22:00 and 22:59 – when charging sessions set to 'minimise cost' would begin.

Table 12-17: % of Charge Events Beginning in the Evening Peak and 22:00 – 22:59 Weekday and Weekdays

Time Period		% of Charge Events Beginning in Time Window	
		Outside of Trial 3 (no ToU)	Trial 3 (ToU)
Weekday	Evening Peak (16:00 – 19:59)	38.4% of 34,131	22.9% of 7,007
	Minimise Cost Start Time (22:00 to 22:59)	5.8% of 34,131	24.7% of 7,007
Weekend	Evening Peak (16:00 – 19:59)	28.5% of 12,489	18.5% of 2,643
	Minimise Cost Start Time (22:00 to 22:59)	4.0% of 12,489	16.0% of 2,643

There was a statistically significant **decrease** in the proportion of charge events beginning in the evening peak for weekdays and the weekend[205]. The **increase** in the proportion of charging events beginning between 22:00 and 22:59 was also statistically significant[206]. The

[205] Z test. Weekday 38.4% vs. 22.9% Z = 24.7. Weekend 28.5% vs. 18.5% Z = 10.6.
[206] Z test. Weekday 5.8% vs. 24.7% Z = 50.3. Weekend 4.0% vs. 16.0% Z = 23.4.

extent to which behaviour changed for participants who used the app (method 2 in the bullets above) vs. those who didn't (method 3) is explored in the next section.

App Users vs. Non-App Users

As described above, participants could change their charging behaviour to avoid charging at peak times by either user a timer on their vehicle, or via the app. Each participant has been categorised as an 'app user' (i.e. those who used a non-default profile at least once, so must have used the app) or a 'non-app user' (all their charging events were on the default profile – the use of the term app user/non-app user is based purely on the use of charging preferences and does not take high priority requests into account, or those who just used the app to view their reward balance). 61% of participants were 'app users'.

The analysis above shows that there was a substantial difference in the time charging began (but not plug-in time) during Trial 3, but does not show whether this was achieved by those using the app, or also by those who used vehicle timers alone ("non app users"). The profiles below show the % of charging events beginning in each hour during Trial 3 and before (for weekdays), first for app users, and then non-app users.

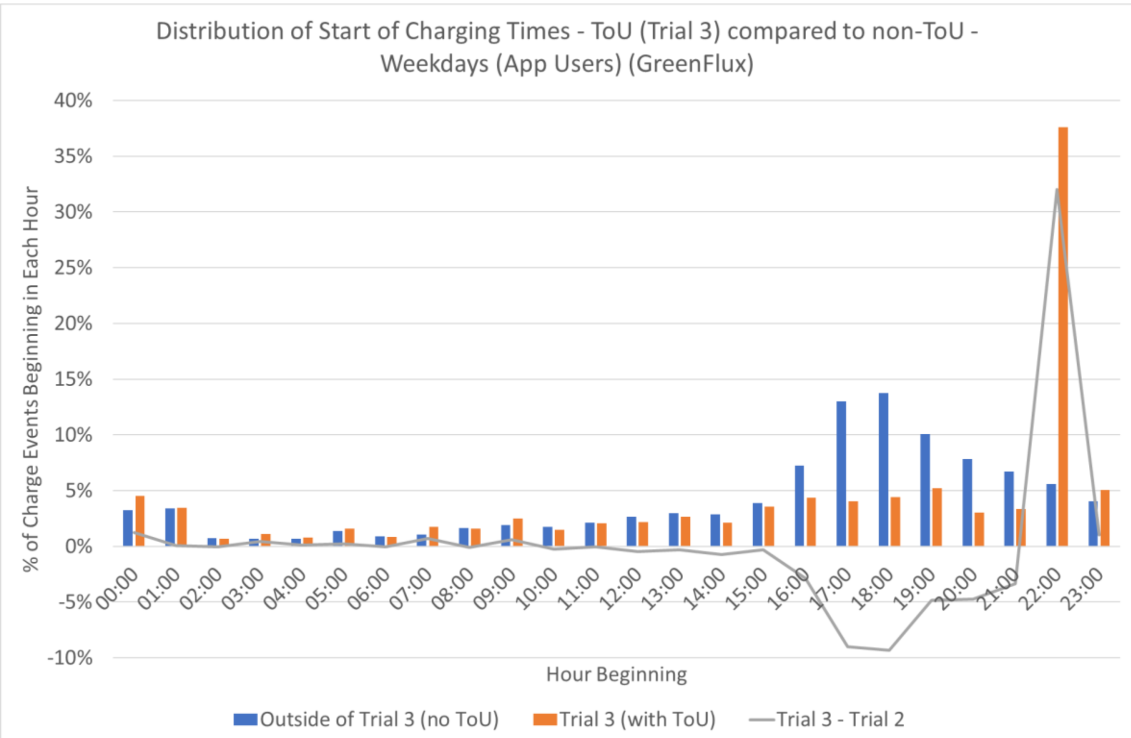

Figure 12-49: % of charge events starting in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) App Users – Weekday

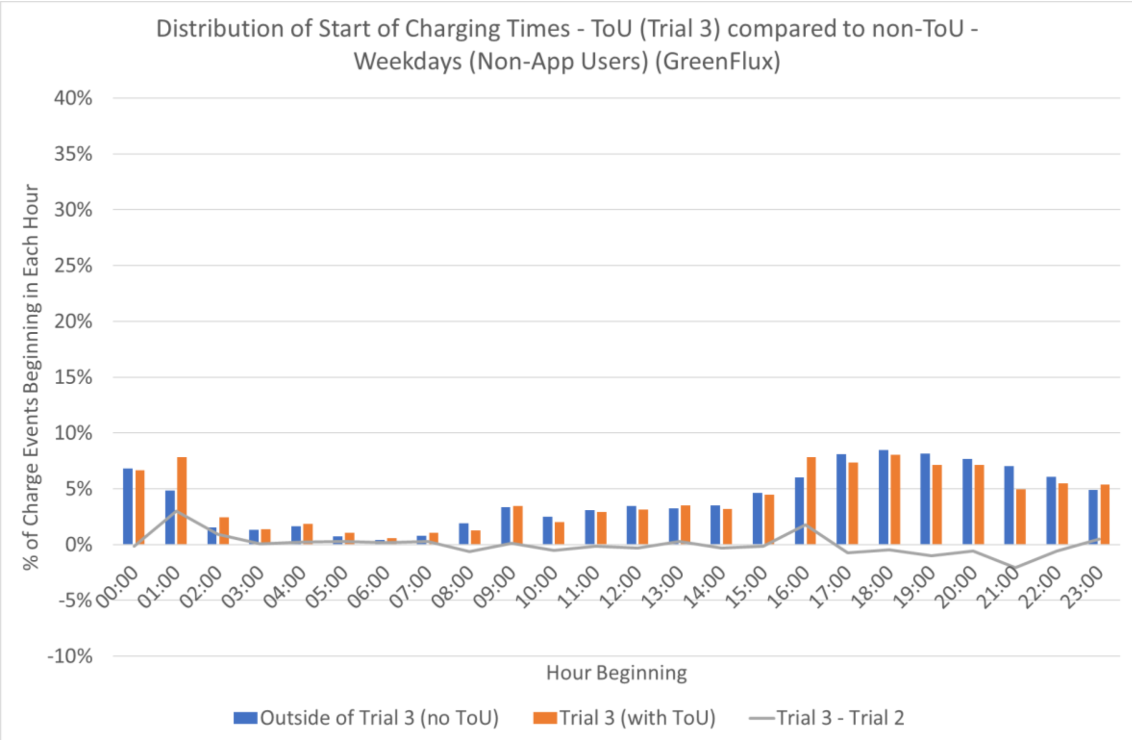

Figure 12-50: % of charge events starting in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) Non-App Users – Weekday

Table 12-18: Comparing % of Charge Events Starting in Different Time Windows - App Users and Non-App Users

Time Period		% of Charge Events Beginning in Time Window	
		Outside of Trial 3 (no ToU)	Trial 3 (ToU)
'App Users'	Evening Peak (16:00 – 19:59)	44.1% of 19,603	18.0% of 4,200
	Minimise Cost Start Time (22:00 to 22:59)	5.6% of 19,603	37.6% of 4,200
'Non App Users'	Evening Peak (16:00 – 19:59)	30.7% of 14,528	30.3% of 2,807
	Minimise Cost Start Time (22:00 to 22:59)	6.1% of 14,528	5.5% of 2,807

Comparing the 'Outside of Trial 3' data for the two groups shows that 'non-app users' were already significantly less likely (c.f. 'app users') to start their charging events in the peak price period before Trial 3 began[207], so they were less likely to be affected by the peak prices. This may explain the groups continuing use of the default charging preference –

[207] Z test. 44.1% (app users) vs. 30.7% (non-app users). Z = 25.2.

because they were charging in the peak less often, they saw less of a benefit from the 'minimise cost' (or 'optimise time and cost') profile accessed via the app.

The 'Trial 3' behaviour in the first graph shows the dramatic change made by app users. The proportion of charging events beginning the evening peak (16:00 to 19:59) dropped substantially (44% of all charging events outside of Trial 3 began between 16:00 – 19:59 for this group, compared to just 18% in the same time window during Trial 3). This was result was statistically significant[208]. Most of these events now begin at 22:00, when all chargers on "minimise cost" begin charging.

Those participants who did not use the app (Figure 12-50) did not make the same level of changes. For this group 30.7% of their charging events began between 16:00 and 19:59 before Trial 3. During Trial 3 30.3% of charge events began in the same period – no statistically significant difference[209]. Figure 12-50 appears to show a slight increase in the proportion of charging events beginning between 00:00 and 01:59. Outside of Trial 3, 11.6% of 'non-app' users charging events began in this window. This increased to 14.5% during Trial 3 – a statistically significant increase[210].

The two plots below show the same analysis, for weekend days.

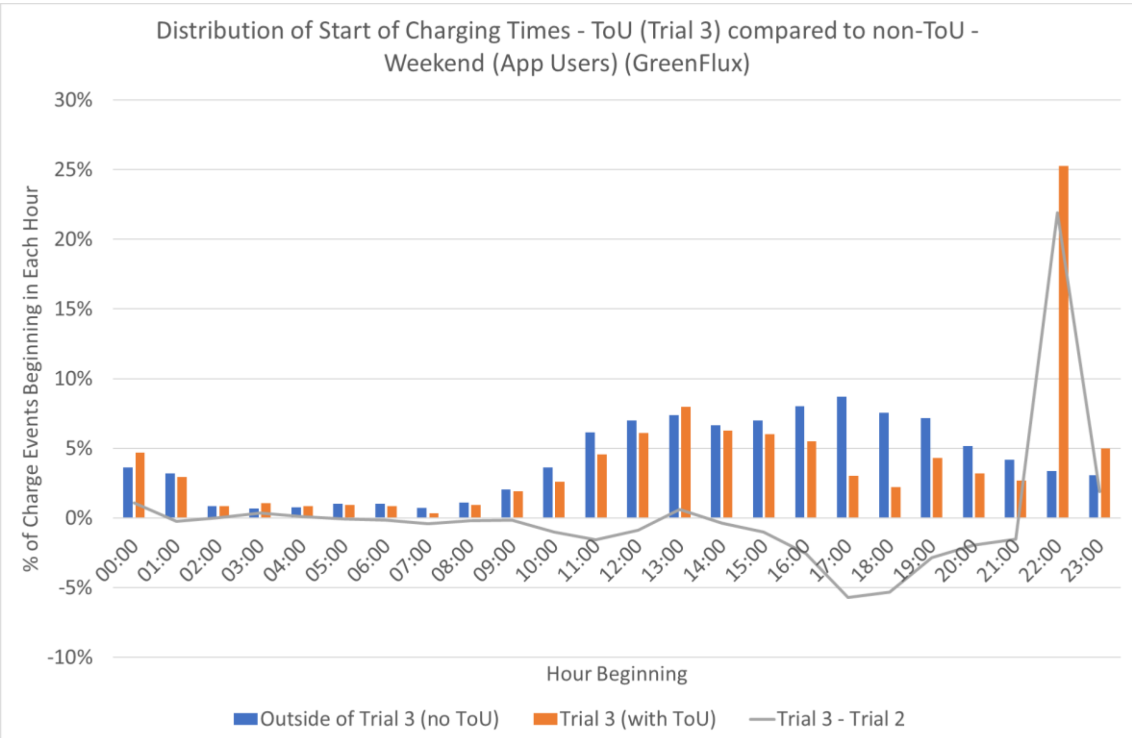

Figure 12-51: % of charge events starting in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) App Users – Weekend

[208] Z test. 44.1% vs. 18%. Z = 31.4.
[209] Z test. 30.7% vs. 30.3% Z = 0.42.
[210] Z test. 11.6% vs. 14.5% Z = 4.32.

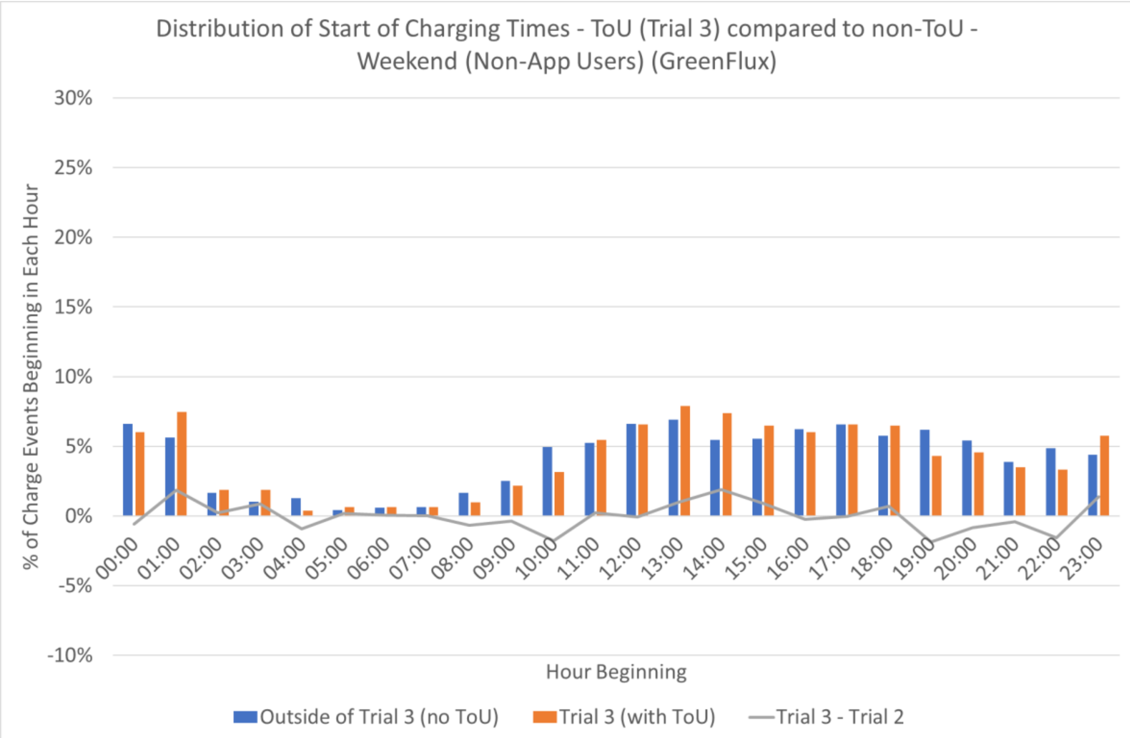

Figure 12-52: % of charge events starting in each hour - Trial 3 (ToU) vs. Rest of Trial (no ToU) Non-App Users – Weekend

The number of charging events which began in the evening peak were lower at the weekend throughout the trial. However, at the weekend this demand was also moved to 22:00 for the ‘app users’ group.

This effect can also be visualised on a participant by participant basis. For each participant, the percentage of their charge events which began in the weekday evening peak (defined as Monday – Friday 16:00 – 19:59) has been calculated, both during Trial 3 and outside it.

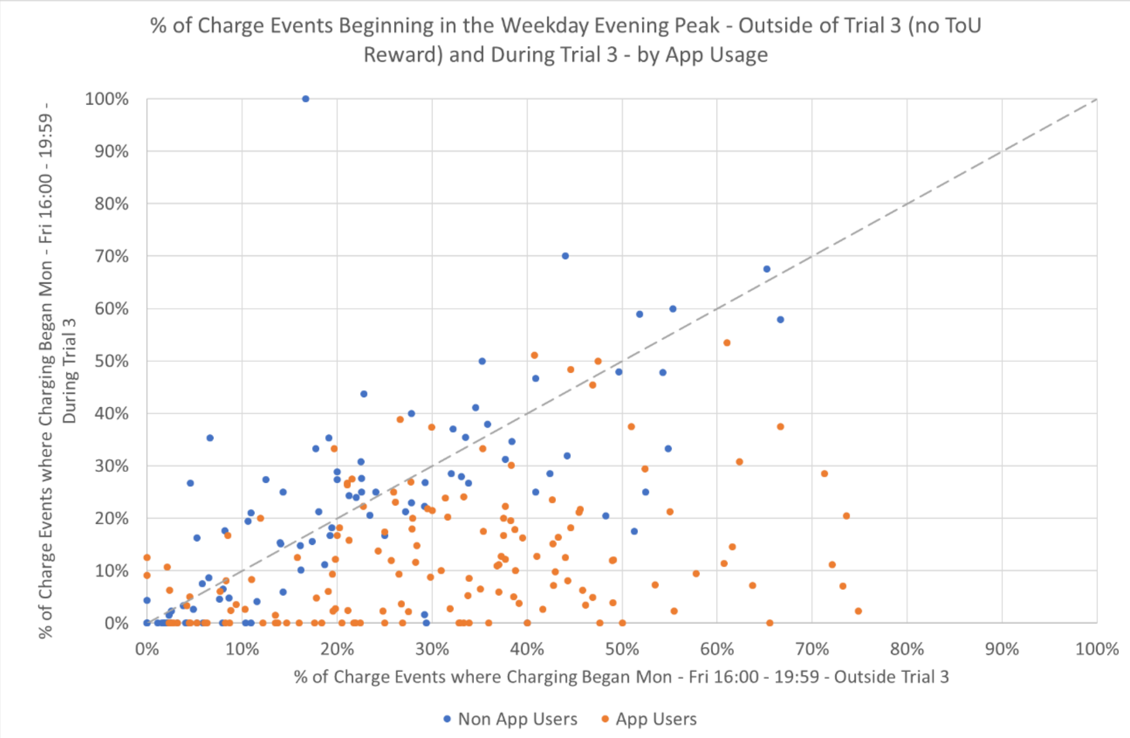

Figure 12-53: % of Charging Events beginning in Weekday Evening Peak for Each Participant - ToU and Non ToU - App Users and Non-App Users

Each dot on the chart above represents a single participant. All participants below the dotted line moved their charging away from the evening peak (i.e. fewer events beginning in the weekday evening peak during Trial 3 than before it). This shows that majority of participants moved in the expected direction based on the financial incentive. It also shows that the changes made by app users were larger – more of the markers in the bottom right are 'app users' (orange). The data in the graph is summarised in the table below.

Table 12-19: Movement of Charging Away from Evening Peak - App Users and Non-App Users

Category	Trial 3 vs. Outside of Trial 3		
	Lower % of Transactions Beginning in the Weekday Evening Peak	**Equal %** of Transactions Beginning in the Weekday Evening Peak	**Higher %** of Transactions Beginning in the Weekday Evening Peak
All Participants	77% (185)	1% (3)	22% (53)
Participants who used the app	89% (131)	0% (0)	11% (16)
Participant who did not use the app	57% (54)	3% (3)	39% (37)

The analysis above shows that although the majority of participants moved their charging away from the evening peak to some extent when incentivised by the tariff/reward system and the largest and most consistent changes were made by those who used the app.

Factors Influencing App Usage

The data provided by GreenFlux for sessions during Trial 3 covers 9,895 charging events[211]. 274 participants were part of the Trial 3 group, and a charging record exists for 246 of these participants (90%). The remaining participants may have not used their charger during the Trial 3 period, or their charger may have been offline.

If any charge events took place on either the 'minimise cost' or 'optimise time and cost' settings then the participant must have interacted with the app, in order to change the preference from the default ('optimise time'). 149 of the 246 participants with transactions during Trial 3 used these preferences (61%). The remaining 39% of participants may have not downloaded the app at all (see Figure 12-41). Alternatively, they may have chosen to remain on the default option and potentially maximised their reward value by charging outside the peak (either due to their plug-in time, or by using a timer). This was shown above.

The box and whisker diagram below shows the distribution of the percentage of plug-in events on either of the 'non-default' options (minimise cost or optimise time and cost), by battery capacity.

[211] Only charging events where greater than 0.5kWh was consumed are included in the analysis.

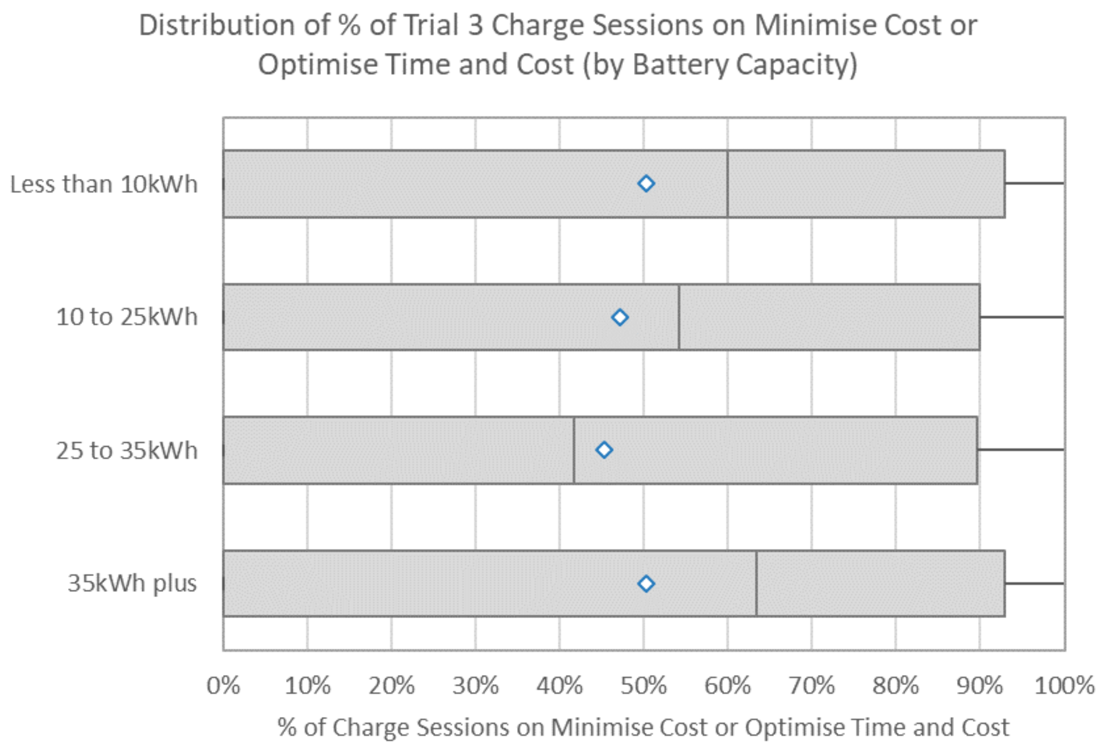

Figure 12-54: Distribution of % of Trial 3 Charging Sessions on 'non default' preference - by Battery Capacity

The plot shows considerable variation in the level of use of different charging preferences by participants, both by EV type and battery capacity, as the interquartile range (the size of the central box) is large. Other factors may also influence the extent to which participants used 'non-default' options. The charging events for each participant have been analysed to determine which charging preference they used most often. The composition of each group of participants has been analysed. Amongst all Trial 3 participants:

- 47% of participants used 'Minimise Cost' most often;
- 6% Optimise Time and Cost; and
- 47% Optimise Time.

If a particular group (e.g. owners of PHEVs) were more likely to use a particular option, then the breakdown for that group would differ. The table below explores this for a variety of vehicle/driver attributes which may influence the tendency of a participant to either be flexible with their charging behaviour or seek to maximise their financial reward. The table shows the percentage of the group using each of the three options most option. It also shows the proportion of each group who used a "non default" preference most often (i.e. either 'minimise cost' or 'optimise time and cost'). These participants have chosen to use a non-default option and the tendency of each sub-group (e.g. PHEV owners) to do this has been compared to the population as a whole, and between sub-categories (e.g. PHEV vs. REX or PHEV vs. BEV). The results of this analysis are described below the table.

Table 12-20: % of Different Sub-Groups Using Different Charging Preferences Most Often

	Category	No. of Participants	% of Group Using Preference Most Often			% of Group Using a Non-Default Option Most Often
			Minimise Cost	Optimise Time and Cost	Optimise Time	
	All Participants	244	47%	6%	47%	53%
EV Type	PHEV	95	51%	6%	43%	57%
	REX	34	56%	3%	41%	59%
	BEV	115	42%	6%	52%	48%
Battery Capacity	Less than 10kWh	66	48%	6%	45%	55%
	10 to 25kWh	62	50%	3%	47%	53%
	25 to 35kWh	69	46%	1%	52%	48%
	35kWh and above	47	43%	15%	43%	57%
Age	No response	13	54%	8%	38%	62%
	18 to 35	32	53%	3%	44%	56%
	36 to 45	69	49%	3%	48%	52%
	46 to 55	74	47%	4%	49%	51%
	56 to 64	36	42%	8%	50%	50%
	65+	20	35%	20%	45%	55%
Uses of the Vehicle	Social Only	38	34%	11%	55%	45%
	Business and Commuting	65	51%	6%	43%	57%
	Commuting	79	52%	3%	46%	54%
	Business	27	44%	7%	48%	52%
Ownership Type	Bought the Vehicle	91	58%	10%	32%	68%
	Leasing Vehicle	58	41%	2%	57%	43%
	Company Car	46	54%	4%	41%	59%
Motivation for Getting a EV Included:	Lower running costs	130	58%	6%	36%	64%
	Environmental benefits	111	50%	5%	45%	55%
	Like to have the latest technology	69	65%	7%	28%	72%
	Easier /smoother drive	33	67%	6%	27%	73%

	Category	No. of Participants	% of Group Using Preference Most Often			% of Group Using a Non-Default Option Most Often
			Minimise Cost	Optimise Time and Cost	Optimise Time	
	Company scheme available	28	39%	7%	54%	46%
Use of other charging facilities[*1]	Home only	128	47%	5%	48%	52%
	Charging at work	36	75%	8%	17%	83%
	Charging elsewhere	23	52%	9%	39%	61%
Typical weekly mileage	0 to 75 miles	29	62%	0%	38%	62%
	75 to 200 miles	95	52%	7%	41%	59%
	200 to 350 miles	50	48%	6%	46%	54%
	350+ miles	21	52%	10%	38%	62%
PV Installed at Home	No	178	47%	6%	47%	53%
	Yes	53	45%	4%	51%	49%

[*1]: Definitions have been used as defined in Section 8.3. Participants have been categorised using the responses they gave in the Trial 3 survey.

Each sub-group has been compared against the population as a whole to show which groups had a statistically significant lower or higher tendency to select a non-default option:

- Participants who had bought their vehicle were significantly **more likely** to use a non-default option (68% of this group, compared to 53% of the whole population[212]);
- Participants who leased their vehicle were significantly **less likely** to use a non-default option (43% of this group) (significant at the 10% level)[213];
- Participants whose motivation for getting a PEV included the following reasons were significantly **more likely** to use a non-default option[214]:
    - Lower running costs (64% of this group)
    - Latest technology (72% of this group)
    - Easier/smoother drive (73% of this group)
- Participants who also charged their vehicle at work were significantly **more likely** to use a non-default option (83% of this group)[215].

[212] Z = 3.68
[213] Z = 1.71 (a value of 1.64 indicates confidence at the 10% level – 1.96 would be required for the 5% level).
[214] Lower running costs Z = 3.67. Latest technology Z = 3.85. Easier/smoother drive Z = 2.46.
[215] Z = 3.97

There may also be differences within sub-groups – for example, were participants who owned their vehicle through a company scheme significantly more likely to use a non-default option when compared to those who leased their vehicles. The statistically significant differences are summarised below:

- Participants who bought their vehicle were significantly **more likely** to use a non-default option compared to those who leased their vehicle (68% vs. 43%)[216];
- Participants who only charged their vehicle at home were significantly **less likely** to use a non-default option compared to those who also charged at work (52% vs. 83%)[217];
- Participants who were motivated to get a PEV by the environmental benefits were **less likely** to use a non-default option compared to those who were motivated by a desire to have the latest technology (55% vs. 72%)[218];
- Participants who were motivated to get a PEV because of the availability of a company scheme were **less likely** to use a non-default option (46%) compared to both those motivated by an interest in the latest technology (72%) and those who were attracted by an easier/smoother driving experience (73%)[219]. If a 10% confidence level is used then they were also **less likely** to use a non-default option compared to those motivated by lower running costs (64%)[220]; and
- Participants who were motivated by an easier/smoother driving experience were **more likely** (73%) to use a non-default option compared to those who were motivated by the environmental benefits of PEVs[221] (55%).

Use of “non default” (minimise cost or optimise time and cost) charging preferences may have varied through the course of Trial 3. This has been visualised in the heat map below which shows a row for each participant (only including those who used a non-default option in at least one week during Trial 3 (Week 43 (w/c 22nd October) to Week 50 (w/c 10th December). The three plots below each represent one third of the participants.

[216] Z = 3.02
[217] Z = 3.34
[218] Z = 2.28
[219] Company scheme vs. latest technology Z = 2.42. Company scheme vs. easier/smoother drive Z = 2.15.
[220] Z = 1.77 (1.96 required for 5% confidence level, 1.64 required for 10%)
[221] Z = 1.85

% of Charge Events on Non-Default Option - by Week Number

43	44	45	46	47	48	49	50
100%	100%	100%		100%	100%		100%
100%	100%	100%	100%	100%	100%	100%	100%
		100%				100%	50%
0%	0%	100%	100%	100%	100%	100%	100%
50%	100%	75%	50%	67%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
75%	82%	100%	71%	100%	100%	64%	9%
100%	100%	100%	100%		100%	100%	
0%	0%	100%	100%	100%	100%		100%
67%	100%	100%	100%	100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	100%
0%	0%	33%	0%	100%		100%	
100%	100%	0%	0%	0%	0%	0%	0%
100%	100%	100%	100%		100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	33%	83%	100%	100%	100%	100%	100%
0%	0%	0%	67%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	67%	100%
0%	0%	0%	100%	100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	33%	71%	100%
0%	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	67%	100%	100%
0%	0%	0%	0%	18%	0%	0%	33%
100%	100%	100%		100%		100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	
100%	100%	100%	50%	75%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
0%		100%	100%	100%	100%		100%
100%	100%		100%		100%	100%	
100%	100%	100%	100%	100%	100%	100%	100%
0%	0%	0%	0%	0%	0%	0%	0%
100%		100%	100%	100%	100%	100%	100%
0%	0%	0%	0%	57%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	14%	0%	0%	0%
100%	100%	100%	100%	100%	75%	100%	100%
0%	0%	0%	100%	100%	100%	100%	100%
100%	100%			100%	100%	100%	100%
		100%			100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%

% of Charge Events on Non-Default Option - by Week Number

43	44	45	46	47	48	49	50
0%	0%	100%	100%	100%	100%	100%	100%
0%		33%			100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%		100%	100%
0%	0%	20%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	67%	100%	100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
50%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	89%
100%	100%	100%	100%	100%	100%	100%	50%
100%	100%			100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	80%	80%
0%	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%		100%	100%	100%	100%	100%	100%
0%		100%	100%	100%	100%	100%	100%
		100%		100%	100%		
0%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	100%	100%	100%	100%	100%
100%		100%	100%	100%		100%	
100%	100%	100%		100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
		100%		100%	100%		
100%	100%	100%	100%	100%	100%	100%	100%
	0%		0%	0%	0%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
0%		100%	100%	100%	100%	100%	0%
		100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	88%	57%	100%	100%	100%	100%	86%
100%	100%	100%					
100%	100%	100%	100%	100%	100%	100%	100%
0%	0%	0%	0%	0%	0%	0%	0%
							100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
	0%	100%					

% of Charge Events on Non-Default Option - by Week Number

43	44	45	46	47	48	49	50
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
0%	0%	0%	40%	40%	100%	100%	100%
100%		100%	100%	100%	100%		
100%	100%	100%	100%	100%	100%	100%	100%
100%		100%	100%		100%	100%	100%
100%	100%	100%	100%		100%	100%	
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
0%	0%	0%	0%	0%	0%	0%	0%
0%	0%	33%	83%	100%	100%	100%	100%
	100%	100%	100%	100%	100%	100%	80%
100%	100%	100%	100%	100%		100%	100%
100%		100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	73%	100%
78%	100%	100%	100%	100%	73%	90%	89%
0%	0%	22%	100%	100%	100%	100%	100%
0%	33%	100%	100%	100%	100%	100%	100%
67%	100%	100%	100%	100%	100%	100%	100%
67%	100%	100%	100%	100%	100%	100%	100%
0%	0%	100%	100%		100%	100%	100%
100%	100%	100%		100%	100%	100%	100%
	100%	100%	100%	100%	100%	100%	100%
0%	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%			
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
					100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
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100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%		100%		100%	
0%	100%	100%	100%	100%	100%	100%	100%
0%	0%	100%		100%	100%		100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	75%	0%	0%	100%	25%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	
	80%				67%	100%	100%
100%	100%		100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%
100%	100%		100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%		
0%	25%	100%	100%	100%	100%	100%	100%
	0%	100%	100%	100%	100%	100%	100%
100%	100%	100%	67%	50%	100%	100%	50%

Figure 12-55: Heat Map - % of Charge Events on a non-default profile, by week number, one row per participant

- % figures show the proportion of charge events for each participant, for each week, where either 'Minimise Cost' or 'Optimise Time and Cost' were used
- Colour coding is based on % of charging events in week. Red fill indicates a week where all charge events were on 'Optimise Time'. Green fill indicates all charge events were on 'Minimise Cost' or 'Optimise Time and Cost'. Weeks with no charging events are blank (no number, no fill).

This appears to indicate that for the majority of participants once they had changed their preference (either to a non-default option, or back to the default) they kept the same preference, as rows generally remain the same colour across multiple weeks. A smaller number of participants have switched preferences from week to week (e.g. the bottom row of the right-hand plot, or five rows down in the left-hand plot). This also appears to indicate that the majority of participants either use a non-default option for all their transactions, or not at all (as participants who never used minimise cost or optimise time and cost are excluded from the above plot).

12.2.4.4 Reward Values

All participants began Trial 3 with a reward value of £10. Regularly charging during the peak period (where the price was greater than 15p/kWh) would decrease the reward value and charging in the 'off-peak' time would increase the reward value. Once a participant had reduced their reward to zero it did not decrease any further – so a change in behaviour would immediately start increasing reward value. At the end of the trial, the reward values were converted to an Amazon voucher (as a proxy for the saving in charging cost they had achieved) which was issued to each participant. The average reward was £22.41.

The histogram below shows the final reward values achieved by the 246 participants who used their charger during Trial 3.

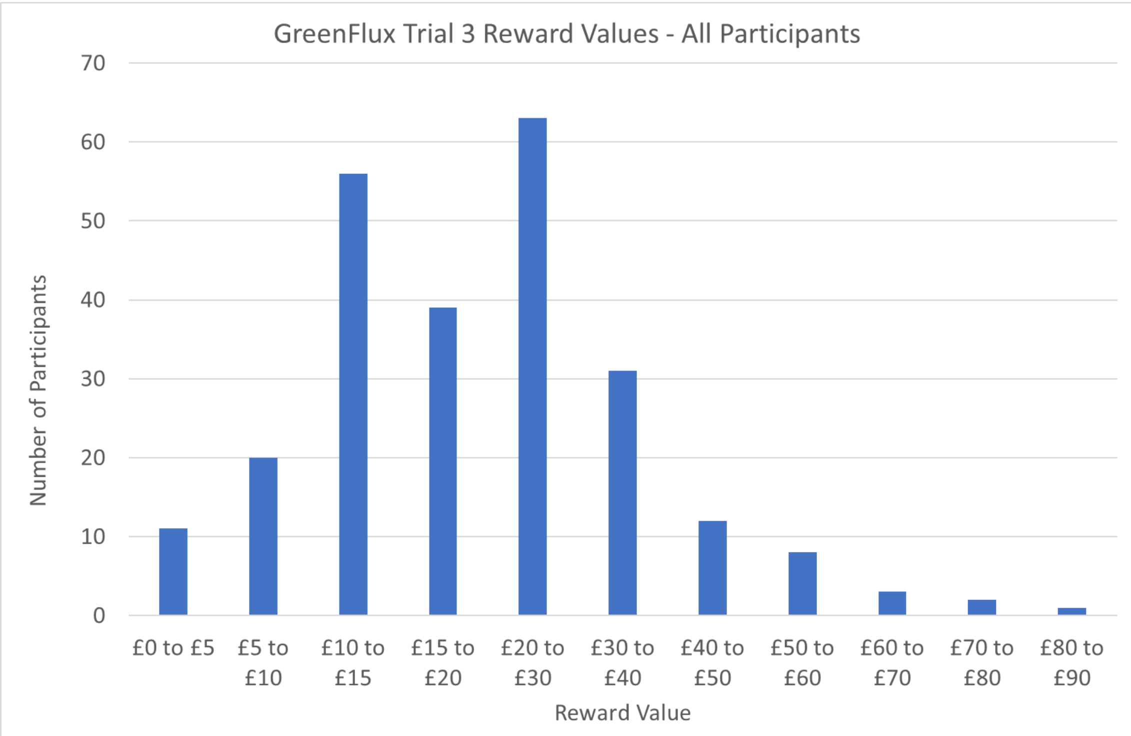

Figure 12-56: GreenFlux Trial 3 Reward Values

The box and whisker diagrams below compare the reward values obtained by different groups – first by 'App Users' and 'Non-App Users', then by participant's most frequently used charging option.

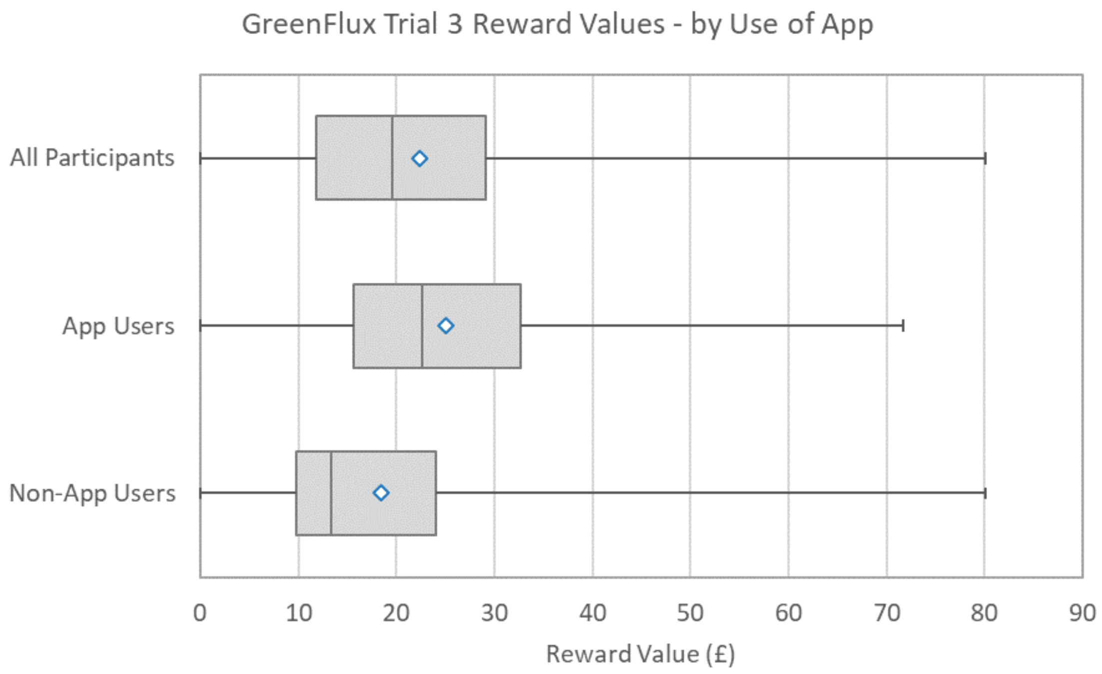

Figure 12-57: Distribution of Trial 3 Reward Value - by App Users and Non-App Users

This shows that the majority of the 'app users' earned a higher reward value than those who did not use the app (higher lower quartile, median and upper quartile). App users were significantly more likely to earn a higher reward than non-app users[222]. However, the two participants who earned the highest, and second highest, reward values were not app users – it is likely that these participants were already charging outside of the peak prior to Trial 3 (e.g. they were on Economy 7), particularly when viewed alongside the graphs showing the change in the time when charging began for the 'non-app users' group, above.

[222] Significance test for independent means. Z = 3.64.

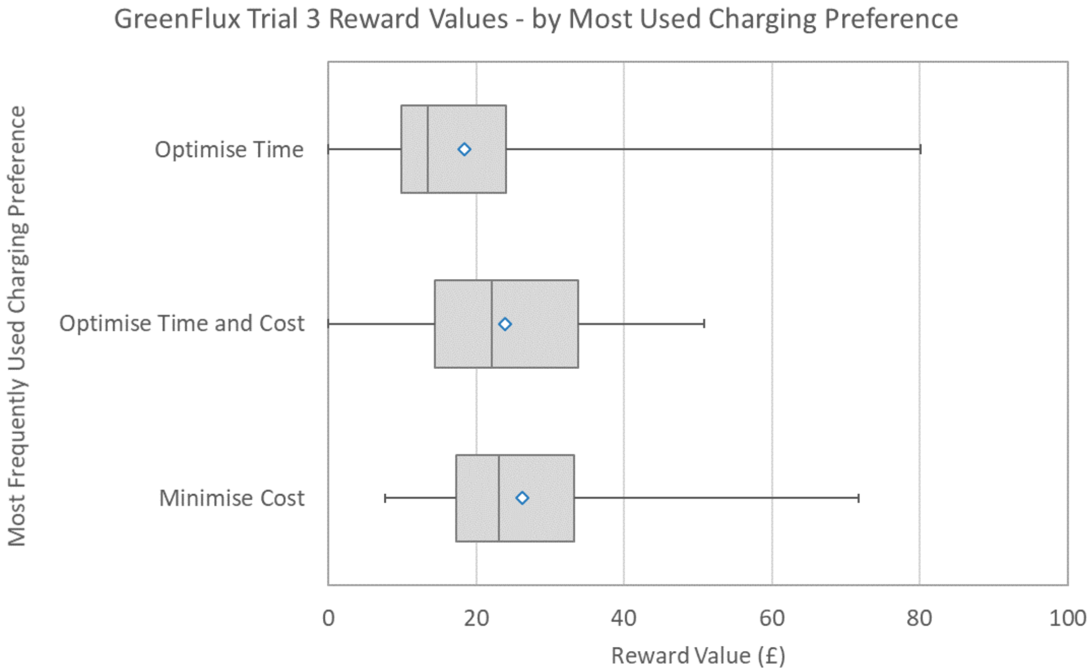

Figure 12-58: Distribution of Trial 3 Reward Value - by Most Used Charging Preference

This shows that participants who selected an off-peak option tended to earn a higher reward value. Participants who used the 'Minimise Cost' option most often earned a statistically significant higher reward than those who used 'Optimise Time[223]' (the differences in relation to 'Optimise Time and Cost' were not statistically significant due to the small sample size[224]). However, even among the 'Optimise Time' group the median reward value was above the £10 starting value (£13.50). A unit consumed in the peak would reduce the reward value by 14p, compared to a unit consumed off-peak increasing it by 5p. This differential suggests that for a 'non-app user' (or a participant who used 'optimise time' most frequently) to increase their reward value they would have needed to carry out the majority of their charging outside of the peak period.

12.2.5 Customer Research Results

Trial 3 participants were asked to complete a survey by Impact between 5th December 2018 and 8th January 2019. Those who completed the survey were rewarded with a £10 Amazon voucher (on condition that they had also completed the Recruitment and Baseline surveys). All qualifying Trial 3 participants were invited to complete a survey, regardless of whether they had downloaded or used the GreenFlux app. This reward was in addition to any reward they received linked to their charging behaviour and the time of use tariff.

[223] Significance test for independent means. Z = 4.27.

[224] Significance test for independent means. Z = 1.31 (Optimise Time vs. Optimise Time and Cost) and Z = 0.63 (Minimise Cost vs. Optimise Time and Cost).

The Trial 3 survey consisted of many of the same quantitative and qualitative questions that appeared in the Baseline and Trial 1 and 2 surveys, allowing charging behaviour and attitudes towards charging arrangements to be tracked through the different phases of the project. In addition, the Trial 3 survey collected information about participants attitudes towards the time of use tariff.

The full text of the GreenFlux Trial 3 survey can be found in Appendix 10. The response rate for this survey is shown below.

Table 12-21: GreenFlux Trial 3 Survey Response Rate

	Surveys Issued	Surveys Completed	Response Rate (%)
GreenFlux Trial 3	273	207	76%

All participants who were invited to complete a Trial 3 survey took part in Trial 3 (i.e. their charger was managed as part of a Trial 3 group) and they had been invited to download the updated version of the app. Due to variations in charging behaviour, and the fact that downloading the app was optional, the 207 respondents used the app to varying extents and earned differing reward values. Links between satisfaction and acceptability and the use of different charging preferences and the reward value earned are explored in Section 12.2.6.

12.2.5.1 Reported change in charging behaviour

Participants were asked if their charging behaviour had changed since the last survey. Most (87%) reported that their charging behaviour had not changed substantially. A selection of the responses received from those who had changed their behaviour is shown below (Figure 12-59).

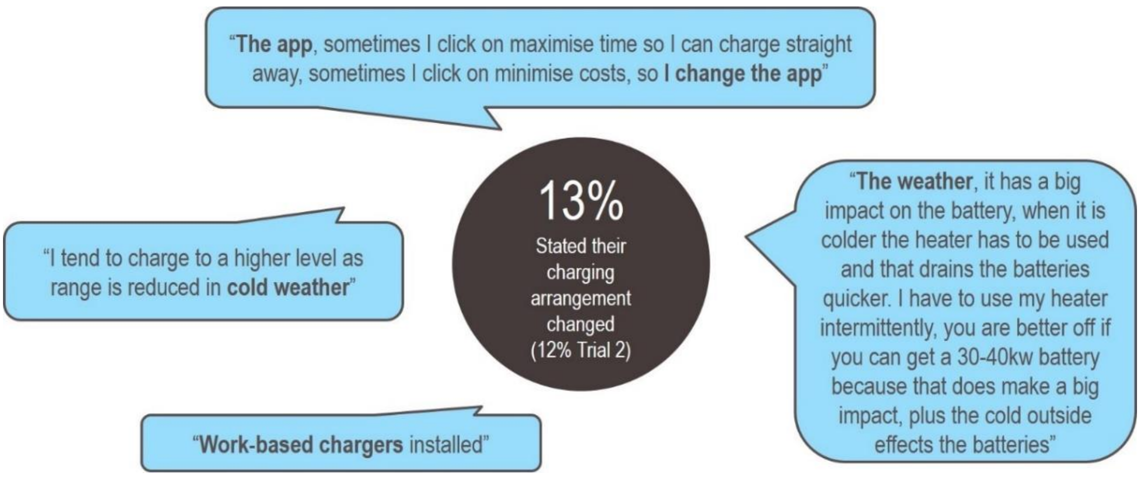

Figure 12-59: Reported change in charging behaviour (Base: all respondents (207), of which 27 changed behaviour)

27 participants indicated that they had changed their charging behaviour. The survey offered participants a series of pre-populated options to describe the change they had

made, alongside a free text box for 'other' changes. 8 respondents used the free text box, and of these, 4 responses related to the GreenFlux app and the reward system.

The proportion of participants who stated that their charging arrangements had changed was much smaller than the proportion who had begun using the app (see Section 12.2.4).

This suggests that participants may not have viewed this as a 'change' – perhaps because they were still plugging and unplugging at the same time, and charging with the same frequency, despite the fact that the time at which charging actually occurred was now being controlled by the app. Further participant responses in relation to the time of use tariff are shown in below.

12.2.5.2 Attitudes to the App and Time of Use Tariff

In Trial 3 the GreenFlux app was updated and participants could select from one of three "charging preferences". These preferences determined what time of day their vehicle would charge (at their home charger) and were aligned with the ToU tariff. The reward system and charging preferences were explained to participants when Trial 3 was launched in mid-October 2018.

The Trial 3 survey asked similar questions regarding participants awareness of the app and its features, their reasons for using (or not using) it and collecting feedback on it (e.g. ease of use, additional features) as Trial 2. In addition, participants were asked about the time of use reward system and charging preferences, and what impact this had on their charging behaviour.

The first question sought to establish the level of awareness of the GreenFlux app, and what proportion of participants who were aware of the app had used it.

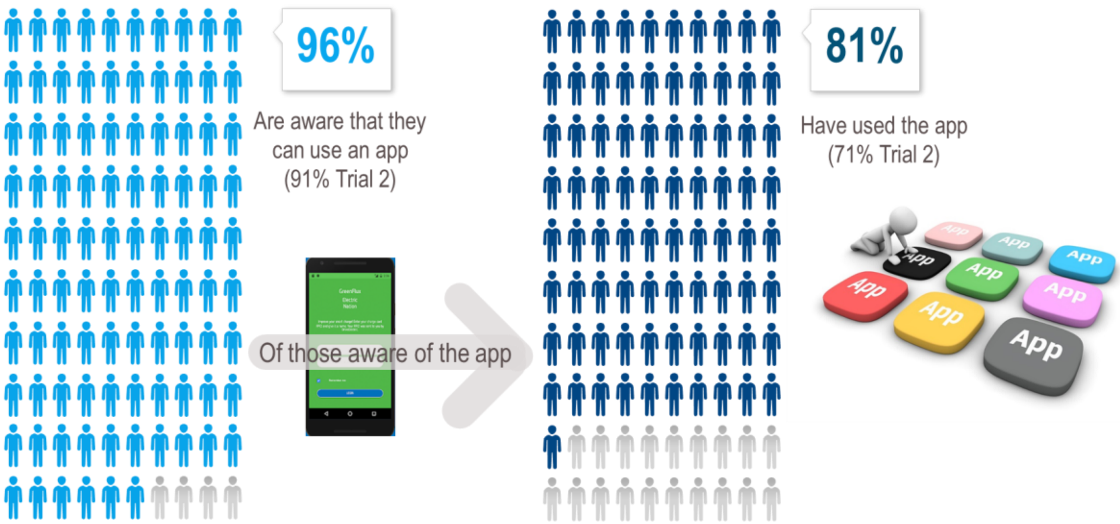

Figure 12-60: Awareness and Use of the GreenFlux App (Base: Awareness – all respondents (207), Use – all those aware of the app (199))

Both awareness and use of the GreenFlux app increased in Trial 3. In addition, 85% of all respondents were aware that the app had recently been updated. The largest change was in the proportion of participants who said they had used the app (81% in Trial 3 compared to 71% in Trial 2) – a statistically significant increase[225]. This increase in use may have been due to the financial incentives available for using the app, meaning the benefits of using it had increased.

The 'Optimise Time' profile was chosen as the default option. This setting allowed charging at all times of day, regardless of the tariff price. This avoided potentially inconveniencing participants who did not use the app, as their charger would still operate at all times (although it may also lead to them having a smaller reward value). A question was included in the Trial 3 survey to determine whether participants who did not use the app were aware of this default option.

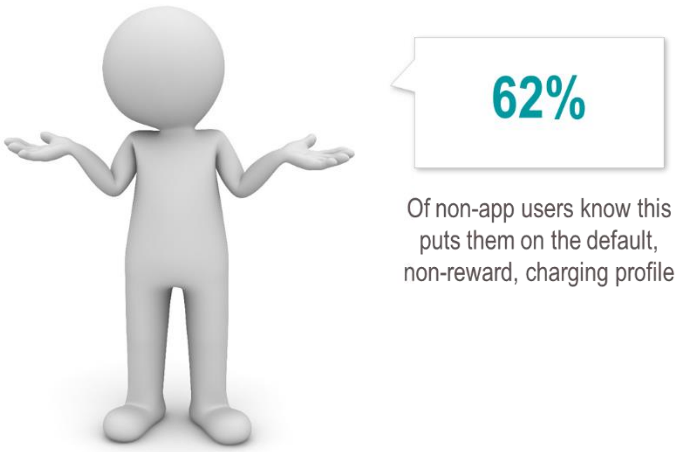

Figure 12-61: Awareness of default profile among those who didn't use the app (Base: 37 – those who were aware of app but had not used it)[226]

This question was asked to participants who were aware of the app but had not used it. 62% of respondents were aware of the default profile. The analysis above (see Section 12.2.4) shows that participants who didn't use the app (based on the charging preferences they used) tended to charge less in the peak period. It is possible amongst those who said they didn't use the app was a group who were aware of the default but chose this because they were not charging in the peak periods. The remaining 38% of respondents (i.e. those who were not aware of the default) may have been less engaged by the trial, as the default option was explained within the material sent to participants at the launch of Trial 3.

The 37 participants who had not used the app were asked to explain the reasons behind this in a free-text response. The reasons given have been categorised and are shown below.

[225] Trial 2 71% of 209 respondents had used app. Trial 3 81% of 199 respondents. Z = 2.36.
[226] N.B. in this case, "non-app users" are defined as survey respondents who said they did not use the app in the question above. It is not based on the use of charging preferences described in Section 12.2.4.

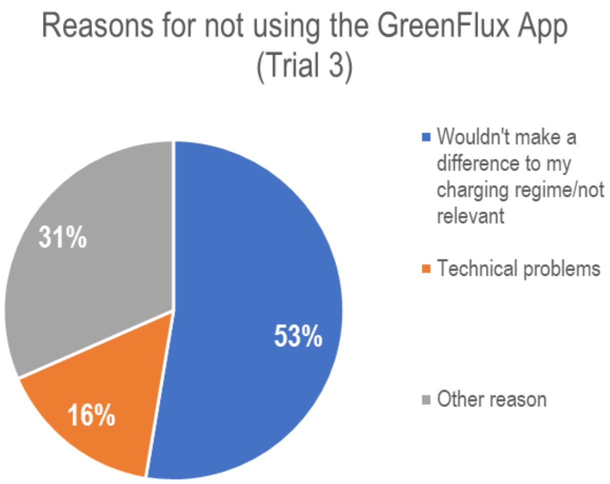

Figure 12-62: Reasons for not using the GreenFlux App (Base: 37 – those aware of the app but had not used it)

A selection of free text responses for each category is shown below.

Figure 12-63: Free Text Reasons for Not Using the GreenFlux App

The majority of reasons participants gave were related to not seeing the relevance/benefits that the app would offer them. For example, because they were already charging overnight. In some cases it appears participants were not clear about the app's features and how this could benefit them – for example:

- "…I have a BMW app that lets me manage my car charging" – this app may allow the participant to set a timer, but would require configuration to take the tariff system into account, whereas this was integrated into the GreenFlux app.
- "it is not the first thing I turn to really. I don't think "I have just parked up, I need to get my Phone out"…" – the GreenFlux app/charging preference was "set and forget" so the participant wouldn't have had to use their phone each time they plugged in.

Respondents were asked which features of the app they had used. The graphic below shows the proportion of respondents who said they had used each feature.

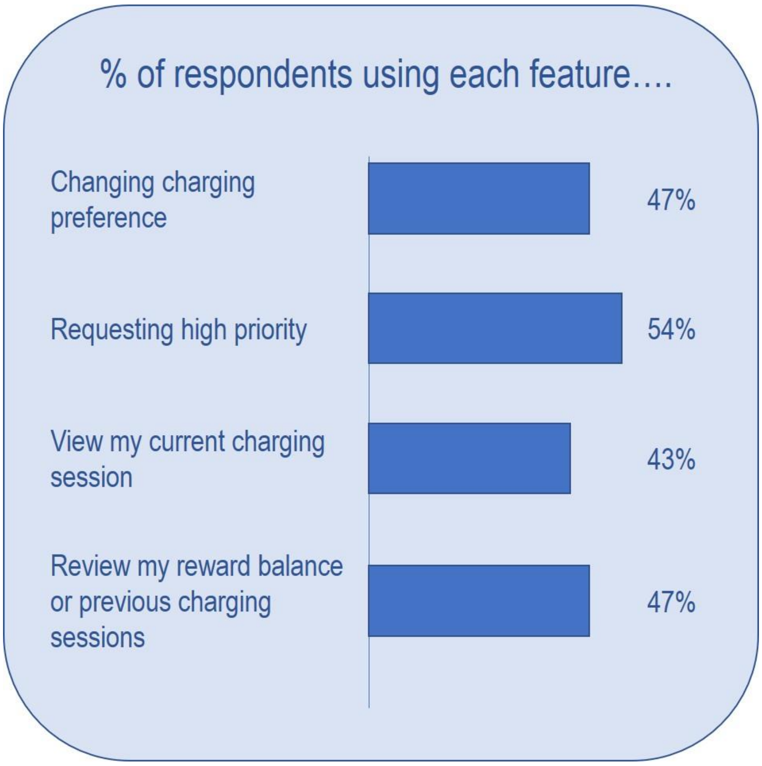

Figure 12-64: Proportion of Responses using App Features (Base: 199 – those who were aware of the app). Respondents could select multiple options.

This shows that requesting high priority continued to be the most used function (although some respondents may have selected 'requesting high priority' based on their behaviour in Trial 2). 64% of respondents selected more than one of the functions listed above.

Participants were also asked about their use of charging preferences. The number of times they reported changing their charging preference ("Optimise Time", "Minimise Cost" etc.) is shown below.

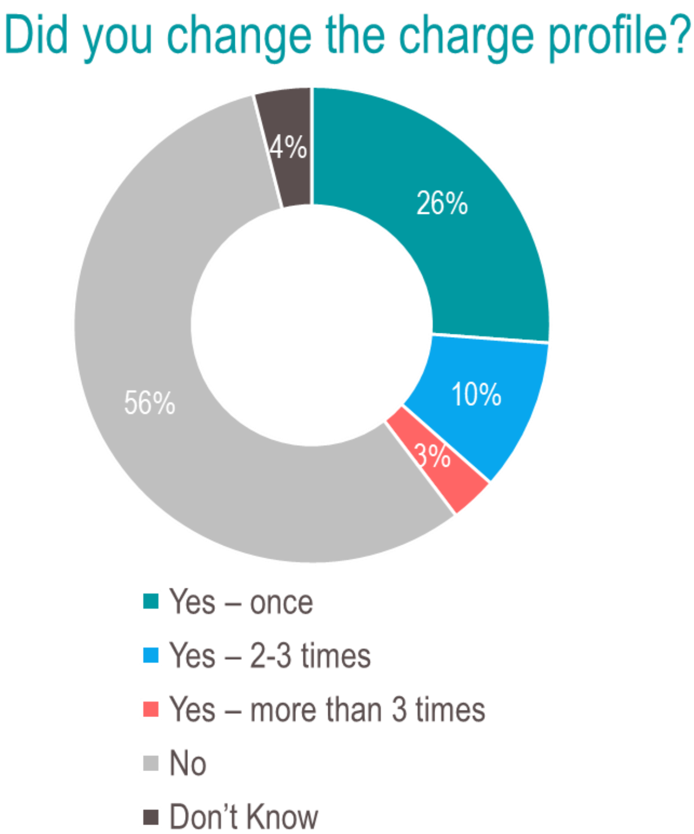

Figure 12-65: Have you changed your charging preference? (Base: 135 respondents – those who had used any feature apart from 'request high priority')

56% of participants said they had not changed their charging preference – in this case all their charging sessions would have been on the 'optimise time' default and they would be defined as a 'non app user' in Section 12.2.4.3. The data provided by GreenFlux showed that 61% of participants had used a preference other than 'optimise time' (and so must have changed away from the default).

Based on the data above participants only tended to change their preference a small number of times - 50 respondents said they had changed their charging preference, and of these 50, 66% reported changing it once, and only 8% reported changing it more than three times. This aligns with heat map analysis shown in Figure 12-55. The reasons given by participants for changing their preference are shown below.

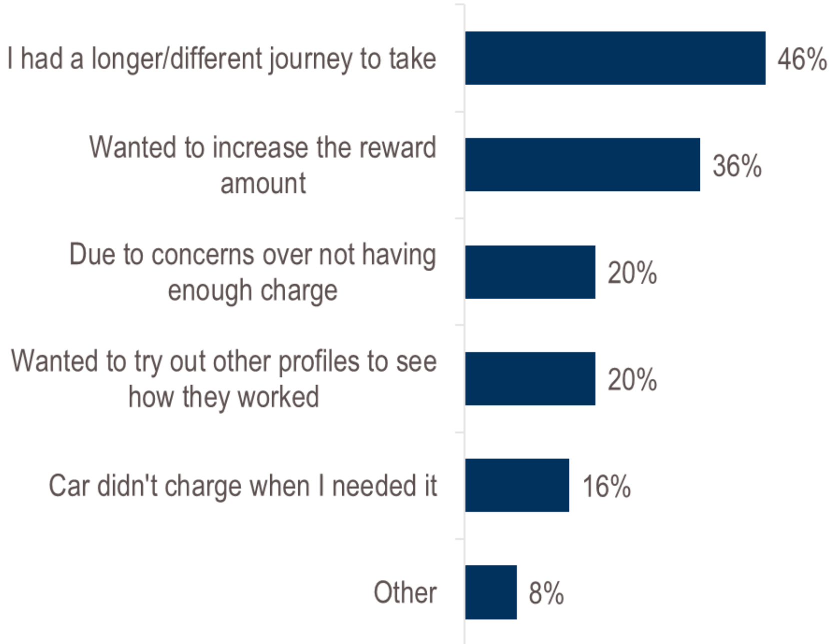

Figure 12-66: Reasons for changing charging profile (Base: 50 – those who stated they had changed their charging profile at least once). Respondents could select multiple options.

In some instances, these reasons are similar to those participants gave for using the high priority feature in Trial 2; journey requirements or concern about not having enough charge, and an interest in experimenting with the new feature. As expected, increasing the reward balance motivated participants to change their charging preference.

Participants were asked if there were any additional features that they would like to be included in the app. 68% of respondents didn't expect any additional functionality (compared to 55% in Trial 2). The functions suggested are shown below.

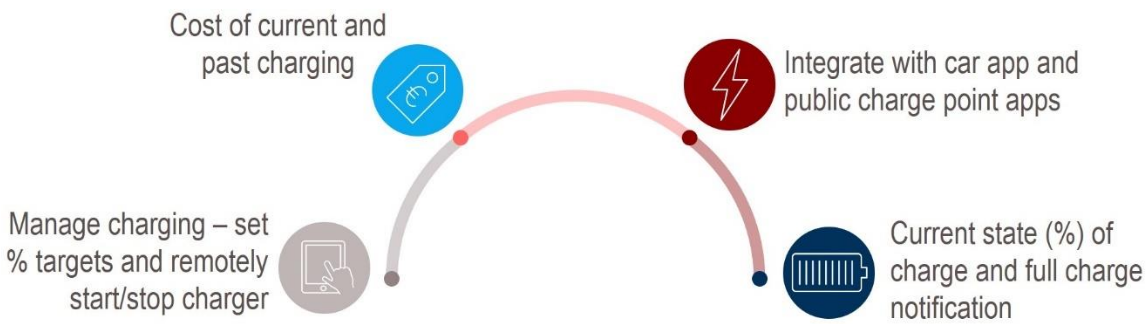

Figure 12-67: Additional app features suggested by GreenFlux participants

Two of the features suggested ('managed charging – set % targets and remotely start/stop charger' and 'current state (%) of charge and full charge notification') are not currently possible using the existing standard communications protocol for AC charging, as the state of charge of the vehicle is not communicated to the charger.

Trial 3 introduced a time of use tariff to participants and the app allowed them to select charging preferences which were tailored to the tariff. The Trial 3 survey asked several questions focussing on their response to, and understanding of, the Time of Use reward structure.

Participants who had used the app to review or change their charging preferences were asked how easy they found it to understand the reward structure based on the time of use tariff. The results are shown below.

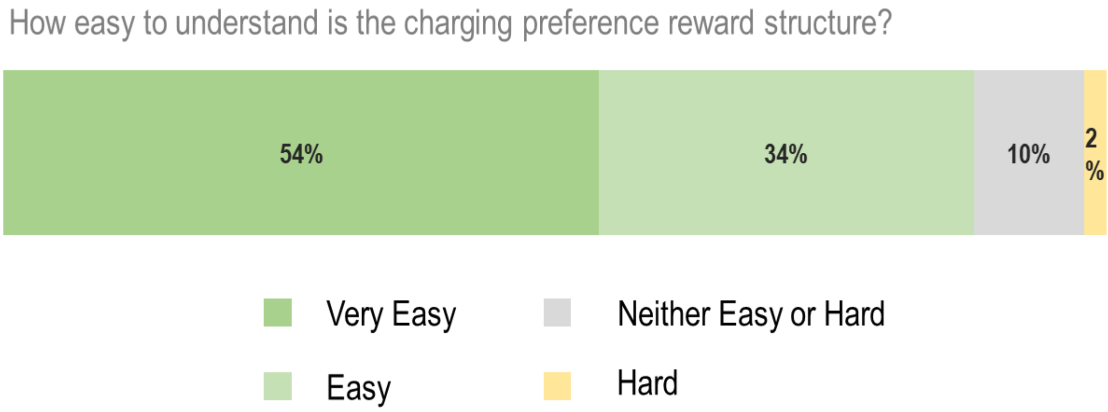

Figure 12-68: Ease of understanding the reward system (Base: 108 – those who had used the app to review or change their charging preferences)

The information provided to participants at the launch of Trial 3, and within the app made the tariff/reward structure easy to understand, with 88% of respondents finding it either "very easy" or "easy" to understand. No respondents found it "very hard" to understand.

Participants that had used the app to change or review their charging preference were asked whether they thought that the ToU tariff incorporated into the app would encourage drivers to change their charging behaviour in the future. The results are shown in Figure 12-69 below.

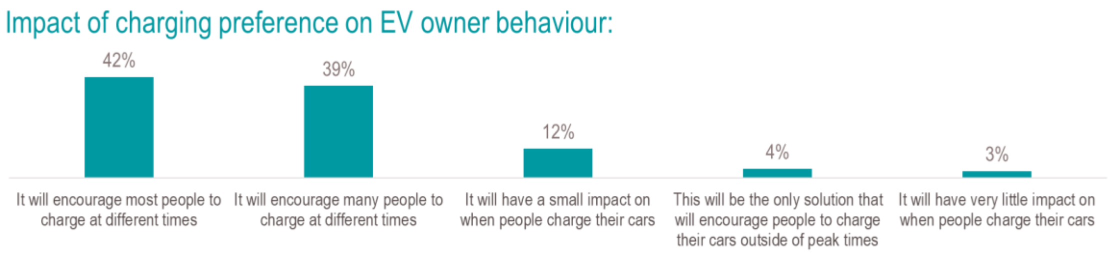

Figure 12-69: To what extent do you think the charging preferences will encourage EV drivers to charge their cars outside of peak times? (Base: 108 - those that have used the app to change or review their charging preference)

This shows that participants who used the charging preferences believed that similar incentives would encourage "most" or "many" other drivers to charge at different times (81% of responses). This question was only answered by respondents who had used the charging preference's, so the views of those who had not used this functionality within the app may have differed.

All respondents were asked how likely they were to use a similar app in the future and the results are shown in Figure 12-70 below.

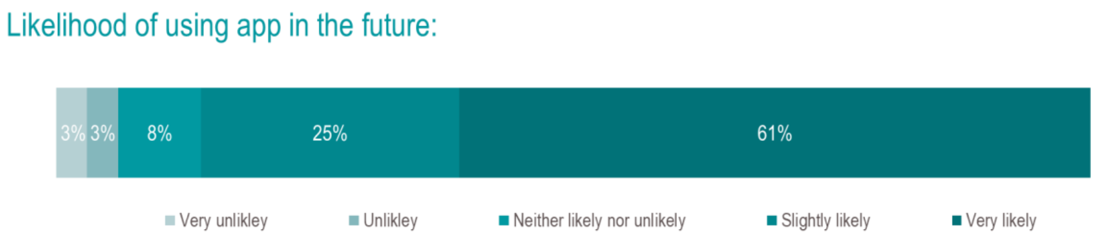

Figure 12-70: Likelihood of using a similar app in the future (Base: 207 – all respondents)

86% of participants stated that they were likely to use a similar app if it was available in the future. This was slightly higher than the proportion who used the app during Trial 3 (86% vs. 81%, see Figure 12-60). It was also a statistically significant increase compared to Trial 2, when 63% of respondents said that they were either "slightly likely" or "very likely" to use the app in the future[227].

12.2.5.3 Acceptability and Satisfaction with charging arrangements

One of the key elements of the Electric Nation trial was to understand the acceptability of smart charging amongst participants, and the factors which affect this. Participants were asked a consistent series of questions at multiple points through the project – before management (the Baseline survey, see Section 9.1), as part of Trial 1 (see Section 10), Trial 2 (Section 11) and Trial 3 (this section). This allows participants' attitudes towards their charging arrangements to be compared through the trial as they experienced different aspects of smart charging.

This section shows the results of this part of the survey and compares the responses to those received in the Baseline, Trial 1 and Trial 2 surveys, showing the effect that the time of use reward system (alongside an app) has. Section 12.2.6 relates these scores to the reward which participants earnt during Trial 3 and which charging preferences they used.

The results presented in this sub-section are for participants who completed all four surveys (Baseline, Trial 1, Trial 2 and Trial 3) so that acceptability/satisfaction can be compared between trials. The results for all respondents to the GreenFlux Trial 3 survey can be found in Appendix 3.

[227] Z test. Trial 2 63% of 230. Trial 3 86% of 207. Z = 5.47.

Participants were asked to rate the acceptability of their current charging arrangements on a scale of 1 (completely unacceptable) to 10 (completely acceptable). Figure 12-71 below, shows the proportion of participants who gave a score of 8, 9 or 10 for the Baseline, Trial 1, Trial 2 and Trial 3 surveys. The results are for the participants who responded to all four surveys.

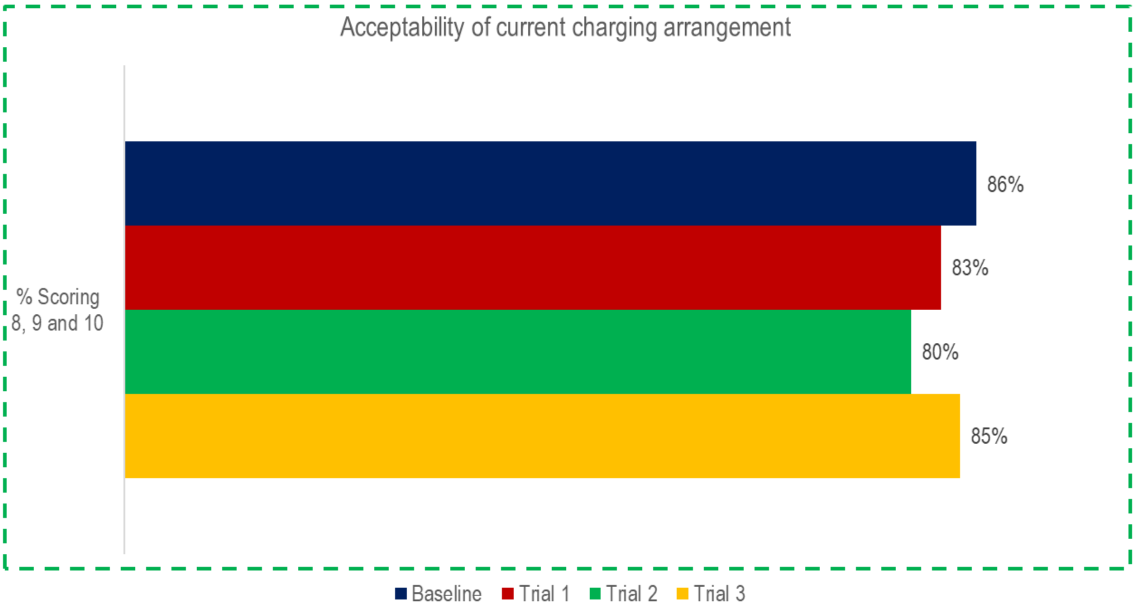

Figure 12-71: % of Responses giving score of 8 - 10 for acceptability of charging arrangements (Base: Baseline 102, Trial 1 - 104, Trial 2 - 103, Trial 3 104) excludes those who answered 'don't know'

The introduction of the ToU reward system and updated app in Trial 3 increased the proportion of participants giving the highest scores for the acceptability of their charging arrangements although the change is not statistically significant[228].

Participants were also asked to the score their satisfaction with their charging arrangements on a 1 to 10 scale. Figure 12-72 compares the level of satisfaction for the whole population in the Baseline, Trial 1, Trial 2 and Trial 3 surveys.

[228] Z test. Z value = 0.94 for Trial 2 v Trial 3

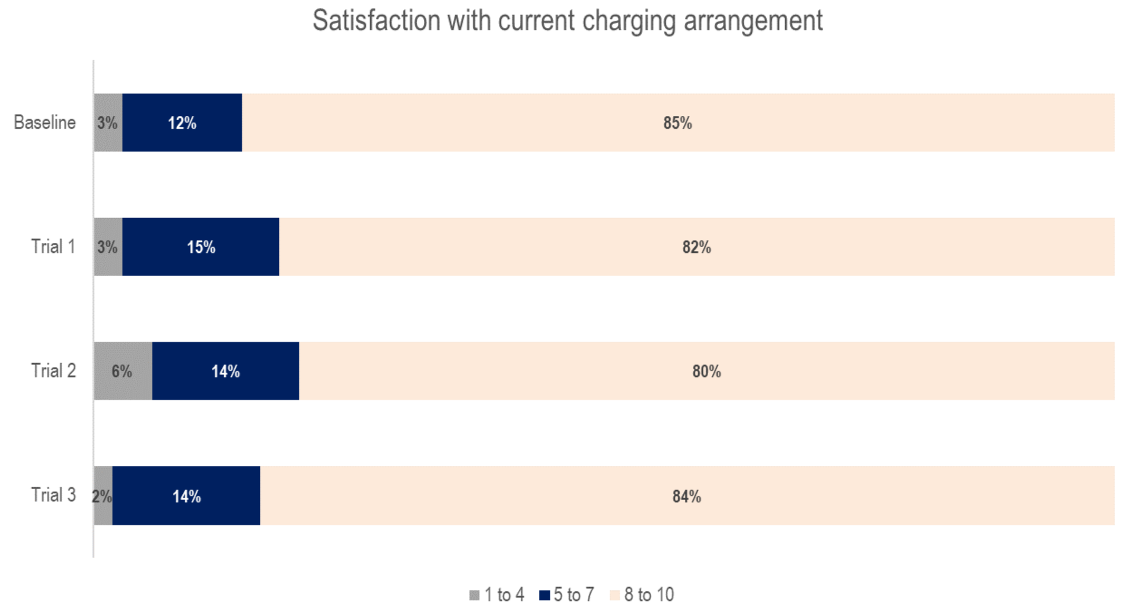

Figure 12-72: Satisfaction with charging arrangements (Base: Baseline - 103, Trial 1 - 104, Trial 2 - 104, Trial 3 - 104) excludes those who answered 'don't know'

This shows that the proportion of participants who were highly satisfied increased between the Trial 2 and Trial 3 surveys (when ToU rewards were available alongside the app). However, this change is not statistically significant[229].

Table 12-22 compares the proportion of participants who were highly satisfied (score of 8 to 10) for all four surveys disaggregated by PEV type and battery capacity.

Table 12-22: Comparison of % of Respondents Giving Satisfaction Scores of 8. 9 or 10 between Baseline, Trial 1, Trial 2 and Trial 3

Group		Sample Size	% of Survey Responses Scoring 8 - 10			
			Baseline	Trial 1	Trial 2	Trial 3
PEV Type	REX	18	78%	78%	78%	78%
	PHEV	42	85%	86%	81%	86%
	BEV	44	89%	80%	80%	84%
Battery Capacity	Less than 10kWh	25	92%	84%	80%	88%
	10 to 25kWh	33	85%	88%	88%	82%
	25 to 35kWh	30	83%	77%	73%	80%
	35kWh+	16	81%	75%	75%	88%

[229] Z test. Z value = 0.72.

Satisfaction levels between Trial 2 and Trial 3 either increased or stayed the same for all groups except the participants with battery capacities of 10 to 25kWh. However, none of the differences are statistically significant[230]. Although the proportion of 'highly satisfied' participants varies between the sub-groups in each of the surveys, there are no statistically significant differences[231].

The links between use of charging preferences, reward values and satisfaction/acceptability scores are explored in Section 12.2.6.

Participants were also asked to state for how long they would be willing to continue with their current charging arrangements. Figure 12-73 shows the breakdown across the whole trial population for all respondents who completed a Baseline, Trial 1, Trial 2 and Trial 3 survey.

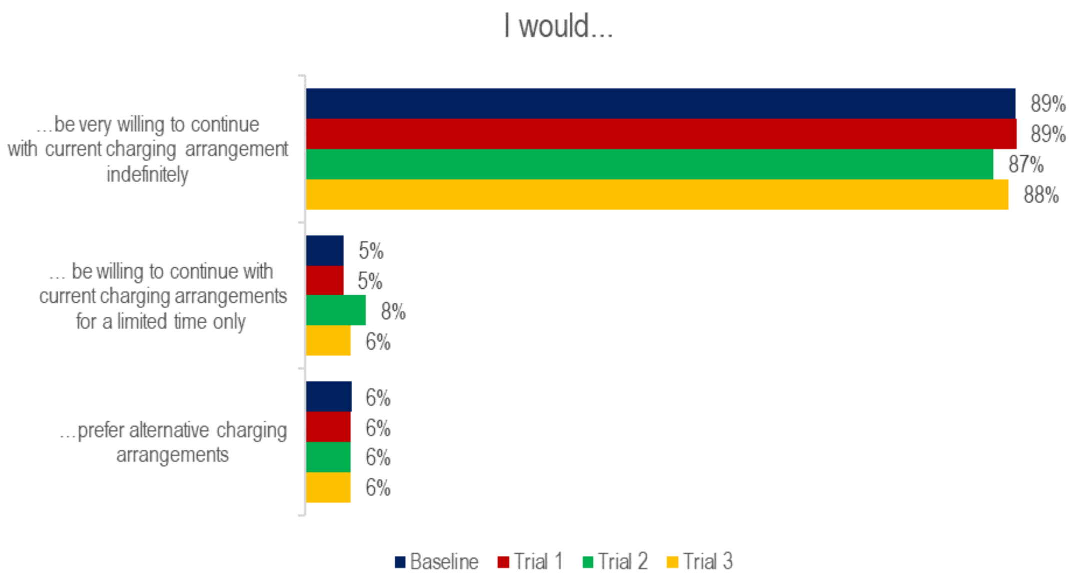

Figure 12-73: Willingness to continue with charging arrangements (Base: Baseline - 103[232], Trial 1 - 104, Trial 2- 104, Trial 3 - 104)

Overall participants' views remained similar across all four surveys. The changes in each category between the Trial 2 and Trial 3 surveys are not statistically significant[233]. The majority of participants remained willing to continue with their charging arrangements indefinitely throughout the trials.

[230] Z test. Z values range from 0 for 'REX' up to 0.91 for participants with vehicles having a battery capacity >35kWh.
[231] Z test. For Trial 3, Z values range from 0 between battery capacities of <10kWh and >35kWh up to 0.80 between battery capacities of 25 to 35kWh and <10kWh.
[232] Excludes one participant who responded: 'I cannot continue with current charging arrangements'
[233] Z test. For Trial 3, Z value = 0.42 and 0.55 for 'willing to continue indefinitely' and 'willing to continue for a limited time' respectively.

Table 12-23 disaggregates the results from the Baseline, Trial 1, Trial 2 and Trial 3 surveys and shows the proportion of participants who would be willing to continue with their charging arrangements indefinitely by PEV type and battery capacity.

Table 12-23: Proportion of Participants Willing to Continue with Charging Arrangements Indefinitely - by PEV Type and Battery Capacity

Group		Sample Size	% of Survey Respondents Willing to Continue with Charging Arrangements Indefinitely			
			Baseline	Trial 1	Trial 2	Trial 3
PEV Type	REX	18	89%	94%	83%	94%
	PHEV	42	90%	88%	95%	88%
	BEV	44	88%	89%	80%	86%
Battery Capacity	Less than 10kWh	25	96%	92%	96%	92%
	10 to 25kWh	33	88%	91%	91%	88%
	25 to 35kWh	30	90%	90%	80%	87%
	35kWh plus	16	75%	81%	75%	88%

Willingness to continue increased from Trial 2 to Trial 3 for both REX and BEV groups, but decreased for the PHEV group. However, these changes were not statistically significant[234].

With respect to battery size, the willingness of the two smaller battery size sub-groups to continue at the end of Trial 3 had slightly decreased from Trial 2 whereas, for the largest two battery sub-groups, it had increased. Comparing the battery capacity subgroups to each other for the Trial 3 survey only, there is no statistically significant difference between the number of participants willing to continue indefinitely[235]. As shown above, willingness to continue with charging arrangements indefinitely remained high.

Participants were asked about their concerns regarding smart charging. The results from the Baseline survey (before management), Trial 1 (management, but no app), Trial 2 (management with app) and Trial 3 (management, app and ToU reward) are shown Figure 12-74 below.

[234] Z test. Z value ranges from 0.85 for 'BEV' up to 1.18 for 'PHEV'.
[235] Z test. For Trial 3, Z value = 0.63 for battery capacities of <10kWh v battery capacities of 25 to 35kWh.

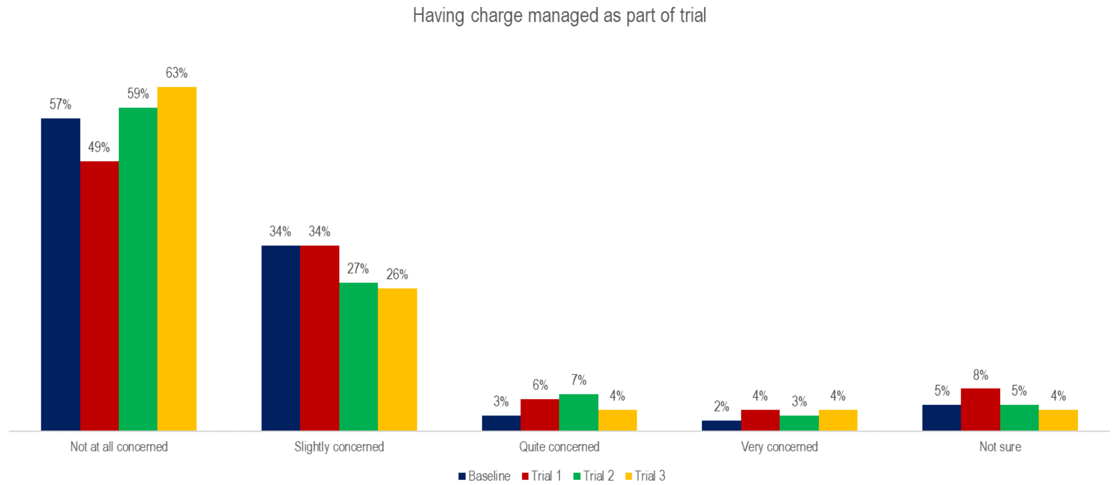

Figure 12-74: Level of concern re: demand management (Base: 104 for all four surveys)

GreenFlux trial participants were least concerned about demand management during Trial 3 (project high of 89% saying “not at all” or “slightly” concerned). However, the increase in the proportion of participants with only slight or no concerns regarding demand management between Trial 2 and Trial 3 was not statistically significant[236]. The proportion of participants who were either 'quite’ or ‘very’ concerned about demand management decreased slightly from Trial 2 to Trial 3 but, again, this is not statistically significant[237].

Very little management took place during Trial 3 (see Table 12-13). There was also no demand management associated with the Baseline survey when 86% of respondents had very few concerns. However, participants knowledge about demand management and its potential impacts was higher at the Trial 3 (lower “fear of the unknown”) and they had a level of control via the high priority button

12.2.5.4 Trial 3 Findings from Focus Groups

Seven GreenFlux participants who took part in the focus group were generally positive about their experience during Trial 3. They demonstrated a high-level engagement with the app and reward system and reported that they earned rewards easily and with minimal changes to their behaviour. On some occasions, participants chose priority charging over earning an incentive. A selection of quotes is shown below:

[236] Z test. Z value = 0.62.
[237] Z test. Z value = 0.49.

Figure 12-75: Quotes from GreenFlux Focus Group (7 participants)

12.2.5.5 Summary

Satisfaction with current charging arrangements among the GreenFlux trial participants remained steady (and high) across Trial 3 and the project lifetime. Acceptability of charging arrangements also remained consistently high.

Three quarters of cohort participants were aware that the app had been updated and 81% had used the new version of it.

Two thirds of participants stated that they had changed their charging preference at least once, however 20% of these participants only did so to see how the different profiles worked. Other participants changed their preferences to ensure that they had sufficient charge for unexpected trips or to plan for long journeys (similar reasons as the use of the high priority feature during Trial 3). 36% of participants who changed their charging preferences wanted to earn a larger reward. Most participants found the charging preference reward structure easy to understand.

12.2.6 Key Findings – GreenFlux Trial 3

- The introduction of the ToU tariff and charging preferences dramatically changed the demand profile. 90th Percentile demand in the traditional evening peak was approximately 370W per charger (compared to 830W per charger in winter). A new peak in demand was created at 22:00 when all the sessions set to "minimise cost" began.
- The change in demand profile meant that no management took place during Trial 3 (once all participants had access to the updated app).

- The peak in demand created at 22:00 may have negative consequences throughout the electricity system, if adoption of such a system was widespread. A tariff alone could create such a spike, but offer no means by which it could be managed. Smart charging could be used to mitigate this impact, for example by randomising the start times of chargers which were set to 'minimise cost' so that the time they began to charge was more evenly distributed (e.g. between, say, 22:00 and 02:00). This would still allow vehicles to obtain a full charge overnight but would avoid the sudden spike in demand shown above.

- Participants delaying charging via the use of the charging preferences did not lead to an increase in the proportion of charging events where the vehicle was unplugged before the battery was fully charged. In fact, this declined from 13.6% in Trial 2 to 11.8% in Trial 3 (the lowest value in the project).

- Table 12-24 below, relates the scores given for participants **satisfaction** with their current charging arrangements in the Trial 3 survey to financial reward they received based on their charging behaviour during Trial 3:

Table 12-24: Relationship between Satisfaction Scores and Reward Value

Group	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		Dissatisfied (1 – 4)	Neutral (5 – 7)	Satisfied (8 – 10)
Reward Value £0 to £10.30 (1st Quartile)	45	7%	27%	67%
Reward Value £10.31 to £17.42 (2nd Quartile)	50	4%	16%	80%
Reward Value £17.43 to £27.76 (3rd Quartile)	54	6%	17%	78%
Reward Value £27.77 to £80.06 (4th Quartile)	59	2%	14%	85%

This shows a slight trend towards higher levels of satisfaction amongst participants who earned a higher reward in Trial 3. Participants in the 4th quartile (earning a reward of more than £27.77) were significantly more likely to be highly satisfied than those in the 1st quartile (earning a reward of less than £10.30)[238].

- Table 12-25, below, relates the scores given by participants for the **acceptability** of their current charging arrangements in the Trial 3 survey to financial reward they received based on their charging behaviour during Trial 3.

[238] Z test. 85% of 59 (4th Quartile) vs. 67% of 45 (1st Quartile) Z = 2.17.

Table 12-25: Relationship between Acceptability Scores and Reward Value

Group	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
Reward Value £0 to £10.30 (1st Quartile)	45	11%	27%	62%
Reward Value £10.31 to £17.42 (2nd Quartile)	50	6%	16%	78%
Reward Value £17.43 to £27.76 (3rd Quartile)	54	6%	13%	81%
Reward Value £27.77 to £80.06 (4th Quartile)	59	3%	10%	86%

Participants who earned the lowest rewards (those in the 1st quartile) were significantly less likely to give a score of 8, 9 or 10 than those in the 2nd (10% confidence level), 3rd and 4th quartiles (5% confidence level)[239].

- As part of Trial 3 GreenFlux participants were again invited to download a smart phone app which would allow them to select a charging preference which could help them maximise their reward value. The 'high priority' feature was retained from Trial 2. By the end of Trial 3 there were 229 downloads of the app, compared to 280 invitations (82%). The equivalent figure at the end of Trial 2 was 69% - a statistically significant increase.

- High priority requests continued at a similar rate to the end of Trial 2 (despite no management occurring). 2.7% of Trial 3 charging events included a high priority request.

- Participants could use the app to select from one of three charging preferences. During Trial 3, 9,895 charging events occurred – 40% on 'Minimise Cost', 6% on 'Optimise Time and Cost' and 54% on 'Optimise Time' (the default option).

- The dramatic changes in the demand profile noted above was mainly as a result of participants using the app to select the 'minimise cost' option. There was little change in time when vehicles were plugged in compared to the rest of the trial. Amongst participants who did not use the app, there was no statistically significance in the proportion of charging events which began during the evening peak (30.7% outside of Trial 3, 30.3% during Trial 3). (i.e. this group did not alter their behaviour by using vehicle timers in response to the ToU incentive).

- Various factors influenced how likely a participant was to select each charging preference. Analysis of the data shows:

[239] 1st Quartile (62% of 45) vs. 2nd Quartile (78% of 50) Z = 1.71. 1st Quartile (62% of 45) vs. 3rd Quartile (81% of 54) Z = 2.10. 1st Quartile (62% of 45) vs. 4th Quartile (86% of 59) Z = 2.82.

   - Participants who had bought their vehicle were significantly **more likely** to use a non-default option (68% of this group, compared to 53% of the whole population);
   - Participants who leased their vehicle were significantly **less likely** to use a non-default option (43% of this group) (significant at the 10% level);
   - Participants whose motivation for getting a PEV included the following reasons were significantly **more likely** to use a non-default option:
     - Lower running costs (64% of this group)
     - Latest technology (72% of this group)
     - Easier/smoother drive (73% of this group)
   - Participants who also charged their vehicle at work were significantly **more likely** to use a non-default option (83% of this group).
- The charging preference which each participant used most often has been linked to the acceptability and satisfaction scores they gave in the Trial 3 survey:

Table 12-26: Link between Satisfaction Score and Most Used Charging Preference

Most Frequently Used Charging Preference	Sample Size	% of Survey Responses (% of Satisfaction Scores)		
		1 – 4	5 – 7	8 – 10
Minimise Cost	99	1%	16%	83%
Optimise Time and Cost	11	18%	27%	55%
Optimise Time	77	5%	17%	78%

Table 12-27: Link between Acceptability Score and Most Used Charging Preference

Most Frequently Used Charging Preference	Sample Size	% of Survey Responses (% of Acceptability Scores)		
		1 – 4	5 – 7	8 – 10
Minimise Cost	99	4%	11%	85%
Optimise Time and Cost	11	27%	18%	55%
Optimise Time	77	6%	18%	75%

Participants who used 'Optimise Time and Cost' most often were significantly **less likely** to give a high score for satisfaction and acceptability than either those who used 'Minimise Cost' most (5% confidence)[240] or those who used 'Optimise Time' (10% confidence).

[240] Satisfaction: Optimise Time and Cost vs. Minimise Cost (55% of 11 vs. 83% of 99) Z = 2.21. Optimise Time and Cost vs. Optimise Time (55% of 11 vs. 78% of 77) Z = 1.66. Acceptability: Optimise Time and Cost vs. Minimise Cost (55% of 11 vs. 85% of 99) Z = 2.46. Optimise Time and Cost vs. Optimise Time (55% of 11 vs. 75% of 77) Z = 1.67

- Awareness and use of the app had increased slightly compared to Trial 2 (96% ‘aware’ compared to 91% in Trial 2, 81% ‘used’ in Trial 3 compared to 81% in Trial 2). The reasons given by participants for not using the app were similar to Trial 2; that it was not relevant to their charging regime (e.g. because they already charged overnight) or because they had experienced technical problems.
- Participants changed their charging preference relatively infrequently. The reasons which motivated them to change their preference were often due to journey requirements, or to maximise their reward value.
- Participants who had used the app to review or change their charging preference were asked how easy they found it to understand; 88% found it either “easy” or “very easy” compared to only 2% who found it “hard” to understand.
- There were no statistically significant changes in the level of acceptability/satisfaction of current charging arrangements or the proportion of participants willing to continue with these arrangements indefinitely. These metrics remained positive throughout the trials (e.g. 88% of Trial 3 respondents willing to continue with their current charging arrangements indefinitely).
- Participants in the focus groups were generally positive about their experience in Trial 3. They demonstrated a high-level engagement with the app and reward system and reported that they earned rewards easily and with minimal changes to their behaviour.

13 Final Survey Findings

As discussed in Section 6.8, following the completion of the demand management trials Electric Nation participants were requested to complete a final trial survey. This survey was issued to all participants and assessed the following:

- The participants attitude towards PEVs, and those of their family;
- The participants attitude towards charging their vehicle at home and elsewhere;
- Their experience of participating in the project;
- How acceptable they found the smart charging alternatives trialled in the project; and
- Whether participants' experience in the trial was likely to have resulted in long term behaviour change.

Participants received a £25 Amazon voucher upon completion of this survey. 514 completed survey responses were received by Impact, resulting in a response rate was 76%. This survey was available to participants between 10th January and 14th February 2019. A copy of the survey can be found in Appendix 11.

Where the outputs of this survey provide extra background on the trial participant characteristics, these responses have been included in Section 7. This chapter summarises participant attitudes and habits at the end of the trial and compares participant attitudes to the three demand management trials throughout the project. Information from the focus groups has been included in this section where relevant.

13.1 Changes to participants' habits, lifestyle and attitudes over the lifetime of the trial

Trial participants were asked a number of questions in order to ascertain the extent to which changes other than the impact of the charge management trials may have impacted their experience of the Electric Nation trial.

Participants were asked when they bought or leased their first PEV.

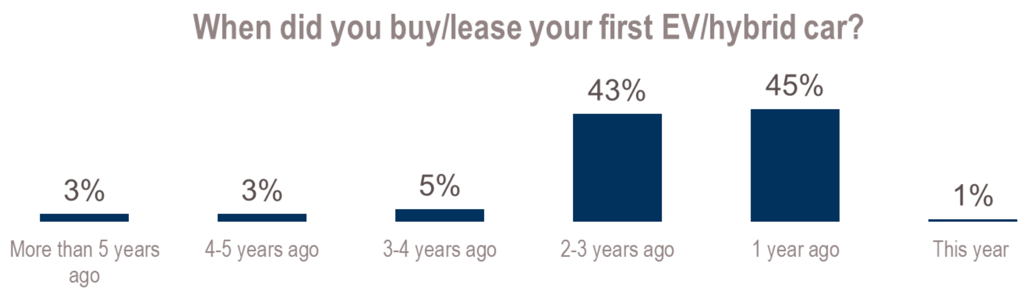

Figure 13-1: When did you purchase/ lease your first electric/hybrid vehicle (Base All respondents 514)

Figure 13-1 shows that most triallists have owned an EV for less than three years. Participants who took part in Electric Nation were eligible for the Home Charge grant based on their plug-in vehicle. The grant can only be obtained once for each vehicle. Installation of chargers (and therefore claiming of the grant) took place between January 2017 and July 2018, so participants are likely to have bought/leased the PEV which they registered as part of Electric Nation between one and two years before taking the final survey. The results above would appear to indicate that the PEV registered as part of Electric Nation was their first PEV for the majority of participants, as very few had bought or leased their vehicle before the trial began.

Participants were then asked if they still had the same EV that they had been driving at the start of the trial.

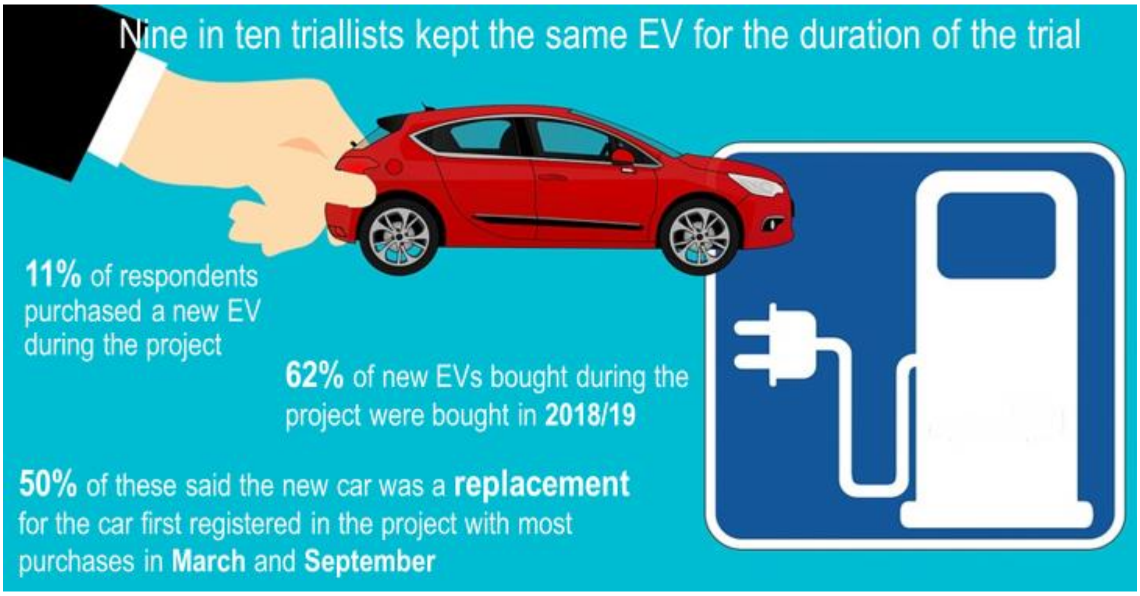

Figure 13-2: Have you bought another EV during the trial? (Base all respondents 514), When did you buy your EV (those who had bought an EV during the trial (58), Is this a replacement for the EV that you initially registered on the project? (those who had bought an EV during the trial (58)

Figure 13-2 shows that about a tenth of participants replaced the EV that they initially registered with the project with a newer model during the lifetime of the project. Where participants informed DriveElectric of the change in vehicle, this has been taken account of within the data analysis presented in earlier sections.

Major lifestyle changes may alter a household's routine and therefore their charging patterns and attitudes to demand management. Participants were asked if they had experienced any major lifestyle changes during the timeline of the Electric Nation project that might have affected their EV usage. Respondents could choose one or more options from a list of potential upheavals, including 'other' and 'no major life changes'. The figure below summarises responses.

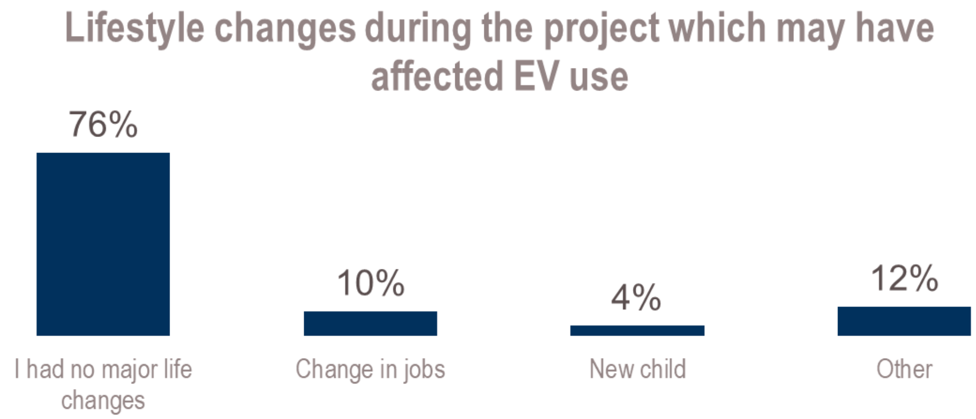

Figure 13-3: Thinking about your time on the Electric Nation project, have you had any major life changes that have affected your use of the EV? (Base all respondents 514)

Figure 13-3 above shows that about a quarter of participants had experienced a major lifestyle change during the trial. The extent to which these changes may have affected vehicle use is likely to vary from participant to participant. Participants were asked as part of each trial survey whether their charging behaviour had changed since they last completed a survey. The proportion of participants who reported changes was low in each case (lower than the 24% shown above). The changes reported in the trial surveys were often related to seasonal changes (e.g. charging more frequently in winter) and the impact of these has been analysed and reported elsewhere in the report – e.g. charging frequency by season shown in Figure 8-13.

The survey respondents were then asked what fuel type they would choose to replace the vehicle that they had registered with the trial. Figure 13-4 shows the breakdown for all participants. This is disaggregated for the vehicle type of the participants' current vehicle in

Table 13-1 below.

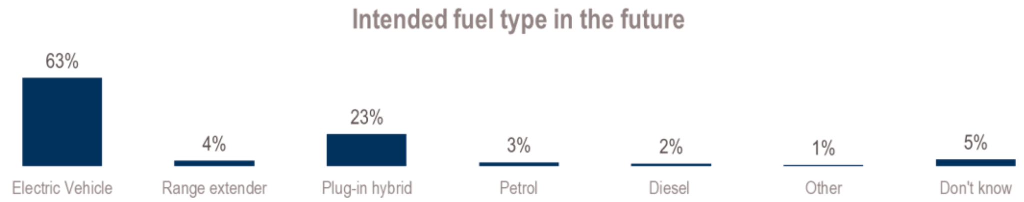

Figure 13-4: When you next look to replace your current car, which fuel type are you most likely to choose? (Base All respondent 514)

Table 13-1: Fuel Type of Next Vehicle, by PEV Type

Current Vehicle Type	Sample Size	Fuel Type of Next Vehicle (% giving response)						
		Electric vehicle	Plug-in Hybrid	Range Extender	Petrol	Diesel	Don't know	Other
BEV	243	86%	5%	2%	3%	0%	3%	1%
PHEV	204	33%	50%	1%	3%	4%	8%	0%
REX	66	71%	3%	18%	0%	2%	5%	2%

90% of all trial participants plan to continue driving a PEV (BEV, range extender or plug-in hybrid) in the future, as shown in Figure 13-4 above. Amongst BEV and PHEV drivers, there is a tendency to prefer their current vehicle type, although a third of PHEV drivers plan to move to a full BEV in the future. REX drivers in the trial all owned a BMW i3 range extender and the majority of these (71%) plan to upgrade to a BEV for their vehicle. REX drivers are significantly more likely to consider another REX for their next vehicle compared to both BEV and PHEV drivers[241]. They are the only group who are considering a REX in the future to any significant extent.

23 participants said they intended to return to either a petrol or diesel vehicle. For all participants, all the satisfaction scores they gave throughout the project have been averaged. The distribution of the scores for the 23 participants who said they would return to either a petrol or diesel vehicle has been compared to the scores from those who intended to get another PEV (291 responses with a satisfaction score). There is no statistically significant difference between the two[242]. This suggests that it not their experience of managed charging in Electric Nation which has led to them to consider returning to a petrol or diesel vehicle. Free text responses provided by some of these participants as qualifiers to the question "How acceptable have you found your charging arrangements overall, including when you are away from home?" are cited below.

[241] 18% REX drivers vs. 2% BEV drivers Z =5.1. 18% REX drivers vs. 1% PHEV drivers Z = 5.43

[242] Significance test – independent means. PEV Sample: sample size = 418, mean satisfaction score = 8.41, standard deviation = 1.72. Petrol/diesel Sample: sample size = 23, mean satisfaction score = 8.79, standard deviation = 1.41. Z = 1.02.

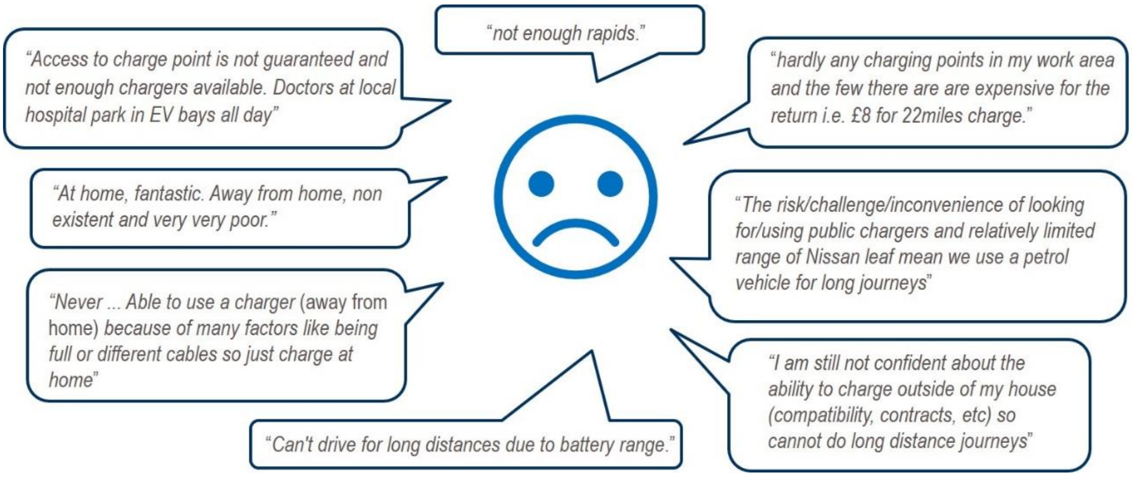

Figure 13-5: Free text responses provided by participants who stated that their next car would be petrol or diesel (Base: Petrol and Diesel 23 participants)

They were also more likely to fall into the following categories:

Figure 13-6: Categories most likely to apply to participants who stated that their next car would be petrol or diesel (Base: Petrol and Diesel 22 participants)

13.2 Charging Behaviour

Participants were asked whether they were likely to change their charging behaviour following the end of the project.

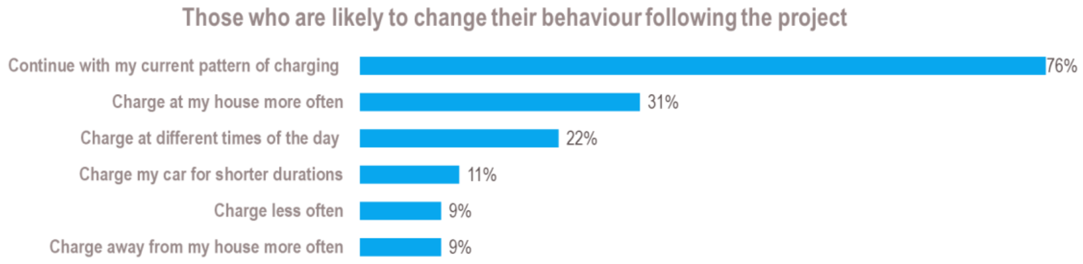

Figure 13-7: As a result of the Electric Nation project, how likely is it that your behaviour will change in the following ways when compared to your initial charging behaviour? (Base All respondents 514)

Most participants claim that they will continue their current charging patterns after the end of the project. On this basis, the predicted EV demand (as outlined in Section 8.10) is likely to be a good prediction of future demand from this population. Other populations may have different charging behaviour – for example people with very high mileages for whom PEVs are not currently a viable option. However, the mileages that participants reported driving each week broadly align with the UK population. In the absence of further detailed monitoring of PEV drivers and their charging in the future (when a more representative population are driving PEVs) the Electric Nation dataset represents the largest and most in-depth analysis of its type in the UK.

13.3 Participants Satisfaction with Charging Arrangements – at home and away from home

In the final survey participants were asked two questions about the acceptability/ satisfaction of charging infrastructure:

1. How acceptable have you found your charging arrangements overall, including when you are away from home?; and
2. How satisfied are you with your current charging arrangements at home?

The bar chart below compares the results from the two questions.

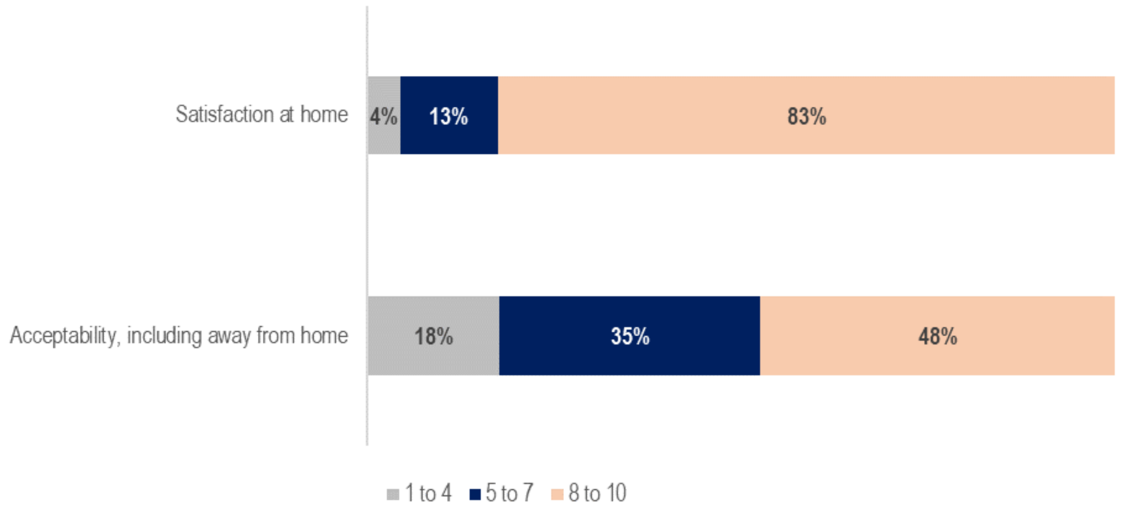

Figure 13-8: Comparing satisfaction/acceptability at home, and including away from home (Base: Acceptability 505, Satisfaction 506 – excludes 'don't know')

In response to the first question, when participants were specifically asked to consider their experience away from home only 48% of participants gave a score of 8 to 10, compared to 83% giving a high satisfaction score for charging at home. The reasons for their scores tended to focus on the availability and reliability of infrastructure away from home, with some quotations shown in Figure 13-9 below.

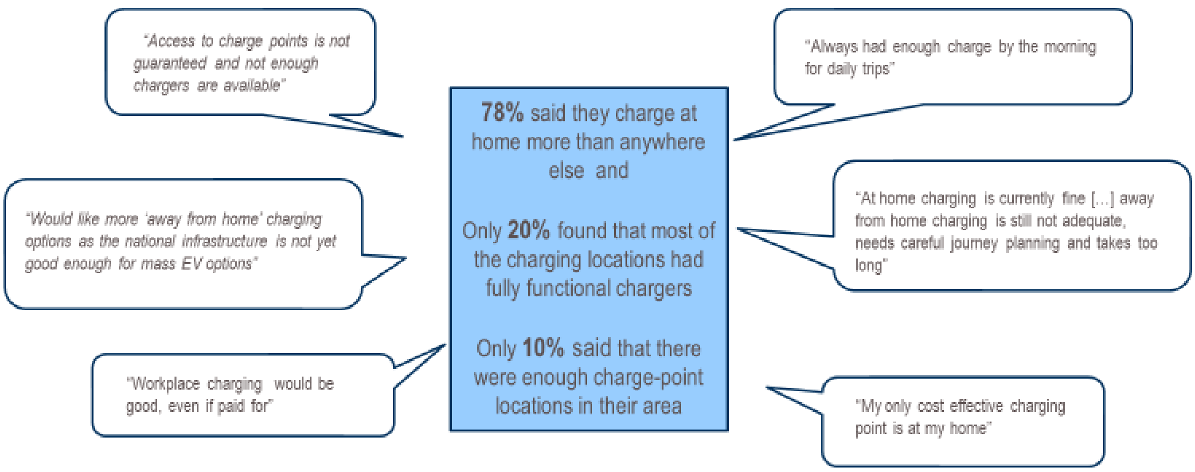

Figure 13-9: Participant attitude to charging away from home (To what extent to you agree or disagree with the following statements (514), Why do you say that (514))

13.4 Comparison of Participant Satisfaction Across All Three Trials

As noted above, throughout the project the base content of the surveys was kept identical when comparing participant satisfaction and acceptance of each trial solution to allow for comparison across the trials. This was to allow comparison of attitudes to each solution.

Each of the individual trial sections above (Sections 10, 11 and 12) reported on the scores given by participants at each point in detail, including disaggregating by PEV type and battery capacity in many cases. This section summarises the results given for CrowdCharge and GreenFlux, based on only those participants who completed all four surveys (Baseline, Trial 1, Trial 2 and Trial 3).

13.4.1 CrowdCharge

The graph below compares the satisfaction scores given by the 84 CrowdCharge participants who completed all four surveys.

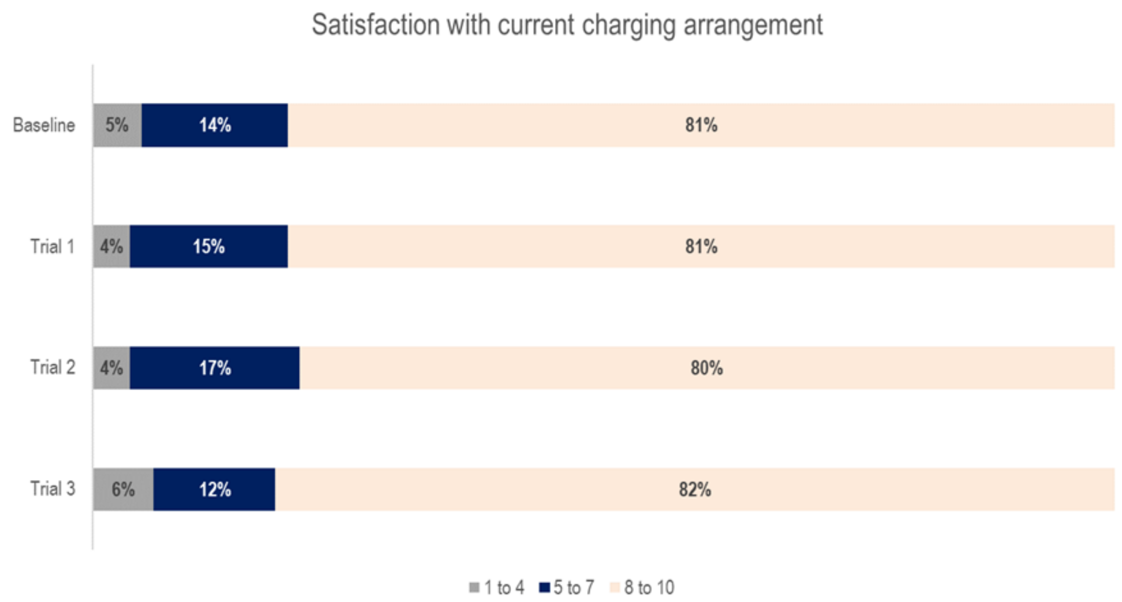

Figure 13-10: Satisfaction Scores - CrowdCharge (Base: 84 respondents who completed all four surveys)

Levels of satisfaction remained high throughout the project. There were no statistically significant changes in the proportion of participants who were highly satisfied across the three trials, despite regular demand management. Analysis within the individual trial sections showed that there was no statistically significant relationship between the amount of management participants experienced and the proportion of participants who were highly satisfied. Trial 1 showed a statistically significant trend towards neutrality (score of 5 to 7) amongst participants who experienced more restrictive management. Combining the 'never managed' and '1st Quartile[243]' groups showed that 10% of these participants gave a neutral score, compared to 28% of the '4th Quartile' group[244].

App usage in Trial 2 also made no statistically significant difference to the level of satisfaction with their charging arrangements which participants experienced – satisfaction

[243] Participants who experienced the least restrictive management in Trial 1, based on CrowdCharge Management Factor. For more detail see Section 10.1.6.
[244] Z test. Z = 2.0

levels remained high amongst all groups. There was also not a linear relationship which suggested that a greater financial reward in Trial 3 was associated with higher levels of satisfaction.

13.4.2 GreenFlux

The graph below compares the satisfaction scores given by the 104 GreenFlux participants who completed all four surveys.

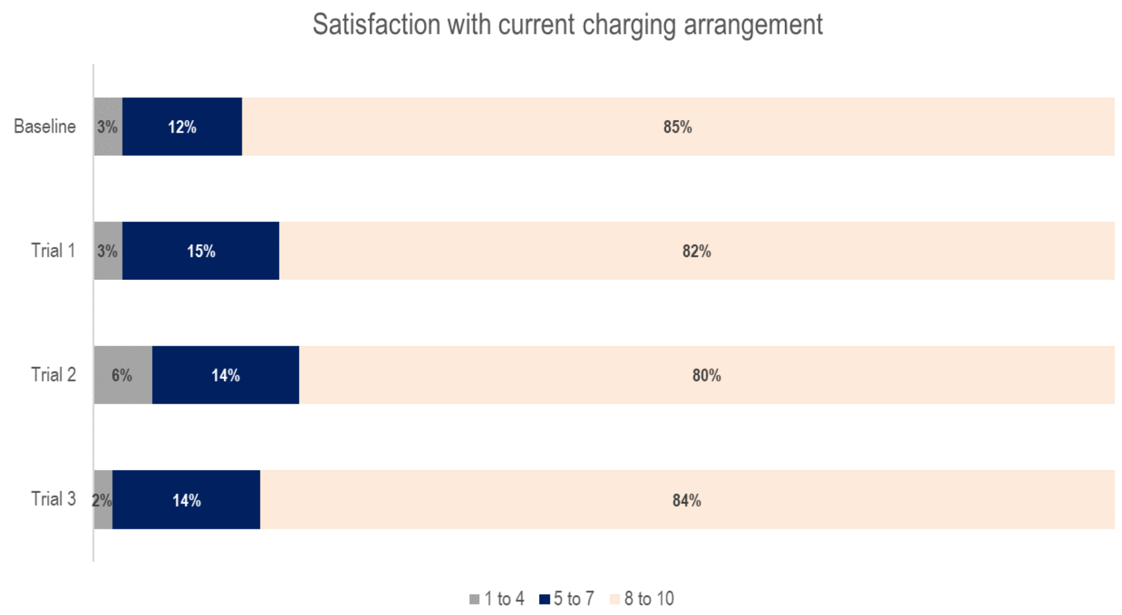

Figure 13-11: Satisfaction Scores – GreenFlux (Base: those who completed all four surveys)

Levels of satisfaction remained high throughout the project. There were no statistically significant changes in the proportion of participants who were highly satisfied across the three trials, despite regular demand management. Analysis within the individual trial sections showed that there was no statistically significant relationship between the amount of management participants experienced and the proportion of participants who were highly satisfied. This remained the case in Trial 2, and the results of customer survey also showed that participants who used the high priority feature more often were not more likely to be dissatisfied. In Trial 3 higher levels of financial reward for changing charging behaviour were linked to higher levels of satisfaction. However, amongst those who earned the lowest rewards (less than £10.30) 67% were highly satisfied (score of 8 to 10) and 27% neutral (scores 5 to 7).

13.5 Participant Preference Between Trials

In the final survey, participants were asked which out of the trials they preferred to be involved in, whether they would be likely to sign up to if it were made available in the future, and whether they would recommend each trial to a friend. This section reports the results of these questions for CrowdCharge and GreenFlux.

13.5.1 CrowdCharge

109 participants took part in all three trials and responded to the survey question asking to choose their preferred trial. The results are shown below.

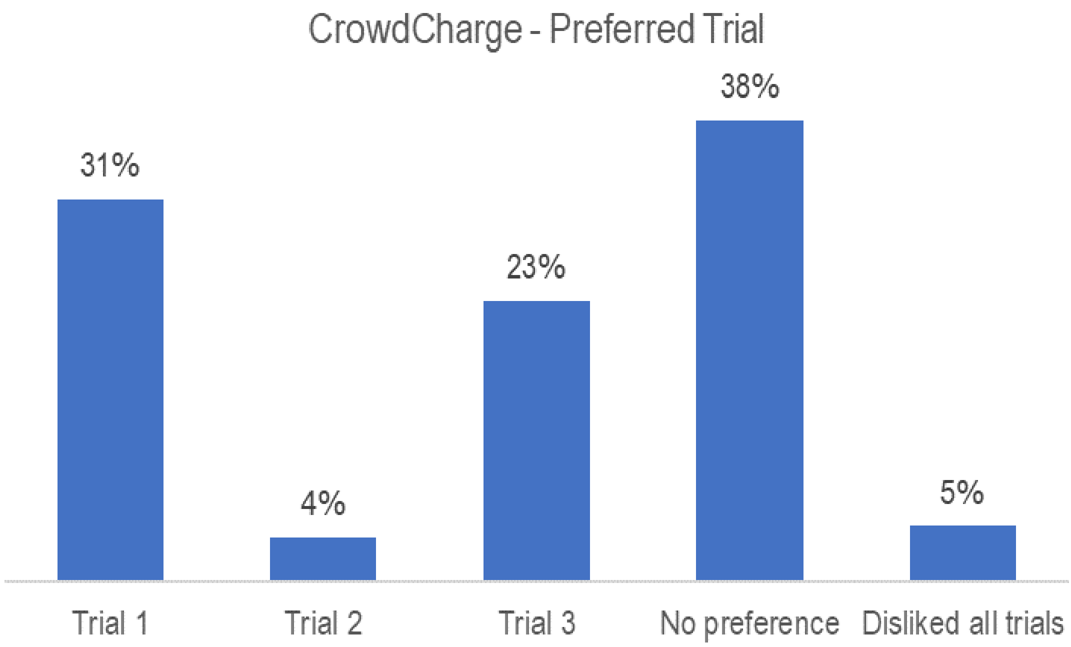

Figure 13-12: Preferred Trial Amongst CrowdCharge Participants (Base: 109 survey responses from participants who experienced all three trials)

The largest group of respondents had no preference between the thee trials. It may be that, apart from the financial reward offered in Trial 3, the participant's experience was similar. The second largest group of respondents preferred Trial 1 – the simplest system, although without any method to influence the likelihood of demand management and no financial reward for taking part.

Participants were also asked how likely they would be to adopt each trial, again shown below for the participants who completed this survey question and took part in all three trials.

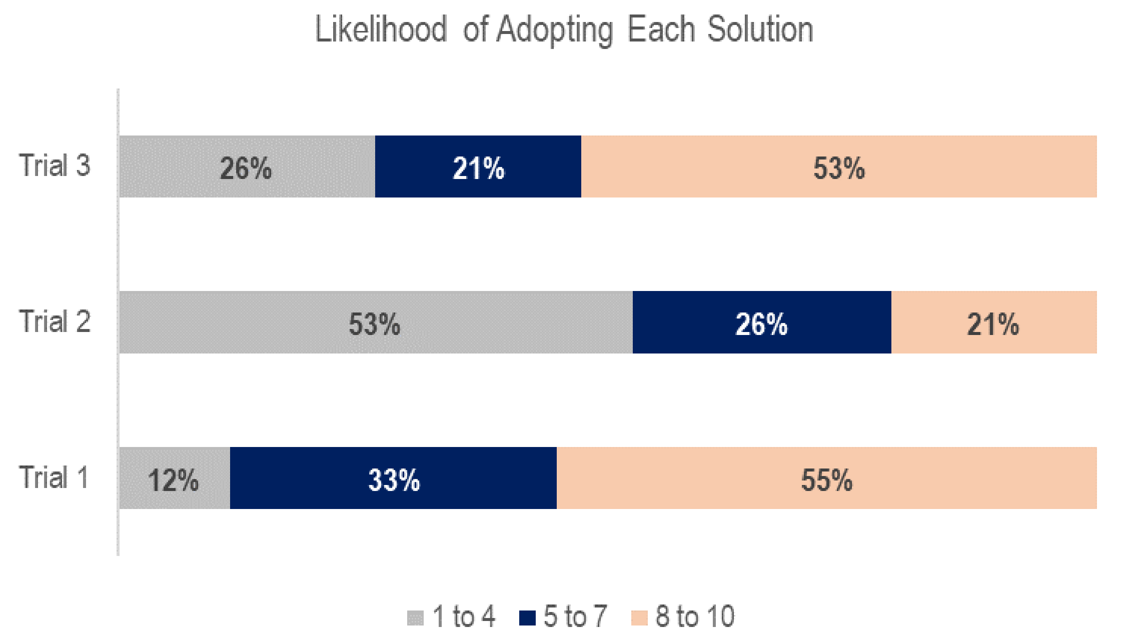

Figure 13-13: CrowdCharge - Likelihood of Adopting Each Solution (Base: took part in all three trials, responded to each question (likelihood to adopt each of Trial 1, 2 and 3) – Trial 1 = 78, Trial 2 = 38, Trial 3 = 38). Excludes 'don't know' responses.

The likelihood of adopting each solution broadly follows the preferences shown in Figure 13-12 above. A majority of participants would adopt either Trial 1 or Trial 3. The proportion of participants who would not adopt (scores 1 to 4) Trial 2 was high. It may be that the additional effort involved in using the app, combined with a lack of financial reward, reduce the likelihood of participants to adopt this solution. The free text responses shown below for Trial 1, 2 and 3 illustrate the reasoning behind the scores that respondents gave.

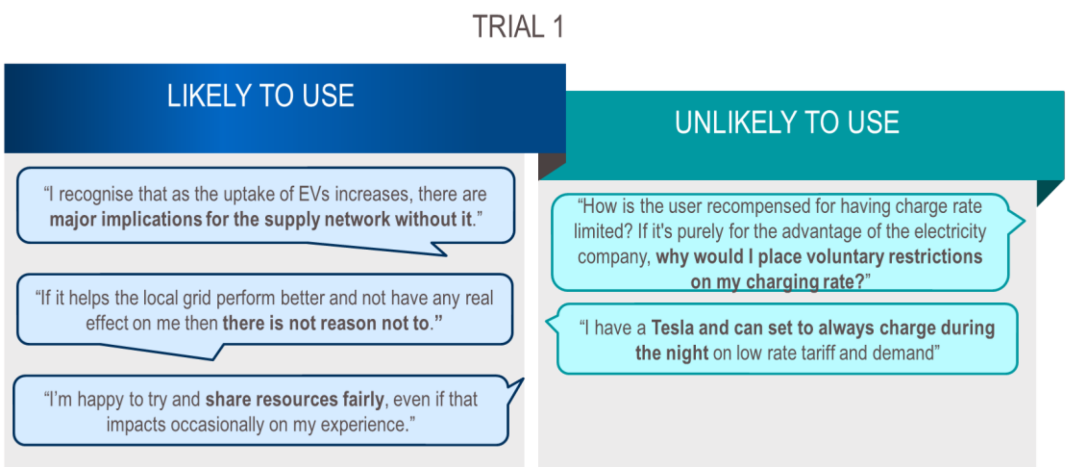

Figure 13-14: Free Text Responses - CrowdCharge Trial 1

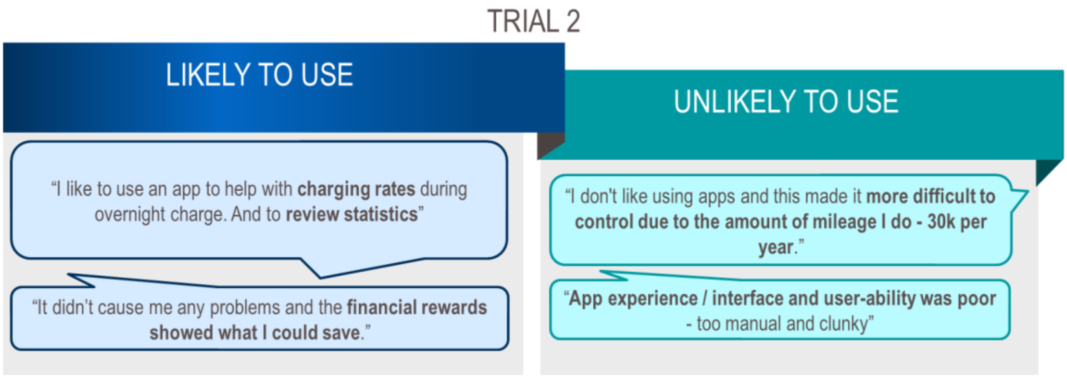

Figure 13-15: Free text responses - CrowdCharge Trial 2

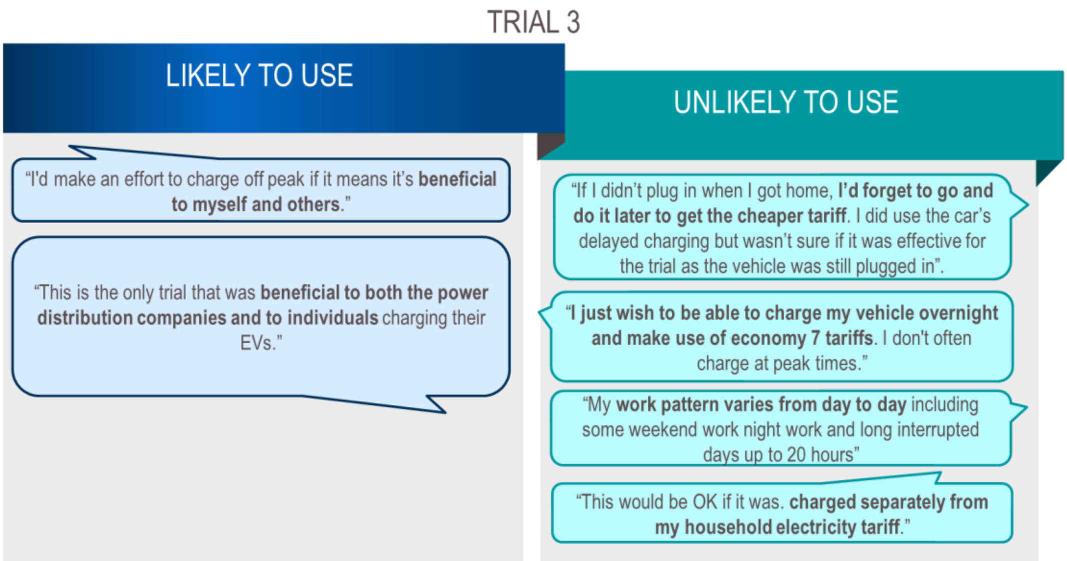

Figure 13-16: Free text responses - CrowdCharge Trial 3

Participants were also asked how likely they were to recommend the solution from each to a friend (on a 1 to 10 scale).

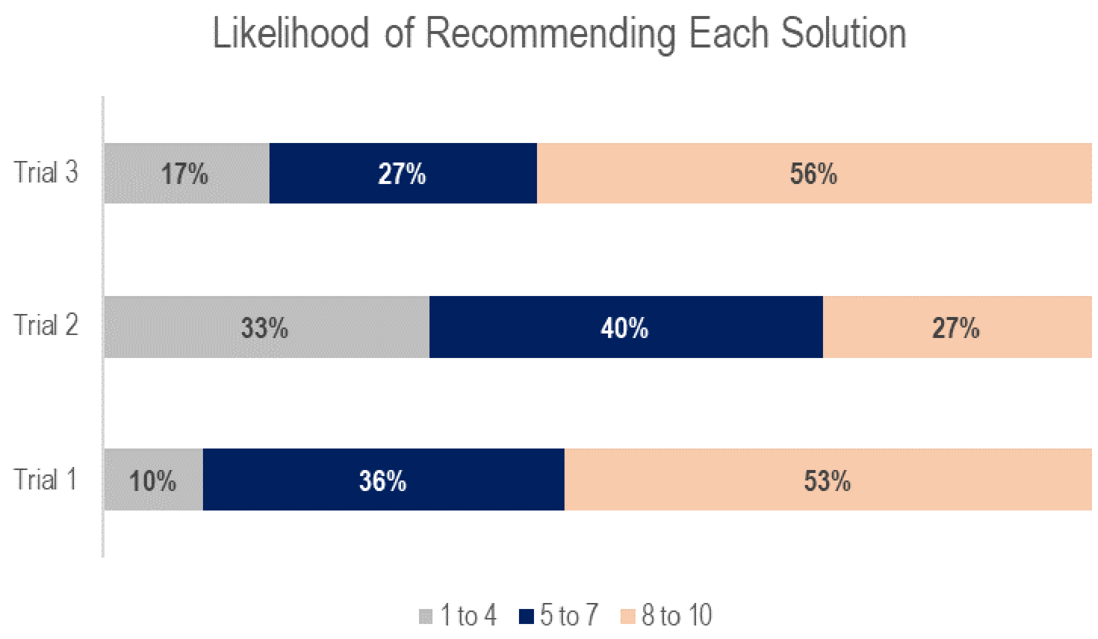

Figure 13-17: CrowdCharge - Likelihood of Recommending Each Solution (Base: took part in all three trials, responded to each question (likelihood to recommend each of Trial 1, 2 and 3) – Trial 1 = 118, Trial 2 = 103, Trial 3 = 107). Excludes 'don't know' responses.

The likelihood that CrowdCharge participants would recommend each solution to a friend was broadly similar to the likelihood that they would adopt it themselves. A majority (56% and 53% respectively) would recommend either Trial 1 or Trial 3.

The likelihood that CrowdCharge participants would recommend each solution to a friend was broadly similar to the likelihood that they would adopt it themselves. A majority (56% and 53% respectively) would recommend either Trial 1 or Trial 3. For these two trials only a small minority would not recommend either solution (17% and 10% respectively).

13.5.2 GreenFlux

144 participants took part in all three trials and responded to the question asking them which trial they preferred. The results are shown below.

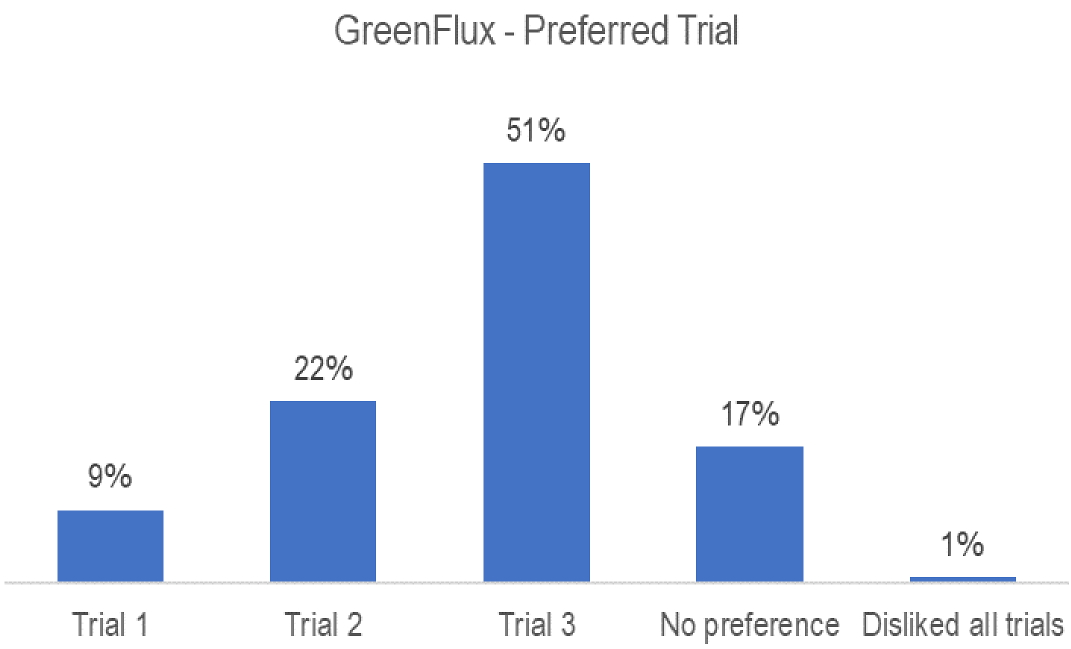

Figure 13-18: Preferred Trial Amongst GreenFlux Participants (Base: 144 survey responses from participants who experienced all three trials)

Trial 3 was the preferred solution for the majority of GreenFlux participants. Trial 2 was also preferred by a larger proportion of participants than Trial 1[245]. This may be because Trial 2 introduced level of control for participants via the high priority feature. Trial 3 allowed this control and also financially rewarded participants for changing their charging behaviour. Participants in Trial 3 also experienced very little management as shown in Section 12.2.3.

Participants were also asked how likely they would be to adopt each trial, again shown below for the participants who completed this survey question and took part in all three trials.

[245] Statistically significant Z = 3.05.

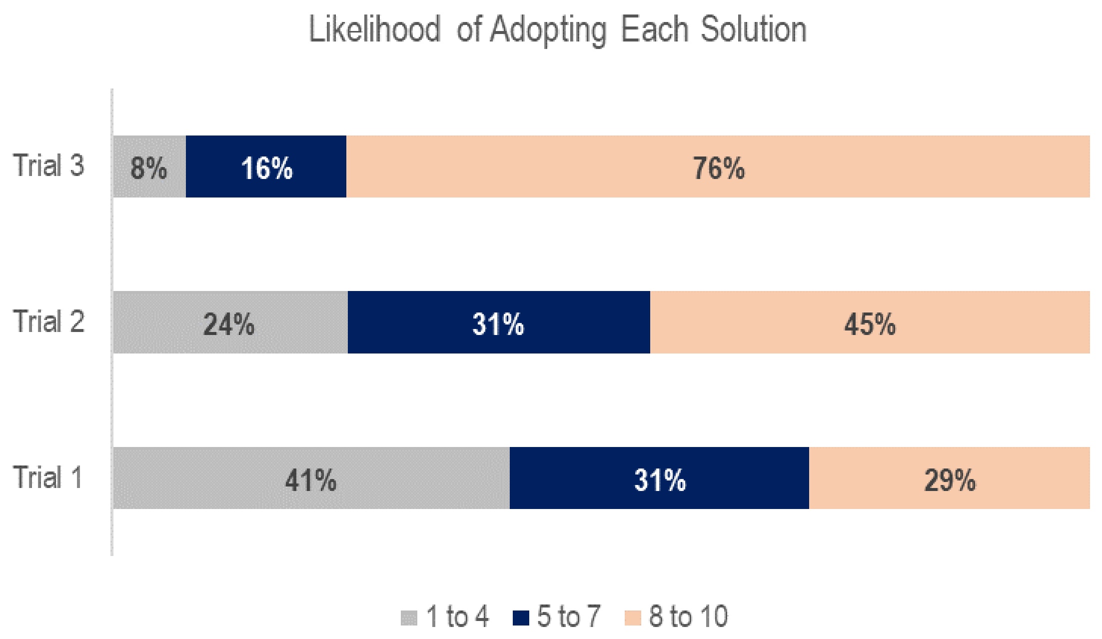

Figure 13-19: GreenFlux - Likelihood of Adopting Each Solution (Base: took part in all three trials, responded to each question (likelihood to adopt each of Trial 1, 2 and 3) – Trial 1 = 108, Trial 2 = 120, Trial 3 = 104). Excludes 'don't know' responses.

Trial 3 was most likely to be adopted by GreenFlux participants, with 76% of respondents giving a score of 8 to 10. This may be because GreenFlux participants found the Trial 3 app 'low maintenance', whilst providing them with control over their charging when they needed it and an easy to understand reward system. The results mirror those in relation to participants' preferred solution shown in Figure 13-18 – participants are more likely to adopt each successive solution (29% vs. 45% vs. 76% for Trials 1, 2 and 3 respectively).

Participants were able to give a free text response to explain the reasoning behind their score (likelihood of adopting each solution). The figures below show a selection of responses from those who were, and were not, likely to adopt each solution in turn.

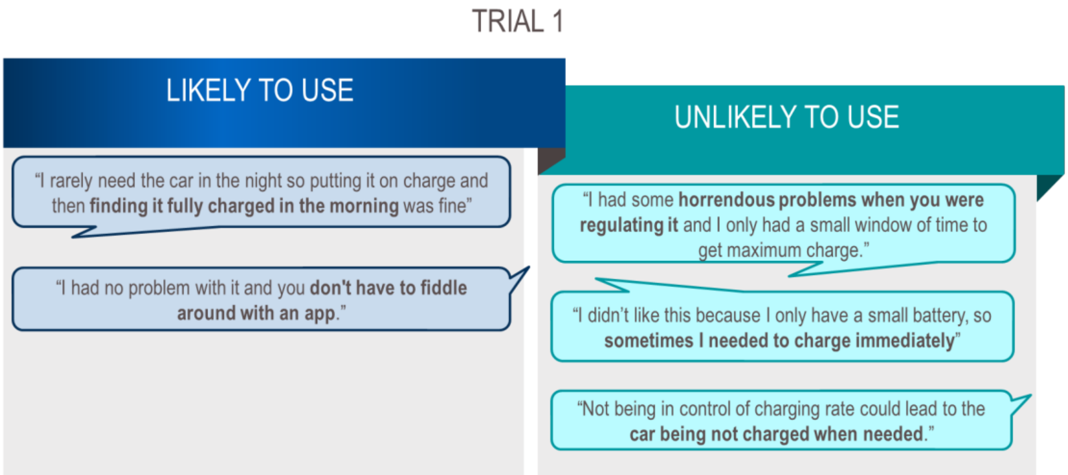

Figure 13-20: Free Text Responses - GreenFlux Trial 1

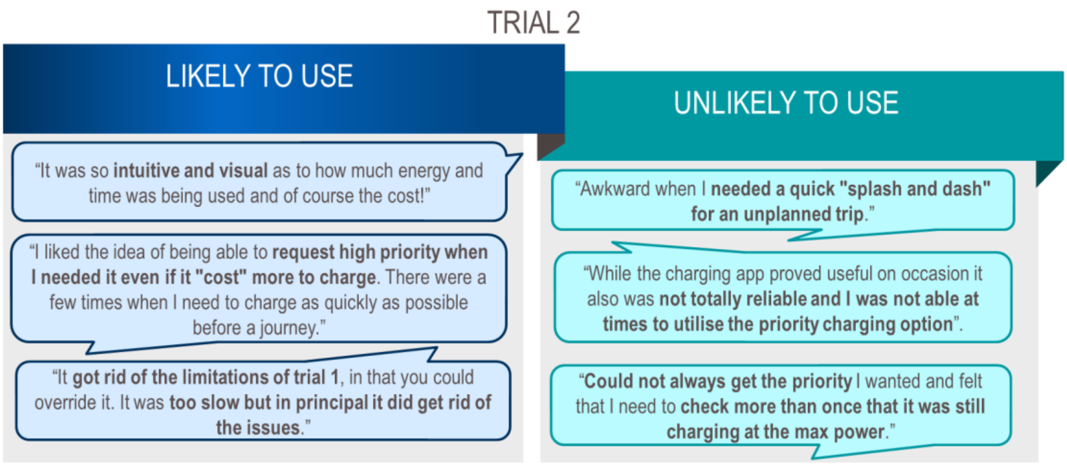

Figure 13-21: Free Text Responses - GreenFlux Trial 2

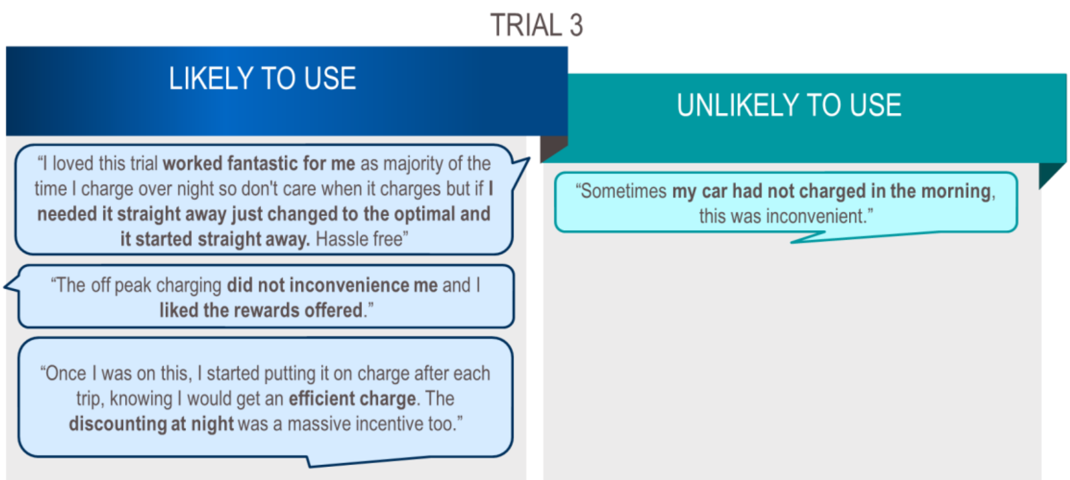

Figure 13-22: Free Text Responses - GreenFlux Trial 3

Participants were also asked how likely they were to recommend the solution from each to a friend (on a 1 to 10 scale).

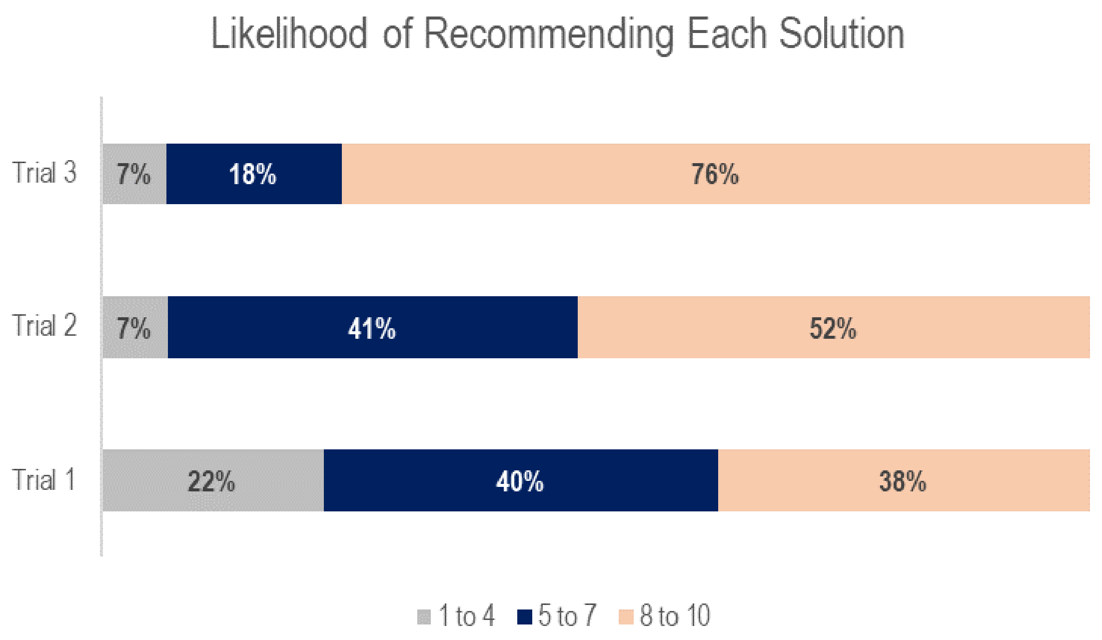

Figure 13-23: GreenFlux - Likelihood of Recommending Each Solution (Base: took part in all three trials, responded to each question (likelihood to recommend each of Trial 1, 2 and 3) – Trial 1 = 138, Trial 2 = 135, Trial 3 = 136). Excludes 'don't know' responses.

Trial 3 was also the solution which participants were most likely to recommend to a friend, with 76% stating they would be likely to recommend it (scores 8 to 10).

13.6 Attitudes Towards Rewards for Smart Charging

Trial 3 provided an insight into whether a reward system could influence charging behaviour. The final survey also included a number of questions to explore this area further.

Rewarding participants for their involvement in a scheme could be key to future PEV owner's engagement with smart charging or demand management schemes to change charging behaviour. 82% of participants who completed the final survey stated that they were likely to sign up for a smart charging scheme that helped to protect the electricity network in the future if they were rewarded.

In the focus groups the level of reward that trial participants may require to participate in smart charging schemes in the future was explored. Quotes from focus group participants are shown in Figure 13-24 below and provide an indication of the level of monetary reward that contributors thought would be necessary to motivate behaviour change.

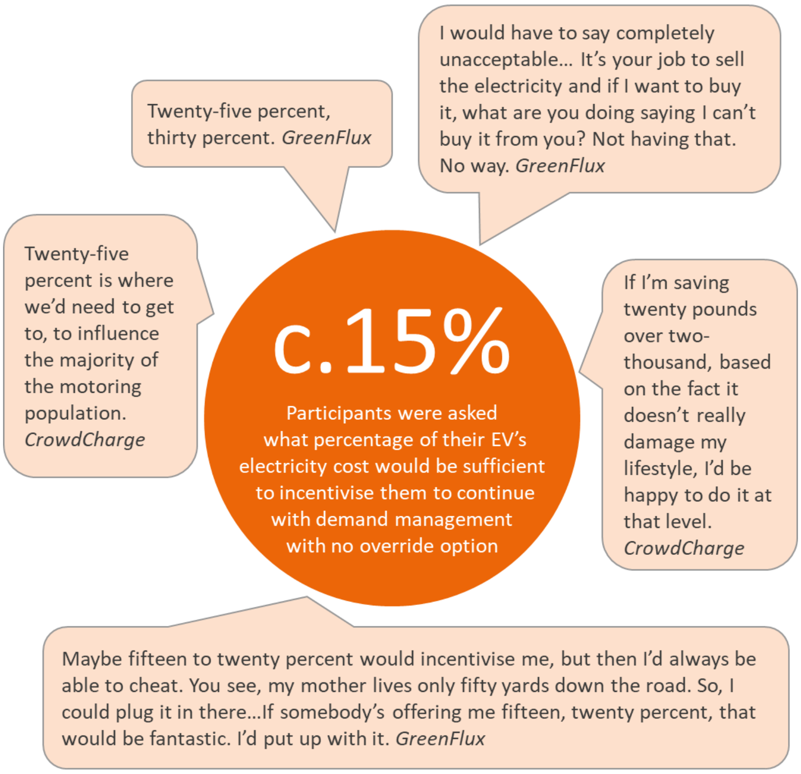

Figure 13-24: Focus group participants views on rewards for participating in a smart charging scheme

Analysis of annual electricity consumption by Electric Nation participants showed that BEV drivers used between 970 and 5000 kWh per annum (wide estimate from 25th Percentile in the 10 to 25kWh category, to 75th Percentile in the 35kWh plus group). This would cost between £140 and £718.50 per year (based on a price of 14.37 p/kWh[246]), so a 15% reduction would be equivalent to between £21 and £108 per year. This can be compared to the rewards earnt by participants in Trial 3. Using the GreenFlux data[247] the interquartile range of the reward value earned by participants was £10.30 to £27.76, from a trial lasting nine weeks (15th October to 16th December). This would be equivalent to a reward of between £60 and £160 per annum – more than the 15% saving cited by participants.

Participants in the focus groups were sceptical that EV drivers would accept smart charging without an incentive when wider adoption occurs, as shown in Figure 13-25 below. They also pointed out the necessity of overcoming technical issues experienced during the trial (e.g. with charger communications) and the stressed the need for increasing public understanding of issues such as network constraints.

[246] Average electricity price per unit taken from: https://www.ukpower.co.uk/home_energy/tariffs-per-unit-kwh Accessed July 2019

[247] GreenFlux data used as it was more representative of the reward earned by participant's as a result of changing their charging behaviour.

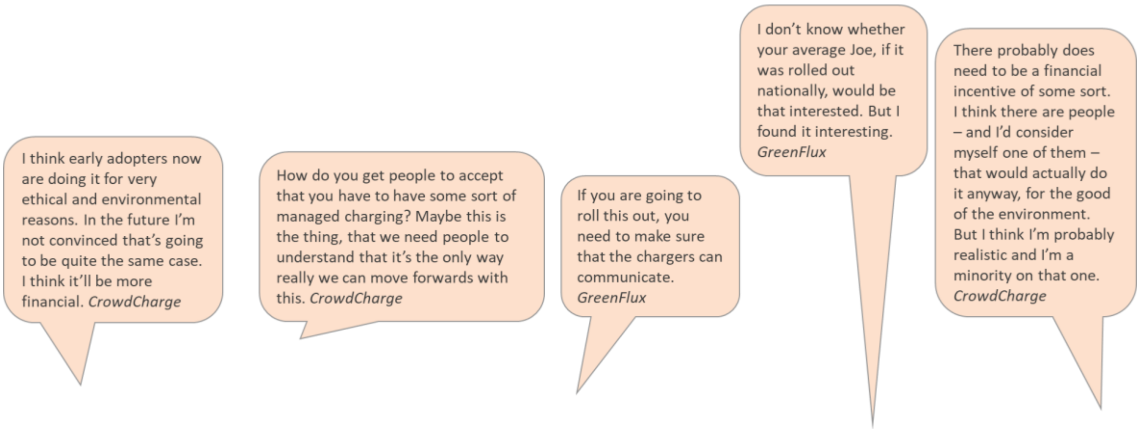

Figure 13-25: How could we encourage wider consumer acceptance of smart charging?

13.7 Participant Attitudes Towards Electricity Tariffs

Participants were asked whether they had changed or would consider changing their electricity tariff as a result of owning an EV.

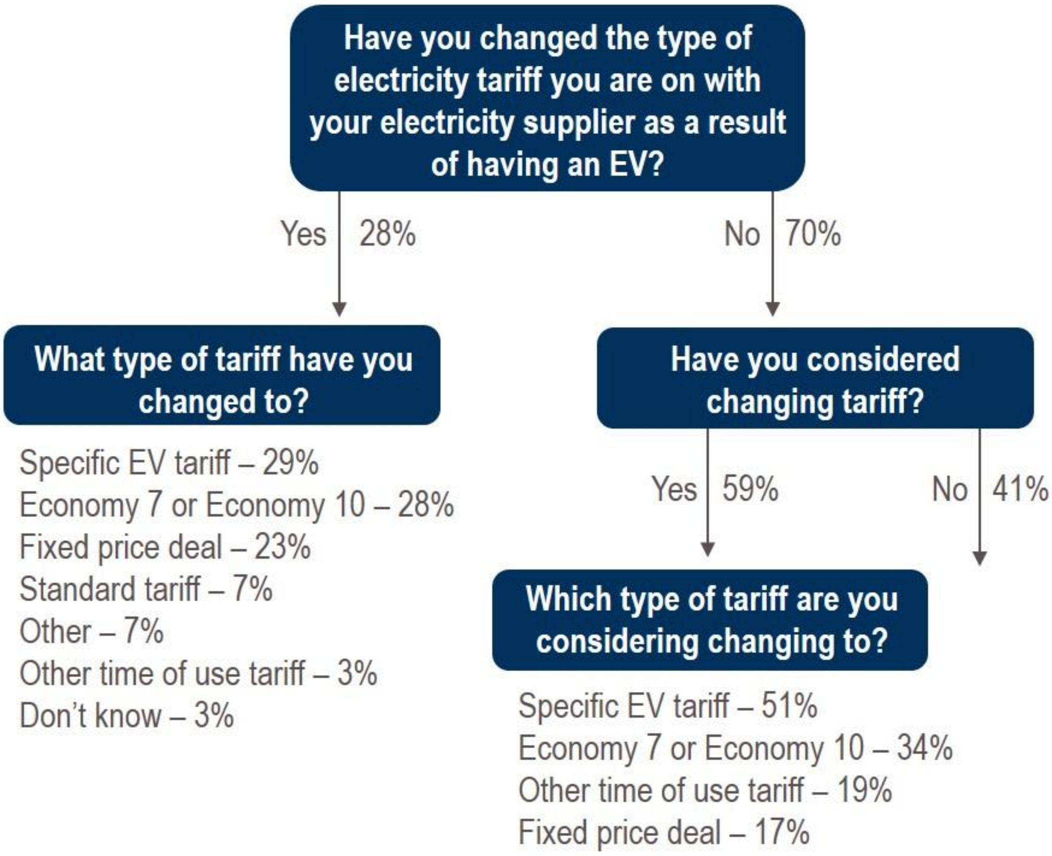

Figure 13-26: As a result of having an EV have you changed the type of tariff you are on with your supplier? (Base: 514), What type of tariff have you changed to? (Base: Had changed - 144) What type of tariff are you considering changing to? (could select multiple options) (Base: Considering changing - 149)

Figure 13-26 shows that 69% of survey respondents had either changed electricity tariff, or were considering doing so as a resulting of owning a PEV (28% had switched, 41% considering it). Switching to either an EV specific tariff, or a time of use tariff were both popular. Of those who had switched 29% had moved to a specific EV tariff, and 31% had moved to a ToU tariff (either Economy 7/10 or another ToU tariff). Participants who were considering switching as a result of having PEV were also likely to opt for either a specific EV tariff (51%) or a ToU tariff (53%).

13.8 Overall Attitude to Apps

The project highlighted the importance of making real time charging data available to smart charging participants, and giving them some control, such as through an override facility. The focus groups clarified that the introduction of an app helped reduce participant anxiety.

53% of survey respondents agreed that having an app for charging is useful. This increased to 62% for GreenFlux participants (who had access to real-time data on the power drawn by their vehicle and a straightforward override facility). Participants with a fully electric vehicle also found an app more useful (59%) – perhaps because the potential impact of smart charging on these participants was greater (their vehicle does not have an alternative fuel source).

13.9 Summary

- A key finding from the project as a whole is that trial participants remained highly satisfied and accepting throughout each trial and demand management algorithm, suggesting high levels of customer acceptability of demand management;
- For most participants who took part in the Electric Nation trial, the vehicle that they had throughout the trial was their first PEV, and they did not have major lifestyle changes;
- Significant discontent with the public charging network impacted participant acceptance with charging however participants were still happy with domestic charging;
- 38% of CrowdCharge participants expressed no preference between the three trials, whilst 31% preferred Trial 1 (the simplest system, with no app). 55% of respondents said they would be likely to adopt Trial 1 in the future and 53% would recommend it to a friend; and
- 51% of GreenFlux participants preferred Trial 3 (App plus ToU rewards). 76% of respondents said they would adopt this in the future and 76% would also recommend it to a friend.

14 Summary of Key Findings

This section sets out five key findings from the Electric Nation customer trial, supported by relevant conclusions.

1) Data from the trial shows flexibility in charging – but without an incentive the demand in the evening peak requires management

The customer trial showed that charging load is highest in the evening peak, when typically, 14% of the population were charging their car. The proportion of the population charging depends on multiple factors, including:

- The time at which drivers plug in their vehicle: on weekdays this is clustered in the evening peak, as the majority of participants returned home from work. 28% of all weekday plug-in events occurred between 17:00 and 19:00.
- The frequency with which participants charge their cars. If all drivers charged every night, then the proportion who were charging in the evening peak would be much higher than the 14% observed in Electric Nation. The data shows that the majority of participants charge between 3 and 4 times a week. Only 15% of drivers charged once a day or more.
- The length of time they charge their vehicle for: if all charging events were short then the proportion of the population charging would not 'build up' through the evening as more vehicles are plugged in (joining those who began charging earlier). For example, if vehicles charged for only an hour, those who plugged in at 17:00 would not contribute to the proportion of the population charging beyond 18:00. Analysis of data from Electric Nation shows that vehicles rated at 3.6kW typically charged for between 1 and 2.5 hours. Vehicles rated at 7kW typically charged for between 1.3 and 3.8 hours – although they can charge twice as fast, they have bigger batteries, so more energy is transferred.

Data from the trial has been analysed to show the flexibility available. A flexibility value of zero would equate to a charging event where the vehicle charged for the whole time it was plugged in. In this case a reduction in charge rate (due to smart charging) would result in the battery having a lower state of charge when it was unplugged (c.f. charging at maximum rate throughout). If the vehicle charged for only two hours out of a plug-in duration of 10 hours, then the flexibility would equal 80%. Flexibility is highest for vehicles plugged in during the evening peak, as shown below.

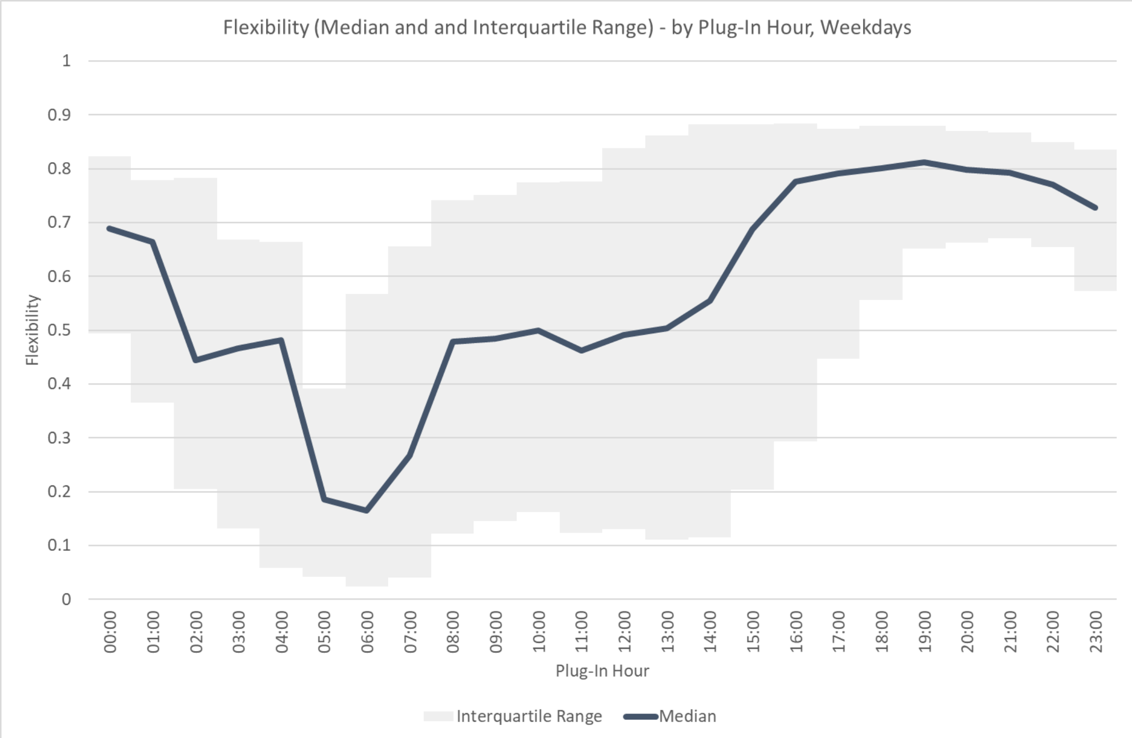

Figure 14-1: Flexibility (Weekdays) by Plug-In Time

This peak in flexibility coincides with the time when management of EV charging load may be required (when demand is highest, and the available network capacity is lowest).

The data from the trial has been used to generate new load profiles which are used within the Network Assessment Tool. This tool allows WPD to predict which networks may require intervention as a result of the additional loading from EV charging, and when this may occur based on current uptake forecasts.

Throughout the trial chargers were managed by CrowdCharge and GreenFlux within groups. These groups were associated with capacity profiles showing the maximum current that chargers could draw at each time of day. These profiles were based on historic data showing available spare network capacity, scaled to reflect the scenario when 30% of vehicles are PEVs. During winter these profiles resulted in demand management becoming active on the majority of weekdays in the evening peak. This provides an indication that management of charging during the evening peak is likely to be needed in the future.

2) Demand management is technically feasible, and acceptable to the majority of trial participants.

The Electric Nation trials have shown that groups of chargers can be managed by the back-office systems provided by CrowdCharge and GreenFlux. These systems operated successfully for the duration of the trial, with participant satisfaction remaining high throughout (further details below). The main challenges associated with operating the systems during the project were:

- Communications reliability:
    - Considerable ongoing effort was necessary from a range of project partners and suppliers to ensure that communications reliability remained high. This level of input is unlikely to be viable if it was required as part of a business as usual deployment – a more robust communications system would be necessary to avoid this.
    - A compromise also needs to be selected to manage the way in which chargers behave in the event of a loss of communications. This compromise needs to balance the risk of breaching capacity limits, whilst minimising the impact on the participant. The CrowdCharge system allowed 'offline' chargers to charge at 7kW – so no inconvenience to the trial participant, but potentially resulting in the capacity limit being breached. GreenFlux chargers reverted to a safe value of 13A after one hour, minimising the chance that the capacity limit would be breached but having a much greater impact on the participant. In some cases, GreenFlux participants who suffered repeated communications issues had to be removed from the 'smart charging' group due to the inconvenience of charging at 13A. A more balanced solution may be for chargers to operate at the maximum rate outside of the evening peak but revert to a safe value (such as 13A) between, for example, 17:00 and 20:00.
- Response of vehicles to demand management: a small number of vehicles experienced difficulties with the smart charging systems. The main issues were experienced with two vehicle makes/models:
    - BMW 330e: these vehicles entered a 'hibernation' state when charging was paused and did not begin charging again when the pause ended. This was the main cause of vehicles in the GreenFlux group being removed from the 'smart charging' group.
    - Renault Zoe: work on the test system showed that Renault Zoe vehicles could not charge when the available current was less than 8A (without a pause occurring). If the current was reduced below 8A then the car would stop charging and not begin again when the current was increased.

Vehicle OEMs should ensure that their vehicles are compatible with smart charging, as defined in BS EN 61851[248] and future similar standards.

Customer research was conducted throughout the project to judge the acceptability of smart charging to trial participants. This showed:

- Satisfaction remained high throughout all parts of the trial. Survey data (acceptability and satisfaction scores) was analysed alongside the management experience of participants. This showed that those who experienced the most management were not more likely to be dissatisfied compared to those who experienced no management.
- The majority of participants were willing to continue with their charging arrangements indefinitely at all stages of the trial, despite the frequency with which management was occurred.
- Some participants chose to interact with the apps provided by GreenFlux and CrowdCharge to influence the likelihood that they would be managed:

    - **CrowdCharge:** 55% of participants chose to register for an account for the CrowdCharge journey planning app during Trial 2. Overall the amount of data entered by participants was low:
        - 65% of those with an account made at least one data entry of any type;
        - 41% entered at least one regular journey;
        - 25% entered at least one 'one-off' journey; and
        - 57% provided at least one state of charge value.

      Participants who were more concerned about demand management did not enter data more frequently than those who were not concerned.

      The customer research survey showed that participants tended to use the app because it was part of the trial (and often they felt it wasn't useful beyond this), or to monitor the cost of charging. The elements which related to journey planning and providing inputs to influence the likelihood of management were also cited as reasons for using the app, but only by 7% of participants.

    - **GreenFlux:** during Trial 2 there were 183 downloads of the app, compared to 267 invitations (69%). Use of the high priority feature which allowed participants to over-ride management was relatively rare, occurring for around 3% of charging events in each week. These requests came from a small group of participants – 20% of participants were responsible for 90% of the requests. Participants who had a vehicle with a battery capacity of

[248] BS EN 61851-1:2011 (Electric vehicle conductive charging system. General requirements) applied during the during the trial. This standard has subsequently been updated to BS EN 61851-1:2019.

35kWh and above were more likely to make high priority requests than the general population. There was no link between the level of concern which participants expressed about demand management and their tendency to use the high priority feature.

Participants most often used the app because of particular journey requirements (e.g. making a longer trip than usual, or another trip later the same day). The second most frequent reasons for using the app was to try it out - in some cases because the participant wanted to understand the feature in case they needed it at a later date.

3) Trial data shows that Time of Use incentives appear to be highly effective at moving demand away from the evening peak – particularly when supported by Smart Charging (with an app) which makes it simple for the user

During Trial 3 CrowdCharge and GreenFlux both updated their back-office systems and customer facing apps in conjunction with a Time of Use incentive system. The aim of this change was to investigate the extent to which these incentives could change charging behaviour.

The system deployed by GreenFlux made the structure of the tariff clear to participants and offered them a simple "charging preference" system to determine when their vehicle would charge, aligned with the peak/off-peak tariff periods. This combination of tariff, app and smart charging functionality resulted in a dramatic change to the demand profile as shown below.

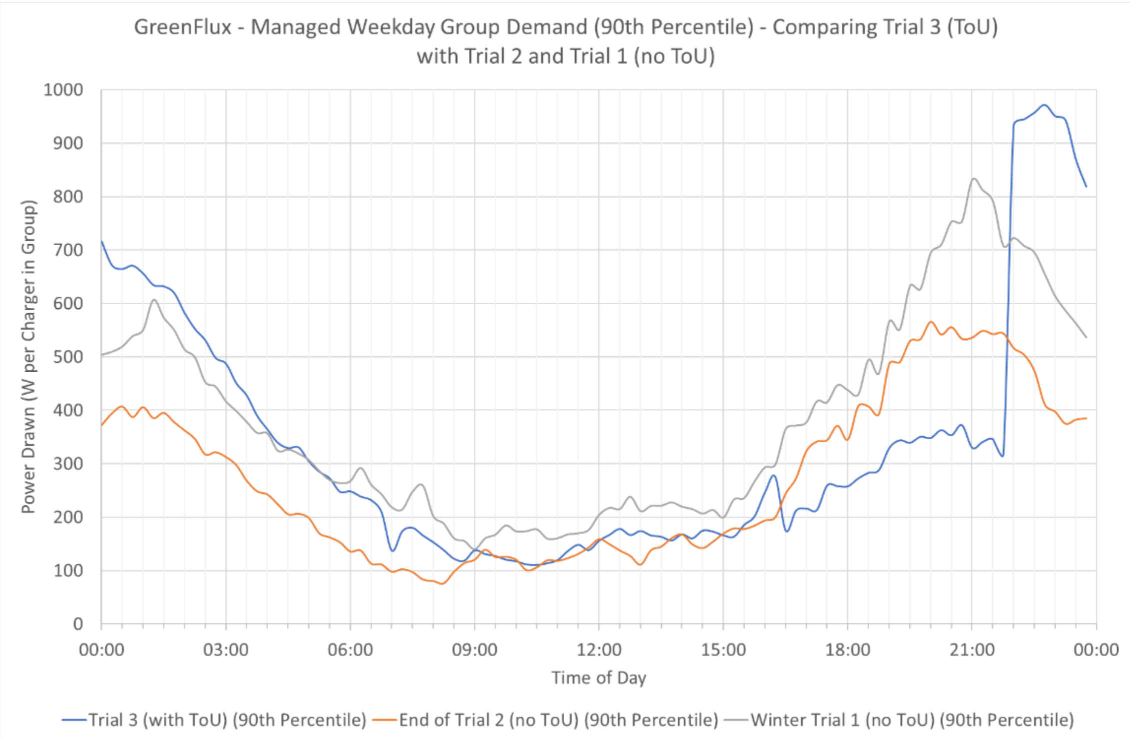

Figure 14-2: GreenFlux Trial 3 Weekday Demand (90th Percentile) compared to Trial 2 and Trial 1 (without ToU incentive)

The app deployed by GreenFlux was a key enabler of this change:

- Use of the app was high – 46% of all charging sessions during Trial 3 were set to either 'Minimise Cost' or 'Optimise Time and Cost' (only accessible by using the app). 61% of participants in Trial 3 used these preferences (and so the app) at least once.

- The change in the demand profile occurred as a result of a change in when charging began – without any significant change in the times when participants plugged their vehicle in.
- Participants who had not used the app were less likely to begin their charging in the evening peak before Trial 3, compared with those who had used the app (31% and 44% of charge events beginning in the weekday evening peak for non-app users and app users respectively). During Trial 3 there was a statistically significant decrease in the proportion of charge events beginning in the evening peak for app users (44% outside of Trial 3, 18% during Trial 3 (weekdays)). There was no similar change for non-app users, indicating that the app was crucial to enabling the change in demand profile shown above.

If a similar time of use tariff had been deployed, without the associated app and smart charging system the change in demand profile is unlikely to have been as great – the data presented above and in Section 12.2.4 shows that participants who did not use the app made minimal changes to their charging behaviour.

Feedback from participants about the GreenFlux Trial 3 app was positive, and indicated that the majority of participants found the reward system and app easy to understand and use:

- 88% of participants found the reward structure either “very easy” or “easy” to understand. Only 2% found it “hard” to understand.
- 86% of participants said they would be either “very likely” or “slightly likely” to use a similar app if it was available in the future.
- Trial 3 was the preferred trial for 51% of GreenFlux participants (compared to 22% and 9% who preferred Trial 2 and Trial 1 respectively).
- 76% of GreenFlux participants would be highly likely (score of 8 to 10) to recommend Trial 3 to a friend.

4) Smart Charging can:

Support the introduction and management of ToU based charging
Provide a means to manage any negative consequences of mass uptake of ToU incentives

The findings presented above show how effective a combination of time of use incentives, an app and smart charging can be in changing participant's charging behaviour and reducing peak demand. Figure 14-2 shows the extent of the change.

The reduction in demand during the traditional evening peak period (when available capacity was lowest) meant that no demand management occurred during Trial 3 once the updated app was available to all participants. The sudden spike in demand at 22:00 (caused by all sessions on 'Minimise Cost' starting at once) was always within the current available in the capacity profile. However, if this had not been the case then demand management would have become active, protecting the distribution network from overload.

The sudden increase in demand at 22:00 is unlikely to be desirable from an energy systems point of view, particularly if such a system was widely adopted. It would require a sudden increase in generation output (which may be achieved with fossil fuel generation such as gas peaking plants). Although unlikely (based on the results shown above), if such a change in demand profile occurred without smart charging then there would be no mechanism available to mitigate these negative impacts. Drivers may have set timers for 22:00 and charging would begin, with no possibility of a signal from the energy system that this is not desirable.

Smart charging offers a way in which any negative consequences associated with a mass uptake of Time of Use tariffs could be mitigated. These could include introducing an element of randomisation into the start time of charge events (i.e. so not all 'Minimise Cost' events started at 22:00). Alternatively, a different incentive package could be formulated in conjunction with an energy supplier, supported by smart charging. Under this model the participant would allow their charging to be managed in return for an incentive (e.g. a fixed discount on their electricity bill each month, a free charger or other incentives). The smart charging operator would then manage the charging under their control using a combination of inputs. These inputs would include those from energy suppliers (linked to the wholesale market and so including generation availability and potentially carbon intensity) and any grid limitations. Participant preference could also be included (such as an override or "charge me now" function).

5) Data from smart chargers, similar to those used in Electric Nation, can provide a strong data source for building an evidence base for future development.

Electric Nation collected data from over 130,000 charging events, lasting over 2 million hours, from a wide range of different types of PEVs. This data, alongside the additional insights available from customer research has allowed a detailed picture of charging behaviour and attitudes towards smart charging to be developed. The work has informed WPD's Electric Vehicle Strategy.

The data collected by Electric Nation provides a valuable resource for others working in this field and will be made publicly available by WPD.

15 Next Steps

The UK is on the cusp of a big change: National Grid scenarios now forecast millions of EVs by 2030, in the run-up to net zero by 2050.

WPD's network will need to grow and adapt to accommodate a steep uptake in low carbon technologies such as EVs and heat pumps, whilst keeping costs to the end customer as low as possible.

As an electricity system operator, WPD's approach is to ensure that a suitable network exists for all charging requirements in all situations. This has many factors as charging requirements vary dependent on the type of vehicle and the owner's access to either their own or public charging infrastructure. Only 60% of car users have access to an off-street parking location which is likely to be suitable for charging and because of Electric Nation, WPD now have a much better picture of this type of charging.

WPD predict that the majority of their larger local transformers will currently be able to accommodate one 35kWh charge every five days for each of the customers connected to it. This provides a charged range of around 150 miles in many EVs and it is likely that this will support a large proportion of home charging. On networks where this is not the sufficient, WPD may deploy a charge system similar to those deployed in Electric Nation. The project has demonstrated that the majority of customers are open to accepting charge management, and it generally doesn't interfere with journey plans. WPD view this system as a short-term solution, and once deployed, it would trigger reinforcement of the network.

Flexibility will provide a key role in delivering EV charging in the future, this is likely to provide solutions for many customer types; from domestic users to fleet users who return their vehicles to a depot overnight. Domestic users will be able to take advantage of time of use tariffs that electricity suppliers offer in conjunction with smart meters. With their vehicles at home when not in use, they will be able to use managed charging to charge their vehicles at times when price signals show it to be beneficial for the wider electricity network, as demonstrated in Electric Nation.

WPD have written an Electric Vehicle Strategy in response to predicted EV growth; the data from Electric Nation has informed the approach taken and the decisions made within the document.

The growth of EVs will impact on DNOs such as WPD in a range of ways, including proposals to install three-phase cables in every new home, working with local authorities to provide enough power to install large numbers of charge points in car parks, and working with companies who are looking to set up high power EV charging hubs. As such, Electric Nation is not the end, but it's the beginning of future innovation projects.

Paul Jewell, WPD Policy Manager

16 Electric Nation Enquiries

For further information, or to request data from the project. Please contact:

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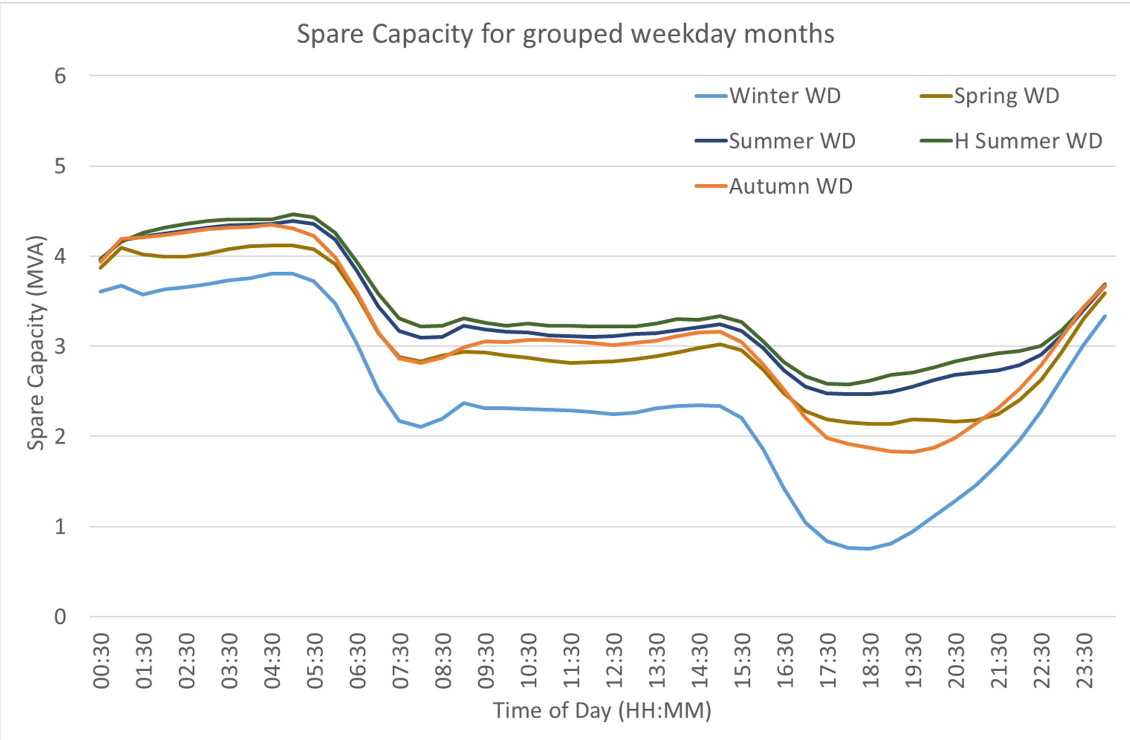
Appendix 1: Process to Generate Capacity Profiles

Introduction

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

Existing Network Demand and Spare Capacity

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.



Appendix Figure 1: Spare capacity for an HV Feeder in the East Midlands

The variations in this profile are as expected. For example, ‘spare capacity’ is lowest in the winter (when loading is highest). The lowest amount of available ‘spare’ capacity occurs at 18:00, due to a combination of higher residential loading (lighting, appliances, cooking etc. as people return home) and some industrial/commercial load. Loading is lower during the summer, so the amount of ‘spare’ capacity is higher.

This spare network capacity is equivalent to the amount of power which could be drawn by PEV charging (or other load growth) on the network without exceeding the networks design limits.

Scaling of Profiles

The profiles of 'spare capacity' described above required 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 – equivalent to 107 chargers drawing 7kW.

Within Electric Nation the capacity profiles were scaled so that participants experienced a similar amount of demand management as the number of chargers under management grew. For example, the first GreenFlux group contained 16 chargers. This was expanded to 31 chargers a few weeks later. Profiles of spare capacity were scaled based on the number of chargers in the group to ensure that management occurred equally frequently regardless of the number of chargers in the group.

The first part of the profile generation process focussed on determining the existing spare capacity on the network, the PEV load for a scenario when 30% of vehicles were PEVs, and the resulting spare capacity, as follows[249]:

1.1. For each half hour, calculate the available capacity on the feeder. This value came from historical demand data for a WPD feeder in the East Midlands. The average value for each HH, across each season was used. This figure was the real spare capacity on the feeder (i.e. no scaling) = Feeder Design Rating (MW) – Average Demand in each HH (MW);
1.2. For this feeder, calculate the number of PEVs which would be present if 30% of those households who owned a car had an PEV, as follows:
    - Total the number of domestic customers on the HV feeder (5,111 for the East Midlands example chosen);
    - Using census data, 74% of households own at least one car = 3,780 households with a car (74% of 5,111); and
    - 30% penetration would be equivalent to 1,134 PEVs (i.e. 30% of the 3,780 households with a car).
1.3. For each half hour, using data from My Electric Avenue[250], calculate the maximum percentage of EV chargers which were active for the given season;
1.4. For each half hour, convert the % of EV chargers active into a PEV load, as follows:

$$\text{PEV Load (MW)} = \left(\frac{\text{\% of EV Chargers Active}}{100} \times \text{Number of PEVs}\right) \times \text{Assumed Charger Load (kW)} \times 0.001$$

Where:

[249] Separate profiles were developed for weekdays and weekends, following the process described, using existing demand data and % of PEV population charging

[250] http://myelectricavenue.info/ LCNF Tier 2 Project delivered by EA Technology on behalf of Scottish and Southern Energy Networks.

- Number of PEVs = 1,134 (see above)
- Assumed Charger Load = 5.5kW (a mix of 3.6 and 7kW vehicles)
- The scaling factor of 0.001 is used to convert the load from kW to MW.

1.5. For each half hour, calculate the spare capacity with EV load = Existing available capacity from Step 1.1 – PEV load from Step 1.4

The second part of the process scaled the profile based on the number of chargers in the Electric Nation trial group (see Section 5.3), as follows:

2.1. For each half hour, calculate the PEV load for the number of chargers in the Electric Nation group, as follows:

$$\text{PEV Load (kW)} = \left(\frac{\text{\% of EV Chargers Active}}{100} \times \text{Number of PEVs in Group}\right) \times \text{Assumed Charger Load (kW)}$$

Where:

- % of EV Chargers Active is based on My Electric Avenue data
- Assumed Charger Load = 5.5kW (a mix of 3.6 and 7kW vehicles)

2.2. For each half hour, calculate a 'Scaled Feeder Available Capacity' as follows:

$$\text{Scaled Feeder Available Capacity (MW)} = \frac{\text{Max. PEV Load across 48 HH} \times 0.001}{\text{Max. PEV Load for 30\% Penetration}} \times \text{Feeder Available Capacity (MW)}$$

Where:

- Max. PEV Load across 48 HH = Maximum value from Step 2.1 (across the day) (kW)
- Scaling factor of 0.001 used to convert to MW
- Max. PEV Load for 30% Penetration = Maximum value from Step 1.4 (across the day) (MW)
- Feeder Available Capacity = Value for given half hour from Step 1.1

2.3. For each half hour, convert the Scaled Feeder Available Capacity (MW) to Amps[251] = (Scaled Feeder Available Capacity from Step 2.2 (MW) x $1\text{x}10^6$)/250

GreenFlux and CrowdCharge were issued with capacity profiles containing 96 values – the available current in each half hour period, for weekdays and weekends.

[251] Equation converts power in MW to W and divides by 250 (assumed nominal voltage)

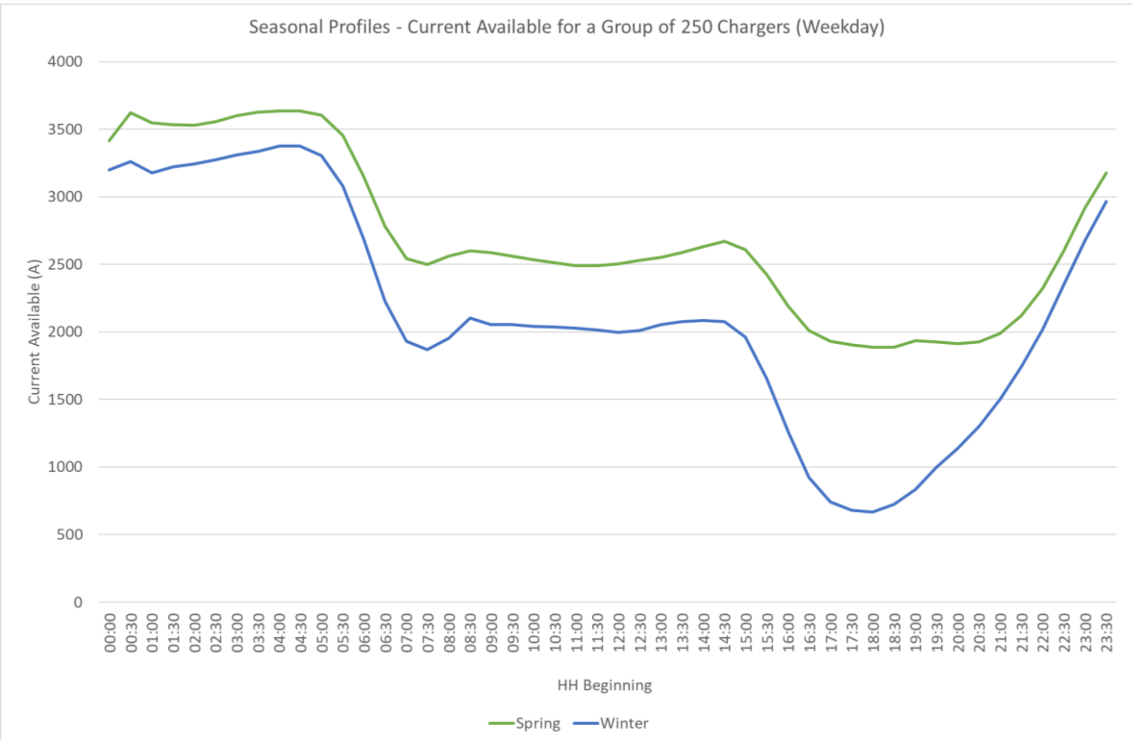
The profiles were further scaled to reflect the reliability of communications. For example, if a group contained 100 chargers, but only 90 were communicating then a profile of available capacity based on 100 chargers would result in demand management happening less frequently than expected. Therefore, the number of chargers in the group was adjusted based on the prevailing communications reliability of the chargers in management over the previous few weeks. For example, if a group contained 150 chargers, with communications reliability of 85% then the profile would be based on 128 chargers (85% of 150) – i.e. a value of 128 would be used in Step 2.1.

Issuing of Capacity Profiles to CrowdCharge and GreenFlux

CrowdCharge and GreenFlux were each issued with 'capacity profiles' (see Section 6.4) which set out the available capacity for EV charging (in Amps) for each half-hour period, separated by weekdays and weekends. Each group had its own capacity profile, derived using the scaling process described above. These profiles also recorded the start and end date/time associated with each profile.

'Spring-Winter' Combined Profiles

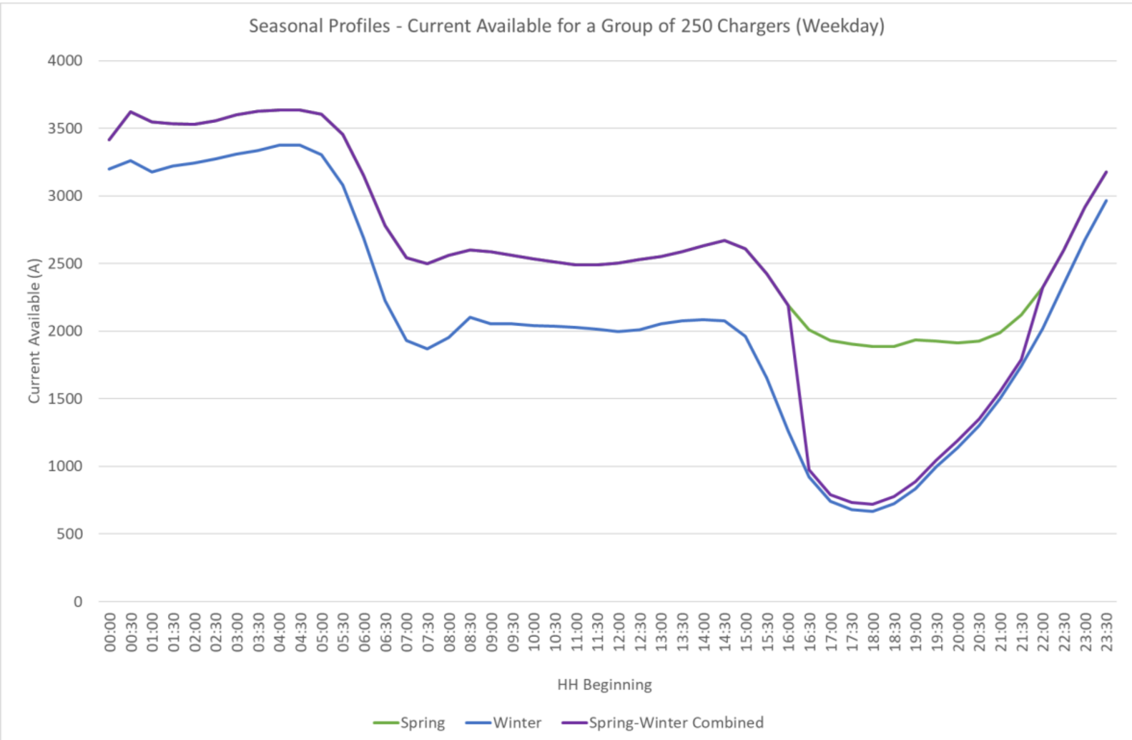
The graph below shows a comparison between the 'winter' and 'spring' weekday profiles for a group of 250 chargers.



Appendix Figure 2: Spring and Winter Profiles

Winter profiles were used in the demand management groups from mid-November 2017 to early April 2018. This was followed by a spring profile. However, the additional available capacity available in spring, particularly during the evening peak, meant that no demand management/smart charging occurred.

A decision was made, in conjunction with WPD, to modify the profile to ensure some curtailment of charging continued. This was still realistic for some networks in a scenario where 30% of vehicles are electric (i.e. those with less spare capacity than the specific East Midlands example chosen), or on the specific network used but with higher PEV ownership levels. This also ensured that the project could continue to test the acceptability of smart charging solutions. The new profile matched the spring profile outside of the evening peak period but reverted to a modified winter profile in the peak. The modification was applied to increase the available capacity slightly compared to winter, therefore reducing the levels of management slightly. The graph below shows the spring, winter and 'spring-winter' combined profiles (again, based on a group of 250 chargers).



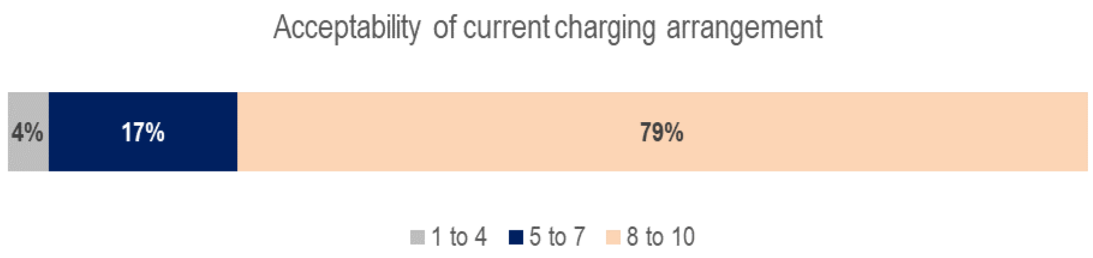
Appendix Figure 3: Winter, Spring and 'Spring Winter Combined' Profiles (Weekday)

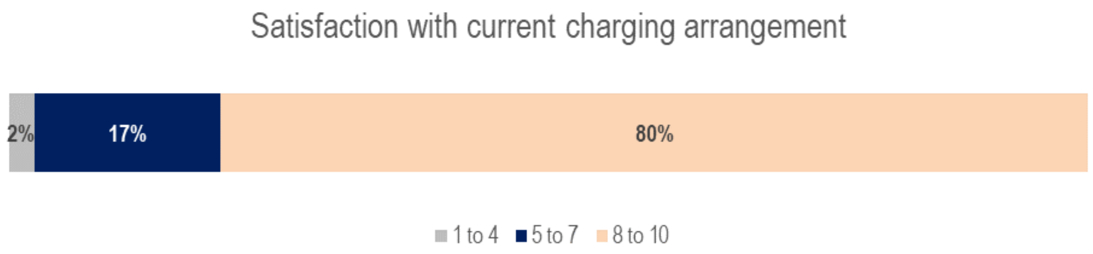
The combined profile was used in both the CrowdCharge and GreenFlux cohorts from late May 2018 until November 2018, when winter profiles were re-applied.

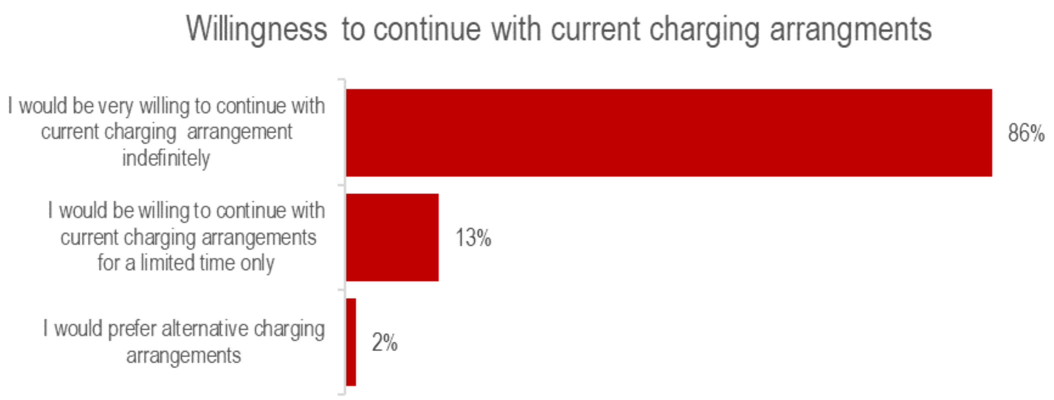
Appendix 2: Acceptability and Satisfaction of Charging Arrangements Results for All Survey Respondents – CrowdCharge

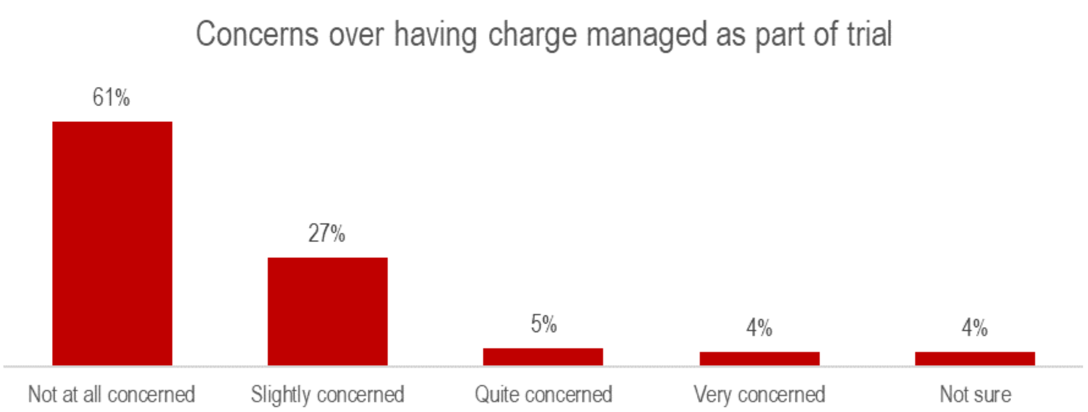
The data presented in the main report on the acceptability/satisfaction with current charging arrangements includes only survey respondents who provided an answer for all four surveys (Baseline, Trial 1, Trial 2 and Trial 3). This approach was taken so that changes in attitudes could be tracked as participants' experiences changed in each part of the trial. However, there was additional data collected from participants who did not complete all four surveys. This appendix shows this data for Trial 1, 2 and 3 for CrowdCharge participants.

Trial 1 – Demand Management, No App (133 respondents)

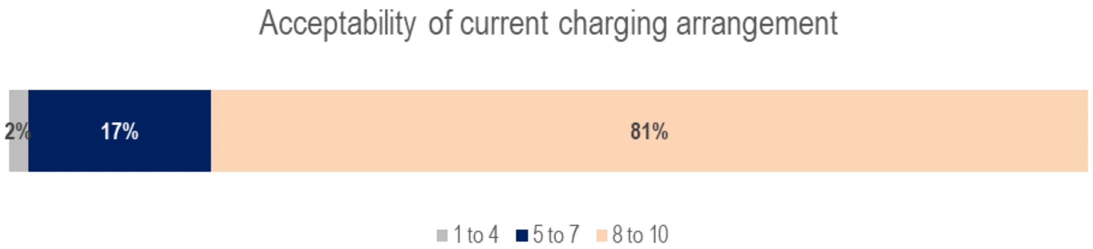


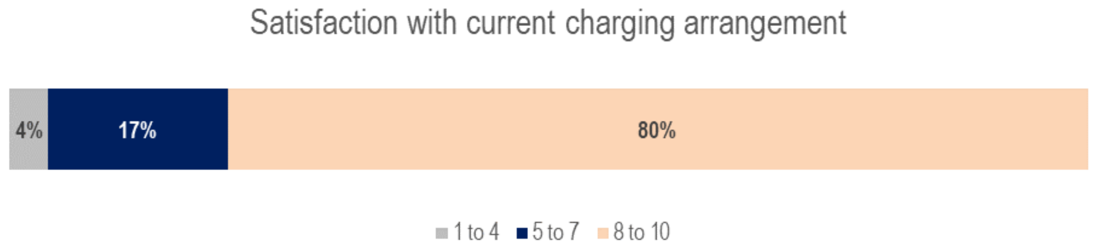


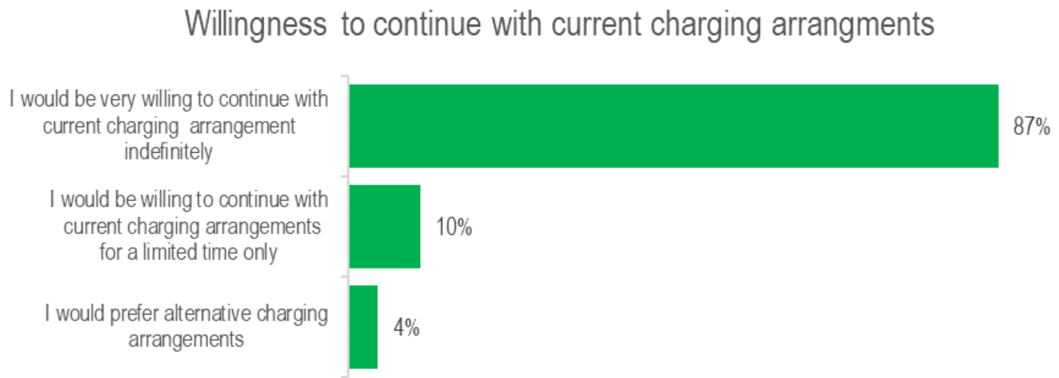


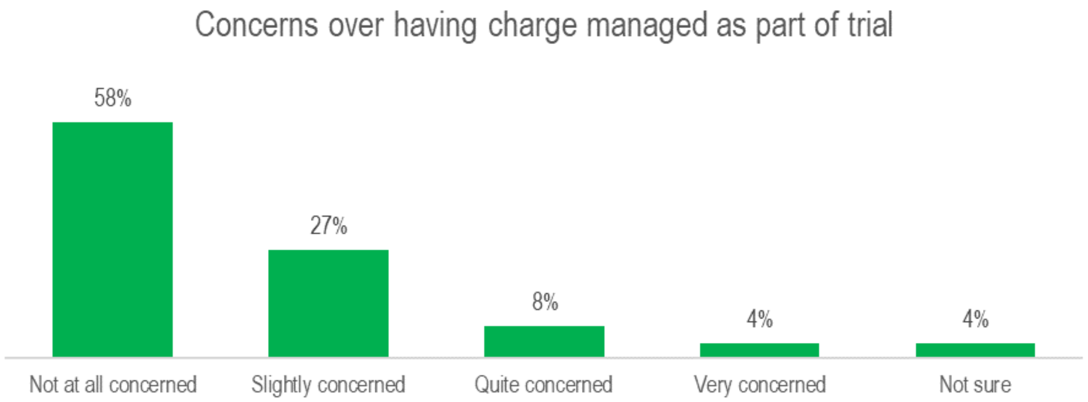


Trial 2 – Demand Management, With App (168 respondents)

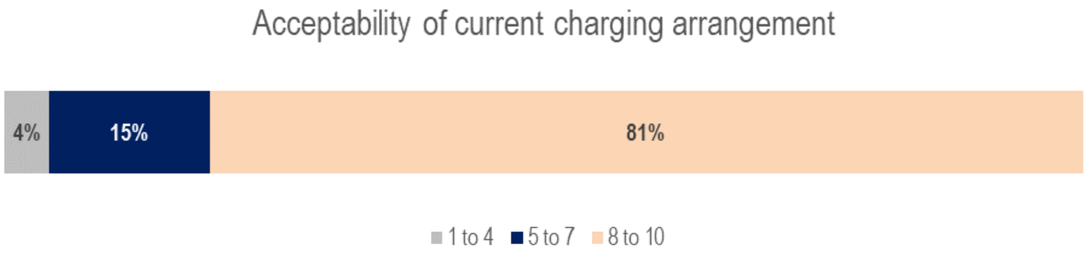


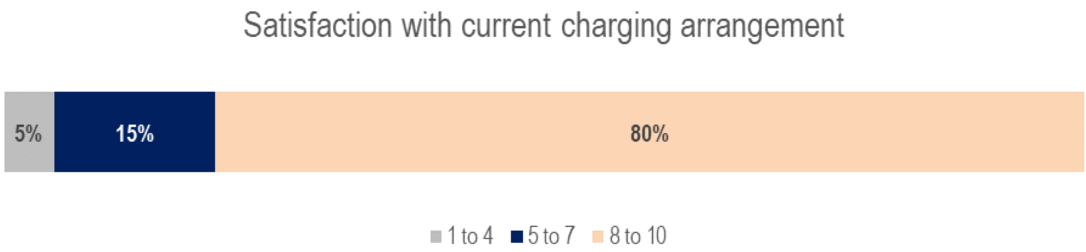


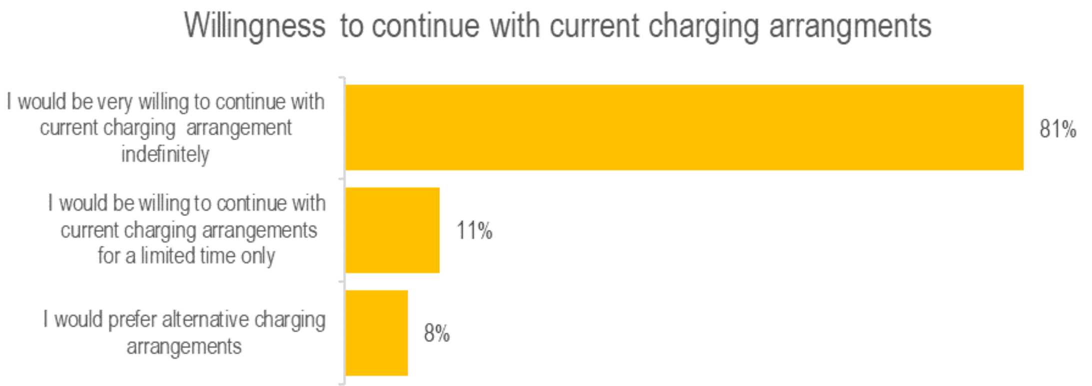


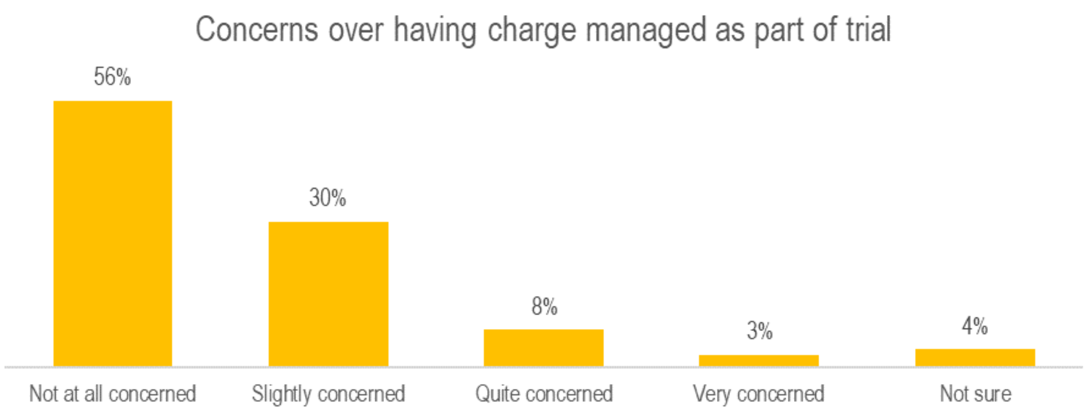


Trial 3 – Demand Management, With App and ToU (194 respondents)





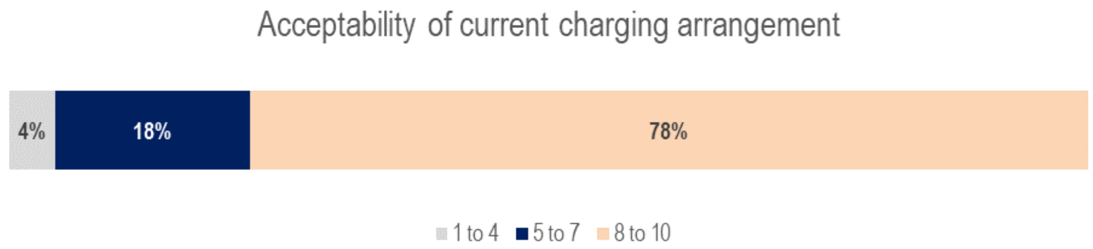


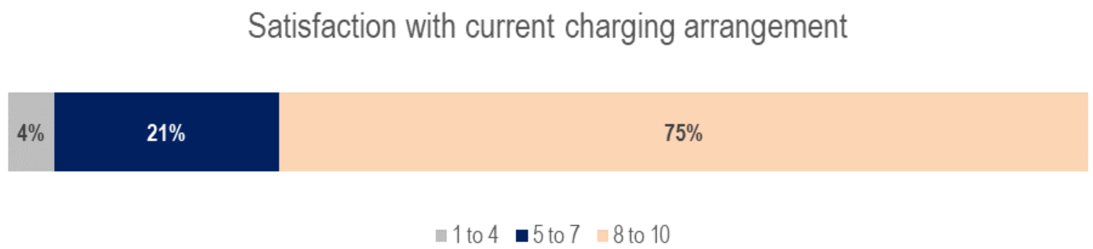


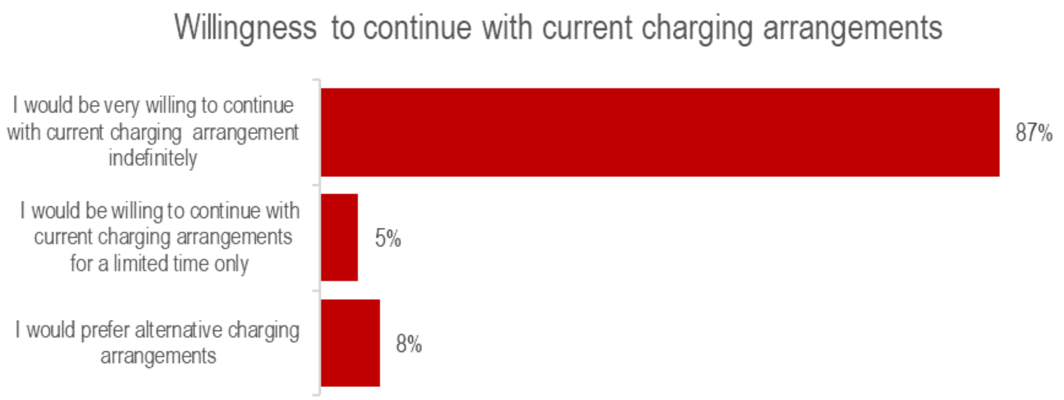
Appendix 3: Acceptability and Satisfaction of Charging Arrangements Results for All Survey Respondents – GreenFlux

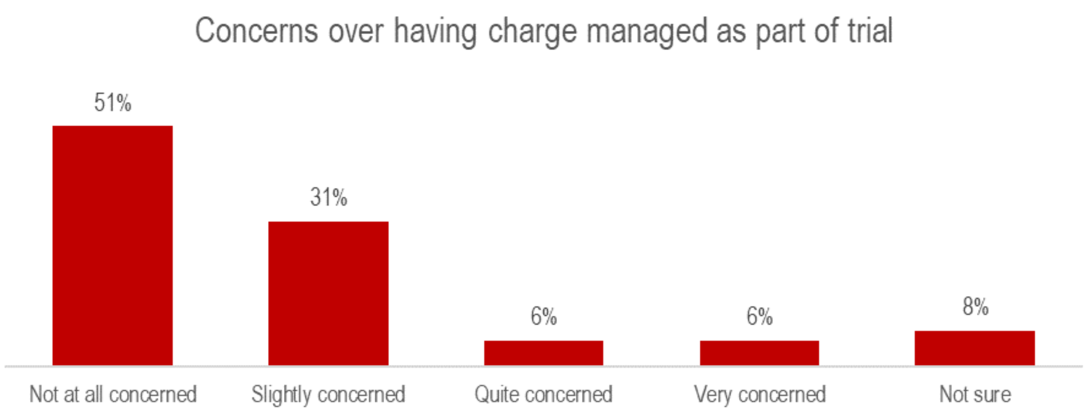
The data presented in the main report on the acceptability/satisfaction with current charging arrangements includes only survey respondents who provided an answer for all four surveys (Baseline, Trial 1, Trial 2 and Trial 3). This approach was taken so that changes in attitudes could be tracked as participants' experiences changed in each part of the trial. However, there was additional data collected from participants who did not complete all four surveys. This appendix shows this data for Trial 1, 2 and 3 for GreenFlux participants.

Trial 1 – Demand Management, No App (144 respondents)

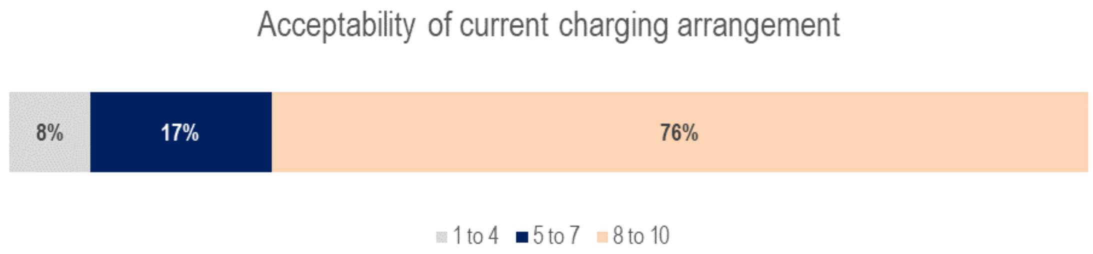


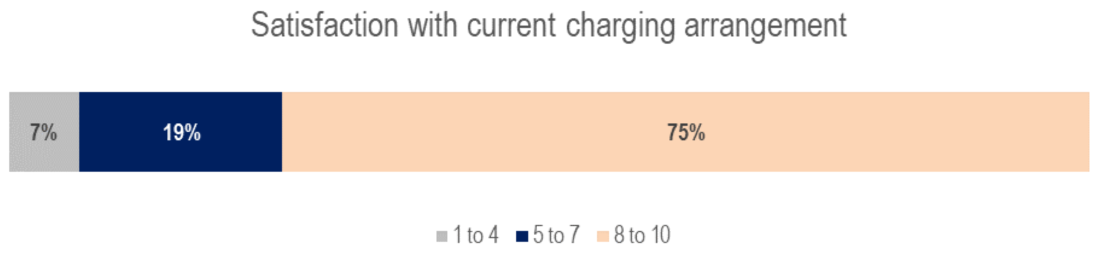


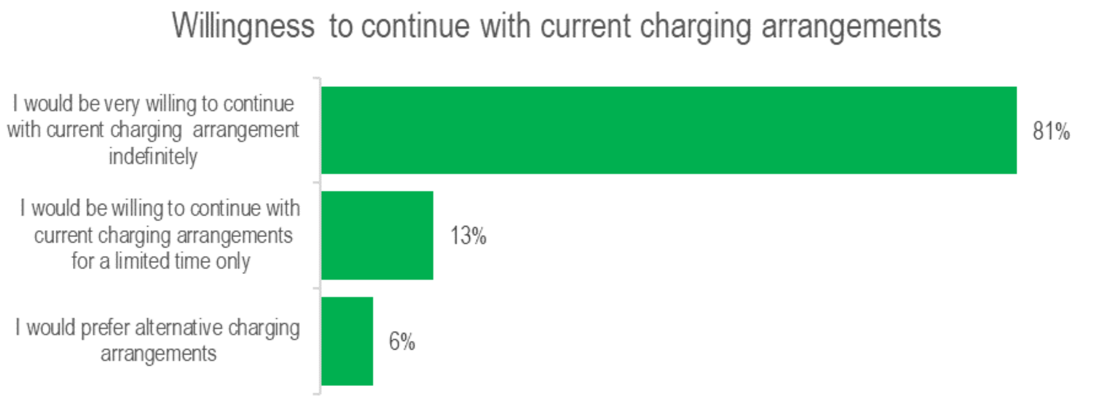


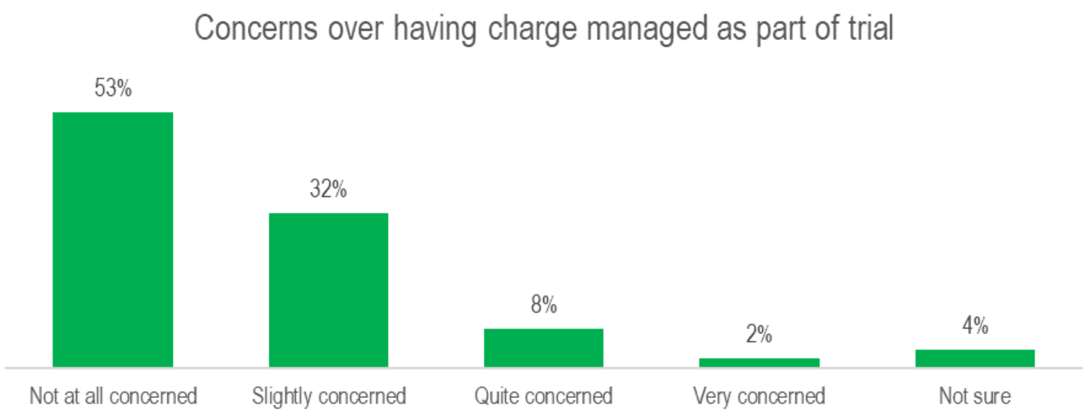


Trial 2 – Demand Management with App (229 respondents)

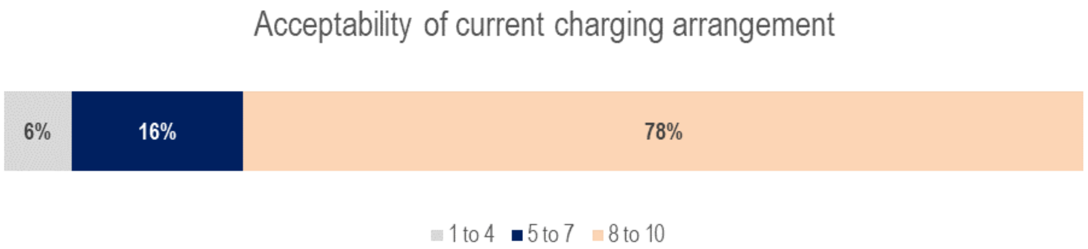


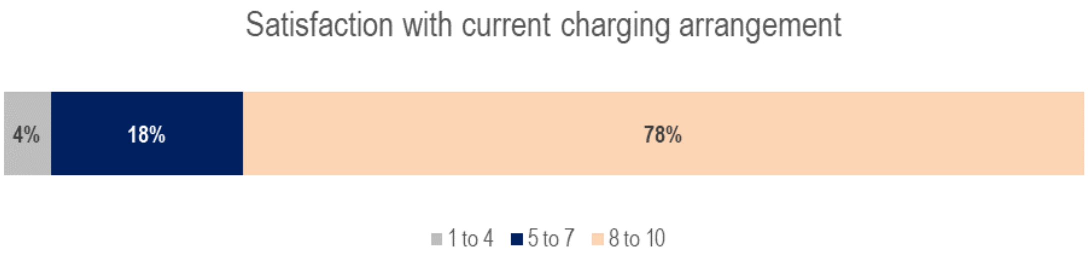


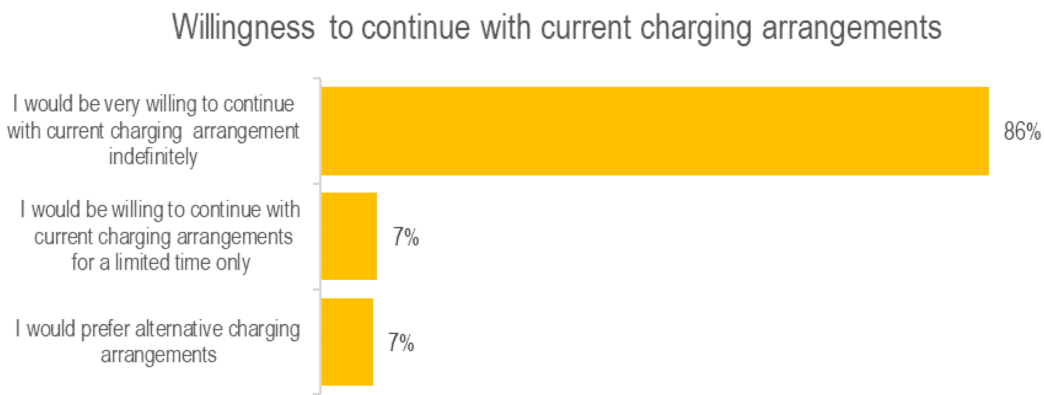


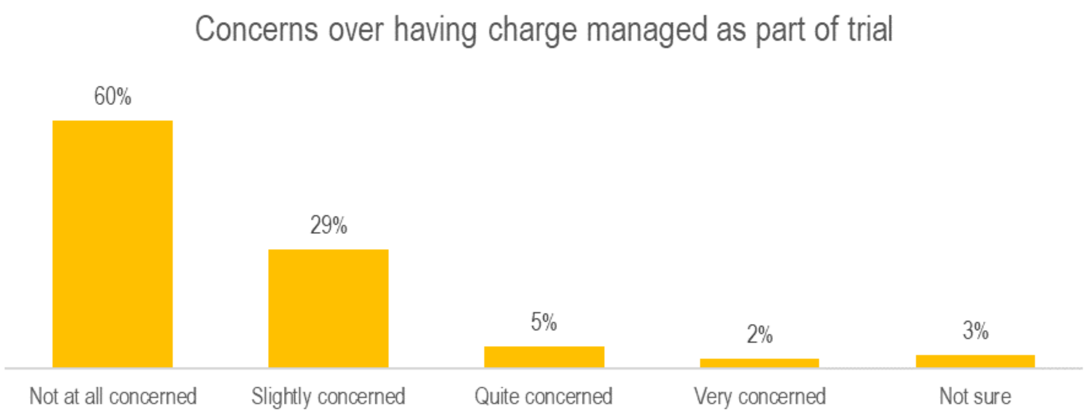


Trial 3 – Demand Management with App and ToU (208 respondents)









Appendix 4: Recruitment Survey

Electric Nation Recruitment Questionnaire
December 2016

568 Electric Nation	ONLINE SCRIPT	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 ***<u>your</u>*** 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 5: Baseline Survey

Electric Nation Baseline 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?

<u>INSTALLATION QUESTIONS (DE)</u>

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 6: CrowdCharge and GreenFlux Trial 1 Survey

Electric Nation Trial Questionnaire
July 2017

568 Electric Nation	ONLINE SCRIPT	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. 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 third 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

Firstly we would like to ask you a couple of classification questions. You may have answered these in the past, however, we would like to understand if anything has changed since you were last interviewed.

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)

S ASK IF A3=1, 2, 3, OR 4

A4 Since we last spoke (INTERVIEWER: this could be the baseline survey OR another trial survey) do any other plug-in vehicles, not previously registered on the trial, now have access to your home charge point?

1) Yes
2) No

S ASK IF A4= 1

A5 How frequently does this vehicle use your home charge point?

1. More than once a day
2. Once a day
3. 5-6 times a week
4. 3-4 times a week

5. Once - twice a week
6. Once a fortnight
7. Less than once a fortnight

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

S ASK ALL

B1b Have your charging arrangements changed recently? By this we mean since you last completed a survey.

1) Yes
2) No
3) Don't know

MC ASK IF CODE 1 SELECTED AT B1B

B1c How have your charging arrangements changed? Which of the following apply to you?

1) I tend to charge my vehicle more or less frequently than I did before
2) I tend to charge my vehicle at different times of the day
3) I have changed how long I tend to charge my vehicle for
4) Other **[PLEASE SPECIFY]**

SC ASK IF CODE 1 SELECTED AT B1C

B1d How has the frequency with which you charge changed?

1) I charge my vehicle much more
2) I charge my vehicle slightly more
3) I charge my vehicle less
4) I charge my vehicle much less

MC ASK IF CODE 1 SELECTED AT B1B

B1e Why has your charging arrangements changed? (INTERVIEWER SELECT RELEVANT CODE)

1) Change in lifestyle
2) Changes in household status e.g. presence of children
3) Change in job/ hours
4) Change in job location
5) Other reason (please specify)

M ASK ALL, MULTICODE

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

1) Home
2) Service station (motorway) / Petrol station
3) On street charge point
4) Work
5) Supermarket/Shopping centre car parks
6) Other Car parks (please specify)
7) Friend/relative's house
8) Other (please specify)
9) 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?

OE **ASK ALL**

B14 Is there anything else that you would like to share about your experience of being part of the Electric Nation project so far that hasn't already been covered in this interview?

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. If you have any questions 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 7: CrowdCharge Trial 2 Survey

Electric Nation Trial 2 Questionnaire
July 2018

568 Electric Nation	ONLINE SCRIPT FV 05/07/17	Helen Rackstraw, Evelin Roberts, Nicole McNab

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. 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 fourth 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

Firstly we would like to ask you a couple of classification questions. You may have answered these in the past, however, we would like to understand if anything has changed since you were last interviewed.

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)

S ASK IF A3=1, 2, 3, OR 4

A4 Since we last spoke (INTERVIEWER: this could be the baseline survey OR another trial survey) do any other plug-in vehicles, not previously registered on the trial, now have access to your home charge point?

1) Yes
2) No

S ASK IF A4= 1

A5 How frequently does this vehicle use your home charge point?

1. More than once a day
2. Once a day
3. 5-6 times a week

4. 3-4 times a week
5. Once - twice a week
6. Once a fortnight
7. Less than once a fortnight

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

S ASK ALL

B1b Have your charging arrangements changed recently? By this we mean since you last completed a survey.

1) Yes
2) No
3) Don't know

MC ASK IF CODE 1 SELECTED AT B1B

B1c How have your charging arrangements changed? Which of the following apply to you?

1) I tend to charge my vehicle more or less frequently than I did before
2) I tend to charge my vehicle at different times of the day
3) I have changed how long I tend to charge my vehicle for
4) Other [PLEASE SPECIFY]

SC ASK IF CODE 1 SELECTED AT B1C

B1d How has the frequency with which you charge changed?

1) I charge my vehicle much more
2) I charge my vehicle slightly more
3) I charge my vehicle less
4) I charge my vehicle much less

MC ASK IF CODE 1 SELECTED AT B1B

B1e Why has your charging arrangements changed? (INTERVIEWER SELECT RELEVANT CODE)

1) Change in lifestyle
2) Changes in household status e.g. presence of children
3) Change in job/ hours
4) Change in job location
5) Smart charging
6) Other reason (please specify)

M ASK ALL, MULTICODE

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

1) Home
2) Service station (motorway) / Petrol station
3) On street charge point
4) Work
5) Supermarket/Shopping centre car parks
6) Other Car parks (please specify)
7) Friend/relative's house
8) Other (please specify)
9) 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?

App Usage

S **ASK ALL**
B14 Are you aware that you can access an app to interact with your smart charging system?
1) Yes
2) No
3) Not sure

S **ASK IF CODE 1 AT B14**
B15 Have you used the app?
1) Yes
2) No

OE **ASK IF CODE 2 SELECTED AT B15**
B16 Why have you not used the app?

MS ASK IF CODE 1 AT B14

B18a Which of the following functions, that are available on the app, are you aware of? *Please select all that apply*

1) Ability to enter your journeys into a planner as: daily grind/commute, weekly/regulars or occasional
2) Ability to view a breakdown of your entered journeys by day, week and month and cost of these journey/electricity used
3) Ability to view your charge point usage broken down by month/day of energy used (kWh)/cost (£)
4) Ability to enter the state of charge (% of battery) of your vehicle. CrowdCharge use this information to help ensure you receive enough charge to complete your next journey
5) None of the above

M ASK IF NOT CODE 5 AT B18A AND CODE 1 AT B15 – ONLY SHOWING OPTIONS SELECTED AT B18A

B18b Which of the following have you used on the app? *Please select all that apply*

1) Ability to enter your journeys into a planner as: daily grind/commute, weekly/regulars or occasionals
2) Ability to view a breakdown of your entered journeys by day, week and month and cost of these journey/electricity used
3) Ability to view your charge point usage broken down by month/day of energy used (kWh)/cost (£)
4) Ability to enter the state of charge (% of battery) of your vehicle. CrowdCharge use this information to help ensure you receive enough charge to complete your next journey
5) None of the above

OE ASK IF CODE 1 AT B15

B19 Can you explain why you use the app?

OE ASK IF CODE 1 AT B14

B20 Are there any other functions that you expected to see on the app?

S ASK ALL

B21 How likely are you to use the app going forward?

1) Very likely
2) Slightly likely
3) Neither likely nor unlikely
4) Slightly unlikely
5) Very unlikely

S **ASK IF CODE 1 AT B14**

B22 To what extent does the app alleviate your concerns about managed charging?

1) I had no concerns regardless of the app
2) I had concerns and the app alleviates some of them
3) I had concerns and the app alleviates most of them
4) I had concerns and the app alleviates all of them
5) Not sure

S **ASK IF CODE 1 AT B15**

B23 How easy do you find using the app?

1) Very Easy
2) Easy
3) Neither easy or hard
4) Hard
5) Very hard

OE **ASK ALL**

B24 Is there anything else that you would like to share about your experience of being part of the Electric Nation project so far that hasn't already been covered in this interview?

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. If you have any questions 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 8: GreenFlux Trial 2 Survey

Electric Nation Trial 2 Questionnaire
July 2018

568 Electric Nation	ONLINE SCRIPT FV 05/07/17	Helen Rackstraw, Evelin Roberts, Nicole McNab

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. 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 fourth 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

Firstly we would like to ask you a couple of classification questions. You may have answered these in the past, however, we would like to understand if anything has changed since you were last interviewed.

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)

S ASK IF A3=1, 2, 3, OR 4

A4 Since we last spoke (INTERVIEWER: this could be the baseline survey OR another trial survey) do any other plug-in vehicles, not previously registered on the trial, now have access to your home charge point?

1) Yes
2) No

S **ASK IF A4= 1**

A5 How frequently does this vehicle use your home charge point?

1. More than once a day
2. Once a day
3. 5-6 times a week
4. 3-4 times a week
5. Once - twice a week
6. Once a fortnight
7. Less than once a fortnight

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

S **ASK ALL**

B1b Have your charging arrangements changed recently? By this we mean since you last completed a survey.

1) Yes
2) No
3) Don't know

MC **ASK IF CODE 1 SELECTED AT B1B**

B1c How have your charging arrangements changed? Which of the following apply to you?

1) I tend to charge my vehicle more or less frequently than I did before
2) I tend to charge my vehicle at different times of the day
3) I have changed how long I tend to charge my vehicle for
4) Other [PLEASE SPECIFY]

SC **ASK IF CODE 1 SELECTED AT B1C**

B1d How has the frequency with which you charge changed?

1) I charge my vehicle much more
2) I charge my vehicle slightly more
3) I charge my vehicle less
4) I charge my vehicle much less

MC **ASK IF CODE 1 SELECTED AT B1B**

B1e Why has your charging arrangements changed? (INTERVIEWER SELECT RELEVANT CODE)

1) Change in lifestyle
2) Changes in household status e.g. presence of children
3) Change in job/ hours
4) Change in job location
5) Smart charging
6) Other reason (please specify)

M **ASK ALL, MULTICODE**

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

1) Home
2) Service station (motorway) / Petrol station
3) On street charge point
4) Work
5) Supermarket/Shopping centre car parks
6) Other Car parks (please specify)
7) Friend/relative's house
8) Other (please specify)
9) 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?

App Usage

S **ASK ALL**

B14 Are you aware that you can access an app to interact with your smart charging system?

1) Yes
2) No
3) Not sure

S **ASK IF CODE 1 AT B14**

B15 Have you used the app?

1) Yes
2) No

OE **ASK IF CODE 2 SELECTED AT B15**

B16 Why have you not used the app?

S **ASK IF CODE 1 AT B14**

B17a Are you aware that you can use the app to request high priority charging?

1) Yes, and I have used it
2) Yes, but I have not used it
3) No
4) Not sure

OE **ASK IF CODE 1 AT B17a**

B17b What were your reasons for requesting high priority charging?

OE **ASK IF CODE 1 AT B14**

B20 Are there any other functions that you expected to see on the app?

S **ASK ALL**

B21 How likely are you to use the app going forward?

1) Very likely
2) Slightly likely
3) Neither likely nor unlikely
4) Slightly unlikely
5) Very unlikely

S **ASK IF CODE 1 AT B14**

B22 To what extent does the app alleviate your concerns about managed charging?

1) I had no concerns regardless of the app
2) I had concerns and the app alleviates some of them
3) I had concerns and the app alleviates most of them
4) I had concerns and the app alleviates all of them
5) Not sure

S **ASK IF CODE 1 AT B15**

B23 How easy do you find using the app?

1) Very Easy
2) Easy
3) Neither easy or hard
4) Hard
5) Very hard

OE **ASK ALL**

B24 Is there anything else that you would like to share about your experience of being part of the Electric Nation project so far that hasn't already been covered in this interview?

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. If you have any questions 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 9: CrowdCharge Trial 3 Survey

Electric Nation Trial 3 Questionnaire
November 2018

568 Electric Nation	ONLINE SCRIPT	Helen Rackstraw, Evelin Roberts, Nicole McNab

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. 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 fourth 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

Firstly we would like to ask you a couple of classification questions. You may have answered these in the past, however, we would like to understand if anything has changed since you were last interviewed.

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

M 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)**

S ASK IF A2 = YES SHOW ALONGSIDE INPUTTED ANSWER FROM A2a

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)

REPEAT FOR EACH ADDITIONAL CAR

S ASK IF A3=1, 2, 3, OR 4

A4 Since we last spoke (INTERVIEWER: this could be the baseline survey OR another trial survey) do any other plug-in vehicles, not previously registered on the trial, now have access to your home charge point?

1) Yes
2) No

S ASK IF A4= 1

A5 How frequently does this vehicle use your home charge point?

1. More than once a day
2. Once a day
3. 5-6 times a week
4. 3-4 times a week
5. Once - twice a week
6. Once a fortnight
7. Less than once a fortnight

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

S ASK ALL

B1b Have your charging arrangements changed recently? *By this we mean since you last completed a survey.*

1) Yes
2) No
3) Don't know

MC ASK IF CODE 1 SELECTED AT B1B

B1c How have your charging arrangements changed? Which of the following apply to you?

1) I tend to charge my vehicle more or less frequently than I did before
2) I tend to charge my vehicle at different times of the day
3) I have changed how long I tend to charge my vehicle for
4) Other [PLEASE SPECIFY]

SC **ASK IF CODE 1 SELECTED AT B1C**

B1d How has the frequency with which you charge changed?

1) I charge my vehicle much more
2) I charge my vehicle slightly more
3) I charge my vehicle less
4) I charge my vehicle much less

MC **ASK IF CODE 1 SELECTED AT B1B**

B1e Why has your charging arrangements changed? **(INTERVIEWER SELECT RELEVANT CODE)**

1) Change in lifestyle
2) Changes in household status e.g. presence of children
3) Change in job/ hours
4) Change in job location
5) Smart charging
6) Other reason (please specify)

M **ASK ALL, MULTICODE**

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

1) Home
2) Service station (motorway) / Petrol station
3) On street charge point
4) Work
5) Supermarket/Shopping centre car parks
6) Other Car parks (please specify)
7) Friend/relative's house
8) Other (please specify)
9) 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?

App Usage

S **ASK ALL**

B14 Are you aware that you can access an app to interact with your smart charging system?

1) Yes
2) No
3) Not sure

S **ASK IF CODE 1 AT B14**

B14B During 2018, did you register for the CrowdCharge app (even if you didn't use it)?

1) Yes
2) No
3) Not sure

OE **ASK IF CODE 2, 3 AT B14B**

B14C Why didn't you register for the app?

S **ASK IF CODE 1 AT B14**

B14A Are you aware that the app has been recently updated? (i.e. within the last 2 months)

1) Yes
2) No

M **ASK IF CODE 1 AT B14A**

B15a Have you used the new version of the app? *Please select all that apply*

1) Yes - to enter my journeys into the planner
2) Yes - to review entered journeys
3) Yes - to review my charge point usage broken down by day, week or month and energy used (kWh)/cost
4) Yes - entered the state of charge (% of battery) of your vehicle
5) Yes - to review my reward balance
6) Yes - other use of the new version of the app (please specify)
7) No

OE **ASK IF CODE 7 SELECTED AT B15A**

B16 Why have you not used the new version of the app?

OE **ASK IF CODE 1 AT B14A**

B32B Have you experienced any problems with the updated app?

1) Yes (please tell us what problems you have had)
2) No

S ASK IF NOT SELECTED NO AT B15A

B34 Have you changed your charging behaviour because of the Time of Use tariff offered through the app? By this we mean plugging in your vehicle at different times or more or less often

1) Yes
2) No
3) Not sure

OE ASK IF CODE 1 AT B34

B34B How have you changed your charging behaviour?

S ASK IF NOT SELECTED NO AT B15A

B36 As a result of the Time of Use tariff offered through the app, have you changed your journey pattern(s)? By this we mean amending when you travel, either by inputting more journeys or altering saved/planned journeys

1) Yes – once
2) Yes – 2-3 times
3) Yes – 4-5 times
4) Yes – more than 5 times
5) No
6) Don't Know

OE ASK IF CODE 1-4 AT B36

B36B Can you describe how you have changed your journey pattern(s)?

S ASK IF NOT SELECTED NO AT B15A

B37 As a result of the updated app, has your vehicle had sufficient charge to make journeys at your planned departure times?

1) Yes, it has always had sufficient charge
2) No, I once didn't have sufficient charge
3) No, I have had to make a few journey adjustments
4) No, I have had to make a lot of journey adjustments
5) No, since the update, I have never/rarely had sufficient charge
6) Don't know

M **ASK IF CODE 1-4 AT B15A**

B35 Which of the following features have you used on the app?

1) Chargerpoint usage – breakdown of energy usage/cost by month/day
2) My Journeys – review entered journeys, round trip distance and estimated energy/cost
3) My Calendar – breakdown of user entered journeys by day, week, month
4) New Journey – input a new journey into 'daily grind', 'weekly/regulars' or 'occasional'
5) Set Range – enter the current state of charge of your vehicle's battery (available range)
6) Reward balance – View your balance based on when you are charging
7) None of the above (exclusive answer)

G **ASK THOSE THAT SELECT AT LEAST ONE OPTION AT B35 – ONLY SHOWN OPTIONS 1-6 SELECTED ABOVE**

B31a How useful do you find the feature(s) you have used?

	Not at all useful	Not very useful	Somewhat useful	Quite useful	Very useful
INSERT ALL SELECTED AT B35					

S **ASK IF CODE 1-6 SELECTED AT B35**

B33 How often do you use the feature [PIPE IN B35] in the app?

1) Several times a day
2) Once a day
3) Every few days
4) Once a week
5) Once a fortnight
6) Less often than fortnight
7) Don't know

OE **ASK THOSE THAT SELECT AT LEAST ONE OPTION AT B35**

B31B How can the feature(s) be improved? *Please make clear which feature you are referring to – e.g. when viewing the reward balance, I would like to see…*

S **ASK IF CODE 1 SELECTED AT B14A**

B28 How easy to understand is the reward structure based on the app time of use tariff?

1) Very Easy
2) Easy
3) Neither easy nor hard
4) Hard
5) Very hard
6) Not Applicable

OE **ASK IF CODE 1 - 4 SELECTED AT B15A**
B29 Are there any other functions that you expected to see on the app?

S **ASK IF CODE 1 - 4 SELECTED AT B15A**
B30 To what extent do you think the Time of Use tariff incorporated in the app (i.e. where you can be rewarded for charging outside of peak hours) will encourage EV drivers to charge their cars outside of peak times?

1) It will have very little impact on when people charge their cars
2) It will have a small impact on when people charge their cars
3) It will encourage many people to charge at different times
4) It will encourage most people to charge at different times
5) This will be the only solution that will encourage people to charge their cars outside of peak times
6) Don't know

S **ASK ALL**
B21 If there was a similar scheme/app available to you in the future, how likely would you be to use it?
1) Very likely
2) Slightly likely
3) Neither likely nor unlikely
4) Slightly unlikely
5) Very unlikely

OE **ASK ALL**
B24 Is there anything else that you would like to share about your experience of being part of the Electric Nation project so far that hasn't already been covered in this interview?

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. If you have any questions 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 10: GreenFlux Trial 3 Survey

Electric Nation Trial 3 Questionnaire
November 2018

568 Electric Nation	ONLINE SCRIPT 13/11/18	Helen Rackstraw, Evelin Roberts, Nicole McNab

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. 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 fourth 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

Firstly we would like to ask you a couple of classification questions. You may have answered these in the past, however, we would like to understand if anything has changed since you were last interviewed.

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

M 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)**

S ASK IF A2 = YES SHOW ALONGSIDE INPUTTED ANSWER FROM A2a

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)

REPEAT FOR EACH ADDITIONAL CAR

S ASK IF A3=1, 2, 3, OR 4

A4 Since we last spoke (INTERVIEWER: this could be the baseline survey OR another trial survey) do any other plug-in vehicles, not previously registered on the trial, now have access to your home charge point?

1) Yes
2) No

S ASK IF A4= 1

A5 How frequently does this vehicle use your home charge point?

1. More than once a day
2. Once a day
3. 5-6 times a week
4. 3-4 times a week
5. Once - twice a week
6. Once a fortnight
7. Less than once a fortnight

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

S ASK ALL

B1b Have your charging arrangements changed recently? By this we mean since you last completed a survey.

1) Yes
2) No
3) Don’t know

MC ASK IF CODE 1 SELECTED AT B1B

B1c How have your charging arrangements changed? Which of the following apply to you?

1) I tend to charge my vehicle more or less frequently than I did before
2) I tend to charge my vehicle at different times of the day
3) I have changed how long I tend to charge my vehicle for
4) Other [PLEASE SPECIFY]

SC ASK IF CODE 1 SELECTED AT B1C

B1d How has the frequency with which you charge changed?

1) I charge my vehicle much more
2) I charge my vehicle slightly more
3) I charge my vehicle less
4) I charge my vehicle much less

MC **ASK IF CODE 1 SELECTED AT B1B**

B1e Why has your charging arrangements changed? (INTERVIEWER SELECT RELEVANT CODE)

1) Change in lifestyle
2) Changes in household status e.g. presence of children
3) Change in job/ hours
4) Change in job location
5) Smart charging
6) Other reason (please specify)

M **ASK ALL, MULTICODE**

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

1) Home
2) Service station (motorway) / Petrol station
3) On street charge point
4) Work
5) Supermarket/Shopping centre car parks
6) Other Car parks (please specify)
7) Friend/relative's house
8) Other (please specify)
9) 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?

App Usage

S **ASK ALL**

B14 Are you aware that you can access an app to interact with your smart charging system?

1) Yes
2) No
3) Not sure

S **ASK ALL**

B14a Are you aware that the app has been recently updated? (i.e. within the last 2 months)

1) Yes
2) No

M **ASK IF CODE 1 AT B14**

B15 Have you used the app? *Please select all that apply*

1) Yes - to change my charging preference
2) Yes - to request high priority
3) Yes - to view my current charging session
4) Yes - to review my reward or previous charging sessions
5) No

OE **ASK IF CODE 5 SELECTED AT B15**
B16 Why have you not used the app?

OE **ASK IF CODE 5 SELECTED AT B15**
B16A Did you know that by not accessing the app, you are on the default 'optimise time' profile (i.e. charging at any time of the day regardless of the price) which means you are not able to accrue additional time of use charging rewards?

1) Yes
2) No
3) Not sure

M **ASK IF CODE 1 3 or 4 SELECTED AT B15**
B25 Which charging preference have you used so far? *Please select all that apply*

1) Minimise Cost – restricting the charging to between 10pm and 4.30pm
2) Optimise Time & Cost – avoiding charge at peak times but charging can occur between 7pm and 10pm
3) Optimise Time – charging all times of the day regardless of the price. This is the default setting so if you have not changed it you will be on this preference
4) I did not change it
5) Don't know

OE **ASK IF CODE 1,2,3 B25 – REPEAT FOR EACH PROFILE**
B26A Have you experience any problems with the **[PIPE IN SELECTED AT B25]** profile?

1) Yes (please tell us what problems you have had)
2) No

OE **ASK IF CODE 4 AT B25**
B26B Have you experienced any problems using the app?

1) Yes (please tell us what problems you have had)
2) No

S **ASK IF CODE 1,2,3 SELECTED AT B25**
B27 Have you changed charging preference (e.g. from 'minimise cost' to 'optimise time'?

1) Yes – once
2) Yes – 2-3 times
3) Yes – more than 3 times
4) No
5) Don't Know

M ASK IF CODE 1,2,3 SELECTED AT B27

B27A Why did you change tariff profiles? *Please select all that apply*

1) Wanted to increase the reward amount
2) Due to concerns over not having enough charge
3) Felt the rewards were not high enough to charge outside peak times
4) Wanted to try out other profiles to see how they worked
5) Car didn't charge when I needed it
6) I had a longer/different journey to take and therefore needed charging soon
7) Other (please specify)

S ASK IF CODE 1 or 3 SELECTED AT B15

B28 How easy to understand is the charging preference reward structure?

1) Very Easy
2) Easy
3) Neither easy nor hard
4) Hard
5) Very hard

M ASK IF CODE 1 3 or 4 SELECTED AT B15

B31 Which of the following features have you used on the app?

1) Ability to review previous charging history – energy usage
2) Ability to review when you were plugged in and unplugged
3) Reward balance
4) Recent transactions
5) None of the above (exclusive answer)

G ASK THOSE THAT SELECT AT LEAST ONE OPTION AT B31 – ONLY SHOWN OPTIONS SELECTED ABOVE

B31a How useful do you find the feature(s) you have used?

	Not at all useful	Not very useful	Somewhat useful	Quite useful	Very useful
INSERT ALL SELECTED AT B31					

OE ASK THOSE THAT SELECT AT LEAST ONE OPTION AT B31

B31b How can the feature(s) be improved? Please make clear which feature you are referring to – e.g. when viewing the reward balance, I would like to see…

OE ASK IF CODE 1 or 3 SELECTED AT B15

B29 Are there any other functions that you expected to see on the app?

S ASK IF CODE 1 or 3 SELECTED AT B15

B30 To what extent do you think the charging preference (i.e. where you can be rewarded for charging outside of peak hours) will encourage EV drivers to charge their cars outside of peak times?

1) It will have very little impact on when people charge their cars
2) It will have a small impact on when people charge their cars
3) It will encourage many people to charge at different times
4) It will encourage most people to charge at different times
5) This will be the only solution that will encourage people to charge their cars outside of peak times
6) Don't know

S ASK ALL

B21 If there was a similar scheme/app available to you in the future, how likely would you be to use it?

1) Very likely
2) Slightly likely
3) Neither likely nor unlikely
4) Slightly unlikely
5) Very unlikely

OE ASK ALL

B24 Is there anything else that you would like to share about your experience of being part of the Electric Nation project so far that hasn't already been covered in this interview?

<u>CONTACT INFORMATION</u>

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. If you have any questions 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 11: Final Survey

Electric Nation Final Questionnaire
January 2019

568 Electric Nation	ONLINE SCRIPT	Nicole McNab, Helen Rackstraw, Evelin Roberts

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 15 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 will be the final survey you will be asked to take part in during the trial and should take no more than 15 minutes to complete, depending on the answers you give us. The purpose of this survey is to gather your opinion on the time you have spent as a participant in the Electric Nation trial. 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.

Firstly, we would like to ask you a couple of questions about you and your vehicle.

S **ASK ALL**

Q1 When did you purchase/lease your first electric/hybrid vehicle?

1. More than 5 years ago
2. 4-5 years ago
3. 3-4 years ago
4. 2-3 years ago
5. 1 year ago
6. This year

S **ASK ALL**

Q2 Which of the following statements describes you best?

1. I like to be one of the first people to have a new technology/gadget
2. I'm not always the first to buy a new technology/gadget, but I tend to buy it before most others
3. I prefer for other people to test out the technology/gadget before I buy it myself
4. I prefer to wait until the price drops to buy a new technology/gadget
5. I'm usually one of the last people I know to buy a new technology/gadget

M **ASK ALL- RANDOMISE**

Q2b What were your motivations toward buying/leasing your first EV? *Please select all that apply*

1. Lower costs of running an EV
2. Environmental benefits
3. Trying out the latest technology
4. Seeking an easier/smoother drive
5. It was offered to me through a company scheme
6. Other (please specify)

S **ASK ALL**

Q3 Which of the following statements describes the vehicle which is registered as part of the Electric Nation project?

1. I bought my current electric vehicle
2. I have leased my current electric vehicle
3. My electric vehicle is a company car
4. Prefer not to say

S **ASK ALL**

Q3A Have you bought another electric vehicle during your time in the study?

1. Yes (please specify make and model)
2. No
3. Prefer not to say

OE ASK IF CODE 1 AT Q3A

Q3B When did you buy your that EV?

Month	*Year*

OE ASK IF CODE 1 AT Q3A

Q3C Is this a replacement for the EV you initially registered on the project?

1. Yes
2. No, I still have the other vehicle but do not use it myself
3. No, I still have the other vehicle and primarily use that

S ASK ALL

Q4 In a typical week, how many miles do you drive in your electric vehicle?

1. Fewer than 20 miles
2. 20-50 miles
3. 51-75 miles
4. 76-100 miles
5. 101-150 miles
6. 151-200 miles
7. 201-250 miles
8. 251+ miles
9. Don't know
10. Prefer not to say

S ASK ALL

Q5 Does anyone else in your household drive the electric car registered as part of the Electric Nation trial?

1. No, and no one ever has
2. No, but someone has occasional use of the vehicle (please specify who)
3. Yes, and someone has regular access to the vehicle (please specify who)
4. Yes, someone has had regular use but not for the whole duration on the trial (please specify who)
5. Prefer not to say

S ASK IF CODE 3 OR 4 AT Q5

Q6 Comparing your electric vehicle usage to in your household's car use, which statement is most accurate?

1. I do significantly more miles in the electric vehicle than others in my household
2. I do slightly more miles in the electric vehicle than others in my household
3. I do about the same number of miles as those in my household
4. I do slightly less miles in the electric vehicle than others in my household
5. I do significantly less miles in the electric vehicle than others in my household
6. I am the only one in my household / only one that has a car
7. Don't know
8. Prefer not to say

M ASK ALL

Q7 Thinking about your time on the Electric Nation project, have you had any major life changes that have affected your use of the EV? *Please select all that apply*

1. New child
2. Marriage
3. Retirement
4. House move
5. Change in jobs
6. Other (please specify)
7. Prefer not to say

S ASK ALL

Q8 Thinking about this survey and any previous surveys that you have completed as part of this project; would you agree with the statement that your views of your charging arrangements are the same as those in your household?

1. Yes
2. No
3. There is no one else in my household
4. Don't know

OE ASK IF CODE 2 AT Q8

Q9 How do your views differ to those in your household?

Open text box

S ASK ALL

Q10 Thinking about your friends and family, do you feel that their attitude towards electric vehicles have changed throughout the time you have been on the Electric Nation trial?

1. Yes – they are more positive towards EVs
2. Yes – they are more negative towards EVs
3. No, their attitudes have not changed
4. Don't know

M ASK IF CODES 1 OR 2 AT Q10 - RANDOMISE

Q11 Do you feel their views on electric vehicles are influenced by any of the following… Please select all that apply

1. Media coverage
2. Your personal use of the electric vehicle
3. Relatives/friends views on EVs
4. Car manufacturing advertisement
5. Celebrity advocacy
6. Word of mouth
7. Other (please specify)
8. None of the above

S ASK ALL - RANDOMISE

Q11A When you next look to replace your current car, which fuel type are you most likely to choose?

1. Electric vehicle
2. Range extender
3. Plug-in hybrid
4. Petrol
5. Diesel
6. Other
7. Don't know

S ASK ALL

Q12 As a result of the Electric Nation project, how likely is it that your behaviour will change in the following ways when compared to your initial charging behaviour?
Please use a scale of 1 to 10 where 1 is not at all likely and 10 is extremely likely

	1 – Not at all likely	2	3	4	5	6	7	8	9	10 Extremely likely	Don't Know
I will charge less often											
I will charge at different times of the day											
I will charge at my house more often											

I will charge away from my house more often											
I will charge my car for shorter durations											
I will continue with my current pattern of charging (that was established by the end of the trials)											

TRIALS

Being part of the Electric Nation project you would have taken part in one or more trials in the duration of the project.

Trial 1 – Demand Management

IF CROWDCHARGE USER:
In times of peak demand some chargers were allocated varying power limits, meaning that charging rate for EVs was slowed – this was managed by CrowdCharge, through communication with your smart charger.

IF GREENFLUX USER:
In times of peak demand some chargers were allocated full-rate or slow charging or charging was paused for 15-minute periods, meaning that overall charging rate for EVs was slowed – this was managed by GreenFlux, through communication with your smart charger

Trial 2 – Priority Charging App
IF CROWDCHARGE USER:
An app was available to input your journey plans, the system used your plans to prioritise your charging – overriding demand management if your journey plan required fast charge more urgently – slowing your charging down if your journey plan was less urgent

IF GREENFLUX USER:
An app was available to request priority charging, which meant in times of demand management you could request to either override demand management and get full charging rate throughout

Trial 3 – Time of Use tariffs

IF CROWDCHARGE USER:
A slightly modified app was available, that still required your journey plans, these would be used to minimise your cost of charging against a virtual time of use tariff

IF GREENFLUX USER:
A modified app was available that let you choose between charging immediately and charging to minimise your cost of charging against a virtual time of use tariff

M **ASK ALL**

Q13 Which trial(s) do you believe you were a part of? *Please select all that apply*

1. Trial 1 – demand management
2. Trial 2 – priority charging app
3. Trial 3 – time of use tariffs
4. None
5. Don't know

S **ASK CODE 1-3 AT Q13 - PIPE IN RESPONSE FROM TRIALS SELECTED AT Q13**

Q14 Which charging solution did you prefer?

1. Trial 1 – demand management
2. Trial 2 – priority charging app
3. Trial 3 – time of use tariffs
4. I didn't prefer any charging solution
5. I disliked all trials I was part of

G **ASK CODE 1-3 AT Q13**

Q15 How likely are you to adopt this charging solution if it becomes available in the future?

[PIPE IN SELECTED AT Q14]	1 - Not at all likely	2	3	4	5	6	7	8	9	10 - Extremely likely	Don't Know
Trial 1 – demand management **[hover icon with explanation]**											
Trial 2 – priority charging app **[hover icon with explanation]**											
Trial 3 – time of use tariffs **[hover icon with explanation]**											

OE **ASK EACH TRIAL ANSWERED AT Q15**

Q16 Why do you say that?

Open text box

S **ASK ALL**

Q17A What type of energy tariff are you currently on with your electricity supplier?

1. Standard tariff
2. Fixed price deal
3. Economy 7 or Economy 10
4. Specific EV tariff
5. Other time of use tariff
6. Other (please specify)
7. Don't know
8. Rather not say

S **ASK ALL**

Q17B As a result of having an electric vehicle, have you changed the type of electricity tariff you are on with your electricity supplier?

1. Yes, I have changed my tariff
2. No, but I am considering it
3. No, I have not considered this
4. Don't know

S **ASK IF CODE 1 AT Q17B**

Q17C What type of tariff have you changed to?

1. Standard tariff
2. Fixed price deal
3. Economy 7 or Economy 10
4. Specific EV tariff
5. Other time of use tariff
6. Other (please specify)
7. Don't know
8. Rather not say

M **ASK IF CODE 2 AT Q17B**

Q17D Which type of tariff are you considering changing to? *Please select all that apply*

1. Standard tariff
2. Fixed price deal
3. Economy 7 or Economy 10
4. Specific EV tariff
5. Other time of use tariff
6. Other (please specify)
7. Don't know
8. Rather not say

G **ASK ALL – RANDOMISE**

Q18 To what extent do you agree or disagree with the following statements?

	1-Extremely disagree	2	3	4	5	6	7	8	9	1-Extremely agree	Don’t Know
I am confident I have enough charge between charging stations											
I charge an electric vehicle outside of peak times (i.e. morning and evening) more than I did before I took part in this project											
I generally charge my electric vehicle less than I did before I took part in this project											
I would be confident making long distance (c. 150+ miles) journeys in my electric vehicle											
Having an app to monitor my charging is useful											
There are enough charge-point locations around my area											
There are enough high-speed rapid chargers in my area											

	1-Extremely disagree	2	3	4	5	6	7	8	9	1-Extremely agree	Don't Know
Most of the charging locations have fully functional chargers											
I charge more at home than anywhere else											

S **ASK ALL**

Q19 On a scale of 1 – 10, where 1 is completely unacceptable and 10 is completely acceptable, how **acceptable** have you found your charging arrangements overall, including when you are away from home?

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

OE **ASK ALL**

Q20 Why do you say that?

Open text box

S **ASK ALL**

Q21 Now that the Electric Nation trial is over and demand management has stopped, 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 at home?

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

OE **ASK ALL**

Q22 Why do you say that?

Open text box

S **ASK THOSE MATCHED WITH MASTER DATABASE FOR THOSE TAKING PART IN EACH TRIAL - REPEAT FOR EACH TRIAL**

Q23 On a scale of 1 – 10, where 10 is would recommend and 1 is would not recommend at all, would you recommend trial **[PIPE IN FROM MASTER DATABASE AND HOVER EXAPLANATION CARD]** as a solution for peak demand?

1. 1 – Would not recommend
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9
10. 10 – Would recommend
11. Don't know

S **ASK ALL**

Q24 If in say 5 years' time, smart charging systems were offered which might reward you for helping to protect the electricity network (e.g. by promoting charging outside of peak electricity demand periods), how likely would you be to sign up to this? *Please use a scale of 1 to 10 where 1 is not at all likely and 10 is extremely likely*

1. 1 – Not at all likely
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9 - Extremely likely
10. Don't know

OE **ASK ALL**

Q25 Is there anything else that you would like to share about your experience of being part of the Electric Nation project that hasn't already been covered?

Open text box

END

Thank you for the information you have provided today. If you have any questions 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.