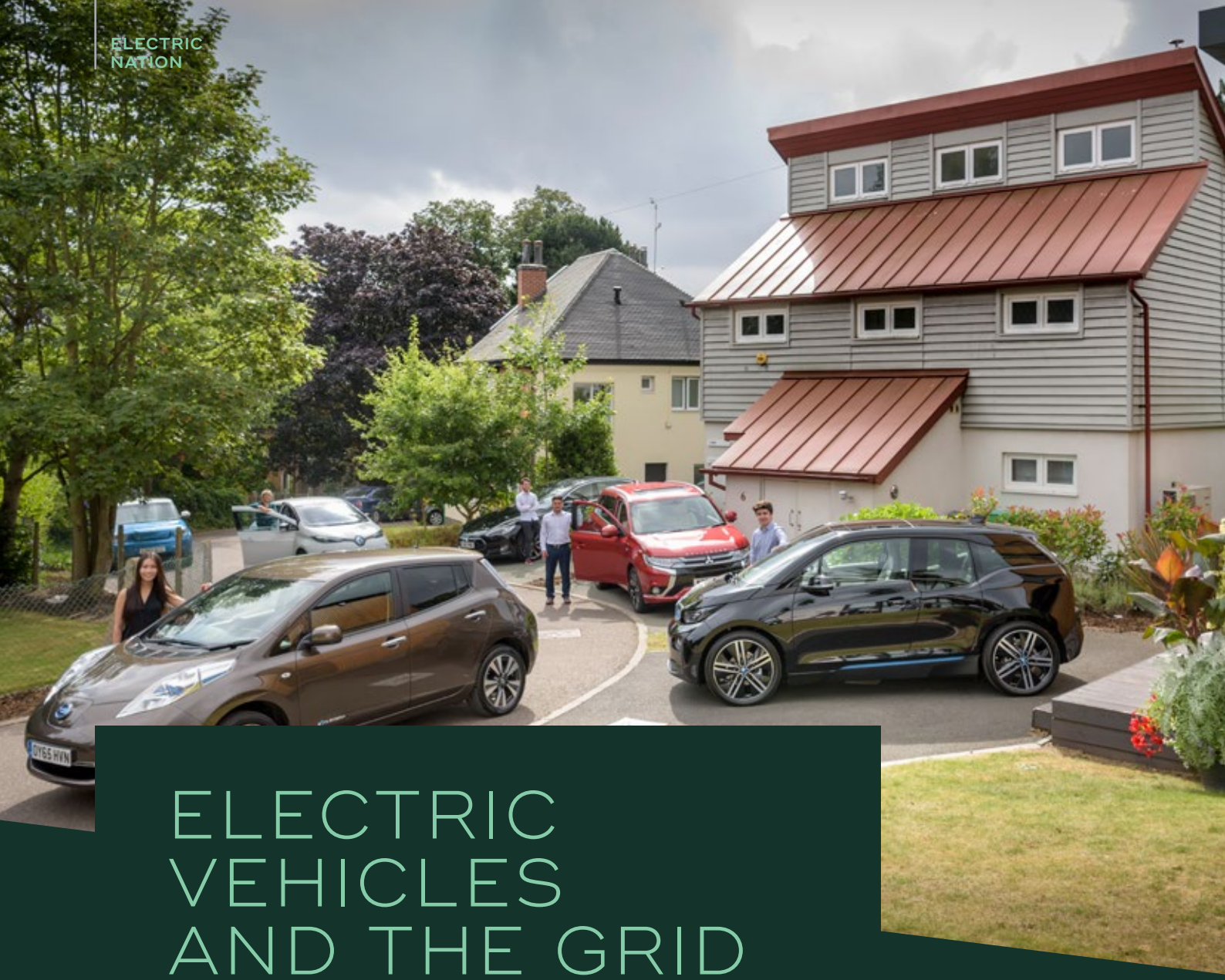
ELECTRIC NATION

YOUR ELECTRIC VEHICLE YOUR SMART CHARGE

SUMMARY OF THE FINDINGS OF THE ELECTRIC NATION SMART CHARGING TRIAL



ELECTRIC VEHICLES AND THE GRID

Electric Vehicles (EVs) are becoming increasingly common on UK roads. The growth in EV ownership could cause challenges for the UK electricity industry if the adoption of electrified transport is widespread, especially if groups of neighbours buy EVs creating localised clusters. These clusters could create issues on 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 suggests that the impact of EV charging on LV networks may result in at least 30% of these networks requiring upgrades by 2050. This would represent a present-day cost of billions of pounds and inevitably create disruption, affecting all of us.

Figure 1 illustrates the potential issue. Existing winter demand (pink) reaches a peak at around 18:00 but is within the capacity of the 11kV feeder (green line). When EV demand is added (blue) the demand is greater than the capacity of the network for a short period. Smart Charging could be used to move this demand to late evening or overnight.

Western Power Distribution (the distribution network operator responsible for delivering electricity to approximately 7.9 million customers across the Midlands, South West England and South Wales) funded Electric Nation ("the Project") through its Network Innovation Allowance. The Project explored whether Smart Charging systems and incentives to EV drivers could reduce, delay or avoid the need to upgrade or replace networks by moving demand for charging to late evening and overnight, and whether this would be acceptable to EV drivers.

ELECTRIC NATION'S SMART CHARGING TRIAL

The trial focussed on domestic EV charging between January 2017 and December 2018.

- 673 smart chargers were installed at participants' homes throughout WPD's licence areas
- The trial included 40 different types, makes or models of EVs
- Smart Charging for the trial was provided by GreenFlux and CrowdCharge. These suppliers used different control algorithms and customer facing systems

For the purposes of the trial, EV owners were given smart chargers that were capable of reporting when an EV was plugged in and when it was actively charging the EV. Additionally, these chargers were also capable of receiving instructions to reduce or pause charging.

Both Smart Charging systems had back-office systems that could monitor the overall demand of chargers under their control and, depending on need, reduce this total demand by instructing individual chargers to reduce the power available to charging EVs – imitating real world EV charging demand management on a constrained distribution network.

The trial captured huge quantities of data – over 130,000 charging events, lasting nearly two million hours.

FIGURE 1

Weekday demand – typical 11kV feeder

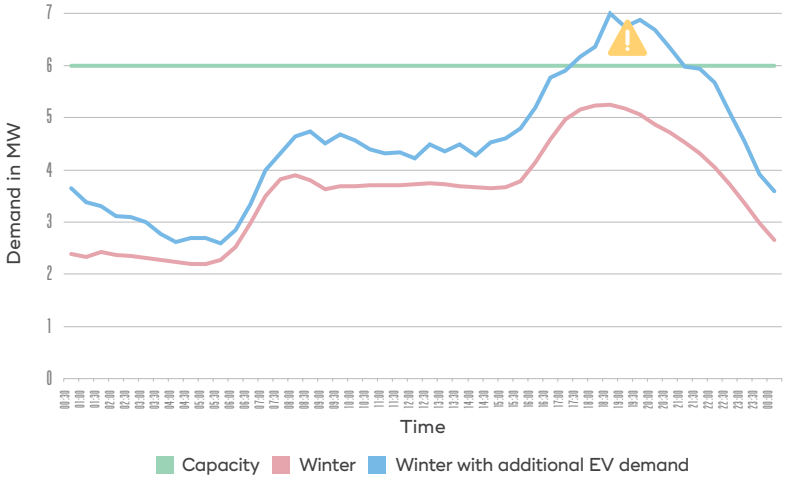


FIGURE 2

Trial participant spread throughout WPD's licence areas

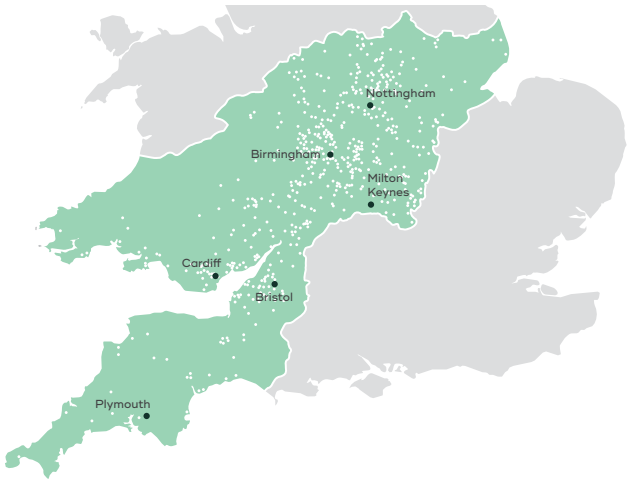
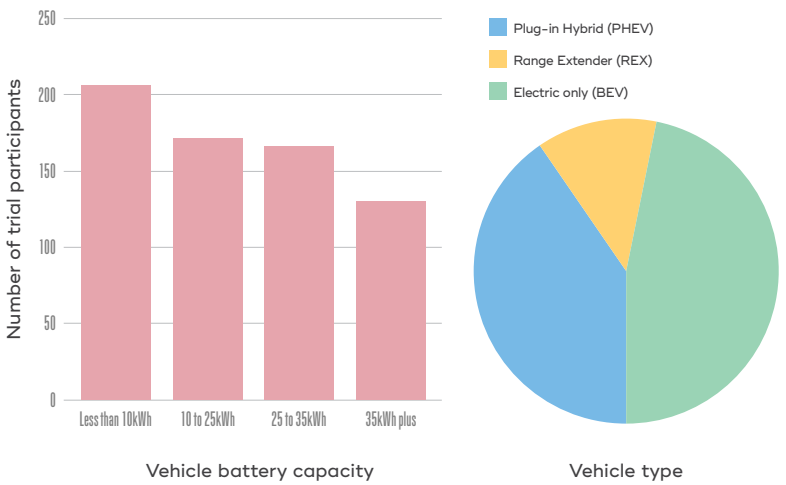


FIGURE 3

Vehicles in the Electric Nation Trial



THE TRIAL

TRIAL 1

Trial participants experienced Smart Charging "blind" – they were not told when it started or when their charging was being managed. Their charging was paused or 'turned down' during this phase of the trial, and they could not interact with the Smart Charging system.

TRIAL 2

Trial participants were given "apps" to enable them to interact with the Smart Charging system.

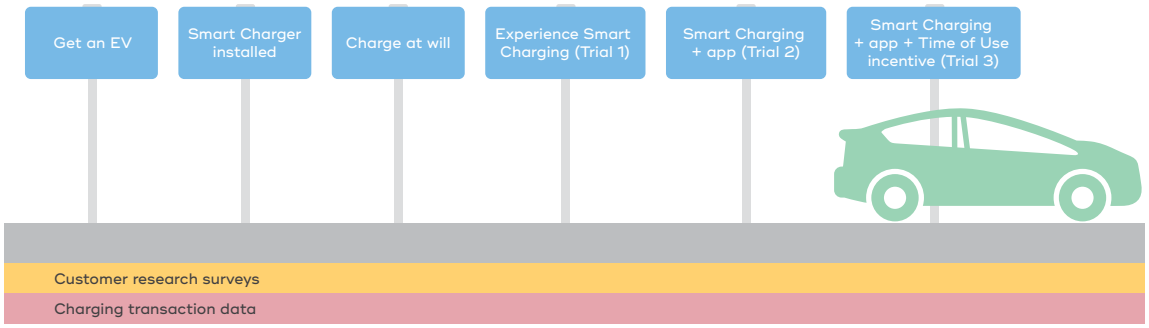
TRIAL 3

This trial introduced a simulated Time of Use (ToU) tariff to reward participants for changing their charging behaviour.

Throughout the trial multiple surveys of the participants were undertaken to investigate their experience of charging at home and satisfaction with their charging arrangements.

At the same time the smart chargers provided data on participants' charging behaviour, including when an EV was plugged in and when the EV actually charged (use of timers and Smart Charging activity).

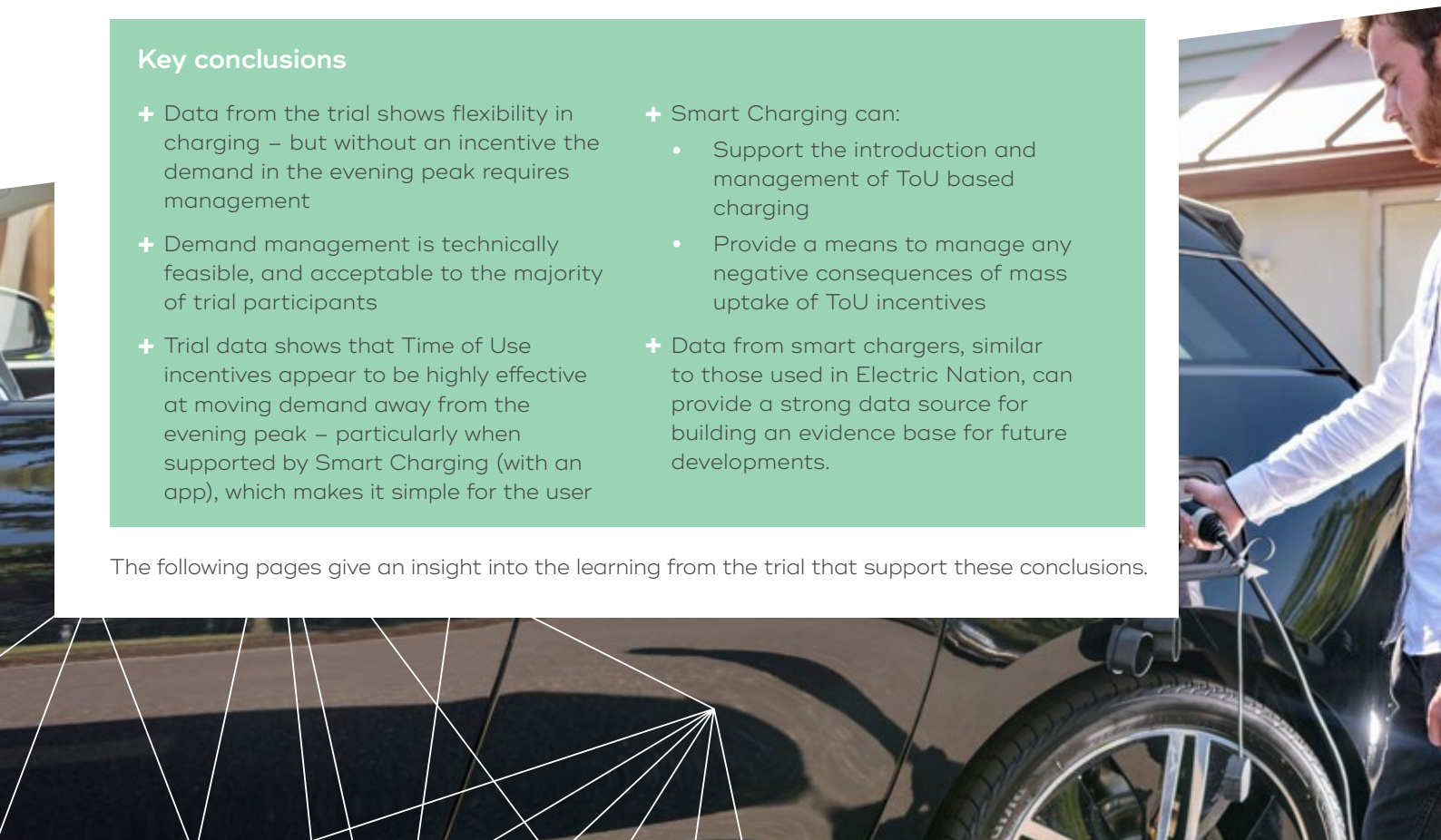
Typical Participant Trial Journey



Key conclusions

+ Data from the trial shows flexibility in charging – but without an incentive the demand in the evening peak requires management
+ Demand management is technically feasible, and acceptable to the majority of trial participants
+ 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
+ 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
+ Data from smart chargers, similar to those used in Electric Nation, can provide a strong data source for building an evidence base for future developments.

The following pages give an insight into the learning from the trial that support these conclusions.



WHEN DO PEOPLE PLUG THEIR CARS IN TO CHARGE, AND WHAT PROPORTION ARE CHARGING AT DIFFERENT TIMES OF DAY?

The percentage of EV drivers in the trial who were charging their vehicle at any one time varies, from none to 6% (early in the morning) to as many as 20% or more in late afternoon-early evening on weekdays.

The most popular time to plug-in EVs is during the evening peak (17:00 – 19:00) on weekdays, as the majority of drivers get home from work.

During the evening peak period, on average, about 14% of the EV population are charging their EV.

IS THERE FLEXIBILITY IN PEOPLE'S CHARGING BEHAVIOUR?

If EVs are plugged in for much longer than they need to charge for, then there is flexibility in when the energy is delivered. 'Flexibility' has been calculated for charging events, using the formula below:

'Flexibility' = 1 – (charging duration/plug-in duration)

This means that if the plug-in duration is much longer than the charging duration then 'Flexibility' is high.

Evidence from the trial suggests that there is substantial flexibility in the evening peak – 75% of EVs plugged in during this period are charging for less than 40% of the time they're plugged in.

The time with the greatest available flexibility (the evening peak) aligns well with highest network demand, when charge management may be required to avoid network overload.

HOW OFTEN DO PEOPLE CHARGE THEIR EVS?

The median charging frequency for all participants is 0.5 charging sessions per day (between 3 and 4 times a week).

A minority of participants (14%) charge at least once a day – this group is dominated by the 'Less than 10kWh' battery size group. Other factors which affect charging frequency include whether or not the driver makes use of other charging facilities (particularly at work) and weekly mileage.

FIGURE 4

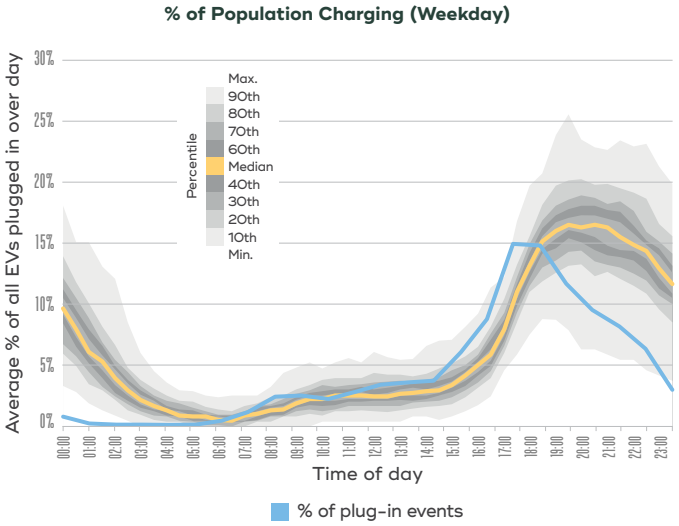


FIGURE 5

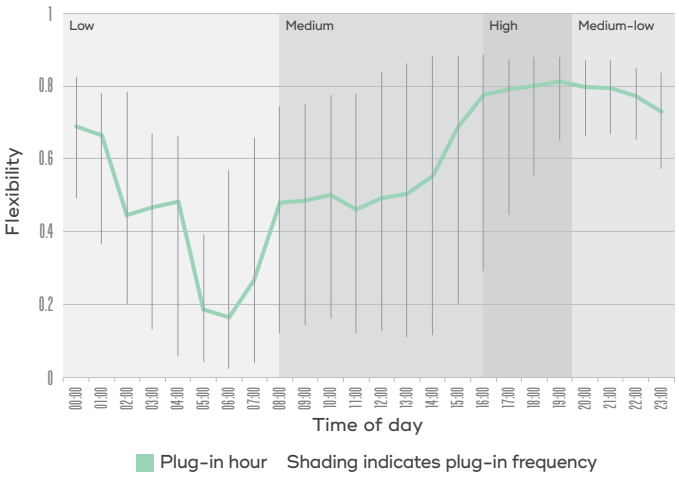


FIGURE 6

Charging Frequency for Different Vehicle Types

Category		Median Charging Frequency (Charge Sessions per Day)
All Participants		0.52
PIV Type	PHEV	0.76
	REX	0.45
	BEV	0.39
Battery Capacity	Less than 10kWh	0.73
	10 to 25kWh	0.63
	25 ro 35kWh	0.39
	35kWh +	0.31

HOW MUCH ENERGY DO EV'S TAKE WHEN CHARGING?

Charging events for EVs with smaller batteries are generally re-filling a greater proportion of their battery capacity. Mean energy consumed for these EVs is 45% to 70% of their battery capacity (Less than 10kWh, and 10 to 25kWh groups).

For vehicles with larger batteries each charge event usually refills about 30% to 45% of the EV's battery capacity.

DOES CHARGING BEHAVIOUR CHANGE ACROSS THE YEAR?

The highest charging frequency is in the winter months between January and February – probably owing to lower battery efficiency in the cold weather, battery conditioning losses and passenger heating requirements.

Similar monthly trends can be observed across all battery capacities.

HOW MUCH ELECTRICITY DOES AN EV USE IN A YEAR?

Annual electricity consumption varies widely and is especially influenced by battery size.

The average for EVs with smaller batteries (0 to 25kWh) is about 1,800-1,900kWh per year.

For larger battery EVs (35kWh plus) it is about 3,500kWh per year.

Annual household electricity consumption (without an EV) varies between 1,900kWh (small house) and 4,600kWh per annum (large house).

Every EV charging at home is equivalent to adding a new home to a network.

FIGURE 7

Energy Consumed as a Proportion of Battery Capacity – by Battery Capacity

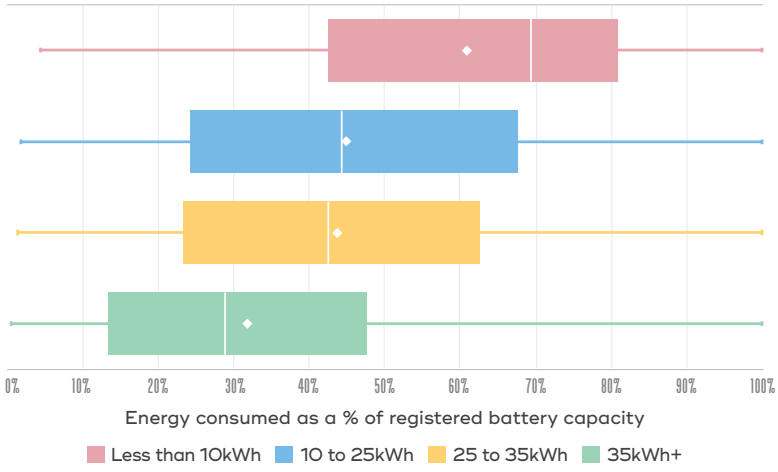


FIGURE 8

Average No. of Charge Events per Day, by Month, by Battery Capacity

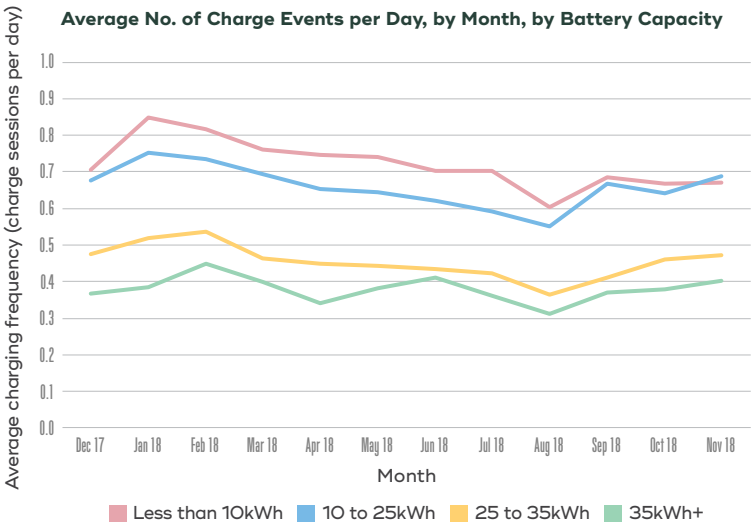
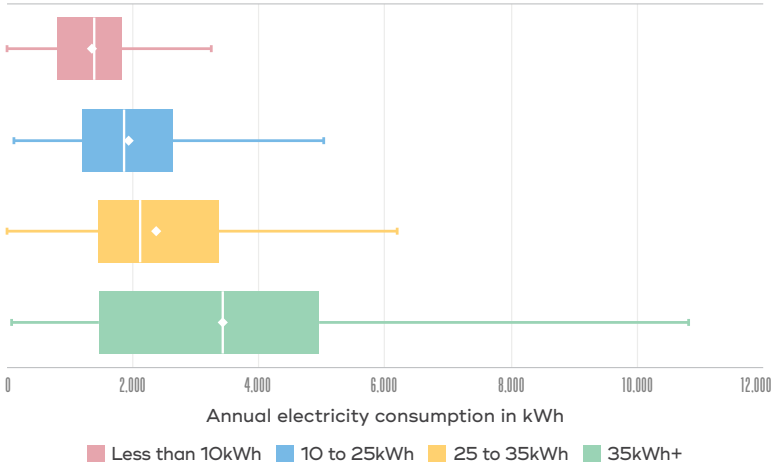


FIGURE 9

Annual Electricity Consumption from Electric Nation Charger – by Battery Capacity



TRIAL 1

Each managed group of chargers (CrowdCharge and GreenFlux) had to ensure total EV charging demand did not exceed a capacity limit. This mimicked all chargers in a group being supplied from the same network (e.g. by the same substation, or on the same feeder). Charger management was required when the demand from all the active chargers in the group exceeded the available capacity. The graphs below show when management was required for each system during the winter period.

FIGURE 10

CrowdCharge Trial 1 – Frequency of Active Management (Winter)

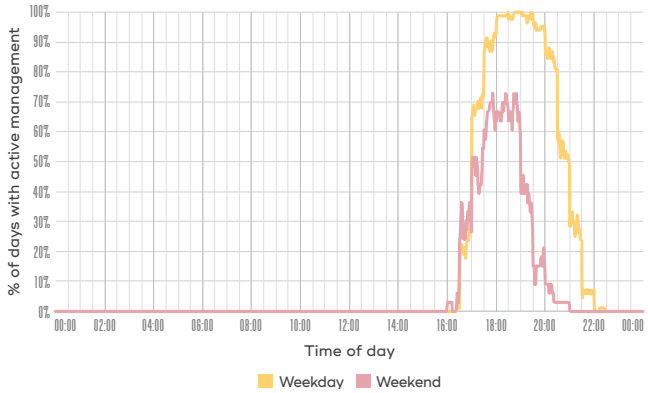
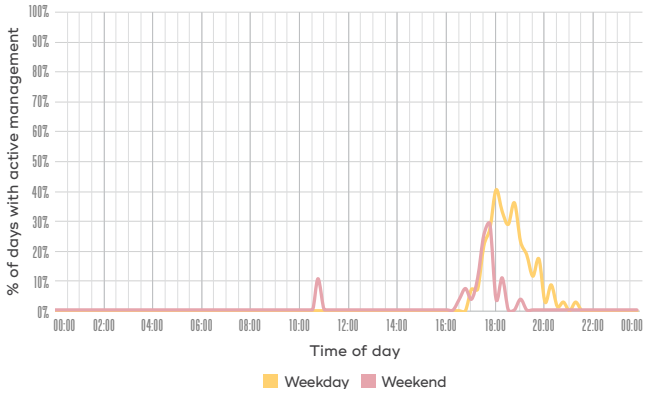


FIGURE 11

GreenFlux Trial 1 – Frequency of Active Management (Winter)



Management was active less frequently in the GreenFlux group due to their ability to distinguish between 3.6kW and 7kW charging EVs, so sharing the available capacity between more EVs before management was required.

Conversely, CrowdCharge did not distinguish between EV charging rates. This meant participants with vehicles rated at 3.6kW (hybrids and some lower capacity battery only EVs) experienced charge management far less frequently than those with 7kW EVs (mostly longer range battery only EVs).

Participant's Experience of Management

Trial participants who usually plugged in their EVs between late afternoon and 21:00 on weekdays would have experienced some management. Some participants would have had their charge managed more than others. Management was only active during the evening peak, so participants who charged outside this time (e.g. overnight on a timer) may not have experienced any management at all.

FIGURE 12

CrowdCharge Trial 1 – Distribution of % of Charge Events Managed – by Vehicle Rating

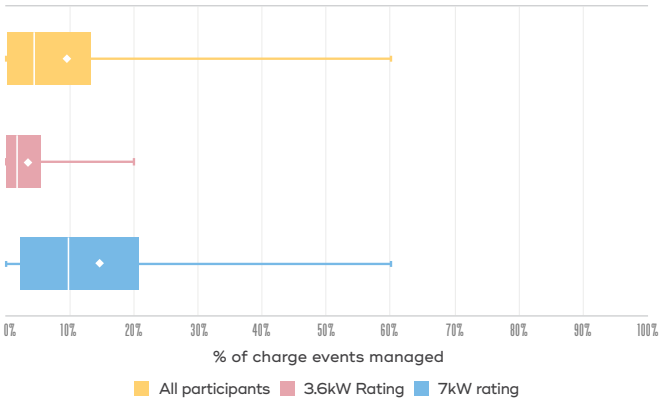
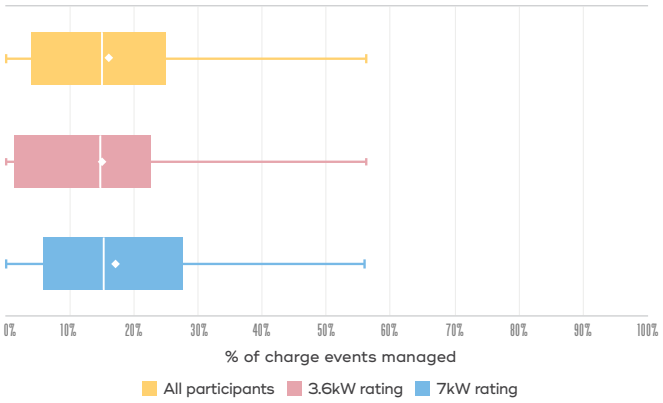


FIGURE 13

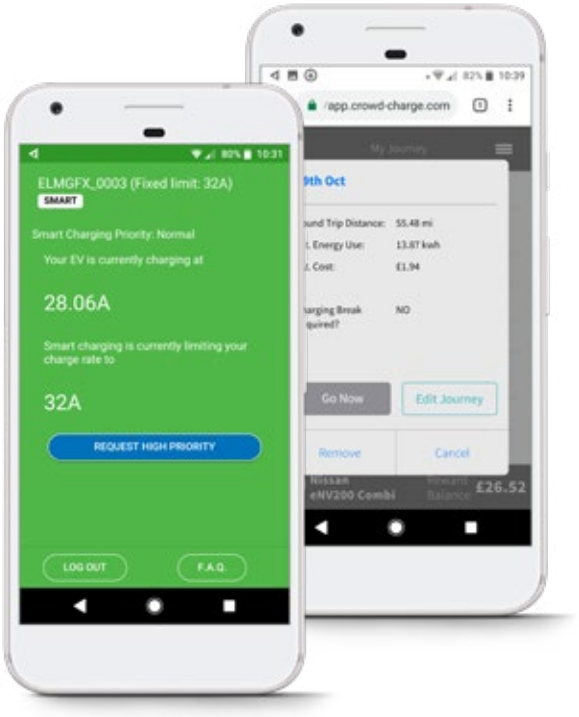
GreenFlux Trial 1 – Distribution of % of Charge Events Managed – by Vehicle Rating



During Trial 1 participants were not informed when they joined the managed group and had no visibility of charge management events, other than observation of their EV directly or through a vehicle app.

TRIAL 2 – INTRODUCTION OF SMART CHARGING "APPS"

Both CrowdCharge and GreenFlux introduced "Apps" to enable trial participants to interact with the Smart Charging systems.



CrowdCharge
Participants were asked to input journey requirements and the State of Charge of their battery each time they plugged in. The system then ensured enough charge for next journey was supplied as a minimum.

GreenFlux
Participants could view their charging session and request High Priority for that session. The High Priority request excluded them from demand management for that session.

The EV Charge management regime occurred in the same way as during Trial 1 – so a limited capacity was available. A slightly less restrictive capacity profile was used during Trial 2. This meant that management occurred on the majority of weekdays for both CrowdCharge and GreenFlux. Management was more frequent in the CrowdCharge group for the same reasons as Trial 1.

Trial 2 showed the extent to which participants interacted with apps:

CrowdCharge:
+ 55% of participants registered for a CrowdCharge app account
+ Participants entered information into the app infrequently. State of Charge was entered most frequently, but fewer than 25% of participants entered this more than once a fortnight

GreenFlux:
+ 69% of participants downloaded the app
+ Requests for High Priority stabilised quickly at the start of the trial, to around 2% to 3% of events

Periodically, throughout the trial, participants were surveyed and asked to score their satisfaction with their charging arrangements (before management, and at the end of Trial 1, 2 and 3).

The variances in participants' satisfaction levels are barely significant between the period when there was no demand management (baseline) and Trials 1 and 2. This suggests that trial participants' satisfaction with their charging arrangements was not affected by the introduction of Smart Charging and the first "Apps" had no discernible effect either. The level of management participants experienced did not correlate with their satisfaction rates.

Free-text responses for participants reporting low satisfaction often referred to dissatisfaction with the public charging network rather than their home charging arrangements and Smart Charging.

FIGURE 14

% of Participants Highly Satisfied with their Charging Arrangement

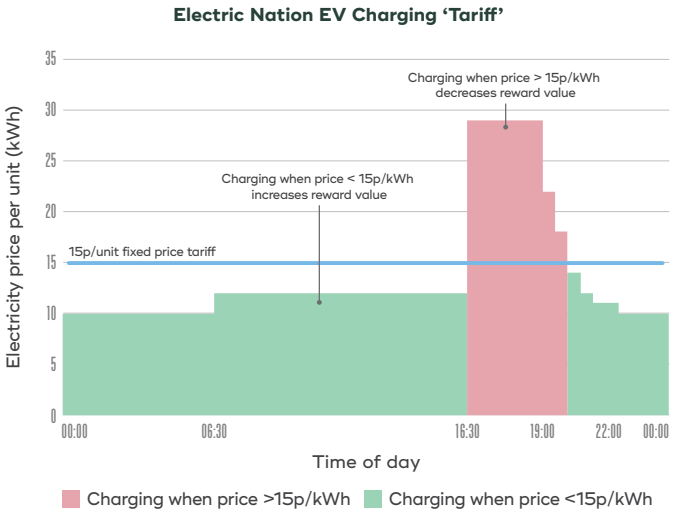
Survey	% Respondents Scoring High-Very High Satisfaction with Charging Arrangements
Trial 2	78%
Trial 1	75%
Baseline	77%

TRIAL 3

In Trial 3, participants were given the opportunity to earn a reward as a substitute for cost savings from their electricity bill for changing their charging behaviour.

This was presented as a Time of Use Tariff, based on historical data from Octopus Energy's Agile Tariff, where trial participants could influence the reward they earned by avoiding charging at peak price electricity periods.

FIGURE 15



GREENFLUX TRIAL 3 SYSTEM

GreenFlux updated their App to deliver this scheme by allowing participants to select a 'charging preference' – choosing between:

+ **Optimise time:** charge regardless of price
+ **Minimise cost:** charge in off-peak period only
+ **Optimise time and cost:** Charge could begin during the shoulder period, but would avoid peak price charging

The selected setting was then applied to all charging transactions until it was changed ("set and forget").

The app updates also added information on recent transaction history, including energy used, time charging and the impact on the reward value.

Participants could still request high priority via the app.

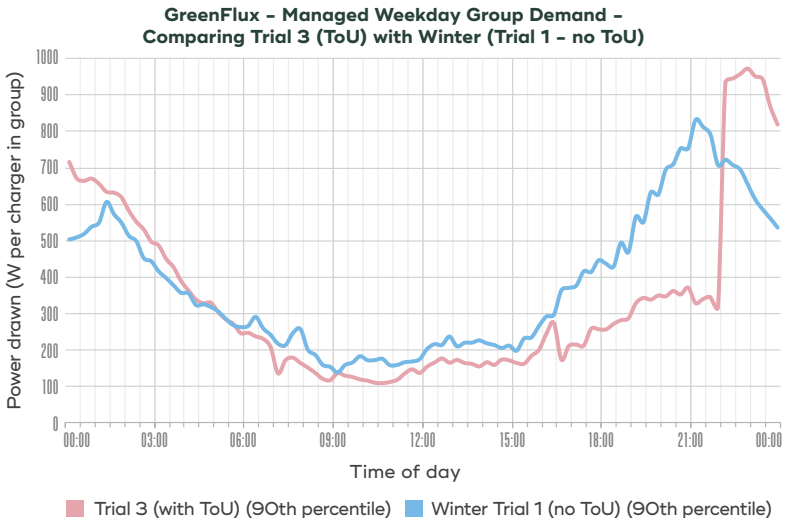
The GreenFlux system would then act on the user's preference, no matter what time their EV was plugged in – so an EV on "Minimise Cost" plugged in at 18:30 would not start charging until 22:00, however another EV on "Optimise Time" would start charging immediately.

IMPACT OF THIS INCENTIVE

During Trial 3 more than 60% of trial participants changed their app preference away from the default "Optimise Time", mostly to the "Minimise Cost" option, avoiding the peak price.

The effect on group demand was dramatic. The early evening peak in EV charging demand disappeared. Demand management was no longer required shortly after introduction of the scheme.

FIGURE 16



By contrast, a sharp increase in demand was observed at the cheap, overnight, price boundary, as many delayed charging events were switched on. This could have negative impacts on various parts of the electricity system. These include step changes in voltage caused by sudden changes in demand, or issues with generation capacity. However, this could be easily mitigated in real-world scenarios by implementing randomised or time-band switching. A tariff based system which was implemented without Smart Charging could create a similar night-time peak in demand, with no means to manage this peak.

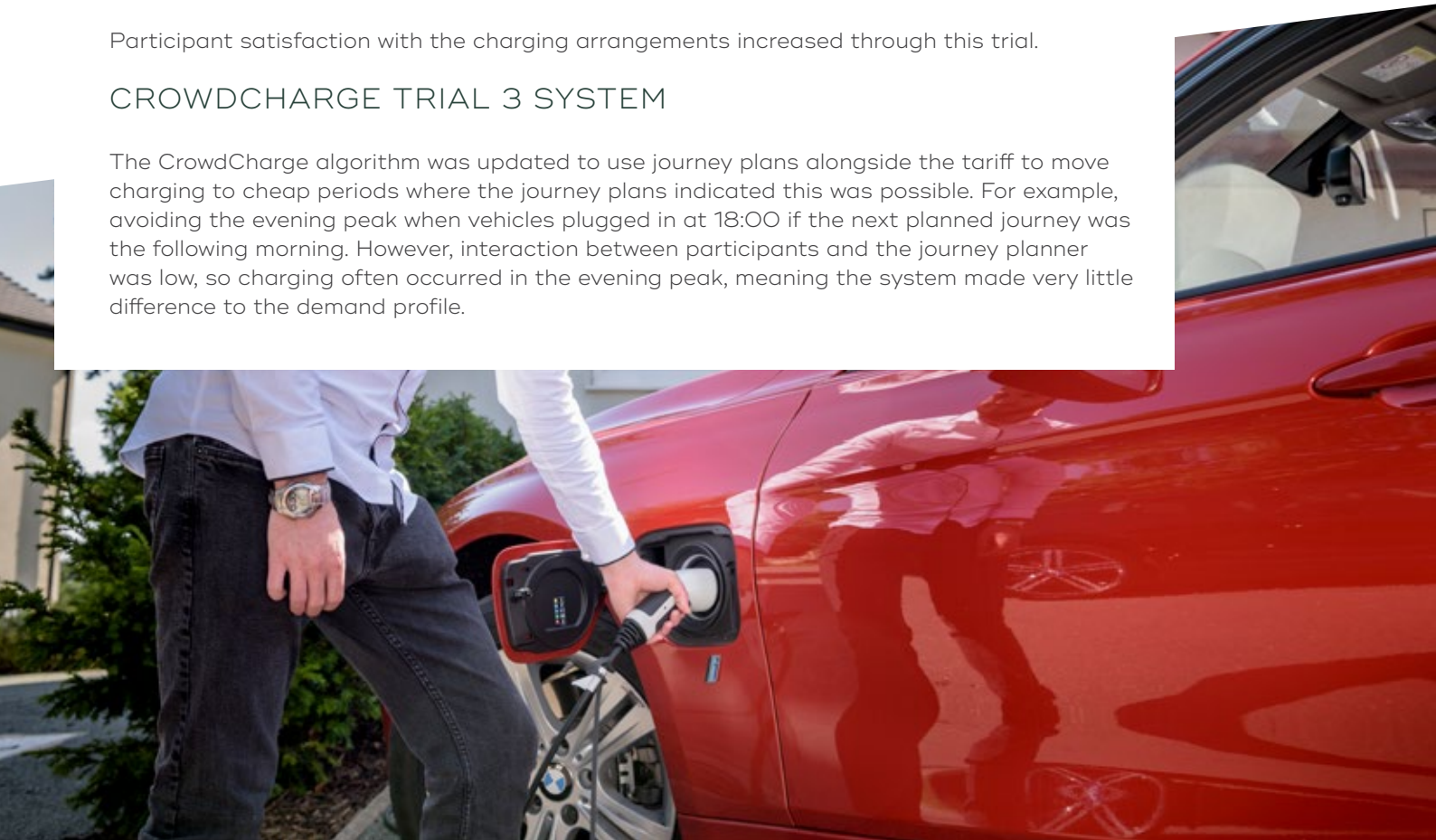
Not all participants used the app to update their charging preference. Even among participants who didn't use the app, a lower proportion of charging events began during the evening peak. This shows that this group also altered their charging behaviour in response to the time of use tariff.

The overall effect of this trial was a clear demonstration that a clearly communicated modest financial incentive can change people's charging behaviour shifting peak period charging to the late evening and overnight. This change is most dramatic with Smart Charging and a relatively simple app (to allow customer interaction with the system), which makes changing behaviour simple.

Participant satisfaction with the charging arrangements increased through this trial.

CROWDCHARGE TRIAL 3 SYSTEM

The CrowdCharge algorithm was updated to use journey plans alongside the tariff to move charging to cheap periods where the journey plans indicated this was possible. For example, avoiding the evening peak when vehicles plugged in at 18:00 if the next planned journey was the following morning. However, interaction between participants and the journey planner was low, so charging often occurred in the evening peak, meaning the system made very little difference to the demand profile.



SMART CHARGING CAN:

+ Support the introduction and management of Time of Use based charging
+ Provide a means to manage any negative consequences of mass uptake of Time of Use incentives

The analysis of Trial 3 data showed that people who used the GreenFlux app made the biggest changes to their charging behaviour:

+ 76% of all GreenFlux participants moved their charging away from the evening peak during Trial 3 – 55% of participants who didn't use the app made this change, compared to 90% of app users
+ App users tended to achieve greater changes than those who didn't use the app – showing the benefit of the app to support changes in charging behaviour

> "I LOVED THIS TRIAL WORKED FANTASTIC FOR ME AS THE MAJORITY OF THE TIME I CHARGE OVERNIGHT SO DON'T CARE WHEN IT CHARGES BUT IF I NEEDED IT STRAIGHT AWAY JUST CHANGED TO OPTIMISE TIME AND IT STARTED STRAIGHT AWAY. HASSLE FREE"

CUSTOMER RESEARCH FEEDBACK FROM GREENFLUX TRIAL 3

The feedback from participants regarding Trial 3 was positive:

+ 88% of participants who had used the app found the charging preferences and reward structure easy to understand

> "I THINK THE CONCEPT OF THE TRIAL IS EXCELLENT, THE APP APPEARS VERY INTUITIVE, AND THE INCENTIVE OF INCREASING REWARDS THROUGH CHARGING HABITS HAS GREAT POTENTIAL"

+ 86% were either 'very likely' or 'slightly likely' to use a similar app in the future
+ Having an app helped reduce participant anxiety about Smart Charging – 62% of GreenFlux participants thought that having an app was useful
+ 81% of participants believed that the tariff structure and charging profiles would encourage many, or most, EV owners to charge their cars outside of peak times

> "THIS IS A GOOD PROJECT, AND IT MAKES PERFECT SENSE TO MINIMISE CHARGING COST IF CAR IS BEING LEFT OVERNIGHT ANYWAY, AND/OR STAGGER CHARGING TO HELP WITH DEMAND IS GOOD FORWARD THINKING"

After all the trials had finished participants were asked how likely they would be to adopt any of the solutions in the future. 76% of GreenFlux participants stated that they were likely to take part in a similar scheme (to Trial 3) if it was available to them. Two thirds (66%) of GreenFlux participants said that they would recommend this solution to their friends.

KEY CONCLUSIONS

+ Data from the trial shows flexibility in charging – but without an incentive the demand in the evening peak requires management
+ Demand management is technically feasible, and acceptable to the majority of trial participants
+ 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
+ Smart Charging can:
  - Support the introduction and management of ToU based charging
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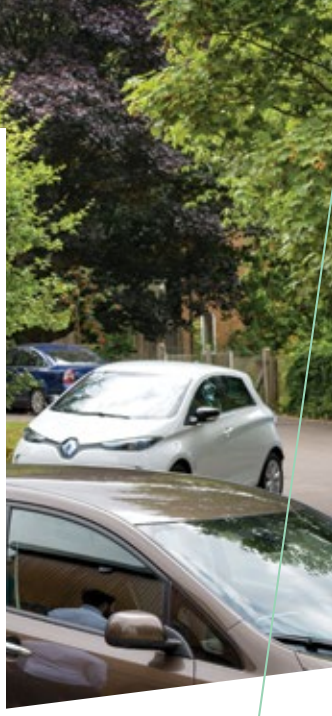
+ Data from smart chargers, similar to those used in Electric Nation, can provide a strong data source for building an evidence base for future developments.



The Electric Nation Smart Charging Trial recruited 673 EV owners, owning more than 40 different makes and models of plug-in vehicles, including plug-in hybrids and battery electric vehicles, to experience Smart Charging (demand management).

Over two years, trial participants experienced periods of no management, and management without and then with apps to enable them to interact with the Smart Charging systems. The trial concluded with participants being financially incentivised to change their charging behaviour, producing clear indications that this could be a successful strategy for addressing distribution network congestion issues that could be created by EV charging at home.

During the trial, data from more than 130,000 charging events lasting nearly 2 million hours was collected.

This brochure summarises the key findings from the Smart Charging Trial Project. Further details are available via the WPD Innovation website.

Electric Nation also:

- Investigated novel network monitoring and analysis techniques to identify EV charging on WPD's networks (delivered by Lucy Gridkey)
- Developed a Network Assessment Tool to assess the impact of EVs 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 (delivered by EA Technology)
- Is delivering a small scale feasibility trial to investigate the impact on driver experience of the first single-phase Vehicle to Grid chargers installed in customers' homes in the UK. These V2G chargers are providing grid services such as charging demand reduction or exporting power from the car battery into the local electricity network (delivered by DriveElectric)

Further information on the other aspects of the Project, and a full technical report on the Electric Nation Smart Charging trial will be published on WPD's Innovation website.

COLLABORATION PARTNERS

Electric Nation is the customer-facing brand of CarConnect, a Western Power Distribution (WPD) and Network Innovation Allowance funded project. WPD's collaboration partners in the Project are EA Technology, DriveElectric, Lucy Electric GridKey and TRL.

ea technology · driveelectric electric car leasing · Lucy Electric · TRL

WESTERN POWER DISTRIBUTION
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