Electric Nation Powered Up

NIA Closedown Report

January 2020 – July 2022

Electricity
Distribution

nationalgrid

Version Control

Issue	Date
0.1	30/09/2022
1.0	09/12/2022
2.0	23/12/2022

Publication Control

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1. Executive Summary

Electric Nation Powered Up, followed on from Electric Nation, and aimed to determine whether a Vehicle-to-grid (V2G) charger could provide a service to Network Operators and more importantly whether customers would engage with that service. The project was started in January 2020 and finished in June 2022. Similarly to the first trial, it was supported by Crowdcharge and EA Technology.

The project sought to test with energy suppliers how a tariff for services could work and moreover the level of service that could be provided along with some insights into the incentives that work and did not work. All of this insight is vital to Network Operators and Suppliers if we are to succeed in the aspiration of a more flexible energy system.

Our project partners were EA Technology, Crowdcharge with support from British Gas, Flexitricity, Igloo Energy, and Green Energy. More information on the basis of the partner's role is provided within this report.

The trials were inevitably impacted by the global pandemic and the various lockdowns especially with regard to installations and rectifying faults. However, despite this and some significant challenges around Supplier failures the results were very encouraging as can be seen in the customer engagement reports and the overall customer feedback.

Despite these challenges the project was extremely successful in validating the viability of such a service however challenges remain in terms of commercial viability but as more vehicles come to market that can provide V2G services this will undoubtedly reduce the disparity that exists within the commercials of the proposal. The costs of the chargers themselves present the largest of the challenges and again as the technology matures this should also be addressed.

Customer feedback was broadly positive and a handful of different approaches were taken in presenting the offer to consumers. Pure financial reward as opposed to other forms of incentive seemed overall more popular than other mechanisms.

In total 97 chargers were installed across the four customer supplier propositions. The results from the trials have resulted in changes to the National Grid Electricity Distribution (NGED) LV Connect planning tool, better allowing us to manage the connection of V2G chargers to the network. The results of this are available on our website and within this report to be shared with the other Network Operators.

As part of the project objectives we wanted to be able to update our policies and procedures pertaining to EV Chargers based on results and we have updated them accordingly based on the findings detailed within this report.

2. Project Background

It is already known that the transition to electric vehicles (EV) will double the load per house where a car is being charged (based on mileage of 12,000 per year). The addition of bi-directional charging that could be in use by 2040 in up to 15% of homes1 brings a potential issue for low voltage networks with multiple cycles of charge and discharge greatly increasing the throughput of energy. This is higher than most stationary battery storage due to higher connection power (up to 7 KW) and much larger battery capacity (up to 90KWh). The energy flow for these batteries will be directed by various energy suppliers and other energy service providers who will give end users low-cost electricity or even pay for use of the battery flexibility. Understanding the nature of this energy flow is essential to develop policies for connection and to allow for planning of network requirements to avoid voltages being over or under statutory voltage limits. In addition, the opportunity to increase load or provide export to reduce load in a given network area is desirable but ascertaining the value of this service is essential to formulate appropriate incentives to electric vehicle battery owners.

In this project, 97 homes with existing EV users were equipped with Vehicle to Grid (V2G) chargers to study and manage the throughput of energy. To replicate the likely future situation, 4 energy service partners were contracted to provide unique energy flow strategies delivered via the aggregated CrowdCharge EV charging optimisation platform (CrowdCharge platform). By utilising the CrowdCharge platform, these partners were able to experiment with charging and discharging the vehicle batteries to suit their energy trading requirements. The chargers were divided into 4 groups of around 25 units each which were offered to partner energy suppliers and aggregators who offered various energy and V2G incentive strategies. This produced a wide range of use cases for which data was gathered to produce charger use profiles. These profiles have been utilised by a network modelling tool (NGED's Connect/LV tool) to model the effect on a range of networks at varying levels of EV penetration. In turn this modelling has been used to provide 'V2G use envelope parameters' that can describe constraints that needs to be applied to the use of these assets.

The CrowdCharge platform was used to control charging across the whole network of 97 V2G chargers, as an additional supervisory control layer, to keep within DSO specified current limits to simulate a constrained mode in the LV network (feeder or substation). Several of the properties also had solar generation attached and study of the whole home demand has been included as part of the customer trial period.

V2G hardware, the associated energy trading services and how these interact and operate together while incorporating network control from the DNO, remains an unknown topic in practice to date. Electric Nation Vehicle-to-Grid (ENV2G) has investigated these areas and will increases the understanding and collaboration between the DNO, the energy suppliers and the charging control platform service provider Crowd Charge in preparation for a future world where V2G charging is commonplace. As V2G technology and energy services had not been investigated in full yet, there was a great opportunity to increase the learning and understanding around the industry of which this project will contribute.

[1] National Grid's Future Energy Scenarios Report 2019 - https://www.nationalgrideso.com/future-energy/future-energy-scenarios/archive

3. Scope and Objectives

The scope of the project is to engage and recruit between 90-110 participants to install V2G charging and control equipment in domestic properties across NGED's four license areas. The chargers will be split into various groups of similar size and assigned to the project's energy supply partners (up to 5). Each energy supplier will then use their group of chargers to test their various energy services utilising Crowd Charge's demand management charger platform which provides optimised charging sessions, while keeping within simulated DNO network limits. The effect of these services on the Low Voltage (LV) network will be modelled and reported on, including the use of this real world V2G data in a network assessment tool.

Table 3-1: Status of project objectives

Objective	Status
Explore and report on the impact of V2G charging on LV network utilising end-user trial charging data and analysis	✓
Demonstrate, via modelling, to what extent can V2G assist with management of LV network demand;	✓
Examine how sophisticated dynamic bi-directional energy services based on vehicle battery storage, from a variety of energy suppliers, may impact the LV infrastructure	✓

4. Success Criteria

Table 4-1 shows the project's success criteria and the status achieved.

Table 4-1: Status of project objectives

Success Criteria	Status
1. Presentation of the final report data analysis and project's findings to NGED and key industry stakeholders at the dissemination event, held in the first quarter of 2022.	✓
2. Recommendations/suggestion to NGEDs V2G services policy and commercial frameworks.	✓
3. Specify and provide a standard data set that can be used by a network modelling tool to evaluate impact of V2G charging on LV networks	✓
4. Using a network modelling tool to provide a forecast of the effect of V2G charging at varying levels of update. This will be based on a mix of dynamic bi-directional energy services.	✓

5. Details of the Work Carried Out

5.1. Trial partners

NGED

National Grid Electricity Distribution (NGED) is the Distribution Network Operator (DNO) responsible for the electricity connections of over 8 million customers from Isles of Scilly to the Lincolnshire coast, covering South Wales, Bristol, Birmingham, Nottingham, and Milton Keynes.

NGED was the Project Sponsor for the Electric Nation Vehicle-to-Grid (PoweredUp) project.

CrowdCharge

CrowdCharge has extensive experience in the optimisation of Low Carbon Technologies (LCTs) through their aggregated EV charging optimisation platform.

Previously to Electric Nation Powered Up, CrowdCharge was a project partner on 2 NIA projects: My Electric Avenue with Scottish and Southern Electricity Network (2013-2016) to understand the impact of EVs on the local networks and Electric Nation 1 with NGED (2016-2019), responsible for deploying around 350 smart V1G chargers, and 3 V2G chargers, and managing them through their aggregated EV charging platform to understand the impact on the low voltage (LV) network specifically from the DNO perspective.

CrowdCharge were also the first company in the UK to gain a G99 grid compliant V2G chargers for retail in the UK market in 2018, so have an industry leading knowledge on V2G technology and services.

Wallbox

Wallbox is a global company dedicated to changing the way the world uses energy. Their Wallbox Quasar V2G charger was engineered to transform electric vehicles into power energy sources. This bidirectional charging technology lets the owner charge and discharge their EV, allowing them to power their home or the grid with the EV battery. The Wallbox Quasar V2G is the world's lightest and smallest DC bidirectional charger.

Wallbox were responsible for providing the Quasar V2G charger and a both a technical and customer support services to CrowdCharge and their participants for the duration of the 1-year customer trial.

Hangar 19

Hangar19 are an engineering solutions company, enabling the development and delivery of electric vehicle services, equipment, and associated energy infrastructure. They have developed and support market leading solutions in the electric vehicle space. CrowdCharge contracted Hangar19 to design, test and build the communications protocol and required hardware to allow the Wallbox Quasar V2G charger, to communicate with CrowdCharge's aggregated EV charging optimisation platform.

They created the CrowdCharge controller box which allowed the Wallbox Quasar to receive commands from the CrowdCharge platform, and respond with various data fields which enabled the operation of smart charging, V2H and V2G features on the trial.

Hangar19 also supported CrowdCharge with technical faults the Wallbox Quasar and Crowd Charge controller during the live customer trial.

5.2. Installers

During the initiation phase of the projects, CrowdCharge contacted several EV ChargePoint installers to coordinate and manage the administrative paperwork and the installation of the project hardware.

Three installers were selected to install the Wallbox Quasar V2G charger, the CrowdCharge Controller and the metering and to provide electrical fault support as required:

- JoJu Solar
- The Phoenix Works (now re-branded as EGG)
- Stratford Energy Solutions

The latter two installers were contracted on the Electric Nation 1 project collectively installing c.300 V1G smart chargers.

5.3. Energy Suppliers

The key differentiator for ENV2G compared to other UK V2G projects, is that for the first time, the project operated 4 different energy supplier V2G strategies simultaneously, using V2G to imitate a future world in which many streets have many EVs charging using different energy supplier tariffs.

To create and implement their V2G energy strategies, CrowdCharge partnered with 3 energy suppliers and 1 energy aggregator:

British Gas / Centrica

British Gas is Britain's leading supplier of energy and services and the country's biggest retailer of zero carbon electricity. They are part of Centrica, a company founded on a 200-year heritage of serving people. They provide energy and services to over 6 million UK homes and businesses.

Green Energy UK

Green Energy UK (GEUK) are the UK's only supplier of 100% green gas and renewable electricity. For over 20 years GEUK have been championing sustainable energy in the UK and were the first energy supplier to offer residential customers TIDE, a Time of Use (ToU) tariff, back in 2017.

Igloo Energy

Igloo Energy were in a position to do something that can help both people and the environment so were developing a product range to help Igloo customers lower their energy usage and consume more flexibly in order to save money. Out of 41 energy companies, Citizens Advice rated Igloo 3rd in terms of their customer service performance; an incredible endorsement for their team.

Due to unprecedented wholesale energy and gas market volatility, Igloo Energy were forced to liquidate during September 2021. The supply for the participants in this group was not disrupted. All participants in this group were migrated to the CrowdCharge-Flexitricity group.

CrowdCharge & Flexitricity (energy aggregator)

Flexitricity is the UKs demand response pioneer. Demand side response, or demand side flexibility, is where businesses are financially incentivised to reduce or increase their energy use to provide flexibility to National Grid, or DNOs as and when they need it.

EA Technology

EA Technology (EATL) are the leading experts in providing DNOs with award winning diagnostic instruments, skills training, and technical services to help develop smart grid solutions for many DNOs across the UK. EATL were the Project Lead on the previous Electric Nation Smart charging trial to understand how EV smart charging may impact the LV network.

In relation to Electric Nation V2G project, EATL were responsible for the development of low voltage (LV) V2G profiles into NGEDs Connect/LV Network Assessment Tool generated from the project's customer trial data, and incorporating the new profiles into the Connect/LV release schedule, thereby ensuring that new profiles are available to all Connect/LV users to help plan networks of the future.

5.4. Recruitment of Participants and Installations

Each section provides an overview of the work undertaken during the Project. Further specific detail on any of the below sections can be found in the Project's Customer Communication and Engagement Reports from 2020 and 2021 – the link to these can be found here:

5.4.1. Project Promotion and Marketing

CrowdCharge was responsible for recruiting participants and marketing the trial, with a project target of recruiting and installing 90-110 V2G chargers in participant's domestic properties. The responsibilities of CrowdCharge and other key suppliers in the marketing and recruitment phase of the trial can been seen in Customer Engagement reports detailed in Section 10.

During the project initiation phase, it was recognised that a specific targeted marketing approach was required to engage with the appropriate EV owner as the V2G capabilities of the trial greatly limited the type of EV that could participate, with only Nissan EVs - Leaf 30kWh or greater and 2018 model 40KWh eNV200s - being compatible with the charger.

This led the marketing and engagement tools to be focused on areas which would gain the most traction. Some specific targeted marketing approaches used; these can be seen in the Customer Engagement reports detailed in Section 10. After 2-3 months of delay due to the outbreak of Covid-19, the project launch on the 3rd of June 2020. Over 750 enquires were received via the Electric Nation Vehicle to Grid project website, this demonstrating the success of the project's marketing and recruitment strategy.

5.4.2. Recruitment Materials

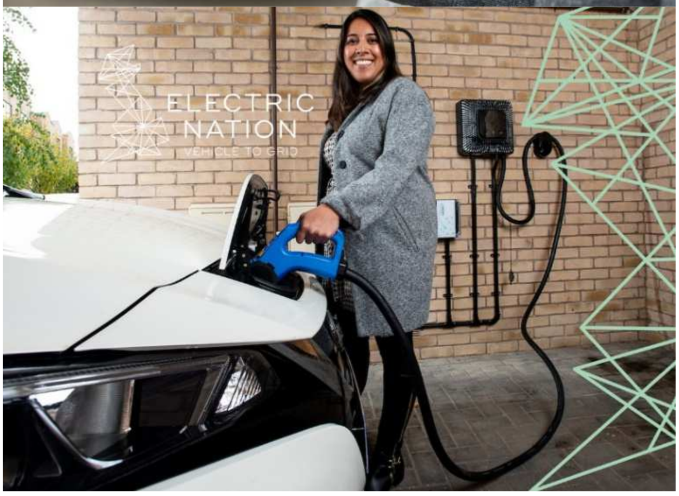
As the first Electric Nation Project was a success in recruiting the target of 700 participants, it was decided that the follow on V2G project should retain the 'Electric Nation' brand, as this already had a strong brand image and reputation in the industry. The Electric Nation Logo was also retained and refreshed with 'Vehicle-to-Grid' to reflect the new project as shown in Figure 5-1.

Figure 5-1- New 'Electric Nation Vehicle to Grid' branding'

Photo and video shoots were undertaken to create the imagery required for the recruitment and PR campaigns. A small selection of the imagery can be seen below – all images have been used throughout the trial to promote the project and aid with recruitment.

Figure 5-2 -Photoshoot imagery to support project recruitment and engagement


EF19 LVG
EY19 VPO
EY19 VPO


ELECTRIC
NATION
VEHICLE TO GRID

At the start of the recruitment process, CrowdCharge created a set of resources which detailed specific information about the project to help inform the prospective user on whether they would be a good fit for the trial. Resources were designed to answer questions that prospective participants may have at the various steps along the recruitment and installation process journey. These are detailed in Table 2.

Table 5-1-Marketing resources created to support the recruitment and engagement phase.

Resource	Purpose
Refreshed Electric Nation Vehicle-to-Grid (V2G) website	To provide a simple way for prospective participants, and interested stakeholders, to gain an understanding of the project specific information.
PR Boilerplate	To provide specific project key messaging to interested PR outlets, to aid with recruitment
Project Information Document (PID)	To provide project participants with all the project specification information including, project aims/objectives, timeline, trial stages, project hardware support information and FAQs

Due to the outbreak of Covid-19 in Spring-2020, no recruitment events took place for the duration of the recruitment phase therefore no event specific material was required.

5.4.3. PR and Social Media to aid recruitment

As the participant eligibility criteria to join the trial was restrictive, a surplus of enquires were required to ensure the project reached the target of recruiting between 90-110 participants. Various recruitment materials and marketing methods were utilized to aid the participant recruitment phase. Google Search, the ZapMap website and Family/Friend Recommendations produce the top three 3 total number of leads for the Project with over 200 received in total for each. A further list of total leads received can be viewed in Customer Engagement reports detailed in Section 10.

Social Media was identified in the communication plan as a key method for marketing, engaging, and recruiting participants for the project. The following methods were used:

- Facebook groups: Various specific Facebook groups were targeted, asking the owner if the project could post to advertise the project for those who are looking to be involved in an innovation trial and test cutting edge technology and energy services.
- Project Twitter account: This was used to publicise key project milestones to drive engagement. Key industry stakeholders, and project stakeholders, tagged and retweeted tweets to reach a wider audience.
- Project LinkedIn accounts: As this project was highly innovative, LinkedIn was utilised as this has a more appropriate reach to the industry and related businesses.

5.4.4. Recruitment Process

The project launched recruitment in June 2020 and concluded in March 2021. In the first 6-months of recruitment, the project received 600 enquiries. On recruitment close, over 760 enquires had been received. Installations began in March 2021, concluding in December 2021 with 97 installations complete. 3 participants dropped out of the trial while it was in operation due to 1 moving out of NGEDs license area, and 2 returning their Nissan EV lease early than expected.

After 9-months of customer engagement and recruitment, the project closed recruitment to all new enquires on the 22nd of March 2021 due to a surplus in eligible applications. **Error! Reference source not found.** below shows the total number of applications made to the project, split against various stage of eligibility:

Table 5-2-Table demonstrating the number of applications made to the project, and these filtered out based on their eligibility requirements

Summary	Grand Total
Electric Nation Website Enquires	768
Dynamics Form Responses (Partial + Complete)	768
Dynamics - All opportunities	463
Open Opportunities	119
Lost Opportunities	345

As shown in Table 3, the Electric Nation Website received in total 768 applications to join the trial. The Electric Nation website form had certain eligibility criteria questions detailed which routed applicants based on their answers. If the applicant was not eligible, for example they did not have off-street parking or a Nissan EV, the form would direct them to a 'Not eligible' page. This filtered out non-starter applications and saved hundreds of hours in processing time for the participant recruitment and engagement team. Out of the 768 total applications, 463 passed the initial eligibility criteria form on the Electric Nation website and were passed through to the CRM system for 2nd line eligibility criteria checks by a member of the team.

5.4.5. Qualification Process

The project was highly restrictive on applications during the recruitment and qualification process due to the complexities involved in trialling V2G and associated energy services.

CrowdCharge designed a detailed qualification process to increase the possibility that the participants would be eligible to join the trial, aid the quality of trial data the project would receive, and to minimise disruption to the trial through participants requesting to leave.

The qualification process was split into 2 stages:

Stage 1 – Mandatory qualification:

This stage included over 30 questions to ascertain their eligibility to join the trial. These questions can be seen in the Customer Engagement reports detailed in Section 10, with a selection shown in section Trial Participant Requirements. These questions were asked via an online web-enquiry form on the Electric Nation website, which filtered out applicants which were not eligible. If eligible, the responses to these questions were automatically populated into the CrowdCharge CRM database.

Stage 2 – Formal qualification call:

If successful in passing the first stage, stage 2 involved a formal qualification phone call from a member of the recruitment and engagement team. A formal project script was created to help ensure all information points were explained to the participant ahead of the next stage of the qualification process.

Acceptance of each information point was recorded in the CRM data. The information points included:

- Re-confirmation of the questions they answered during the stage 1 website application;
- Project's Covid policy understanding;
- Project specific information to ensure they are fully aware of the trials aims / objectives and their obligations on joining the trial, including exit fees;
- Telematics installation requirements;
- Hardware installation parameters;
- G99 LV Grid Connection process.

5.4.6. Trial Participant Requirements

A project objective was to examine how sophisticated dynamic bi-directional energy services, based on vehicle battery storage, from a variety of energy suppliers, may impact the LV infrastructure. This objective caused a restriction to the EV manufacturer and model that could operate bi-directional charging due to the highly innovative nature of V2G services. Several eligibility factors, of both participants and their EV, had to be met to join the trial. These trial participant requirements were as followed:

Participant Eligibility Criteria:

- **Reside within NGED's License Area:** All participants must reside within NGED's License Area and be on supply with HGED;
- **Domestic applications only:** The project could only recruit participants on domestic supply;
- **Off-street parking:** All participants were required to have off-street parking and be able to prove they owned the land their EV would be parked on to charge at home if required;
- **Rented accommodation:** If a participant lived in rented accommodation, they must have shared proof of approval from the landlord to have the charger installed;

- **EV Manufacturer and Make conditions:** 3 types of EV only were permitted on the project, due to their V2G capabilities – these being:
    - The Nissan Leaf, 30kWh or above,
    - The Nissan eNV200 40KWh battery,
    - The Mitsubishi Outlander: CrowdCharge decided to remove this option on the trial due to its small battery size, as this would not of have provided as much real-world learning for NGED and industry).
- **EV Lease condition:** If a participant leased their Nissan EV, they had to prove the lease period ran for the entirety of the project, or confirm they would be willing to extend it;
- **Single EV at property condition:** Only 1 EV at each property could be permitted; multiple EVs at one address were rejected due to out of scope of the project objectives;
- **Telematics:** All participants must agree for specific telematics data gathering as part of the trial;

5.5. Customer Trial

The Customer Trial work package allowed for the implementation and operation of the various energy suppliers' energy strategies. The Customer Trial ran for 1-year, starting on the 1st of June 2021, concluding on the 31st of May 2022.

Within this 1-year period, the Customer trial was split into 4 stages, which can be found in Table 5-3.

Due to Wallbox Quasar hardware / firmware issues, smart scheduling was paused between late August and early October whilst a firmware update was developed and deployed for the Wallbox charger. Participants were reverted to the baseline mode during this period. However, a subset of participants were switched back on to smart scheduling in mid-September. Although it is not expected that this pause in smart scheduling would have significantly affected when participants would have plugged in their vehicles, it would likely affect when charging took place.

Table 5-3: Stages of the Trial

Stage	Date	Details
Baseline	Until June 2021	Monitoring the use of the charger with participants controlling the charger directly via the Wallbox app. The limited number of installations after June 2021 were put into this baseline mode for approximately a week.
Fixed Schedule & local control	June 2021 – August 2021	Fixed charging schedule that was augmented with local state of charge rules enacted by the local CrowdCharge control unit, to test charger control functionality.
Smart Scheduling	August 2021 – May 2022	In this phase, charging and discharging was dynamically controlled using CrowdCharge's systems based on each user's tariff and journey requirements.
Vehicle to Home and solar optimisation	February 2022 – May 2022	Charging was controlled using CrowdCharge's systems to base on each user's tariff and journey requirements. In addition, the system tried to make use of net export due to solar generation to charge the vehicle and power the home.

Each customer was enrolled into one of four V2G strategies from either British Gas, Green Energy UK, Igloo Energy, and CrowdCharge/Flexitricity. These different strategies offered various import and export tariffs, and different rewards for different reward criteria. A full breakdown can be found in Table 14-1 on page 38.

5.5.1. Plug-in Analysis

Each strategy required a certain number of "Compliant plug-ins", where a certain number of full plug-in cycles (from 6 pm to 5am) must be met, and the number varied between suppliers. It is in the DNOs benefit to have as many EV as possible plugged in to draw flexibility services from, so it was encouraging to see a high number of these compliant plug-ins. On average, each participant plugged in for 186 cycles during the year-long trial, and the highest group was for the customers on the green energy strategy. This was the only strategy offering an export tariff as well as a reward, where customers could sell the electricity in their battery back to the electricity system. A full breakdown of compliant plug-ins can be found in the appendix.

5.5.2. Customer Trial Stages

Throughout the different stages of the customer trial (baseline, fixed scheduling, smart scheduling, and V2H optimisation), we were able to obtain graphs showing the different behaviours of EV chargers under the different regimes.

The graphs for the export/import from the grid, the usage in the home, and the usage by the charger for stage 1 can be found on page 48. This shows the typical usage for an EV driver with no Vehicle to Grid charging enabled, and the EV can be seen drawing most often at midnight and in the early morning when the energy prices are cheapest. This would have been set manually by the users.

In stage 2 (graphs on page 50), the fixed charging schedule causes all the charging to happen between 2200 and 0400, which is all coming from the grid, and export to the grid happening between 1600 and 1900. This causes the peak demand from the grid to be overnight.

In stage 3 (page 52), the dynamic scheduling causes the charging to be spread out over the night rather than concentrated in certain hours, and the discharge still takes place at the same times.

In stage 4 (page 54), the optimised charging cause a much more varied response, which depends on the users' requirements and whether their solar panel are generating. This leads to some charging occurring during the middle of the day, but this doesn't cause extra demand from the grid, but still the bulk of charging occurs overnight.

5.5.3. Cost and Carbon Savings

Intelligently scheduling the charging of vehicles for when electricity is cheapest led to cost savings, and this also has had an impact on the carbon intensity of the electricity used by EV drivers. This trial showed that the cost savings got larger with each successive stage, and that those that were on a multi-level import tariff and dynamic export tariff had the biggest savings, as they could exploit the higher export prices over the winter. This was able to save customers nearly all of the cost of charging their vehicle. For those on the export tariffs, they were actually able to make money during a charging cycle, and during December 2021, the average saving was between 100% and 150% of the cost to charge their car (i.e. they were paid up to 50% of the cost to charge their vehicle). The biggest carbon savings also occurred during the winter, as this was because of the large variations between carbon intensity of the grid that occurs during this period, and again during the winter nearly all of the carbon impact of charging their car could be negated.

5.5.4. Testing the effect of DNO limits

The effect of a DNO constraint on a fleet of electric vehicles was investigated by capping the maximum import and export to 30% of the maximum potential power.

In some groups, namely the CrowdCharge/Flexitricity group and the British Gas group, the imposition of the limit didn't particularly affect any individual's charging activity due to the diversity of the group. For example, in the CrowdCharge group, the participants were spread over a range of energy suppliers, which gave different favourable rates at different times throughout the day, which naturally incentivised diversity.

The imposition of a limit did have an effect for Green Energy UK, which was to limit individual's discharging capability. This in turn meant that less import was required as the batteries had depleted less. This lead to an increase in cost to the end consumer, but more from the fact that they could not sell their electricity, rather than from buying electricity at a more expensive time. The graphs showing the different behaviour observed can be found on page 65.

5.6. EA Technology's V2G Profile Modelling for NGEDs Connect/LV Tool

Full detail of the work carried out in this section is in appendix 2.

5.6.1. Initial investigation

EA technology had previously generated profiles from the previous Electric Nation project using a Monte Carlo approach to build a probability distribution of possible load from the charging events. The Monte Carlo analysis developed for the original Electric Nation data runs a simulation from a random sample of the data to assess the load, repeats this many times over and tests whether the distribution of load is approximating to a normal distribution

However, when this was repeated for this project, while the average closely matched the trial, the maximum demand was lower than was observed.

This was due to the Monte Carlo algorithm assuming that the behaviour at any given time slot was independent of other variables, whereas in reality, the behaviour was based on both time and the charging algorithm, so averaging the figures for a given time would not be appropriate. Instead, the chosen approach to build a load profile is to estimate a single load and multiply by the population expected to be connected at a given time.

5.6.2. Method

A conservative per vehicle charging demand would be used during the periods that charging was encouraged by the algorithm, but the demand would be reduce to account for the probability of a given vehicle being connect. The probability of a vehicle being connected was found to be normally distributed.

To account for the variability of demand due to the number of vehicles that might be connected, the following method was followed:

1. Calculate the realistic per vehicle worst case demand and generation.
2. Calculate how many vehicles are likely to be connected at each time.
3. Multiply the two together to give the likely profile.

To calculate the realistic per vehicle worst case demand, the total demand and number of vehicles connected in each half hour of the trial were calculated. The demand or generation per vehicle was then calculated as the total demand divided by the number of vehicles. To find the realistic worst case the highest demand and generation per vehicle were calculated for each day, and the 90th percentile of that value was taken.

The number of vehicles expected to be connected were derived using the Monte Carlo simulation. The results from this confirmed the distribution was normal, including when the tariff was not incentivising behaviour. Therefore, it was used from 6am to 4pm, and 7pm to 11pm load parameters were derived from the mean and standard deviation of the Monte

Carlo simulation in the same way as for the previous Electric Nation project. From 11pm to 6am demand was calculated as the number of vehicles expected to be connected multiplied by the realistic worst-case demand. From 4pm to 7pm generation was calculated as the number of connected vehicles multiplied by the realistic worst-case demand.

This was carried out for 23 vehicle chargers, to match the trial for verification purposes. The values were then scaled down to an individual charger to create profiles that incorporated a mean and variable component. This can be found in

.

Figure 5-3: Load profile for a single EV, with the P, mean demand, and Q, the variable demand, components shown. This represents the 90th percentile of demand.

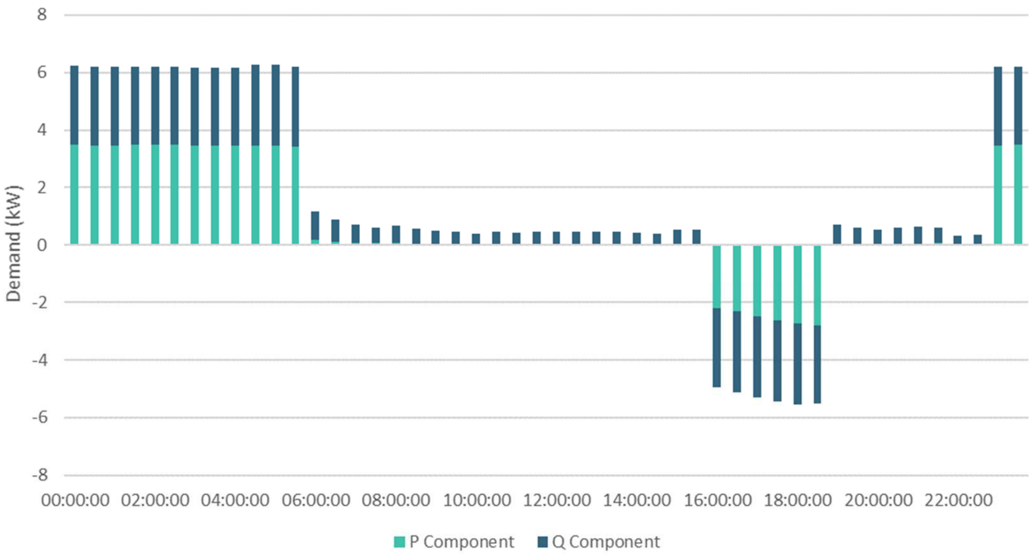
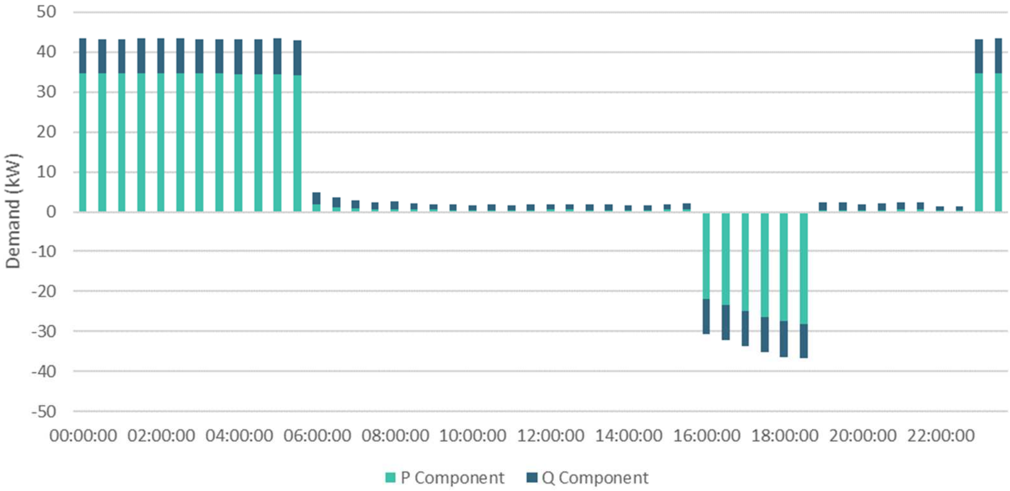


Figure 5-4: load profile for 10 vehicles, with a reduced variable component



The scale of the potential demand for a single vehicle is a lot higher than in previous trials, which is due to them being used to power the network during peak hours, and from the charging algorithms synchronising charging rather than staggering them. The proportion of the variable (Q) component falls with a larger cohort of vehicles due to the larger sample size having a smaller variance than a single vehicle.

Conclusions

The peak load associated with V2G chargers is significantly higher than that associated with even tariff-based charging for non V2G chargers. This is largely because the vehicles are frequently discharged in the evening, resulting in most vehicles requiring overnight charging. Typical electric vehicles do not require charging each night and so contribute less to overnight demand.

It is possible to generate a load profile for electric vehicles participating in V2G charging. To simply allocate demand based on the potential peak draw would over-estimate the potential peak overnight load, as demand can be reduced to allow for occasions when users choose not to connect their vehicle. Equally, applying an average demand overnight would under-estimate the potential peak overnight load and so should be avoided. Assigning the peak to a specific time even if not accurate in all instances would not under-estimate load but could cause network operators to erroneously believe that load would be lower at other times of night.

The approach of using a mean and adding the variable component (ACE49 P+Q) is helpful to represent the demand in this case, however as the distribution of demand is not normal a different approach was required to determine a typical profile. The approach taken remains appropriate to current LV planning practices where more energy constrained options such as cyclic ratings and energy storage are rarely considered. However, if the network state is partially based on previous network states, a scenario-based approach considering charging being prioritised for different times might be more appropriate. This warrants further investigation.

It should be noted that this analysis is based on a small sample size (23 vehicles) controlled by a single charging algorithm. To get a fully representative load profile for V2G operation a large sample size from a range of control algorithms would be required to determine if there are any larger trends visible.

6. Performance Compared to Original Aims, Objectives and Success Criteria

Table 6-1 -Performance summary of project objectives

Project Objective	Performance Summary
Explore and report on the impact of V2G charging on LV network utilising end-user trial charging data and analysis;	**Achieved:** This objective has been achieved, as detailed in section 5.5 & 5.6. CrowdCharge observed that unlike V1G smart charging - where smart charging is condensed into an evening peak or early-hours peak – V2H and V2G operation allowed for the house load to disappear from the LV network by utilising the stored energy in the EV, thus supporting the LV network.
Demonstrate, via modelling, to what extent can V2G assist with management of LV network demand;	**Achieved:** This objective has been fully achieved, as detailed in section 5.6.
Examine how sophisticated dynamic bi-directional energy services based on vehicle battery storage, from a variety of energy suppliers, may impact the LV infrastructure;	**Achieved:** This objective has been fully achieved, as detailed in section 5.5.
Provide recommendations of policy and commercial frameworks on V2G services.	**Achieved:** This objective has been fully achieved, as detailed in section 5.4.3

Table 6-2: Performance summary of project success criteria

Success Criteria	Performance Summary
Presentation of the final report data analysis and project's findings to NGED and key industry stakeholders at the dissemination event, held in the first quarter of 2022.	**Achieved:** This success criteria has been achieved, although delayed from the first quarter of 2022 to the final quarter, due to Covid lockdown knock on delays in the project. A dissemination event took place at Cenex LCV on the 4th & 5th September 2022 where the findings of the project were presented to NGED and industry stakeholders.
Recommendations/suggestion to NGEDs V2G services policy and commercial frameworks.	**Achieved:** This success criteria has been achieved, as detailed in 5.4.3
Specify and provide a standard data set that can be used by a network modelling tool to evaluate impact of V2G charging on LV networks.	**Achieved:** This success criteria has been achieved with EA Technology delivering V2G P & Q profiles into NGED's Connect/LV network assessment tool to help evaluate impact of V2G charging on LV networks.
Using a network modelling tool to provide a forecast of the effect of V2G charging at varying levels of update. This will be based on a mix of dynamic bi-directional energy services.	**Achieved:** This work has been enabled by the generation of the P & Q profiles but these P & Q profiles have not yet been deployed in modelling tools. The real results and simulation work completed by CrowdCharge within the project has investigated the impact of different supplier-led incentives i.e., tariffs on the diversity of charging. An energy service for DNOs to limit group power was simulated.

7. Required Modifications to the Planned Approach during the Course of the Project

Three change requests were submitted for this project. These were for successive delays from the suspension of installs due to the Coronavirus pandemic, when NGED ceased visiting customer premises to install chargers to prevent the spread of the virus. None of these changed any of the costs or hours required for the project, but they did delay certain milestones:

- Pilot Group Testing start
- End User Charger Installations
- Contractual agreement with energy suppliers in place

8. Project Costs

The Project costs can be seen below. This project was able to remain within budget, with minimal variance.

Table 8-1: Project Spend

Activity	Budget	Actual	Variance (£)	Variance (%)
NGED Project Management	83,640	82,749	891	-1.1
Contractor Costs – CrowdCharge	2,184,075	2,184,074	1	0
Total	**2,267,715**	**2,266,833**	**892**	**0**

9. Lessons Learnt for Future Projects and outcomes

Throughout the project a comprehensive learning log was regularly updated to record any notable learning that could benefit key stakeholders, industry and future NGED projects.

The most relevant lessons learnt from the project have been detailed below along with a recommendation:

1) Multiple EVs reside at 1 address

Upon launching customer recruitment, approximately 17% of enquires detailed they have more than 1 EV at their property, this drastically increased from the previous Electric Nation 1 trial with only a handful of multiple EV applications. This multiple EV scenario became problematic for a couple of reasons: 1) Only the project charger would be the live charger at the participants home and as V2G services are only compatible with an EV with CHAdeMO connection, the 2nd vehicle would be unable to charge (if it was anything but a Nissan EV). 2) There are technical software complications with the charger demand management software platform which require further technical thought, consideration and additional development time which are not in scope of this project. These reasons resulted in CrowdCharge unable to offer a space for households with more than 1 EV.

Recommendation: A future trial should specifically investigate V2G services strategies to offer a V2G solution for households with multiple EVs.

2) Long lead times for G99 grid application approval decisions

Out of all G99 grid applications which received a decision (109), on average this took 62 days to receive an approval decision. This is not a suitable review period timeframe for a BAU environment where V2G chargers are being installed in large numbers throughout the UK. Although the current lead times on average for EVs are many months, in a BAU world this is not acceptable to customers to understand if they are able to have a V2G charger installed.

Recommendation: NGED and other DNOs should review their G99 grid connection application process, with a focus on improving the lead time for customers. Perhaps an interactive website where customers can enter their postcode to gain an instant preliminary indication on the likelihood their G99 application would be approved, with information provided if reinforcement works are required. From here the customer can decided whether to submit a full application with their installer. Finally, NGED should look to improve the decision time to a matter of weeks though process efficiencies in preparation for the inevitable uptake of V2G charger applications.

3) Different responses from different Planner Depots

There does not seem to be a standardised response from NGED depots upon submission of G99 application, which can cause confusion with installers. Each depot seems to provide a different approval letter too. Dissemination of NGED policy regarding export limitation at the inception of project which involve export, would help streamline process for project partners and customers in future projects.

Recommendation: Updating installer training documentation, review application process across all depots and review approvals letters to standardise.

4) **Auto fault detection process for hardware on future innovation projects**

Fault detection process required to be able to proactively detect faults or inaccuracies in charge cycle data opposed to customer only reporting faults to project partners. This helps to improve customer experience and ensure chargers are in an operational state for the customer trial to ensure maximum value and learning for project partners/NGED.

Furthermore, Fault fixing was difficult to begin with as CrowdCharge did not have sight of the Wallbox Quasar charger's configuration, and how various parameters in the Wallbox App can interfere with the CrowdCharge Smart Scheduling stage of the trial. In future projects, agreeing with charger manufacturers to provide information from their backend platform for various parameters daily or via an API, such as Firmware Version, App Version, Locked Status, and Schedule applied etc. Participants are able to change this information - either by mistake, or on purpose daily - which in turn could cause an issue. This extra information helps CrowdCharge in diagnoses and ruling our faults - without this information the fault fixing process would be more challenging.

Recommendation: Create an auto-detection fault process for future projects involving innovative hardware which has a high likelihood of faulting. Furthermore, gather as much relatable technical information as possible to inform the fault diagnosis and fixing process, with the aim to improve the customer experience and quality of data on the project due to the reduction in hardware downtime.

5) **Requirement for frequent high-level management meetings with hardware suppliers, if the technology is highly innovative and untested at scale in a BAU sense**

Requirement for a high-level monthly management meeting with hardware suppliers throughout the trial (if the technology is highly innovative and untested at scale in a BAU sense), not just when a major issue occurs. This helps to ensure a constant line of communication is open to key decision makers to ensure they understand the issues and problems occurring in the trial (the meeting can of course be cancelled month by month if no major updates, but the repetition is essential.) This also ensure any issues which are raised, can be escalated accordingly to ensure the resulting fix is applied as efficiently as possible.

Recommendation: Initiate high level frequent meetings with senior management at the inception of a project, to establish a heartbeat update throughout the project, appose to just when an issue occurs.

6) **The size of the project partner has an effect on the timescales taken to complete some of their actions/objectives.**

Working with a large organisation (e.g., British Gas) takes a considerably longer amount of time for progress and internal decision to be made/signed off. This caused a delay in agreeing and issuing the British Gas Energy Proposition to applicants on the trial.

Recommendations: Take this learning into consideration when designing project plans for future innovation projects, to allow ample time for larger organisations.

10. The Outcomes of the Project

Project deliverables are as follows:

June 2020 Customer Engagement Report:
https://www.nationalgrid.co.uk/downloads-view-reciteme/610905

September 2020 Customer Engagement Report:
https://www.nationalgrid.co.uk/downloads-view-reciteme/610906

December 2020 Customer Engagement Report:
https://www.nationalgrid.co.uk/downloads-view-reciteme/610904

Load Profiles as detailed in the Appendix to this report

11. Data Access Details

All reports associated with this project can be found on the project page:

National Grid - Electric Nation - Powered Up

Load profiles, as discussed in Appendix 2, are available on request, through this website:

National Grid - Project data

12. Foreground IPR

The project complied with standard NIA IPR governance and new foreground IPR is limited to the new Connect LV V2G profiles which are being rolled out into the business.

13. Planned Implementation

The V2G load profiles developed as part of the trials analysis are now being rolled out in to the Connect LV planning tool as part of our business as usual processes. The details of the load profile findings are within this Closedown Report and stakeholders can access more information on the profiles by contacting NGED directly.

14. Contact

Further details on this project can be made available from the following points of contact:

Email

Nged.innovation@nationalgrid.co.uk

Postal

Innovation Team

National Grid

Pegasus Business Park

Herald Way

Castle Donington

Derbyshire DE74 2TU

15. Glossary

Abbreviation	Term
EV	Electric Vehicle
DNO	Distribution Network Operator
EV	Electric Vehicle
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
NGED	National Grid Electricity Distribution
PR	Public Relation
SaaS	Software as a Service
CRM	Customer Relationship Management
LCT	Low Carbon Technologies
EATL	EA Technology
LV	Low voltage

Appendix 1 – Customer Trial

Overview

The Customer Trial work package allowed for the implementation and operation of the various energy suppliers' energy strategies. The Customer Trial ran for 1-year, starting on the 1st of June 2021, concluding on the 31st of May 2022.

Within this 1-year period, the Customer trial was split into 4 stages.

Trial Stages Design

The main project phases are described below. These phases have an impact on when charging happens during a connection event, but do not necessarily impact when the connection events take place. Therefore, these phases are useful when considering the historical data, but are not a significant factor in the analysis of the impact of group limits as that analysis is based upon simulating smart charging based on real connection events as further discussed in the Method section.

Stage 1: Baseline Stage (Until June 2021)

During this phase, CrowdCharge's system was only monitoring the use of the charger with participants controlling the charger directly via the Wallbox app. There were a limited number of installations after June 2021, and these new installations were put into this baseline mode for approximately a week.

Stage 2: Fixed Schedule with Local Control (June 2021 to August 2021)

Next, participants were given a fixed charging schedule that was augmented with local state of charge rules enacted by the local CrowdCharge control unit.

Stage 3: Smart Scheduling (August 2021 to May 2022)

In this phase, charging and discharging was dynamically controlled using CrowdCharge's systems based on each user's tariff and journey requirements.

Due to Wallbox Quasar hardware / firmware issues, smart scheduling was paused between late August and early October whilst a firmware update was developed and deployed for the Wallbox charger. Participants were reverted to the baseline mode during this period. However, a subset of participants were switched back on to smart scheduling in mid-September. Although it is not expected that this pause in smart scheduling would have significantly affected when participants would have plugged in their vehicles, it would likely affect when charging took place.

Stage 4: Vehicle-to-Home (V2H) and solar optimisation (Solar-Eating) (February 2022 to May 2022)

In this project phase, charging was controlled using CrowdCharge's systems to base on each user's tariff and journey requirements. In addition, the system tried to make use of net export due to solar generation to charge the vehicle, and to attempt to power the home, during two non-overlapping time windows.

Project Energy Supplier's V2G Strategies

On the customer trial, there were 4 varying energy V2G strategies from suppliers. Each supplier was asked to provide an export tariff due to the nature of the V2G project, however it quickly because clear that some suppliers were not positioned to offer this. CrowdCharge had designed the ability for V2H service to operate so the requirement for all supplier to have an export tariff was not a project requirement.

For all suppliers, if a participant had Solar PV installed, they were able to charge their EV from their surplus generation that was not consumed first by their house.

The below tables details the specific energy tariff prices and proposition information including reward criteria and reward offering from each of the suppliers.

British Gas

Time Period	Import Price (Pence/kWh)
2300 – 0300	6
0400 – 2200	20

Green Energy UK

Time period	Import Price (Pence/kWh)	Export Price (Pence/kWh)
2300 – 0600	7.9	5.5
0600 – 2300	32.5	5.5
1600 – 1900 (weekdays only)	16.3	10

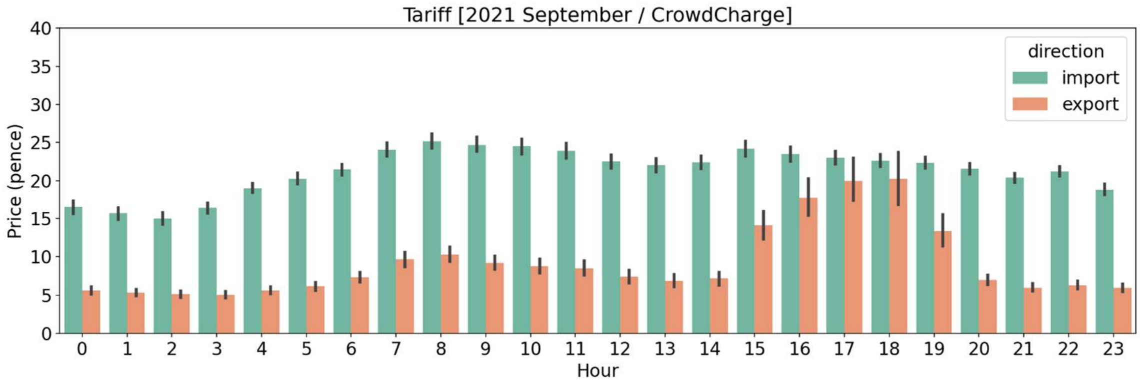
Igloo Energy

Time Period	Import Price (Pence/kWh)
All times of day	13.9-15.5 (depending on participant location)

After Igloo Energy entered administration, the supplier EON Next were allocated as the new supplier. CrowdCharge has participants to confirm once they had received the notification that they were now on supply with EON Next and including their new tariff details. These new tariff details were added to the platform to continuing with the carbon optimisation.

CrowdCharge & Flexitricity

Figure Error! No text of specified style in document.**-1 - Example of tariff distribution for CrowdCharge group in September**



The CrowdCharge & Flexitricity group participants were free to select any tariff, although a majority used dynamic tariffs during the trial. As such, the tariffs across the group varied both as users chose different tariffs and as those tariff prices dynamics changed over time and in many cases daily.

Table14-1: Summary table for the different V2G strategies in place during the trial

Supplier/Aggregator	No. Participants	Import Tariff	Export Tariff	Reward Criteria	Reward
British Gas	20	Variable -Two rate	No Export	For 2 months out of 3 participants must have met 15 full plug-in cycles per month from 6pm-5am; For the remaining 1 month out of 3 participants must have 10 full plug-in cycles per month	3 types offered for a 3-month period: 1. £30 credit to customer bill; 2. £30 Donation to sustainability project or charity; 3. Hive Hub
Green Energy UK	32	Variable -Three rates on weekdays, two rates on weekends	Variable on Weekdays, fixed on weekends	15 full plug-in cycles from 6pm-5am daily per calendar month	2600 free miles of electricity for the year trial. This was paid as £4.11 per month credited to bills
Igloo Energy	23	Fixed – Charging optimised to minimise Carbon impact	No Export	10 full plug-in cycles from 6pm-5am daily per calendar month	2 miles of free electricity for every hour the EV is plugged in and available to charge from Monday to Friday 4pm to 8pm, and 1 mile of free electricity for every hour their EV was plugged in and available outside of these peak hours, up to a maximum or £12 per month
CrowdCharge/ Flexitricity	20	Hourly Variable Rate	Hourly Variable Rate	Two reward stages: Exceeding 10 or 15 plug in cycles	£5 or £10 monthly, depending on the number of plug-in cycles

Energy Proposition Plug-in Analysis & Total Rewards

As detailed in section 5.3.4, each energy supplier trialled a specific energy proposition strategy. All included a compliant plug-in requirement to achieve the reward plugging in every time the EV is at home. This behaviour is important to enable the operation of V2G and V2H functionality.

Error! Reference source not found. below shows the total V2G incentives paid by the energy suppliers, split against quarters of the trial. The most lucrative energy proposition for the participants was the Igloo Energy group, with £93.40 paid on average based on the size of the group, followed by Flexitricity, and British Gas/Centrica with £65.59 and £56.50 respectively. Green Energy UK had the lowest average incentive per participant at £34.06, however they were the only supplier who offered an export tariff so participants were able to earn money by selling their stored electricity.

Table 14-2: V2G incentive payment totals for each energy supplier group, split against quarter

	Participants per group	Quarterly Reward Q1	Quarterly Reward Q2	Quarterly Reward Q3	Quarterly Reward Q4	Grand Total	Average reward per participant
British Gas/Centrica	20	£15.00	£425.00	£360.00	£330.00	**£1,130.00**	£56.50
Flexitricity	32	£29.00	£670.00	£735.00	£665.00	**£2,099.00**	£65.59
Green Energy	23	£23.00	£238.38	£263.04	£258.93	**£783.35**	£34.06
Igloo Energy	20	£20.00	£492.00	£708.00	£648.00	**£1,868.00**	£93.40
Grand Total	**95**	**£87.00**	**£1,825.38**	**£2,066.04**	**£1,901.93**	**£5,880.35**	£61.90

Across the 1-year customer trial, 17,694 compliant charge cycles were completed. Interestingly, although Green Energy UK paid the least in incentive payments per participant as shown in table 3 (£34.06), their group has the high number of average plug-ins at 222 as shown in Error! Reference source not found.. A reason for this is due to their offering of an export tariff, this incentivising participants to plug-in and be able to export to the grid at period of peak demand in the evening. Igloo Energy had the lowest number of average plug-ins at 167, despite having the most attractive plug-in reward incentive (excluding Green Energy UKs export tariff offering).

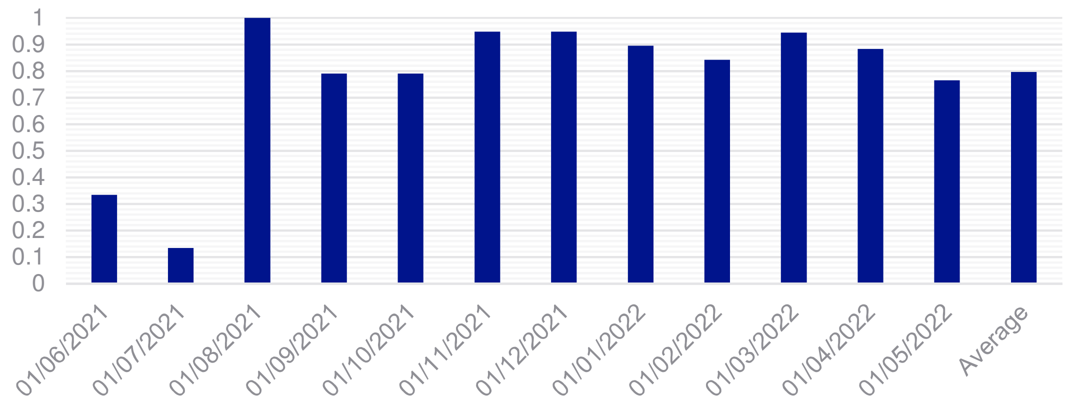
Table 14-3: Total compliant plug-in cycles for each energy supplier group, split against quarter

	Participants per group	Quarterly Reward Q1	Quarterly Reward Q2	Quarterly Reward Q3	Quarterly Reward Q4	Grand Total	Average Plug-ins per participant
British Gas/Centrica	20	750	957	1080	972	3759	188
Flexitricity	32	977	1412	1585	1511	5485	171
Green Energy	23	1002	1275	1401	1429	5107	222
Igloo Energy	20	454	864	1056	969	3343	167
Grand Total	**95**	**3183**	**4508**	**5122**	**4881**	**17694**	**186**

British Gas

Figure 14-2 shows the percentage of compliant plug-ins per month for the British Gas group across the 1-year customer trial. August-21 was the only month were all participants reached or exceeded their reward plug-in requirement. On average, participants in the British Gas group achieved an 80% compliant plug-in rate.

Figure 14-2: Graph showing the fraction of compliant-plugs in per month, for the British Gas group



Green Energy UK

Figure 14-3: Graph showing the fraction of compliant-plugs in per month, for Green Energy UK group

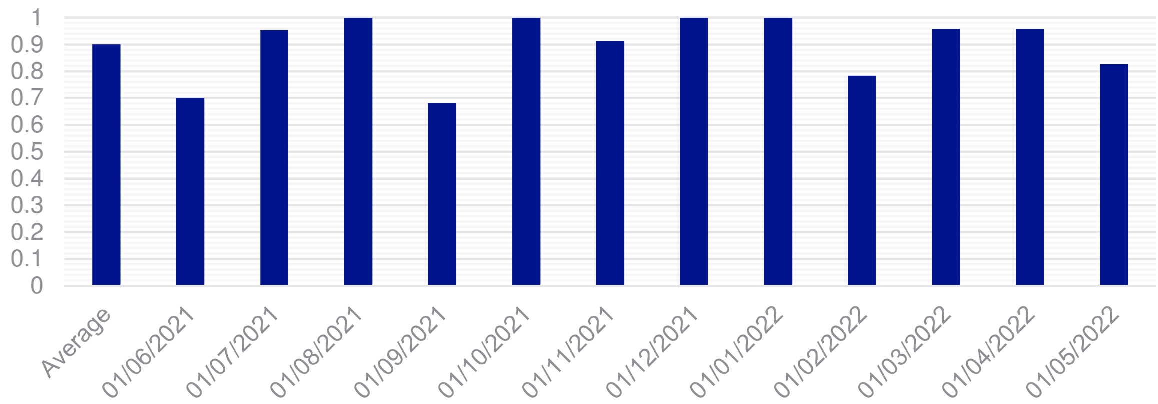
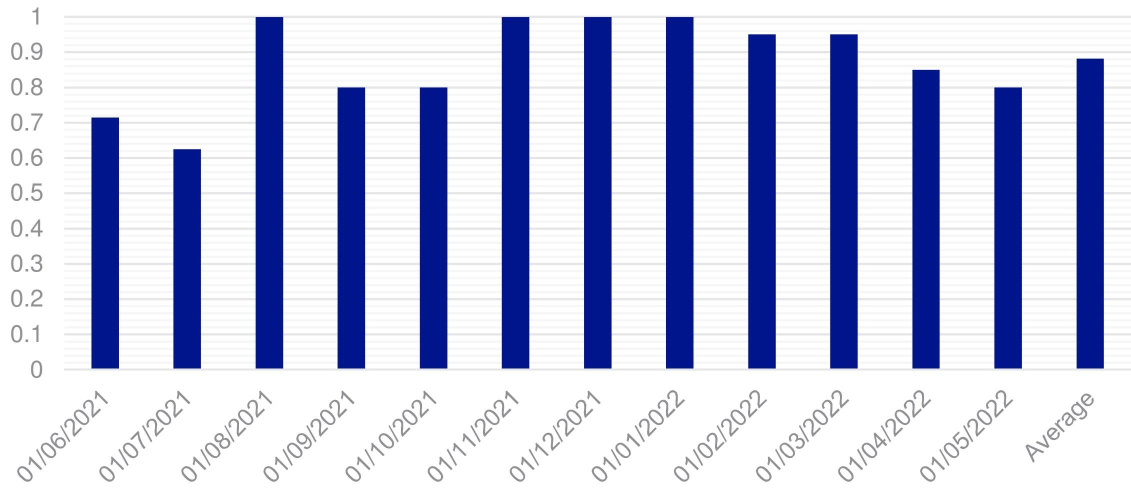


Figure 14-3 shows the percentage of compliant plug-ins per month for the Green Energy UK group across the 1-year customer trial. During August-21, Ocotober-21, Decemeber-21 and January-22, all participants reached or exceeded their compliant plug-in requirements. On average across the 1-year trial, the Green Energy UK proposition group achieved a 90% compliant plug-in rate.

Igloo Energy

Figure 14-4 shows the percentage of compliant plug-ins per month for Green Energy UK across the 1-year customer trial. During August-21, Novemeber-21, December-21, and January-22 all participants reached of exceeded their compliant plug-in requirements. On average across the 1-year trial, the Igloo Energy group achieved an 88% compliant plug-in rate.

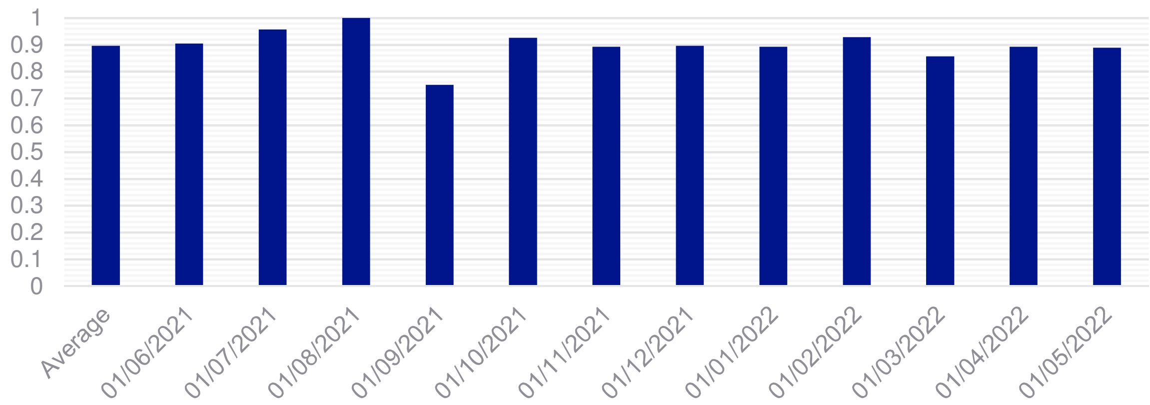
Figure 14-4: Graph showing the percentage of compliant-plugs in per month, for Igloo Energy group



CrowdCharge & Flexitricity

Figure 14-5 shows the percentage of compliant plug-ins per month for the CrowdCharge & Flexitricity group across the 1-year customer trial. During August-21 all participants reached of exceeded their compliant plug-in requirements. On average across the 1-year trial, the CrowdCharge & Flexitricity group achieved a 90% compliant plug-in rate.

Figure 14-5: Graph showing the fraction of compliant plug-ins per month, for CrowdCharge & Flexitricity group



Customer Trial: Stage 1 - Baseline

During this project phase, CrowdCharge's system were only monitoring the use of the charger with participants controlling the charger directly. There were a limited number of installations after June 2021, and these new installations were put into this baseline mode for approximately a week.

Results

Figure 14-6 shows a set of boxplots for all participants during May 2021 (Stage 1) that each show the distribution of energy in each hour of the day from the electricity network, consumed at home, consumed or generated from the vehicle charger, and generated from solar panels.

The key observations from Figure 14-6 are that the greatest proportion of charging takes place over-night between midnight and 2am, likely due to users manually setting their charging schedules via the OEM app or within their vehicle. However, a significant proportion of charging occurs across the day, which likely represents uncontrolled charging when vehicles plug-in. The overall period of peak demand from the grid is overnight, aligned with overnight charging, and is not during the typical evening peak.

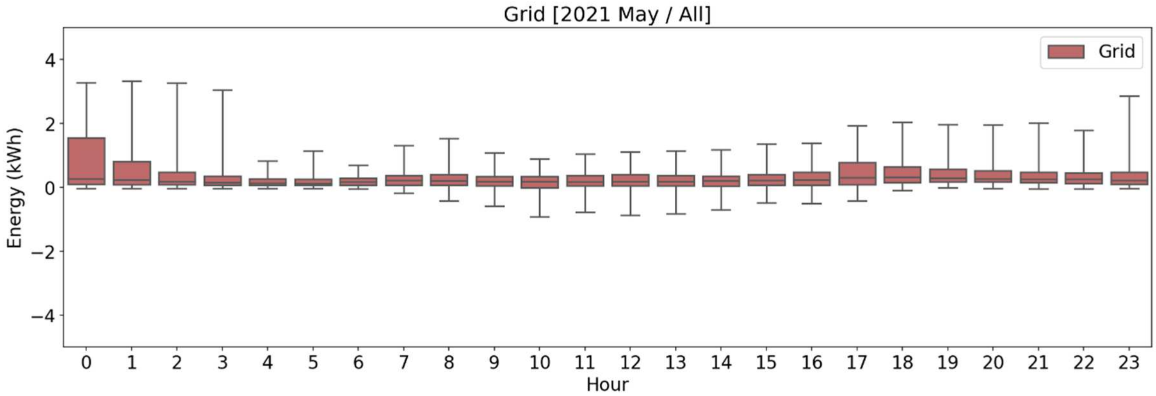
Customer Trial: Stage 2 – Fixed Scheduling

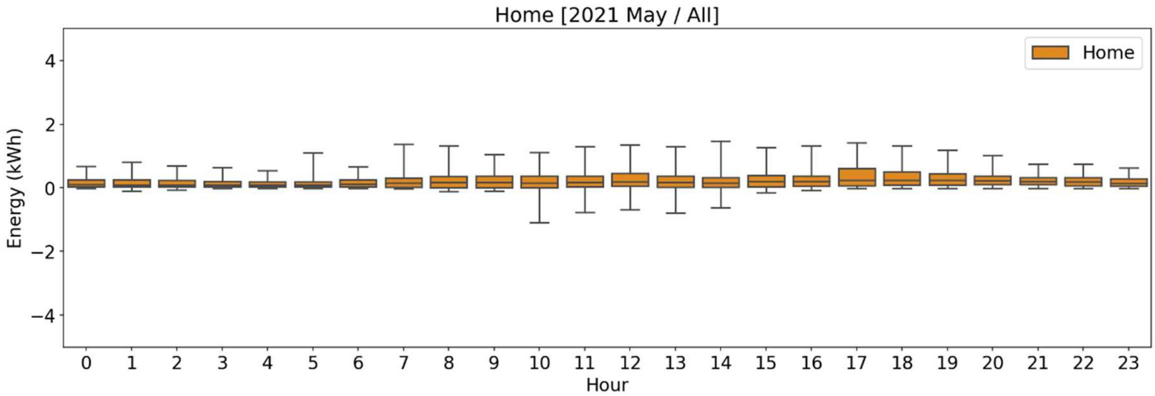
During this project phase, participants were given a fixed charging schedule that was augmented with local state of charge rules enacted by the local CrowdCharge control unit.

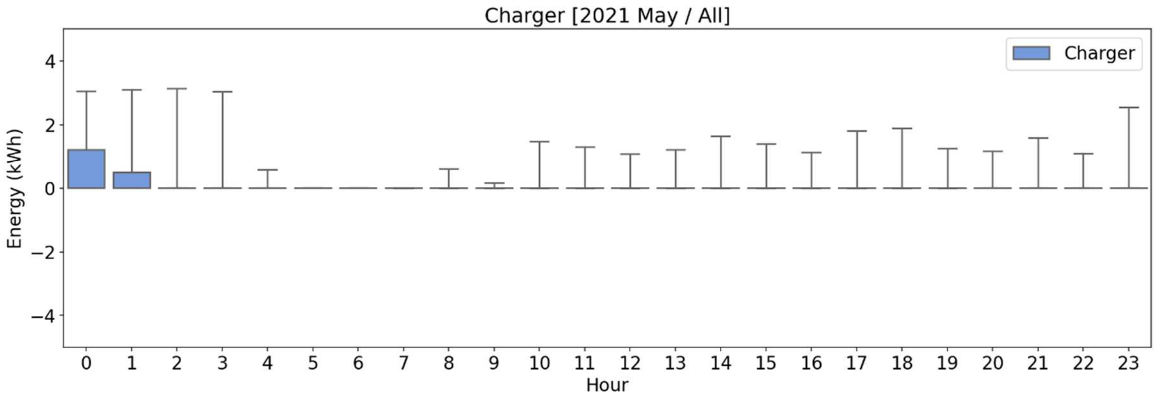
Results

Figure 14-7 shows a set of boxplots for all participants during July 2022 (Stage 2) that each show the distribution of energy in each hour of the day.

The key observations from Figure 14-7 are that almost all charging takes place over-night between 11pm and 2am, due to the fixed schedule, and discharge takes place between 4pm and 7pm due to the fixed schedule. There is no longer any evidence of a traditional evening peak, and in fact there may be evidence of an evening export peak instead. The peak demand from the grid is overnight, aligned with overnight charging, and is again not during the typical evening peak.


Grid [2021 May / All]
Grid
Energy (kWh)
Hour


Home [2021 May / All]
Home
Energy (kWh)
Hour


Charger [2021 May / All]
Charger
Energy (kWh)
Hour

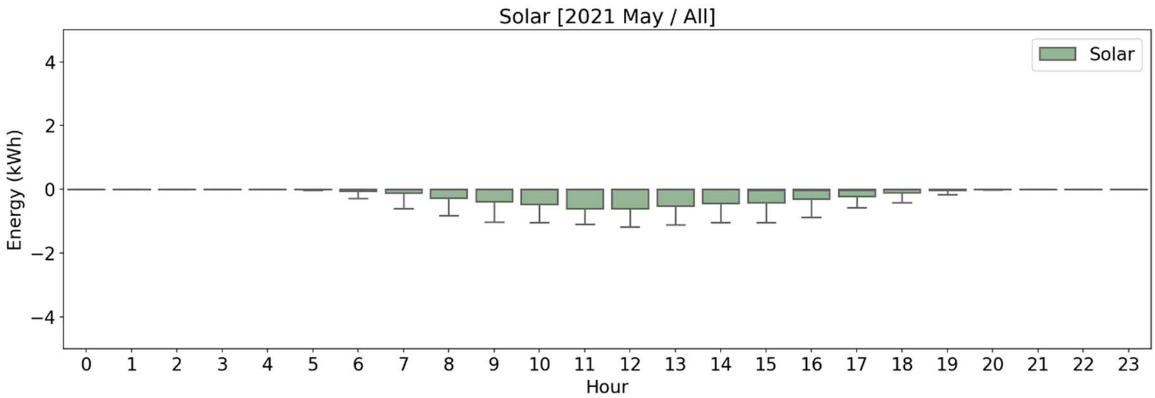
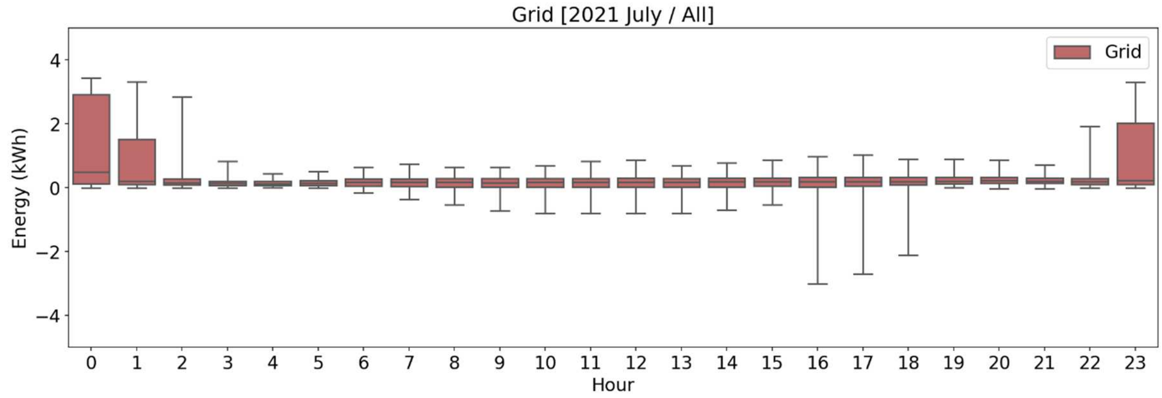
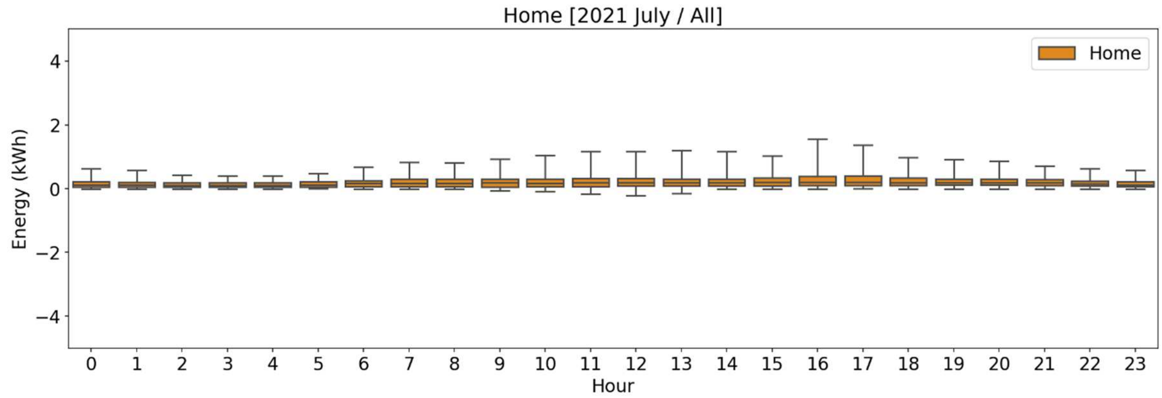
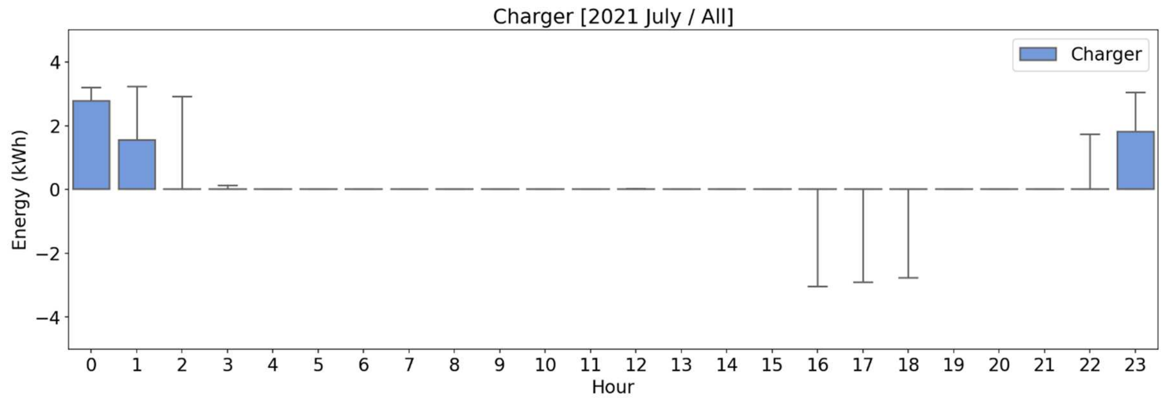

Solar [2021 May / All]
Solar
Energy (kWh)
Hour

Figure 14-6 - Boxplot of energy profiles by hour of day for grid, home, charger and solar across all participants in May 2021. Grid - the metered net energy from or to the grid through the main meter; Home – the calculated energy consumed by the home; charger – the metered energy consumed or generated by the charger; and solar – the metered energy generated from solar panels if present. The solid portion of the vertical bars contain 50% of the data, and the whiskers contain 90% of the data


Grid [2021 July / All]
Grid
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour


Home [2021 July / All]
Home
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour


Charger [2021 July / All]
Charger
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour

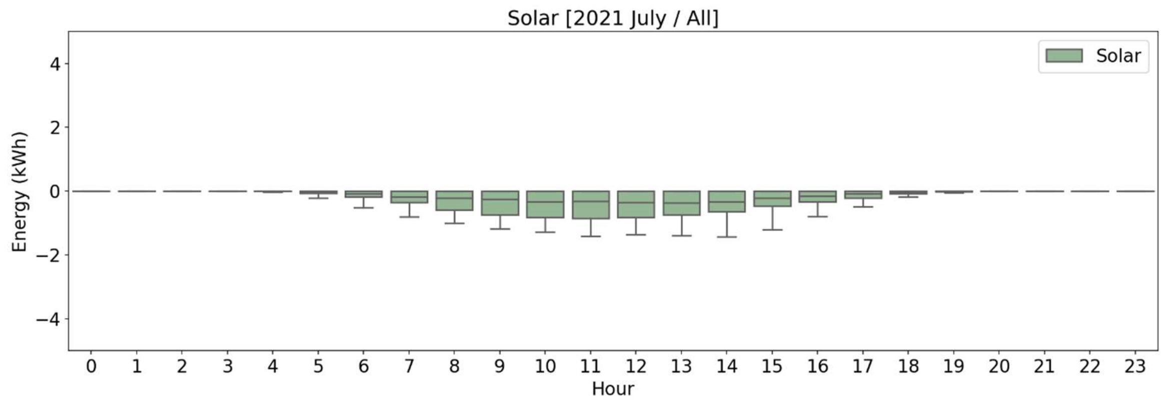

Solar [2021 July / All]
Solar
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour

Figure 14-7 - Boxplot of energy profiles by hour of day for grid, home, charger and solar across all participants during Stage 2 in July 2021

Customer Trial: Stage 3 – Dynamic Scheduling

In this project phase, charging was controlled using CrowdCharge's systems to base on each user's tariff and journey requirements. Due to hardware issues smart scheduling was paused between late August and early October permanently whilst a firmware update was developed and deployed for the Wallbox charger. Participants were reverted to the baseline mode during this period. However, a subset of participants were switched back on to smart scheduling in mid-September. This smart scheduling pause would have affected when charging took place, but it was assumed that it didn't significantly affect when participants plugged in their vehicles.

Results

Error! Reference source not found., shows a set of boxplots for all participants during November 2021 that show the distribution of energy in each hour of the day.

Figure 14-8 shows that over-night charging is more spread compared with Stage 2 due to the dynamic scheduling. Discharge still largely takes place between 4pm and 7pm due to the dynamic schedule and export tariff constraints. There is still no evidence of a traditional evening peak, and in fact there may be evidence of an evening export peak instead. The overall period of peak demand from the grid is overnight, aligned with overnight charging, and is again not during the typical evening peak.

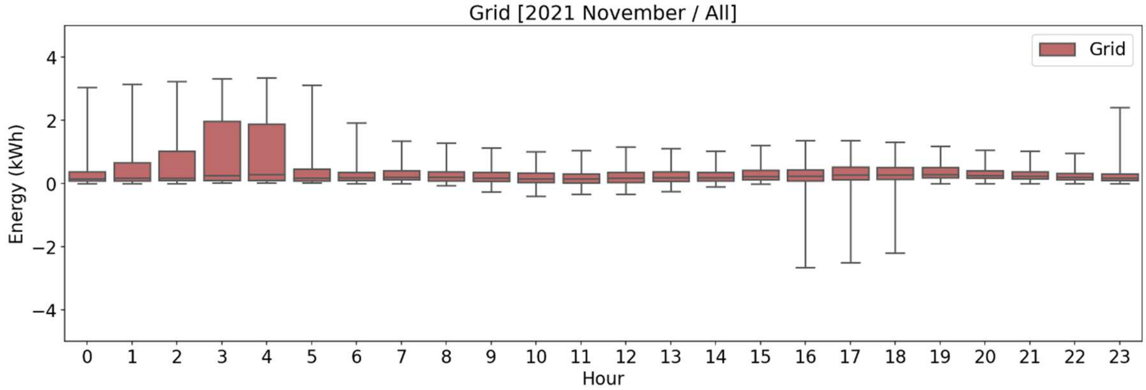
Customer Trial: Stage 4 – CrowdCharge's V2H & Solar Optimisation features

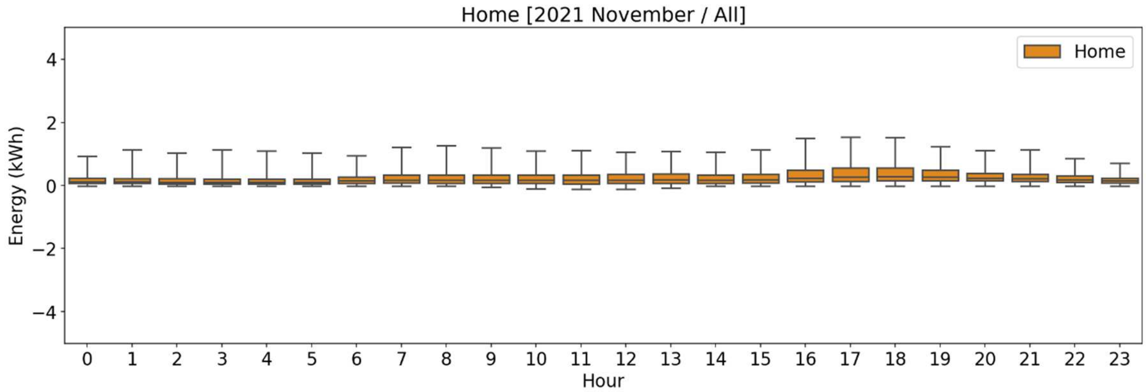
In this project phase, charging was controlled using CrowdCharge's systems to base on each user's tariff and journey requirements. In addition, the system tried to make use of net export due to solar generation to charge the vehicle, and to attempt to power the home, during two non-overlapping time windows.

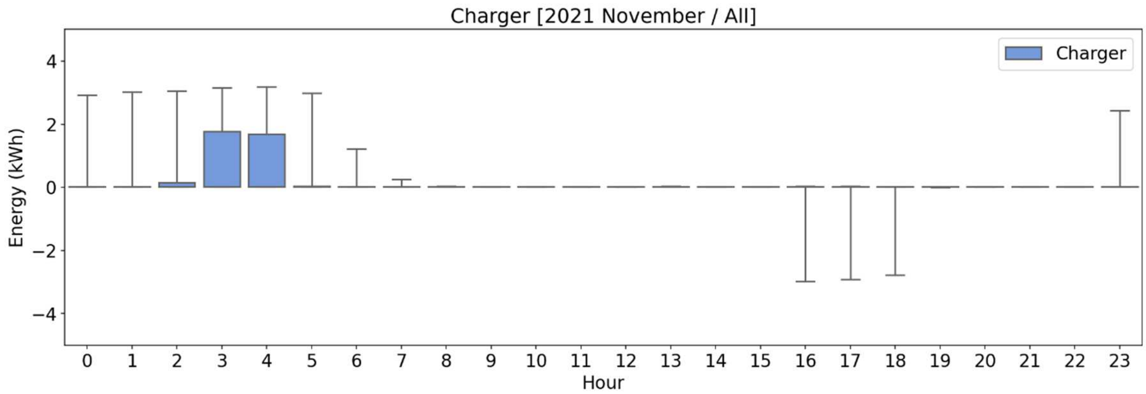
Results

Figure 14-9 shows a set of boxplots for all participants during May 2022 (Stage 4) that each show the distribution of energy in each hour of the day.

Compared to previous stages, there is now significant charging during the day to make use of solar generation, although this charging is at lower power levels than overnight charging as typical solar installations produce peak power in the order 1-3 kW. Discharge during the traditional evening peak has increased across participants as it is now possible to discharge to offset import and power the home rather than only take advantage of advantages export prices. Participants who did not have export tariffs can now benefit from charger exporting. There is now more evidence of net export across participants during the traditional evening peak. Not only has the traditional evening peak gone, it's now a period of net export.


Grid [2021 November / All]
Grid
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour


Home [2021 November / All]
Home
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour


Charger [2021 November / All]
Charger
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour

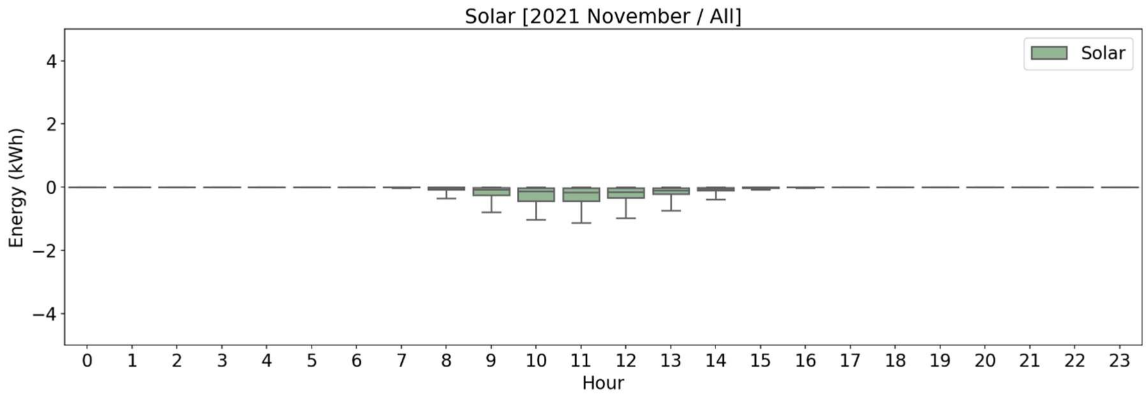
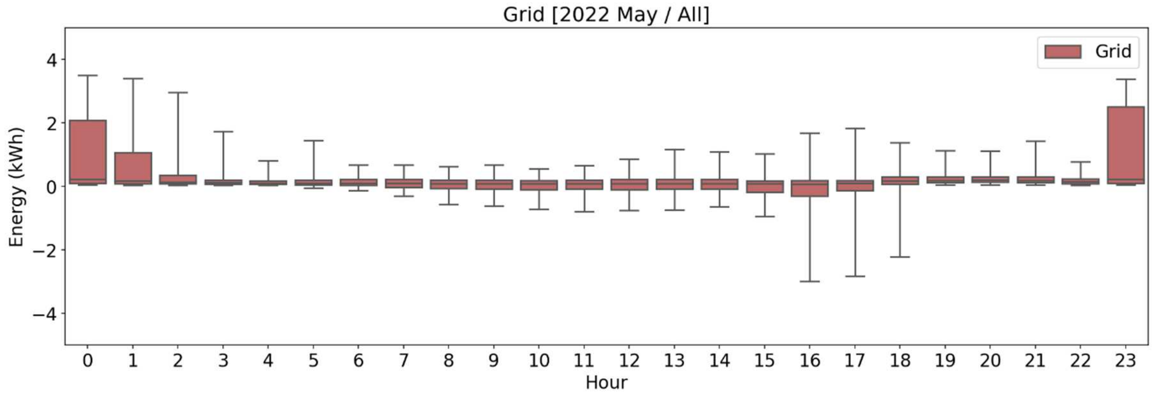
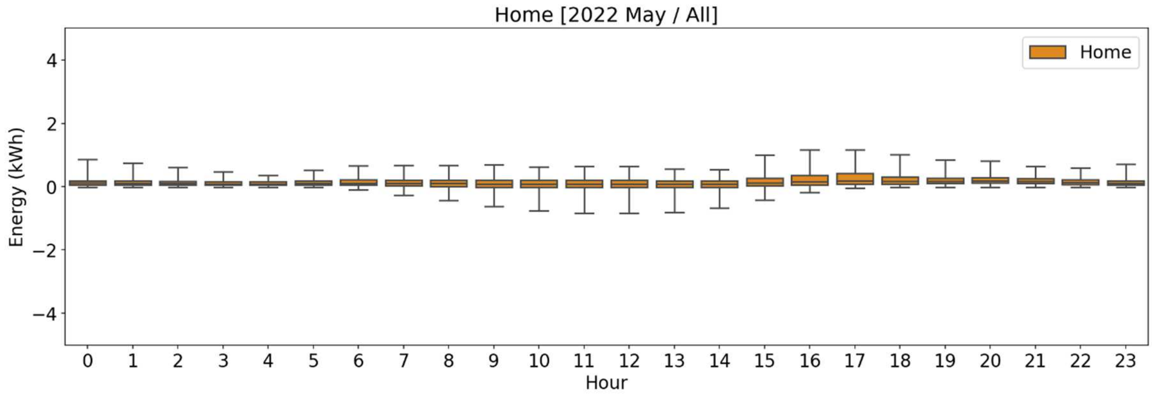
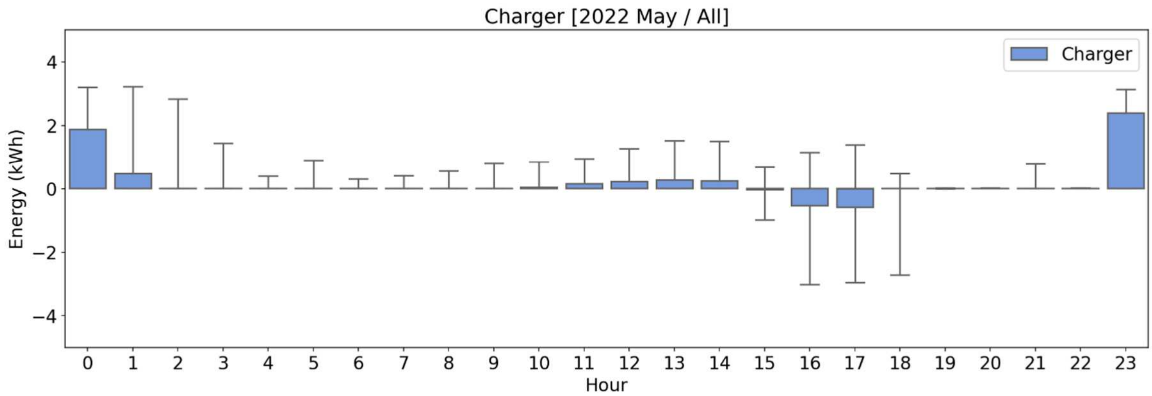

Solar [2021 November / All]
Solar
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour

Figure 14-8 - Boxplot of energy profiles by hour of day for grid, home, charger and solar across all participants during Stage 3 in November 2021


Grid [2022 May / All]
Grid
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour


Home [2022 May / All]
Home
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour


Charger [2022 May / All]
Charger
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour

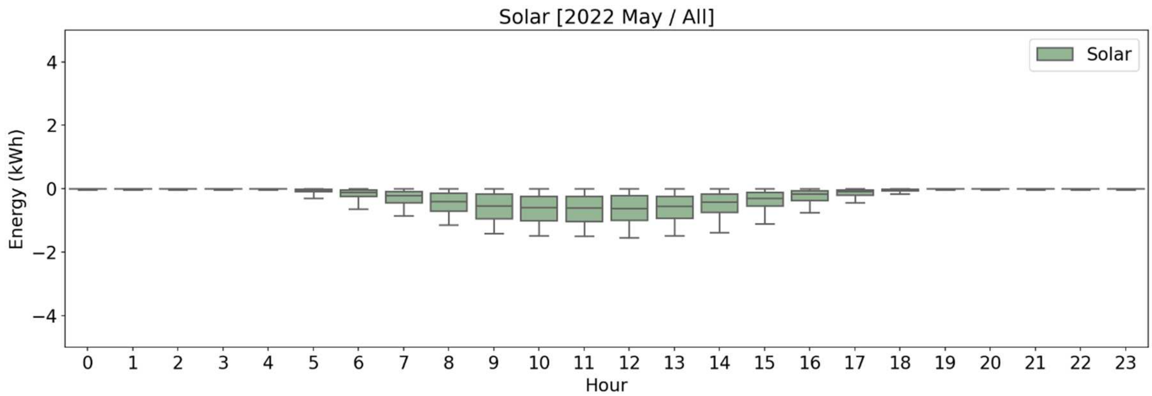

Solar [2022 May / All]
Solar
Energy (kWh)
4
2
0
−2
−4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour

Figure 14-9 - Boxplot of energy profiles by hour of day for grid, home, charger and solar across all participants during Stage 4 in May 2022

Analysis of cost and carbon savings across project stages

Figure 14-10, Figure 14-11, Figure 14-12 all show a distribution of the charge cycle costs, the cost savings compared to unmanaged charging, charge cycle carbon emissions, and carbon savings compared to unmanaged charging. The solid portion of the vertical bars contain 50% of the data, and the whiskers contain 90% of the data. Each colour represents a different project Stage.

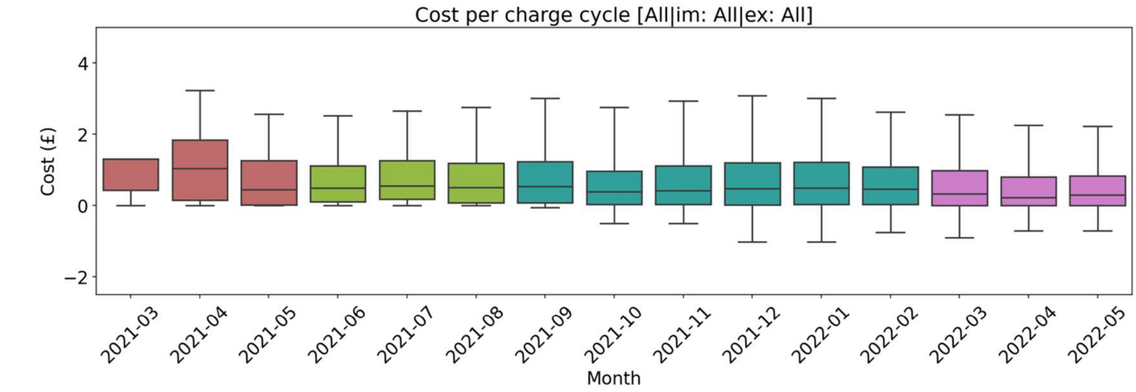
Figure 5-15 shows the costs and savings across all groups and tariffs. The following observations can be made:

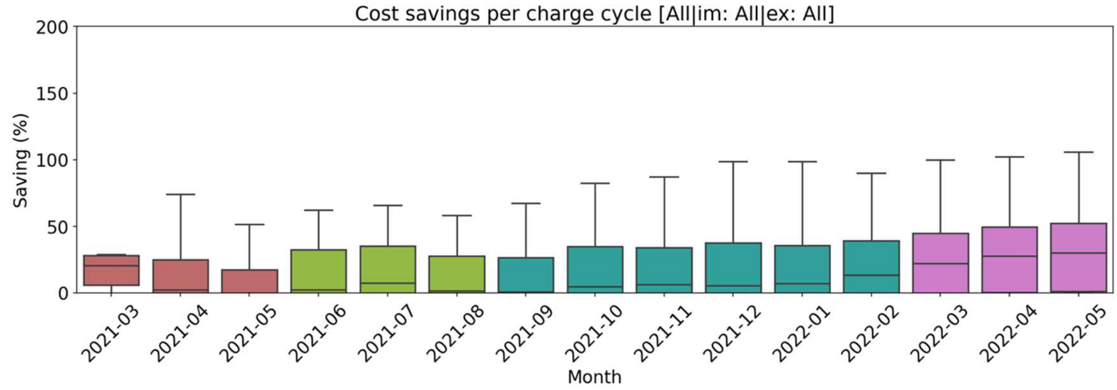
- The cost savings increased across the project and stages.
- Carbon savings peaked over the winter period, likely due to increased differentials between daily maximum and minimum carbon intensity.
- Change cycles that generated money for participants occurred in Stages 3 and 4 as dynamic scheduling became able to take advantage of price differentials and those on dynamic export tariffs experienced relatively high export prices.
- Stage 4 participants were able to offset their import tariff with load following to increase their savings.

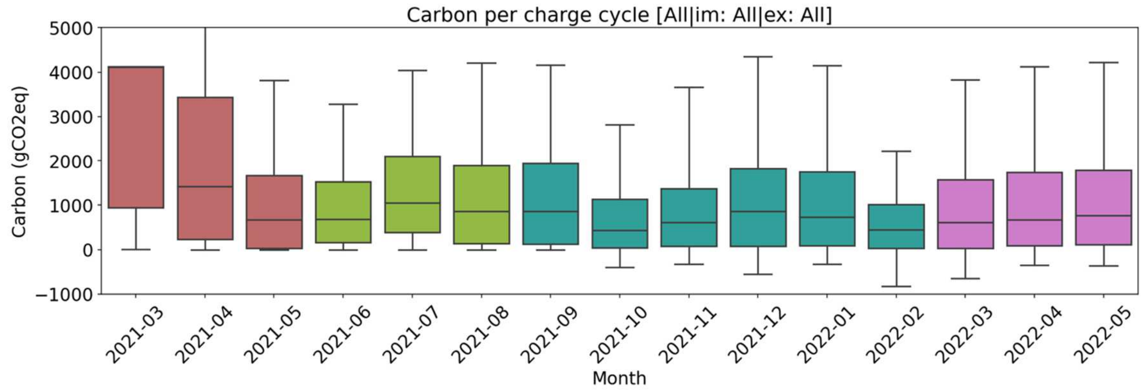
Figure 5-16 shows the costs savings for participants with a multi-level import tariff i.e., with two of three rates across the day, and a dynamic export tariff such as Octopus Outgoing. The following observations can be made:

- Participants on this tariff combination only appeared from October 2021.
- The cost and carbon savings for these participants significantly exceeded those on other tariff combinations.
- Savings were higher in Stage 3 compared to Stage 4 for these participants, likely due to higher export prices during the winter period.
- The Octopus Outgoing export tariff was based on market prices without a cap, unlike the Octopus Agile import tariff. As such, export prices an order of magnitude greater than import prices were able to occur. Nevertheless, the multi-level import tariff was better than the Agile import tariff as the latter did reach its pre-determined cap.

Figure 5-17 shows the costs savings for participants with a flat, single rate import tariff and no export tariff. This shows that participants with single rate tariffs were not able to achieve significant savings compared to unmanaged charging as would be expected.


Cost per charge cycle [All|im: All|ex: All]
Cost (£)
4
2
0
−2
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month


Cost savings per charge cycle [All|im: All|ex: All]
Saving (%)
200
150
100
50
0
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month


Carbon per charge cycle [All|im: All|ex: All]
Carbon (gCO2eq)
5000
4000
3000
2000
1000
0
−1000
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

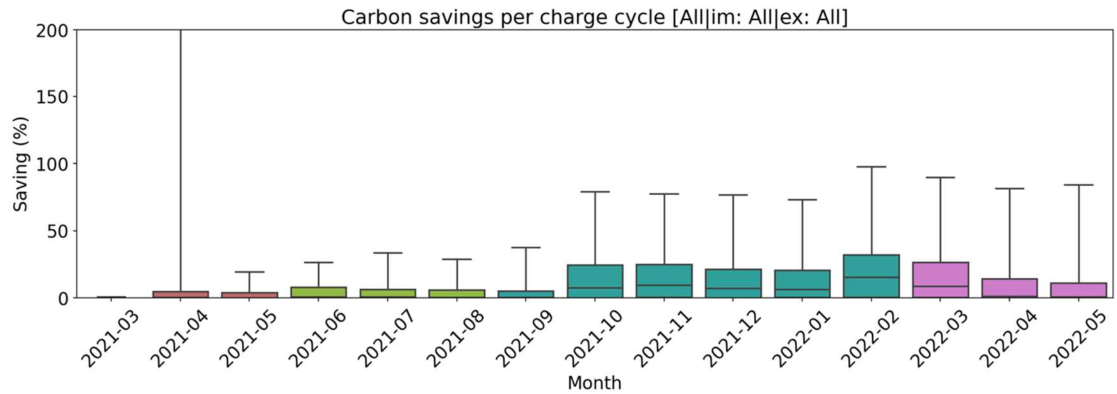
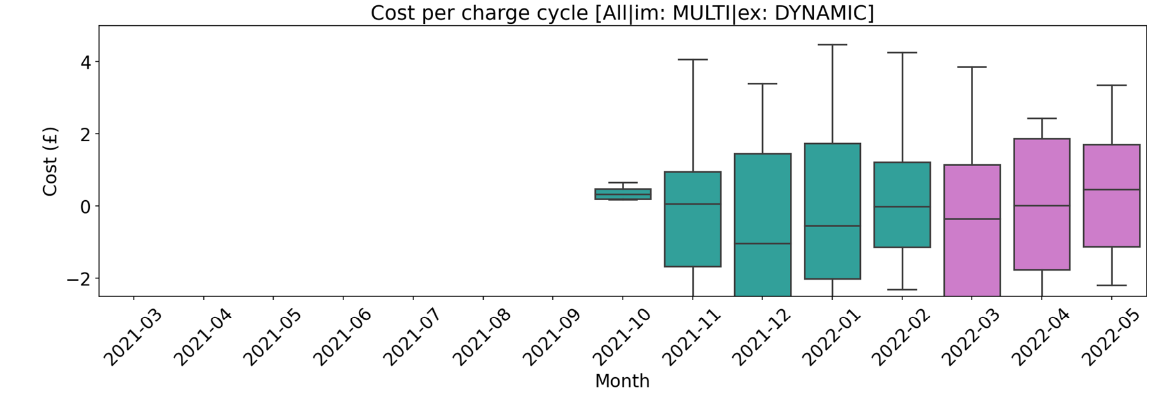
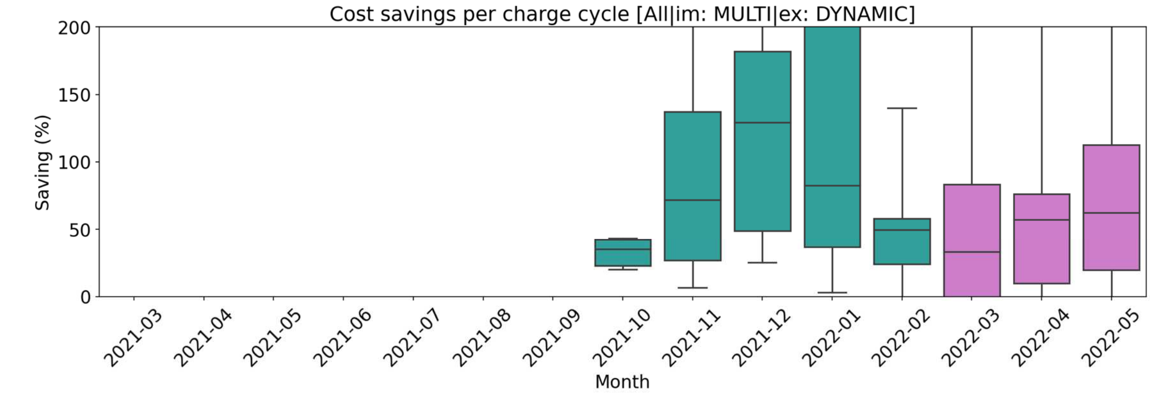

Carbon savings per charge cycle [All|im: All|ex: All]
Saving (%)
200
150
100
50
0
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

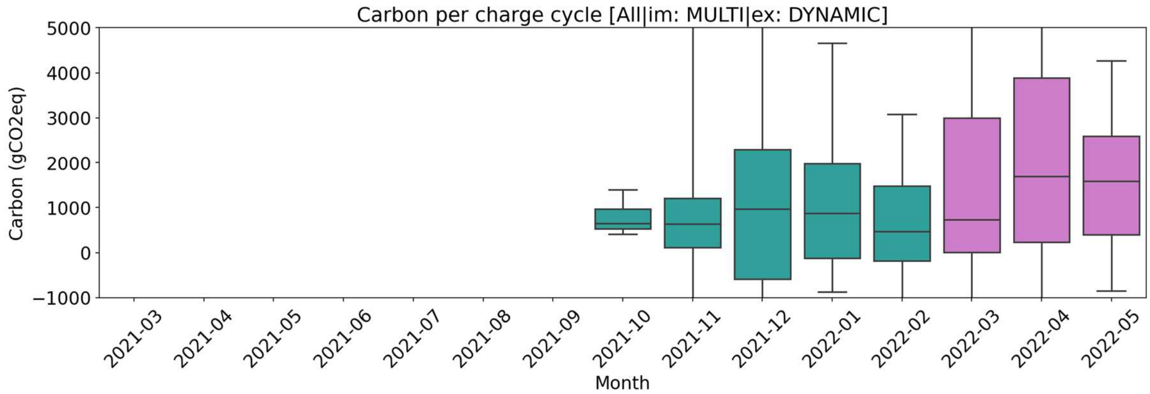
Figure 14-10 - Distribution of charging costs, carbon impact and savings across all project months and stages for all participants. The solid portion of the vertical bars contain 50% of the data, and the whiskers contain 90% of the data. Each colour represents a different project stage.



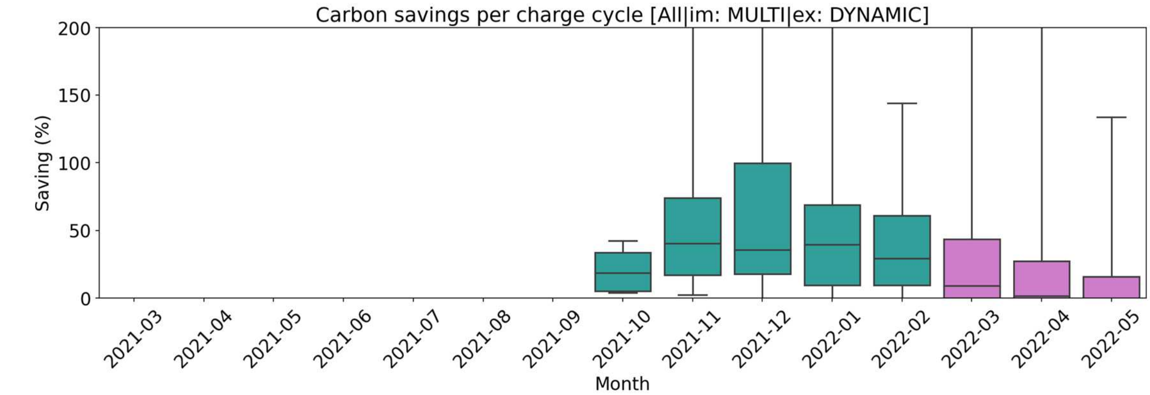
Cost per charge cycle [All|im: MULTI|ex: DYNAMIC]
Cost (£)
4
2
0
−2
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month



Cost savings per charge cycle [All|im: MULTI|ex: DYNAMIC]
Saving (%)
200
150
100
50
0
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

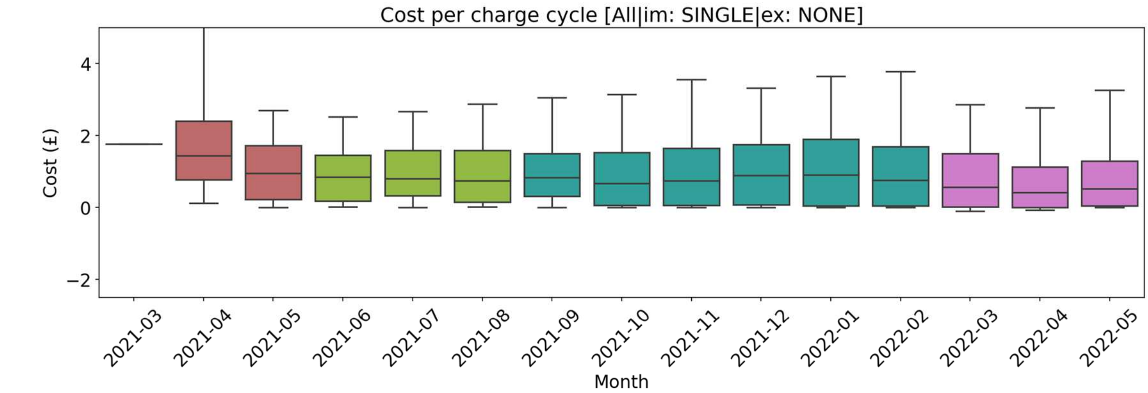


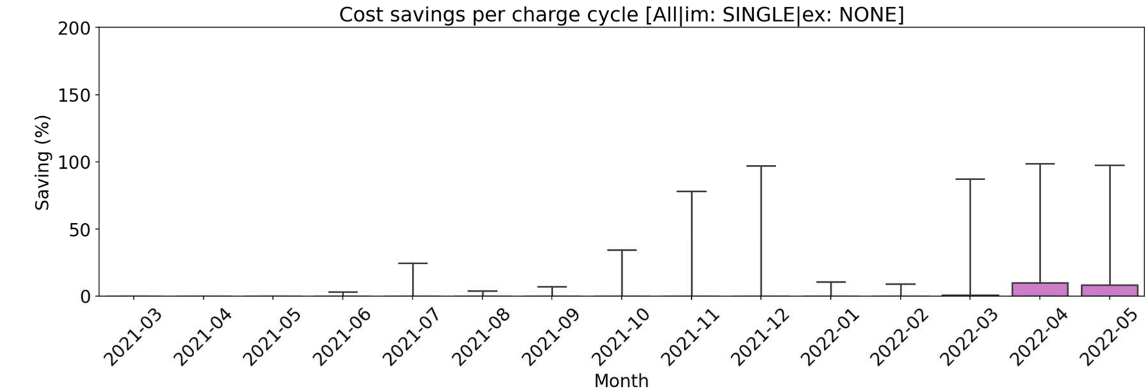
Carbon per charge cycle [All|im: MULTI|ex: DYNAMIC]
Carbon (gCO2eq)
5000
4000
3000
2000
1000
0
−1000
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

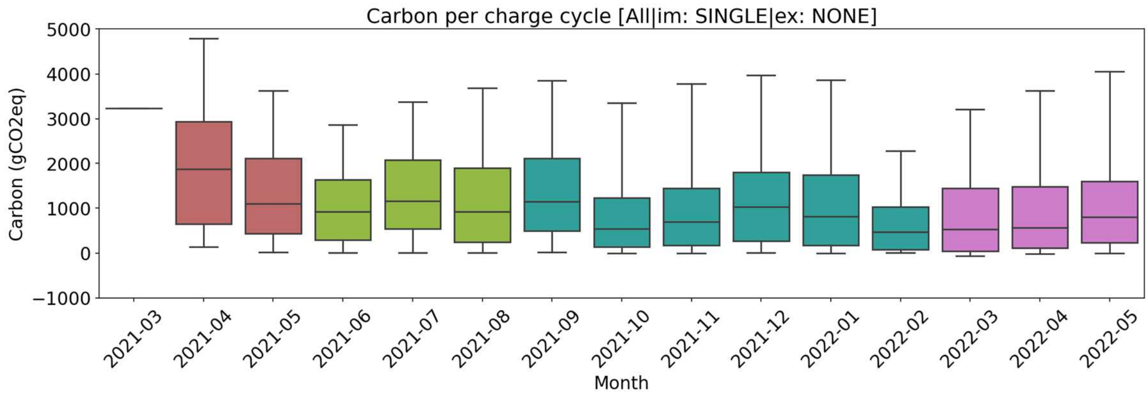


Carbon savings per charge cycle [All|im: MULTI|ex: DYNAMIC]
Saving (%)
200
150
100
50
0
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

Figure 14-11 - Distribution of charging costs, carbon impact and savings across all project months and stages for participants with multi-rate import tariffs and dynamic export tariffs


Cost per charge cycle [All|im: SINGLE|ex: NONE]
Cost (£)
4
2
0
−2
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month


Cost savings per charge cycle [All|im: SINGLE|ex: NONE]
Saving (%)
200
150
100
50
0
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month


Carbon per charge cycle [All|im: SINGLE|ex: NONE]
Carbon (gCO2eq)
5000
4000
3000
2000
1000
0
−1000
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

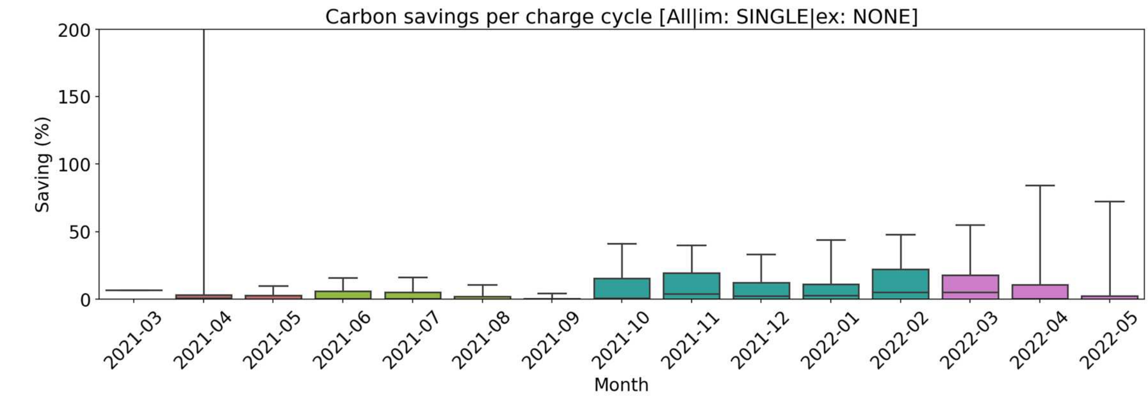

Carbon savings per charge cycle [All|im: SINGLE|ex: NONE]
Saving (%)
200
150
100
50
0
2021-03
2021-04
2021-05
2021-06
2021-07
2021-08
2021-09
2021-10
2021-11
2021-12
2022-01
2022-02
2022-03
2022-04
2022-05
Month

Figure 14-12 - Distribution of charging costs, carbon impact and savings across all project months and stages for participants with single-rate import tariff and no export tariff

CrowdCharge's Simulated DNO Group Limit Analysis

The simulated impact of DNO limits was assessed and broken down by supplier group and then by month from June 2021 to December 2021. Selected simulation results are shown in Figure 14 and Figure 15. For each month in each group, the following simulations were performed:

- Distribution of charger power per half-hour across the group without any DNO limits. In theory, this figure should be similar to the power distribution for the same group and month in the historical data. However, due to the installation of chargers over time, faults, and user behaviour (i.e., using immediate charging rather than managed charging), these results are not always similar. This simulated profile is a fairer comparison to use for the remaining simulated results.
- Distribution of charger power per half-hour across the group with a flat DNO import limit set to 30% of the max potential power for the group.
- Distribution of charger power per half-hour across the group with a flat DNO import and export limit set to 30% of the max potential power for the group.
- Total group power for each day of the month without any DNO limits.
- Total group power for each day of the month with a flat DNO import limit set to 30% of the max potential power for the group.
- Total group power for each day of the month with a flat DNO import and export limit set to 30% of the max potential power for the group.

Observations by group:

Green Energy UK

Simulated unconstrained smart charging based on real connection periods shows a more uniform response compared to the real historical data with less charging activity outside of the cheap and expensive zones periods. This simulated behaviour occurs as the simulations do not consider faults, or user over-rides.

Imposing a 30% limit on group charging power demand does impact charging in later months when more vehicles within the group are active. With reference to Green Energy UK November, the imposition of a 30% charge limit re-shapes the power distribution but within the cheap overnight period. Due to the diversity in charging due to when people connect their vehicles and their usage requirements, enough flexibility remains within the cheap overnight period.

A 30% limit in group discharging power demand does affect discharging behaviour with discharge activity being limited. As greater discharging triggers more charging to compensate, there is also a matching reduction in charge activity in the cheap overnight period. It is therefore important to consider the increase in charging that is associated with an increase in discharge and appreciate that imposing a limit on export will also impact charging behaviour.
The impact of applying group limits on the net cost of charging is mostly based on missed arbitrage opportunities and not due to charging being pushed into more expensive periods.

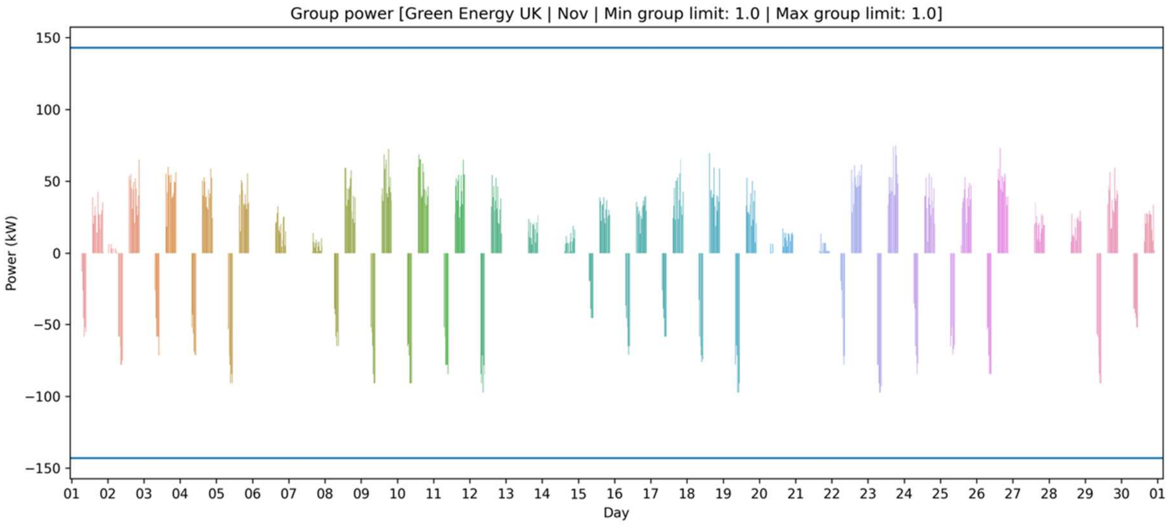
British Gas

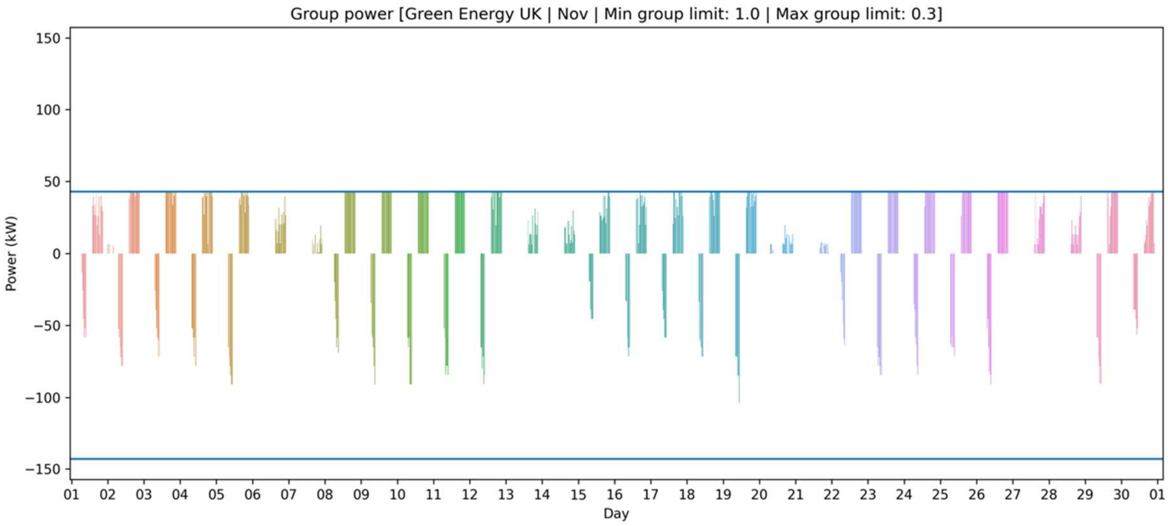
For this group, a 30% limit of group power demand had almost no effect due to the diversity in charging due to when people connect their vehicles and their usage requirements. Should a greater limit have been imposed (i.e., 20%) it is likely that enough capacity would have remained in the cheap period to avoid pushing charging into an expensive period.

CrowdCharge / Flexitricity

For this group, a 30% limit of group power demand had almost no effect due to the diversity in charging due to when people connect their vehicles and their usage requirements. In contrast to groups with a single energy supplier and tariff, this group contained members on a range of tariffs. As a result, both charging and discharging activity was distributed over a wider range of times by the scheduling engine and remained below the 30% group power limit without further intervention.

Furthermore, the proportion of discharging comparing to charging in this group was much lower than in the Green Energy group as not all members had favourable opportunities for discharge based on their tariffs. As result, it is likely the discharge activity will lag behind charge activity as EV update increases both due to diversity of tariffs and also due to availability of V2G compatible vehicles and charging equipment. For example, discharge activity was about 10 % of charge activity within this CrowdCharge group.


Group power [Green Energy UK | Nov | Min group limit: 1.0 | Max group limit: 1.0]
Power (kW)
Day


Group power [Green Energy UK | Nov | Min group limit: 1.0 | Max group limit: 0.3]
Power (kW)
Day

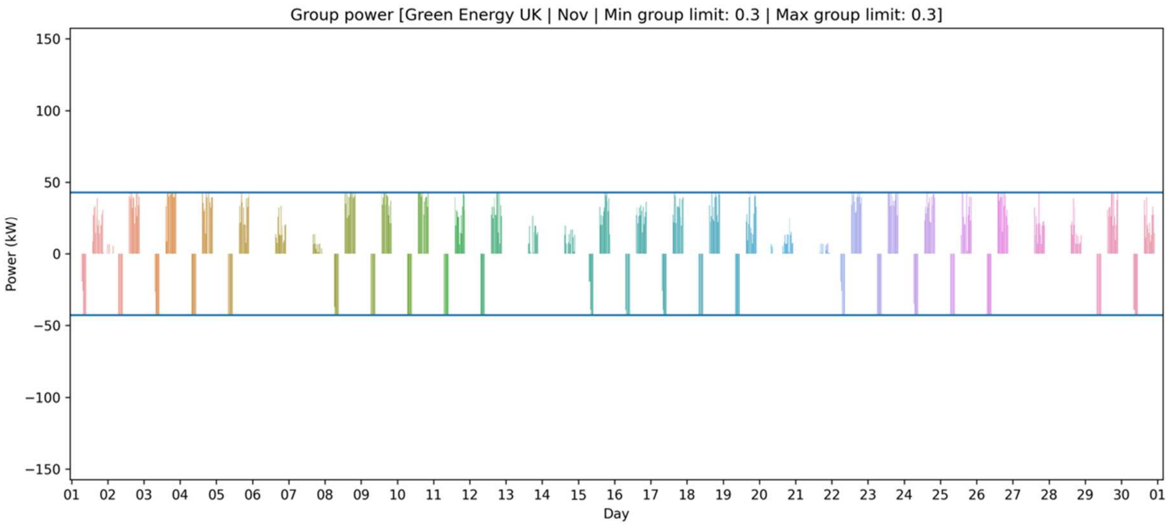
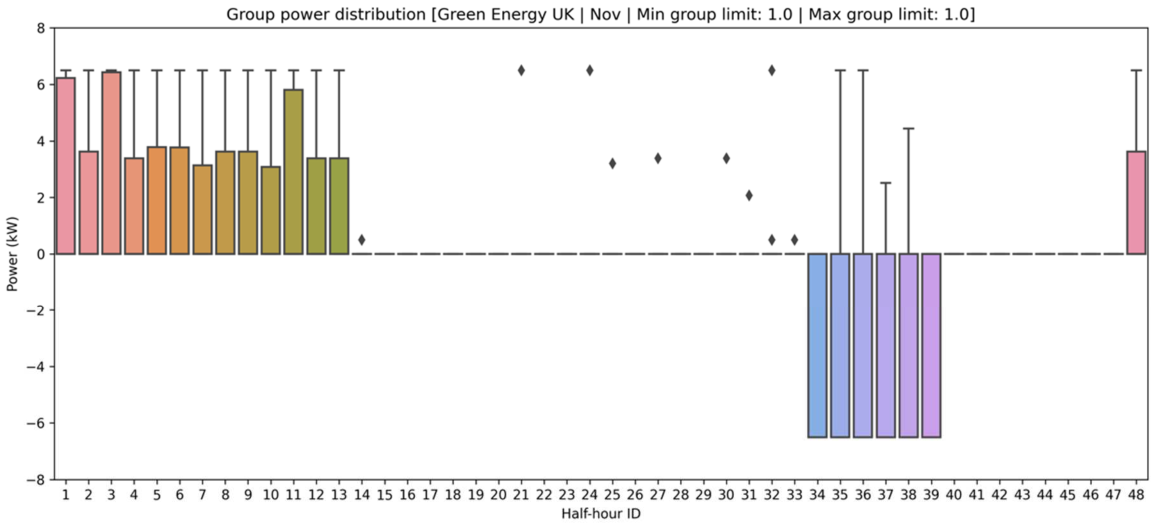
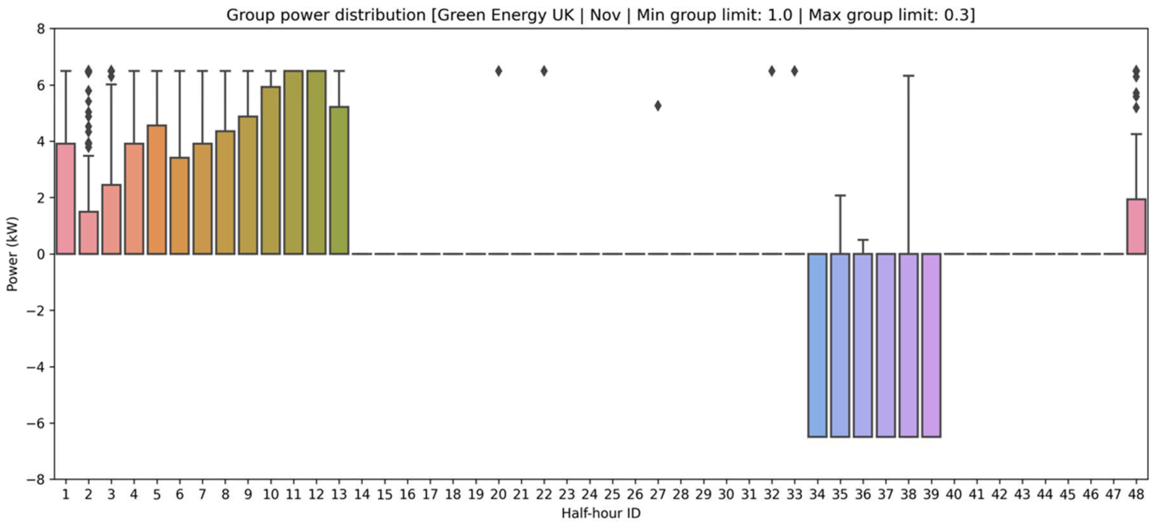

Group power [Green Energy UK | Nov | Min group limit: 0.3 | Max group limit: 0.3]
Power (kW)
Day

Figure 14-13 - Impact of limiting the maximum charging power of a group of EVs on the maximum group power demand. Top: unrestricted; middle: charge power limit to 30% of group maximum; charge & discharge power limited to 30% of the group maximum.


Group power distribution [Green Energy UK | Nov | Min group limit: 1.0 | Max group limit: 1.0]
Power (kW)
Half-hour ID


Group power distribution [Green Energy UK | Nov | Min group limit: 1.0 | Max group limit: 0.3]
Power (kW)
Half-hour ID

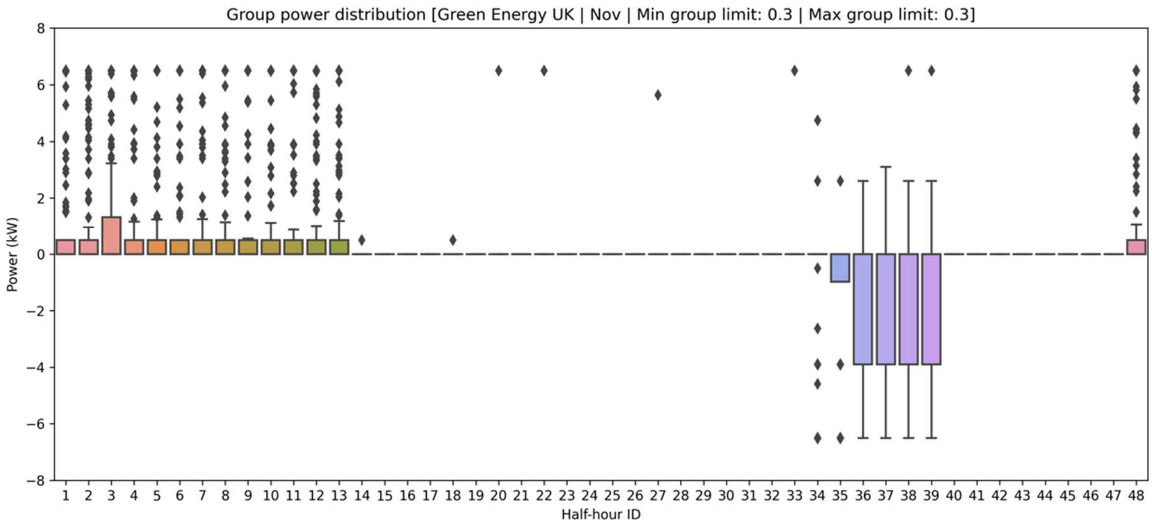

Group power distribution [Green Energy UK | Nov | Min group limit: 0.3 | Max group limit: 0.3]
Power (kW)
Half-hour ID

Figure 14-14 - Impact of limiting the maximum charging power of a group of EVs on the power profiles. Top: unrestricted; middle: charge power limit to 30% of group maximum; charge & discharge power limited to 30% of the group maximum

Appendix 2 – Vehicle-to-grid Profile Modelling

This section has been written by EA Technology.

Load Profile Creation

Profiles in Connect/LV and WinDebut are based on the ACE49 methodology, where load profiles are based on a mean plus a number of standard deviations, so that 90th percentile demand = Mean + 1.28 x Standard Deviation. The aim is to model a credible worst case scenario to get an economic network design which balances the risk of overload with the additional costs of building a network designed for very rare occurrences. There is an underlying assumption that load in each half hour fits a normal distribution.

As each load profile in ACE49 is expressed as a distribution with mean and standard deviation when the profiles are summed the means simply add, but the standard deviations partially cancel out (as it is unlikely that all customers will be drawing their maximum load at the same time). This means the per profile load decreases as the number of profiles increases on a LV network. Therefore, allowing for the maximum practical amount of load to be connected to a LV network while safely remaining within voltage and thermal constraints.

Initial Investigation

EA Technology had previously generated profiles from the Electric Nation project using a Monte Carlo approach to build a probability distribution of possible load from the charging events. The Monte Carlo analysis developed for the original Electric Nation data runs a simulation from a random sample of the data to assess the load, repeats this many times over and tests whether the distribution of load is approximating to a normal distribution.

This was repeated with the Electric Nation V2G project. The average figures from the Monte Carlo algorithm closely matched the real figures from the trial. The maximums simulated however were somewhat lower than was observed which was less positive.

Even in the simulations load was not normally distributed. The analysis used 2,500 simulations for each half hour Table 11 shows how many standard deviations the maximum calculated from the simulation was from the mean from midnight to 6am.

This showed that the simulated maximum should only have occurred once every 100,000+ runs but instead happened in a far smaller number of simulations.

Comparing to the real maximums, observed in only 3 months showed a more significant problem. This is shown in Table 12. In some cases, excel was unable to calculate how many iterations should have been required to reach that outlier, this has been represented by the value “Many”.

Table 14-8: Simulation Output for 23 Vehicles

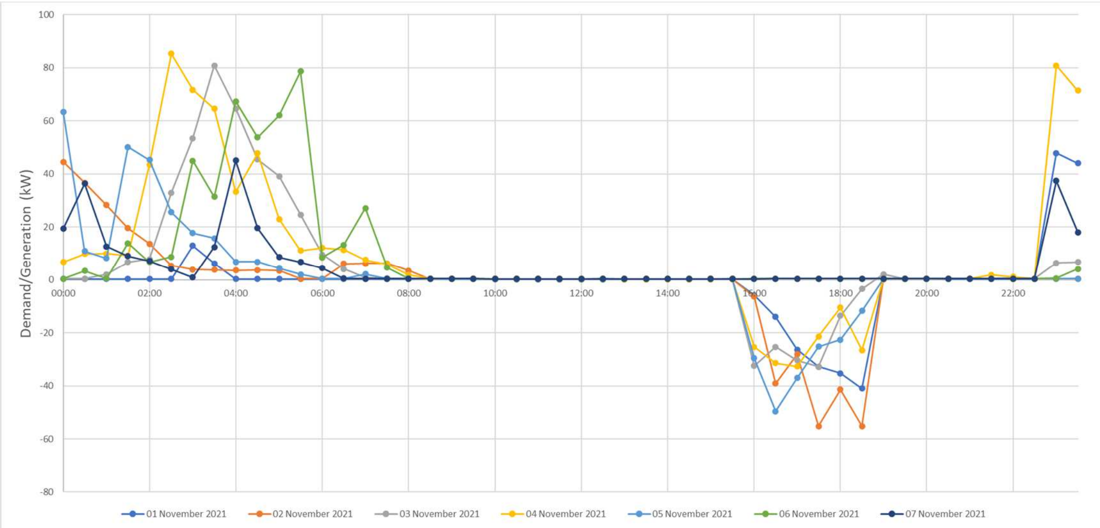
	Mean (kW)	Standard Deviation (kW)	Simulated Maximum (kW)	Number of Standard Deviations from the Mean	Theoretically Required Iterations for this Maximum to occur
00:00	15.80	8.14	47.27	3.86	8,972
00:30	13.61	7.77	52.28	4.98	1,539,910
01:00	13.66	7.54	45.36	4.21	38,427
01:30	18.57	8.66	67.41	5.64	57,705,219
02:00	18.00	8.44	51.87	4.01	16,562
02:30	20.27	9.25	58.78	4.17	32,220
03:00	21.35	9.43	52.66	3.32	1,109
03:30	20.56	8.88	56.13	4.01	16,231
04:00	20.18	8.99	58.42	4.26	47,852
04:30	17.49	8.55	51.81	4.01	16,662
05:00	13.73	7.51	49.73	4.80	621,127
05:30	9.88	6.36	39.73	4.69	372,590

Table 14-9: Comparison of Simulated Output to Observed Data

	Mean (kW)	Standard Deviation (kW)	Observed Maximum (kW)	Number of Standard Deviations from the Mean	Theoretically Required Iterations for this Maximum to occur
00:00	15.80	8.14	87.87	8.85	Many
00:30	13.61	7.77	85.26	9.22	Many
01:00	13.66	7.54	81.97	9.06	Many
01:30	18.57	8.66	93.11	8.60	Many
02:00	18.00	8.44	89.47	8.46	Many
02:30	20.27	9.25	88.54	7.38	6,522,229,728,270
03:00	21.35	9.43	88.03	7.07	643,555,248,267
03:30	20.56	8.88	83.21	7.06	584,617,333,338
04:00	20.18	8.99	87.54	7.50	15,138,150,007,968
04:30	17.49	8.55	90.83	8.58	Many
05:00	13.73	7.51	88.08	9.91	Many
05:30	9.88	6.36	78.70	10.82	Many

Examining observed data showed why this was occurring. The algorithm was locating peak charging at different times each night as shown in Figure 5-18.

Figure 14-15: Measured Load Data in first 7 days of November 2021



This could not be accounted for in the Monte Carlo algorithm, as it assumed that the behaviour during any given time slot was an independent of other variables. In reality the behaviour was not only based on the time, but also a charging algorithm which moved load between time slots. Averaging these figures, as the Monte Carlo simulation did, was not appropriate, as on any given night the peak would be significantly higher at a specific time.

Some diversity between vehicles did remain. This was due to only some customers plugging their vehicles in on a given night. More users plugged their vehicles in than previous trials due to the incentives from the tariff, but nonetheless significantly less than 100% of vehicles were normally connected.

Methodology

It was concluded that a conservative per vehicle charging demand would have to be used during the periods that charging was encouraged by the algorithm. To accurately measure this this, while avoiding a profile that led to unnecessary network reinforcement, demand would be reduced to account for the probability of a given vehicle being connected.

To account for the variability of demand due to the number of vehicles that might or might not be connected, but not due to the peak per vehicle demand the following methodology was decided upon:

4. Calculate the realistic per vehicle worst case demand and generation.
5. Calculate how many vehicles are likely to be connected at each time.
6. Multiply the two together to give the likely profile.

To calculate the realistic per vehicle worst case demand, the total demand and number of vehicles connected in each half hour of the trial were calculated. The demand or generation per vehicle was then calculated as the total demand divided by the number of vehicles. To find the realistic worst case the highest demand and generation per vehicle were calculated for each day, and the 90th percentile of that value was taken.

The number of vehicles expected to be connected were derived using the Monte Carlo simulation. The results from this confirmed the distribution was normal.

The normal probability-based approach was found to be still valid when the tariff was not incentivising behaviour. Therefore, it was used from 6am to 4pm, and 7pm to 11pm load parameters were derived from the mean and standard deviation of the Monte Carlo simulation in the same way as for the previous Electric Nation project. From 11pm to 6am demand was calculated as the number of vehicles expected to be connected multiplied by the realistic worst-case demand. From 4pm to 7pm generation was calculated as the number of connected vehicles multiplied by the realistic worst-case demand.

This was carried out for 23 vehicle chargers, to match the trial for verification purposes. The values were then scaled down to an individual charger to create ACE49 style profiles that incorporated a mean and variable component.

Load Profile

Figure 14-16 shows the resulting load profile, consisting of the P and Q components as described in ACE49.

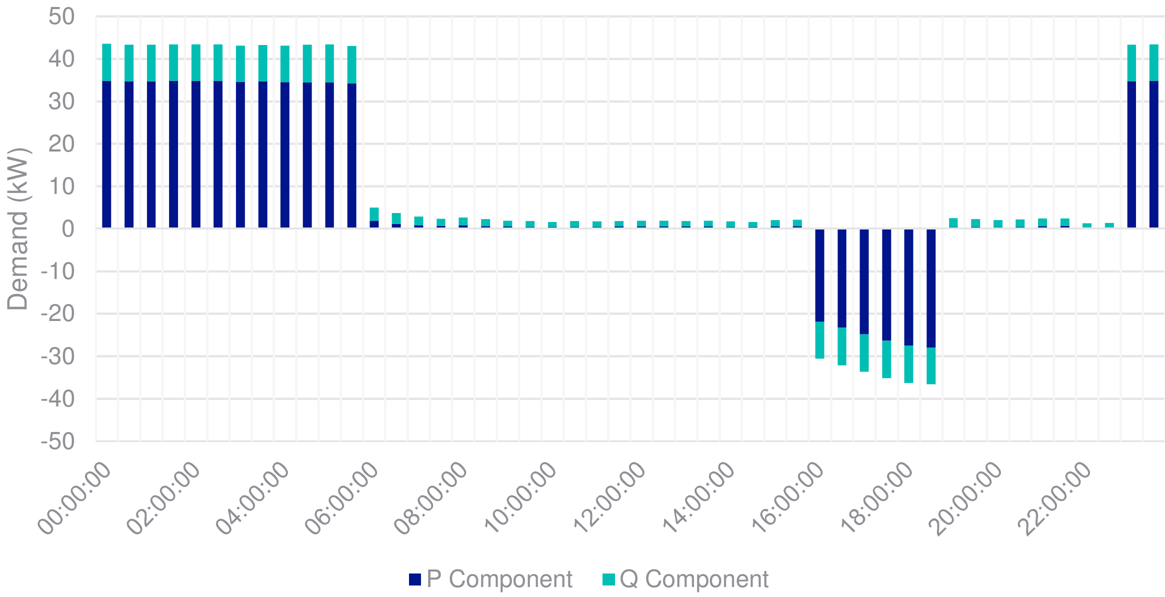
Figure 14-16: ACE49 Style Load Profile

Of obvious note is the scale of the potential net demand. It is considerably higher than reported during previous trials. This is for two reasons. Firstly, in most previous trials the vehicles have not been used to provide power to the network during peak hours. As a result of supporting the network more vehicles need to charge overnight than would otherwise be the case. Secondly, the charging algorithm in this case appears to be more likely to synchronise charging rather than staggering charging events.

Potential load does not vary much overnight, as not many vehicles are plugged or unplugged between 11pm and 6am. Potential generation does increase over time, as in the 4pm to 7pm window vehicles are progressively plugged in.

The large variable or Q component means that per vehicle demand will fall as more vehicles are added to a circuit. This is to be expected, as if only one vehicle is present it is likely there will be times when 100% of vehicles (i.e., the only one) will be connected. As the number of vehicles increase however the per vehicle demand increases by a smaller amount as it becomes progressively less likely they will all be connected simultaneously. Figure 18 shows the expected load profile for 10 vehicles.

Figure 14-17: ACE49 based for load for 10 vehicles



Conclusions

The peak load associated with V2G chargers is significantly higher than that associated with even tariff-based charging for non V2G chargers. This is largely because the vehicles are frequently discharged in the evening, resulting in most vehicles requiring overnight charging. Typical electric vehicles do not require charging each night and so contribute less to overnight demand.

It is possible to generate a load profile for electric vehicles participating in V2G charging. To simply allocate demand based on the potential peak draw would over-estimate the potential peak overnight load, as demand can be reduced to allow for occasions when users choose not to connect their vehicle. Equally, applying an average demand overnight would under-estimate the potential peak overnight load and so should be avoided. Assigning the peak to a specific time even if not accurate in all instances would not under-estimate load but could cause network operators to erroneously believe that load would be lower at other times of night.

The ACE49 P+Q approach is helpful to represent the demand in this case, however as the distribution of demand is not normal a different approach was required to determine a typical profile. The approach taken remains appropriate to current LV planning practices where more energy constrained options such as cyclic ratings and energy storage are rarely considered. However, if the network state is partially based on previous network states, a scenario-based approach considering charging being prioritised for different times might be more appropriate. This warrants further investigation.

It should be noted that this analysis is based on a small sample size (23 vehicles) controlled by a single charging algorithm. To get a fully representative load profile for V2G operation a large sample size from a range of control algorithms would be required to determine if there are any larger trends visible.

Recommendations & suggestions to V2G services policy and commercial frameworks

- Static energy demand profiles for electric vehicles and homes are no longer fit for purpose for planning purposes. Using V2G chargers to self-consume solar generation or to power the home during peak periods results in charging profiles being intrinsically linked to both home energy consumption patterns as well as the weather. The concept of a typical load profile for a charger or home is no longer is fit for purpose. Simplistic assumptions about such profiles are likely to lead to either insufficient or excessive infrastructure costs. Although there is still a role for standardised assumptions, a planning approach driven by simulation that takes in to account the interplay of smart energy assets is critical to ensuring value for money for the council and so for members of the public. It is also critical that all stakeholders (Council, DNOs, and developers) go on the journey together to ensure new assumptions and processes are mutually accepted.

- G99 Grid Connection applications on average took 62 days for an approval decision from NGED planners, out of 109 applications. A preliminary G99 grid application check could help customers understand their likelihood of acceptance, before submitting a full G99 application with their installer via an interactive postcode submission website. A streamlined G99 grid connection process is required, with shorter lead times for a decision from NGED planners. Once a full G99 application is ready to be submitted, an online tool to upload applications and check status for the installer, and customers, would improve the customer experience as the inevitable increase in charger grid connection requests in the short-medium term.

- The electricity tariff can also result in co-ordinated export as the chargers discharge back into the grid. It is possible that some parts of the network will see export peaks replacing the traditional evening import peak. Although this issue self-corrects as the market adapts to the removal of the traditional evening import peak, there is likely to be a transition period of several

Years where this kind of operation is seen. The evolution, or lack thereof, of time of use tariffs, export tariffs, and other mechanisms by which end-users’ costs are influenced is a critical factor in understanding how EV demand will evolve.

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