

# Project Shift

Trialling market based incentives for  
domestic smart electric vehicle charging

**Progress report**

January 2021



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# Glossary of Terms

<b>ADMD</b>	After diversity maximum demand
<b>BEV</b>	Battery electric vehicle
<b>BAU</b>	Business as usual
<b>BM</b>	Balancing Mechanism
<b>CDCM</b>	Common Distribution Charging Methodology
<b>CM</b>	Capacity Market
<b>DCUSA</b>	Distribution Connection Use of System Agreement
<b>DER</b>	Distributed Energy Resources
<b>DNO</b>	Distribution Network Operator
<b>DSO</b>	Distribution System Operator
<b>DSR</b>	Demand Side Response
<b>DUoS</b>	Distribution Use of System Charges
<b>EPN</b>	Eastern Power Networks
<b>ESO</b>	Electricity System Operator
<b>EV</b>	Electric Vehicles
<b>EHV</b>	Extra high voltage
<b>GB</b>	Great Britain
<b>HH</b>	Half hour
<b>HHS</b>	Half hourly settlement
<b>HV</b>	High Voltage
<b>LV</b>	Low Voltage
<b>NTOC</b>	National Terms of Connection
<b>PHEV</b>	Plug-in hybrid electric vehicle
<b>SCR</b>	Significant Code Review
<b>TNUoS</b>	Transmission Network Use of System Charges
<b>ToU</b>	Time of Use
<b>TSO</b>	Transmission System Operator
<b>V2G</b>	Vehicle-to-Grid

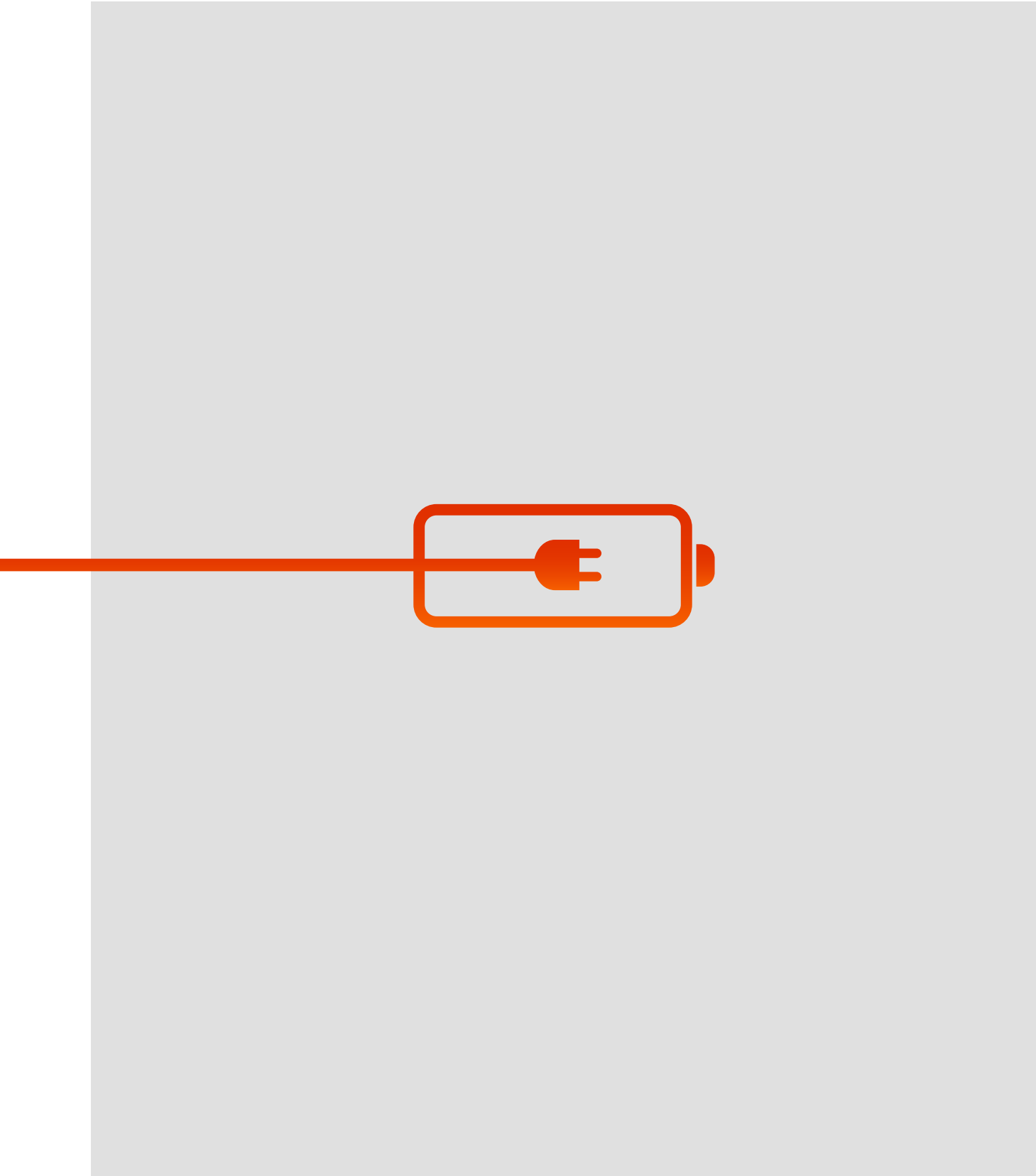
## Contributions from our partners

We would like to recognise the valuable partnerships with Kaluza, ev.energy and Octopus Energy on the project and insights that collaboration with them has enabled. Their contributions to the project have enabled us to develop a richer understanding of market-led smart charging, and the motivations and perceptions of customers involved.

## Share your feedback

As we approach the end of the trials, we are moving into the analysis phase where we will draw insights from the data and survey responses collected. We recognise the pace of change in the industry and want to build on the engagement during the trial development by providing an opportunity to inform our analysis. Let us know what sparked your interest or what you would like to see next at [innovation@ukpowernetworks.co.uk](mailto:innovation@ukpowernetworks.co.uk)

# Executive summary





Facilitating the electrification of transport is central to our role as an electricity network and a key enabler in achieving Net Zero in the UK. We forecast the number of electric vehicles (EVs) on our network to increase from just over 100k currently to 3.6 million over the next 10 years.

Smart charging can reduce the impact of electric vehicle charging on electricity networks, by shifting demand to make better use of existing network capacity. To encourage network friendly charging, we want to create an environment where the value generated by this flexibility is shared with customers.

Smart charging gives customers the ability to plug in their vehicle but shift their EV charging to times when prices are lower or electricity is greener. This can improve the use of the existing network capacity by reducing peaks in electricity demand, especially those in the early evening when electricity use is already high. On some networks, shifting flexible demand, such as EV charging, may be able to reduce or delay network upgrades.

Combining this with other smart solutions, increased network visibility and strategic investment, will enable DNOs to facilitate EV uptake and better meet customers' electricity needs.

Our approach to Smart Charging is market-led. This is where DNOs/DSOs use mechanisms that benefit market participants, such as suppliers and aggregators, when electricity is used at times that make better use of existing network capacity. This, in turn, leads to propositions that encourage customers to smart charge and shift demand away from peak times.

Project Shift focuses on understanding how DNOs/DSOs can implement mechanisms to stimulate the development of propositions which incentivise domestic customers to smart charge at home.

For widespread participation, smart charging needs to be accessible, simple and trusted. To achieve this, mechanisms must be designed around real-world customer behaviour and preferences. To ensure this, project Shift collaborated with Kaluza, Octopus Energy and ev energy to trial three different mechanisms. This has resulted in several customer propositions, being trialled with over 1,000 domestic customers to incentivise smart charging. Through the trials we aim to understand:

- Can mechanisms to incentivise flexibility help DNOs manage network constraints on the low voltage (LV) network?
- What peak load reduction can be achieved under each mechanism, whilst delivering the customers' needs?
- How might these approaches interact with wider market services and electricity network needs?

In this report, we provide an update on our interim results to enable wider parties to understand and respond to the insight we are gathering ahead of completing the project in mid-2021.



## Our approach

Engagement with a range of industry stakeholders and independent research with 800 motorists<sup>1</sup> helped us to define three market mechanisms to be trialled during project Shift. We then partnered with customer centric market participants, selected via an expression of interest process, to trial each of these with domestic customers.

The resulting partners for each mechanism are:

- **Time of Use Distribution Use of System (DUoS) pricing** Kaluza
- **Capacity-based DUoS pricing** Octopus Energy
- **LV flexibility procurement** ev.energy

Price signals through the respective mechanisms were set to incentivise charging outside of the typical residential peak at LV, which occurs between 6-9pm. Consideration was given to ensure incentives reflected realistic values required to be preferable to investing in greater network capacity. Similarly, the capacity-based DUoS and ToU DUoS charges in the trial were designed to reflect residential LV network usage and realistic charges. This was done to observe how these incentives might function alongside wider market price signals.

## Initial results

### Time of use DUoS pricing trial

Under this mechanism, two ToU DUoS price signals were designed to reflect residential LV network usage. The ToU DUoS shapes trialled were 'red peak' and 'shoulder pricing', which were applied to different customer groups. These ToU DUoS prices were combined with the day-ahead wholesale and TNUoS price shapes, against which the Kaluza algorithm optimised the EV charging schedules. This aggregation of network (DUoS and TNUoS) and wholesale price signals was used to observe how the trial's ToU DUoS signals might, function alongside wider market price signals.



Kaluza's customer proposition adopts a fully automated approach, in which the load profile of each individual EV charging session is optimised by an algorithm that delivers customer charging needs at the lowest cost. The smart charging proposition provides customers with either a free or discounted smart charger. The customers were not exposed to an on-going incentive beyond this point. Customers set their charging needs via an app, and have access to a "boost" function that enables them to override smart charging. Kaluza targeted 368 existing customers to participate in the project Shift trial, of which 311 accepted.

Customer overriding led to 31% of charging hours being delivered in a mode where demand was not shifted. This has been broadly consistent throughout the trial. Through customer surveys conducted by Kaluza, factors that could reduce this level of overriding through changes to the customer proposition were identified.

During the LV peak, EV demand reduced by 57-66% (across both groups) in the Kaluza ToU trial. The result reflects the combination of charging which was shifted through Kaluza's optimisation and demand which was not shifted due to overriding. In total, the diversity of electric vehicle charging increased across the customer groups, reducing the overall household peak demand by an average of 26% when compared to an unmanaged approach. This charging demand has been shifted to the overnight period, resulting in a reduced 'secondary peak' which occurs when overall system demand is low.

<sup>1</sup> Customer research engaged a separate group of people to those involved in the smart charging trials.



### Capacity-based DUoS pricing trial

Under this mechanism, the market participant books a capacity to cover the expected demand of their customers in a specific network area. Demand which exceeds the capacity booked is charged at a 'penalty price' hence incentivising a flattening of demand. As a relatively novel approach, valuable learnings have been gained by designing and applying this mechanism with Octopus Energy.



Octopus Energy created a tariff as the customer proposition for Shift called 'Octopus Go Faster', which offered customers cheaper charging windows at different times of the day. This incentive was used to stagger charging sessions across customers, ensuring they remained within their booked capacity, as opposed to applying a capacity limit per customer, which is a less familiar approach.

As the tariff is technology agnostic, it allows customers to enact their charging schedule via smart devices or undertake this manually. Customers were settled against these tariffs, and so were exposed to a real incentive on a daily basis, and were also offered £5 for each month if they participated in the trial. Octopus Energy promoted the tariff to their customers as well as on their website and 458 signed up. Subsequently, 143 have dropped out, with many customers moving between the Go Faster and Agile tariff to take advantage of the best offering over the trial period.

The Octopus Energy trial also shifted demand away from peak times; however, the EV demand was not measured in isolation. Of the customers surveyed, 83% indicated that they shifted the use of other device including dishwashers and washing machines, as well as EV charging. Although the customer proposition was effective at incentivising customers to shift demand into the time bands when the cheaper electricity rate applied, on average peak demand increased when compared to the unmanaged baseline. This in part due to the popularity of the reduced rate tariff which started at 20:30, resulting in increased demand toward the end of the evening peak.

### LV flexibility procurement trial

The LV flexibility procurement incentive under this trial was designed to broadly align with our high voltage and extra high voltage flexibility products. Under this mechanism, ev.energy were 'contracted' to limit the charging demand of a portfolio of customers to a pre-determined level during the 'service window', based on the LV peak (6-9pm). Charging schedules were then optimised to respect this agreement, against wider market opportunities or the carbon intensity of the electricity.



ev.energy targeted over 3,000 existing customers to participate in the project Shift trial, of which 445 were recruited by Q2 of 2020. Since then an additional 269 customers have started contributing to the trial, bring the total number to 714. ev.energy's customer proposition is a fully automated approach, with customers utilising smart chargers or smart control via a 'connected car' with charging schedules optimised by ev.energy. Customers set their ready-by-time in the app and charging sessions are scheduled by an algorithm that delivers the customer need at the lowest cost.

On the trial, customers are rewarded for every smart charge they complete with points that can be used to claim rewards. Rewards included free rapid charging (up to £60) when customers agree to smart charge at home; 300 free home charging miles per month; £5 free coffee rewards for every 20 smart charges; £5 Amazon vouchers for every 20 smart charges; and one month of carbon credits for every 20 smart charges. Customers have access to a 'boost' function that temporarily overrides their schedule. The level of overriding throughout the trial remained fairly consistent, with circa 10% of EV charging hours per week performed in this state.



Results to date from this trial have demonstrated an average reduction in charging demand of 80% within the service window across all customers in the trial. At a household level this represents a demand reduction of 1-6%. EV charging demand has been shifted to the overnight period, resulting in a 'secondary peak' for these households which is equivalent to a typical unmanaged evening peak when considered with household load. However, as a mechanism designed to be targeted in specific locations, with control over the service window and contracted level of response, this form of response could be useful to the DNO.

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## Early insights

### A number of insights are emerging from the trials to date:

- Market participants have been able to deploy smart charging propositions, with a range of approaches and hardware requirements for customers – an encouraging sign that market-led smart charging is possible;
- All trials elicited a reasonable response and shift demand away from peak times. Each of the mechanisms has led to a secondary peak in the overnight period;
- High levels of demand reduction over the LV peak (resulting from a single, identical optimisation constraint across an EV portfolio) can reduce charging diversity, leading to secondary peaks, which exceed evening peaks at a household level;
- The impact of secondary peaks on the network depends on the level of EV uptake, proportion of customers who smart charge, and the degree to which they respond;
- The level of override behaviour has been markedly different between individual customers and the Kaluza and ev.energy trial groups, suggesting that the proposition design may be able to reduce this.

### Our focus for the remainder of the project

Data collection will continue until early 2021, when we will conduct our full analysis and review. This will include:

- A full analysis of electricity consumption data and the smart charging response including variability;
- Gathering insight into the customer experience and drivers of behaviour that impact the observed response;
- Assessing factors that affect the level of response, including financial factors such as customer propositions and tariff type; physical factors such as car type, battery size and charge point rating; and behavioural factors such as charging habits, motivations and perceptions;
- Reviewing the commercial products, including the design of the distribution price signals, examining cost recovery, calculating settlement and the impact on customers' bills, and assessing conflicts and synergies with wider system needs;
- Analysing data gathered in each trial and simulating the effect that each could have at the LV feeder level of the network (virtual feeder analysis), based on the implementation approaches proposed; and,
- Assessing how each mechanism could be implemented, identifying limitations, and consideration of the impacts on all customers.

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# 1. Introduction





## 1.1. Our electric vehicle strategy

UK Power Networks owns and maintains the cables and power lines that deliver electricity into people's homes and businesses. It's our job to keep the lights on and, increasingly, to keep transport moving too. As of December 2020 there are roughly 100,000 electric vehicles connected to our networks, a figure we forecast to rise to 3.6m by 2030. In November 2020 the Government brought forward the ban on the sale of new petrol and diesel cars by ten years from 2040 to 2030, which we believe will accelerate the adoption of electric vehicles.

We have a clear strategy to be an enabler of the electric vehicle revolution whilst maintaining our position as the UK's lowest-cost distribution network operator. We are doing this by putting our customers first. We want people to be able to easily connect to our network when they need to. We want everyone to be able to charge where they want at an affordable cost, whether this is at home, en-route, at destination or at work. We are working across many different charging and customer segments across the transport space to understand the infrastructure requirements, consumer behaviours and preferences that are driving this revolution.

Innovation and smart solutions will enable us to meet our customers' evolving needs in the most efficient way. In 2017, we became the first distribution network operator to put in place an electric vehicle strategy, and in 2019, we released an updated version of this strategy<sup>2</sup>. Our approach is to deliver the transition to net zero at the lowest cost to customers by:

- **Forecasting** Using UK's leading network operator electric vehicle forecasts to inform our planning to understand where the uptake will be and when it will occur
- **Monitoring** Increasing visibility of what is happening on our networks utilising our own and third-party data
- **Deploying smart** Optimising network use through innovative technical and commercial solutions including smart charging and V2G. We were the first DNO to adopt a "flexibility first" approach and to champion market-led smart charging.
- **Investing strategically** Flexibility should be maximised first to reduce the investment required, but networks should also invest where it is the best value option to provide capacity to meet our customers' needs

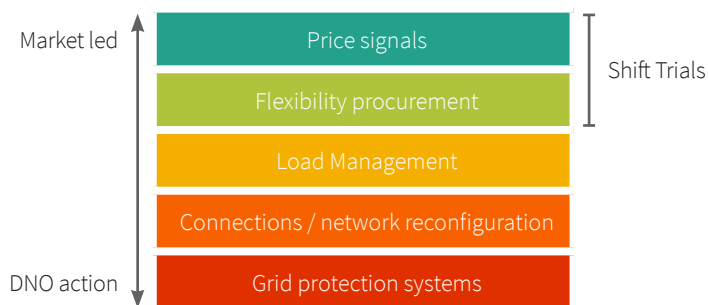


## 1.2. Our smart charging position

Smart charging presents a significant opportunity to optimise existing network capacity. Domestic demand generally peaks in the evening when people get home. Smart charging gives customers the ability to shift their EV charging away from peak times to use cheaper or cleaner electricity. As demand on the electricity networks increases with the uptake of electric vehicles and electric heating, shifting demand can reduce or delay network investment. This enables us to facilitate the transition to a net zero future at a lower cost to customers.

In 2018, our Smart Charging Architecture Roadmap (SmartCAR) project developed the foundation of our smart charging strategy and laid out a view of the hierarchy of mechanisms required to stimulate the market through the provision of price signals and incentives. During SmartCAR we carried out engagement with a range of stakeholders to inform our strategy for smart charging. This led us to our position of pursuing market-led approaches to smart charging as a first option and mobilising the Shift trials to demonstrate how these would work in practice.

**Figure 1** Hierarchy of market mechanisms





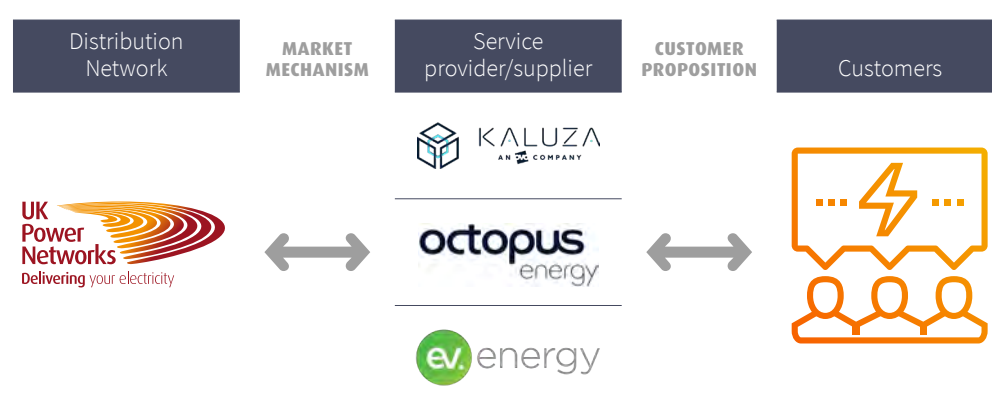
### 1.3. Shift Overview

Shift is investigating a range of market-based smart charging approaches to shift EV demand away from peak times on the low voltage (LV) network. In collaboration with suppliers and service providers, we are trialling different mechanisms and understanding how these can translate into customer propositions to incentivise smart charging as shown in Figure 2.

The trials partnerships are:

- **Capacity-based DUoS pricing** Octopus Energy
- **Time of Use DUoS pricing** Kaluza
- **LV flexibility procurement** ev.energy

**Figure 2** Relationship between Shift trial participants



We are measuring the impact on EV demand with over 900 customers to understand the effectiveness of the different mechanisms and inform answers to the following questions:

- Can mechanisms to incentivise flexibility help DNOs manage network constraints on the low voltage (LV) network?
- What peak load reduction can be achieved under each mechanism, whilst delivering the customers' needs?
- How might these approaches interact with wider market services and DNO needs?

The trials will provide an evidence-base to understand factors that affect customer behaviour and the market's ability to provide smart charging services. Using this data, we will assess the impact of these mechanisms on the network and draw insights that support the development of scalable solutions.

**Table 1** Shift timeline of key activities

2019	2020	2021
Research and design	Trials delivery	Analysis and learning
Stakeholder engagement	Trials execution	Analysis of trial data
Partner selection and mobilization	Customer surveys	Regulatory and market assessment
Commercial design	Preliminary data analysis	Systems architecture review
Customer research	Industry engagement	Share learning

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## 2. Pre-trial research and engagement





## 2.1. Stakeholder engagement

Alongside our work with the Shift partners, we also conducted additional stakeholder engagement to test our position with a range of parties and use their feedback to shape the trials. The stakeholders who contributed to this process are shown in the graphic below.

Stakeholders engaged as part of Shift



Key messages from our stakeholder engagement included:

- Stakeholders agreed that a key overarching objective for these trials should be the investigation of market-based approaches to smart charging, through real-world customer propositions.
- Stakeholders agreed that, whilst it would be of value and interest to trial a range of potential services, we should focus on the provision of a demand turn-down service at peak times, as this is a high-value area and allows for a simpler trial which can focus on core learnings.
- Stakeholders agreed that we should align our commercial product design with a set of principles that are broadly aligned to Ofgem's direction of travel in the Access & Charging review, in order to ensure that our approaches are realistic.
- Stakeholders agreed with our proposal to trial flexibility procurement, ToU DUoS, and a capacity-based charge, to inform Ofgem's thinking in the Access & Charging review. There are mixed views as to the appropriateness and potential effectiveness of these methods, but all agreed that this is for the trials to investigate. We have designed the incentives carefully, and have based values on the real-world network costs, to ensure that findings generated are reflective of real-world conditions.
- Stakeholders raised that it will be paramount to understand the impact that the trials have on customers, and not just to focus on the outcomes for the network. As a result, we will ensure that as part of each trial we calculate settlement of the charges under the new arrangements (whilst in reality, they will be settled via their current arrangements), and we conduct customer surveys to understand their experience.
- In general, stakeholders felt that propositions would need to be simple, transparent, and automated, in order to develop customer trust and have the desired impacts. However, as part of this trial we are looking to our trials partners to design propositions that they see fit to enact the required services, and whilst we will provide feedback and work with them, ultimately we will allow the market to innovate.



## 2.2. Customer research

In addition to the stakeholder engagement that we conducted, independent research carried out by Delta EE during the research phase of Shift engaged over 800 motorists, including EV drivers and non-EV drivers. The objectives of the research were broken down into two primary aims:

- Provide customer insight to inform and shape the design of Shift including insight into how customers will respond to smart charging as a concept as well as the different elements of a market-led smart charging proposition.
- Gather primary evidence on customer perception of a market-led approach to smart charging, to understand both the value of this approach (as there is not a consensus on this amongst all UK electricity system stakeholders), and gather insight on how customers engage with the complex concept.

The research involved the following activities to gather insights:

- **Focus groups and co-creation workshop** This included three focus groups with 20 prospective<sup>3</sup> and 20 current EV drivers and a co-creation workshop with five prospective EV drivers and five current EV drivers.
- **Customer survey** An online survey with 750 participants and ~30 questions. Participants included 236 current EV drivers, 414 prospective EV drivers with off-street parking and 100 prospective EV drivers with on-street parking.

The research provided valuable insight into customers' attitudes towards smart charging. Extensive learnings were captured from these activities, which we have summarised and published on our website<sup>4</sup>. In summary, the survey research revealed that:

- The majority of EV and non-EV drivers preferred a market-led approach over a load management approach.
- The vast majority of BEV drivers surveyed had typical daily journeys of 60 miles or less and more than two-thirds only feel the need to charge their EV when the battery has 50 miles or less of range left.
- 75% of all participants were 'quite' or 'very' happy with the idea of a third party managing their vehicle's charging outside of peak times under the condition that their mobility is not affected.
- A small proportion of EV and non-EV customers surveyed were not open to the idea of smart charging and indicated no level of reward would incentivise them to allow a third-party organisation to manage their EV charging.
- More than two-thirds of all participants would allow an organisation to manage their EV smart charging for £4 or less a month.
- More than a third of all participants indicated they did not require an incentive to allowing smart charging to occur. Non-EV drivers and those living in rural and semi-rural areas were more willing to allow smart charging to occur for no compensation.
- 85% of participants would trust their DNO to act in an emergency on the grid: they prefer third party intervention to a possible power outage, with the preferred intervention method for 6 out of 10 being the pausing of one's EV charging.

3 Looking to purchase an EV within 5 years  
4 <https://innovation.ukpowernetworks.co.uk/projects/shift/>



- The need to provide customers with ‘peace of mind’ when it comes to meeting their mobility needs was reinforced by nine out of 10 participants rating the ability to override the smart charging process as important. Charging customers to be able to override smart charging is a contentious issue for customers, and something a majority will not pay additionally for.
- Customers would like their service provider to make smart charging recommendations to them. These recommendations should provide insight on which smart charging tariff/package is best suited to the customer as well recommendations, which educate customers on the best practice for smart charging.

The customer research activities were conducted with a separate group of people to those involved in the smart charging trials. These insights will be compared to behaviour observed through the trials and surveys conducted with trial participants during the final report. These insights will be used to understand how applicable the insights are to our customers, both now and in the future.

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## 2.3. Market review

Within the Shift project, we developed three commercial products that would enable EV customers to access this value through a free market. These were developed in collaboration with energy market specialists from Baringa and subject matter experts in our smart grid, income management, and regulation teams.

To design these products in such a way that would be valuable to the network customers and the market, we initially reviewed the network needs and explored the conflicts and synergies between existing products on the market.

### 2.3.1. Network needs and services

At the start of the project, we developed a preliminary cost-benefit analysis (CBA) tool that produced a high-level assessment of the value of LV smart charging to networks (in terms of network reinforcement deferral) to inform the design of the LV flexibility products, the volume of flexibility required and what proportion of required flexibility EVs can contribute. We will update the CBA towards the end of the project and the insights from this and other Shift activities will inform inputs to our internal investment tools. We will also consider how the evidence from the Shift trial can inform other DSO services, such as voltage management and unplanned interruptions. Hence, we progressed with assessing how this would compare to other market services.

### 2.3.2. Conflicts and synergies

We did a market scan to understand the context of DSO services in relation to other market services that are already established such as wholesale and ancillary services. We aimed to understand the potential conflicts and synergies between DSO products and those in other markets. Some of the key questions we were looking to answer during this initial assessment and will review following the trials are:

- Which of these services can EVs provide?
- What other technologies are competing in those markets?
- What is the outlook for those markets in terms of price, volume and policy risks?
- Can EVs compete in both DSO and ESO services at once or are there physical and contractual conflicts?



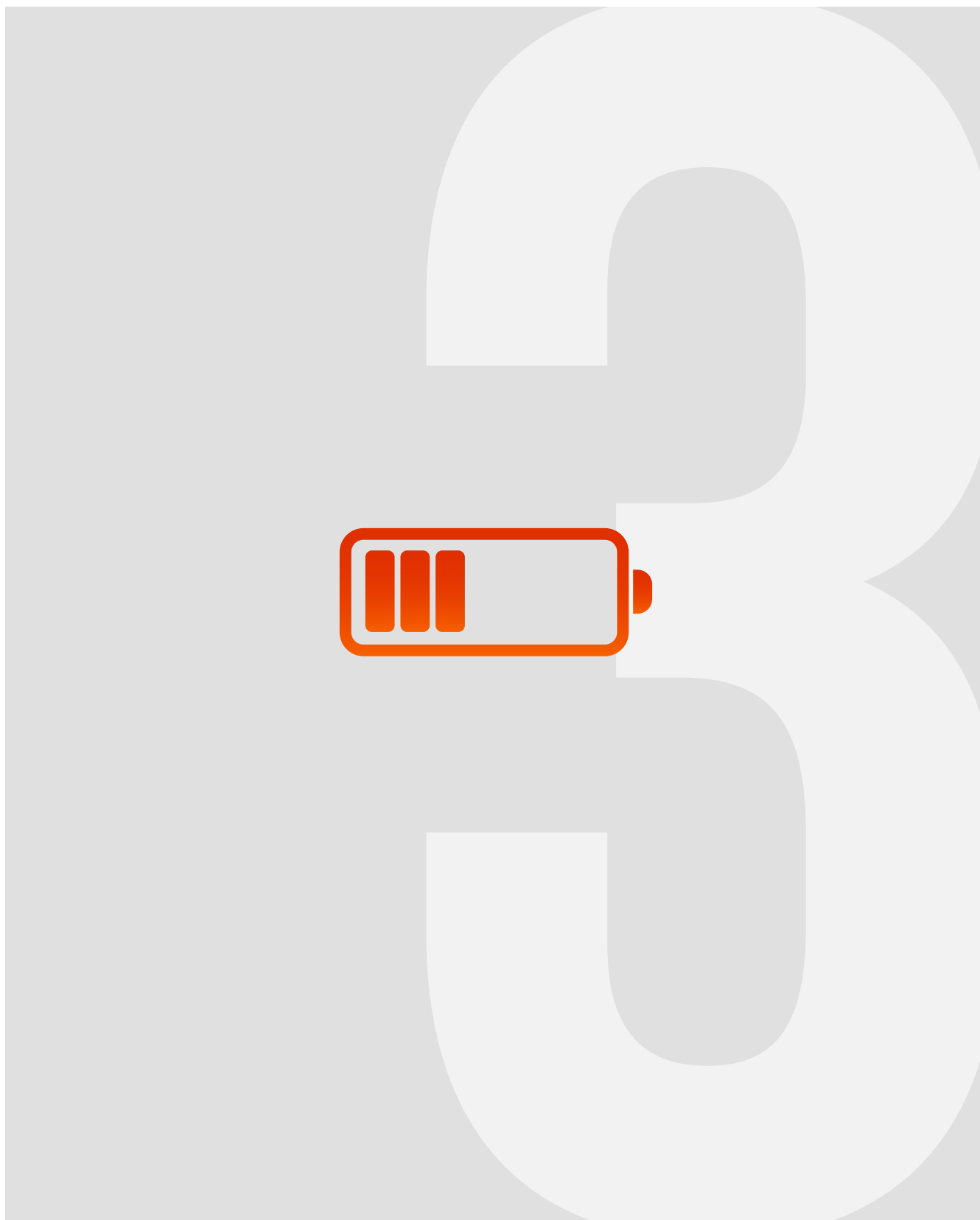
We have summarised some of the early views that we were able to draw around a DSO service based on network reinforcement deferral, which is the most typical network need for the LV network. The interactions that an LV network reinforcement deferral service would have with other markets are as follows:

- **Frequency Response** The frequency services are generally mutually exclusive with DSO services as they can work in conflict. Hence, if the DSO window overlaps with Electricity Forward Agreement blocks, the Distributed Energy Resources (DER) would have to forgo the income from two Firm Frequency Response (FFR) windows. Additionally, there may be some operational restrictions given the nature of the frequency response products as there may be requirements on the level of charge in the batteries.
- **Wholesale market arbitrage** If high wholesale market prices correspond with LV network peaks then flexibility providers will shift charging to cheaper periods. This could provide an additional incentive to shift demand away from peak times but also means that if the EV would not have been charging at that time that they would not be able to respond to a turndown by the DSO.
- **System price** The price of the Balancing Mechanism (BM) is more volatile compared to the Wholesale market. It can reach high positive prices or even negative as it tracks closely how short or long the system is. In this context, the DSO flexibility services for EVs could interact with the BM pricing during the evening charging period of EVs. This interaction could either take the form of a strong alignment, i.e. a high BM price discourages charging at peak times, or of a conflict, i.e. a negative price can incentivise charging and amplify a local constraint.
- **Capacity Market** Unless service providers have an exemption from delivering on their Capacity Market (CM) obligations when a DSO service is required, it is unlikely that providers will try to stack these services, particularly as the penalties for non-delivery in the CM are high. However, providers receive 4 hours warning of a Capacity Market stress event and so may opt into both services if the DSO service has a flexible approach (i.e. positioning for the CM takes priority).
- **EHV/HV Constraints** The extent to which these can act in synergy depends on the overlap of the windows in which the response is needed.

Ultimately, we needed to design several market mechanisms that could enable market participants to access the value of DSO services through a response to network signals specifically. Once we had a view of the needs we needed to address on the network and the value drivers that sit alongside the needs, we were able to design a set of commercial products that could enable us to meet our network needs.

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## 3. Interpretation of results



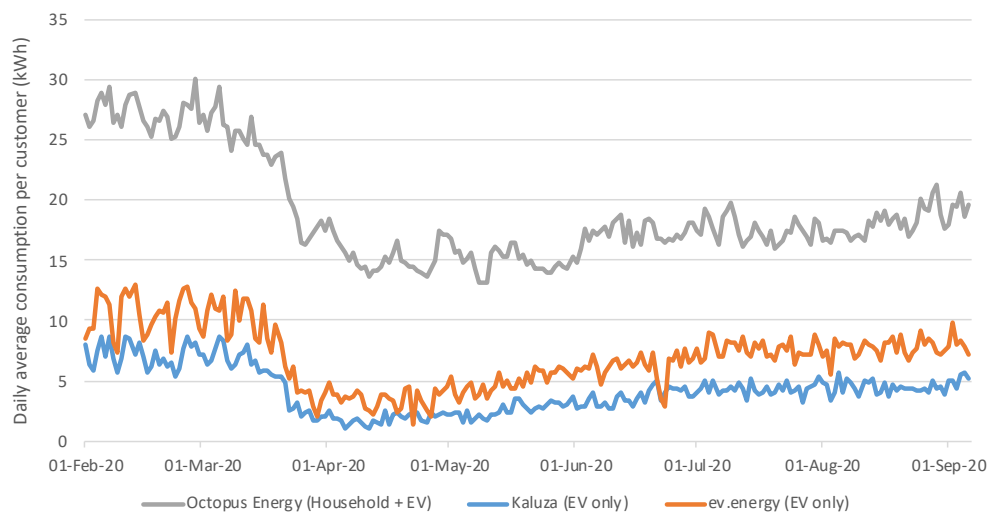


The UK lockdown measures were announced on the 23<sup>rd</sup> March 2020. This had a significant impact on the average electricity consumption across customers involved in the Shift trials. There is uncertainty around the replicability of this behaviour during this period and as a result, the analysis in this report is split into two datasets, before and after the 22<sup>nd</sup> March. In addition to the impact of COVID-19, the impact of seasonal impact over these periods should be considered.

The dramatic impact on demand highlights change which can be catalysed by global events and the need to stress test assumptions about consumer behaviour when considering their impact on the network. We will further analyse data from the trial to understand the effect of COVID-19 on the customer behaviour and make an informed view on how to process the data based on the relative impact.

Figure 3 shows average daily consumption per customer. Due to the data collection methods, the data for Kaluza and ev.energy refer to EV demand only, whereas, the data for Octopus Energy refers to household load.

**Figure 3** Average daily consumption per customer (EV only for Kaluza and ev.energy, household included for Octopus energy)



## 4. Time of Use DUoS trial





## 4.1. Market Design

### 4.1.1. Product overview

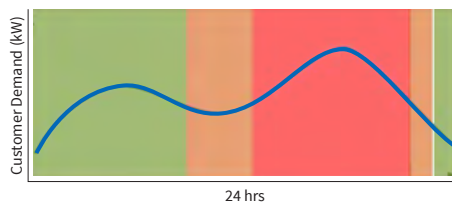
This product is based on exposing suppliers to a ToU DUoS price signal, such that customers have access to network capacity that is subject to peak/off-peak price bands at different time windows in a day. In this trial, the Time of Use pricing is tested at the supplier level, rather than at the individual consumer level – that is, the time-varying costs are exposed to the supplier, with trial customers remaining on their original tariff.

In the Kaluza trial, the arrangement being tested is that the DNO would publish a static peak pricing shape. This would be similar to the way DUoS charges are currently published but at a more granular level. The objective of this mechanism is to incentivise service providers to shift demand away from the peak price bands of the ToU DUoS signal.

In the design of this mechanism the static price shape used sought to better reflect LV network constraints. This ToU DUoS signal would then be aggregated with other costs of electricity supply such as TNUoS and wholesale prices, to create a price signal reflective of both the cost to supply and the local network conditions. Against these aggregated price signals, the service provider would seek to optimise EV charging schedules for its customers, while meeting their mobility needs.

Figure 4 shows a typical demand profile against indicative ToU DUoS price bands, where the red areas refer to times of peak network constraints and green areas refer to times when the network is unconstrained, with the amber areas highlighting the shoulder periods in between.

**Figure 4** Indicative ToU DUoS pricing



### 4.1.2. Product design

The trial's aim is to test different shapes for a ToU signal that could better reflect LV constraints and their impact on the reduction of peak demand from EV charging. The outcomes of the trial were intended to inform Ofgem's Significant Code Review (SCR) on Network Access and Forward-Looking Charges, and therefore the price signals were designed to be consistent with the direction of travel of this review.

A key potential risk of a ToU signal is that it might serve to coordinate EV charging, with multiple EVs beginning to charge at the end of the red band period, thus creating a secondary peak and exacerbating network constraints. To investigate potential mitigations to this risk, two variants of the price signal were designed with different shapes – one a simple red band (Group 1 in Figure 4) and one designed with 'shoulders' or amber bands either side of the central red band (Group 2).



The prices for the red peak band DUoS are based on those for the Eastern Power Networks (EPN - effective 1<sup>st</sup> April 2020); with the times adjusted to better align with times of peak demand at LV level. This is opposed to the existing red band DUoS, which is based on the probability of peaks occurring within the band at all voltage levels.

The shoulder pricing option introduces a high amber band rate on either side of the shifted red band. The red band charge is reduced so an equivalent cost is recovered through the high amber band (set according to the expected demand profile). These prices are shown in Table 2, as well as, in Figures 5 and 6, in combination with other price signals observed during the trial

**Table 2** Shift ToU DUoS Charges

DUoS Option		Red	High Amber	Amber	Green
Shifted LV peak red band	Monday to Friday	18:00 - 21:00		07:00 - 18:00 21:00 - 23:00	00:00 - 07:00 23:00 - 24:00
	Charge (p/kWh)	15.283		0.486	0.135
Shoulder pricing	Monday to Friday	18:00 - 21:00	16:00 - 18:00 21:00 - 23:00	07:00 - 16:00	00:00 - 07:00 23:00 - 24:00
	Charge (p/kWh)	8.842	5.204	0.486	0.135
All options	Saturday and Sunday				00:00 - 24:00
	Charge (p/kWh)				0.135

### 4.1.3. Implementation considerations

One advantage of a ToU DUoS signal as an approach to deliver smart charging is that it is similar to current charging methodologies. Suppliers are already exposed to DUoS charges, to cover the cost of using distribution networks to supply end customers, however these are applied at a licence area level. In a similar way, ToU DUoS charges could be deployed at a more granular level to reflect local network needs. However, whilst the price shape developed for this trial is reflective of a real-world constraint, the timing of constraints varies in different network locations. For this mechanism to be effective, the shape and size of the price signal may also need to vary in different locations, in order to incentivise flexibility when and where it is needed.

To achieve this, the DNO would need to have visibility of the shape of demand at individual substations, at the LV level of the network, and at present this data has a relatively low coverage across the LV network. In the near future this may become more feasible, with the roll-out of monitoring equipment, where it is economic to do so, and potentially through increased use of third party data.

DNOs would then need the ability to publish a variety of DUoS price shapes corresponding to different locations. To ensure that the correct charges are applied, suppliers would need to know the connectivity of their customers to the distribution network. Charging could then be optimised with respect to different price shapes for different customers, and central settlement able to relate individual customers to the specific price that relates to their location. Although the concept aligns to current DUoS charging methods, the complexity to the DNO and to suppliers increases with the granularity of the price signals. We will work with partners in the remaining stages of the trial to propose how such a mechanism could be technically implemented.



This approach also has the potential to lead to distributional impacts between customers – for instance with higher charges being applied to customers without electric vehicles, who may be unable to shift their demand from the red band period. In the remaining stages of the trial we will consider technical and regulatory mechanisms that could address these concerns.

Finally, there is a risk that the optimisation of a portfolio of EVs against a single ToU DUoS signal may lead to a synchronisation of charging. Whilst this is not likely to present an issue at small scales of EV penetration, the risk of secondary peaks presenting network issues will ultimately grow as the uptake of EVs rises. A key objective of this trial is therefore to establish the extent of this risk, and the impact of varying price shapes to mitigate the risk.

In the event that secondary peaks become an issue, a dynamic price might be considered, but implementing such a mechanism would require large scale technology change. Ofgem have been considering through their Access & Forward Looking Charging (A&FLC) Review alternative solutions to today's existing static DUoS price signal. This includes a dynamic ToU DUoS price signal, with a more locationally-granular price component. At the time of writing, Ofgem have not yet communicated a final decision for this charging review and aim to publish their minded-to decision in 2021.

## 4.2. Product delivery and customer adoption

### 4.2.1. Customer proposition

Kaluza offered a £50 incentive to their existing customers to sign up to the Shift trial. The invitation encouraged customers to sign up to help them understand how they can better help protect the electricity network. This was combined with the customers' original smart charging incentive which was received upon first signing up to the Kaluza product which included free or discounted chargepoints, and for customers on a dual-rate tariff – a saving on their electricity bill (depending on the tariff).

The customer can enter their mobility needs into the app whenever they like. This includes their charging ready-by time schedule (i.e. I need my car to be ready and fully charged by 7am), their tariff (i.e. off-peak, or peak times), and their EV's charging needs (i.e. battery capacity). The Kaluza algorithm uses these customer charging needs, together with the trial's price signal to optimise the EV portfolio consumption.

Customers using optimisation apps to set smart charging preferences can override scheduled charging events, also known as boosting. This can be done via the platform provider's app or on the physical charge point. When a session is overridden, the EV will charge at the maximum rate until the battery is full or the customer stops the session.

### 4.2.2. Charging Optimisation

The control approach was third party managed (fully automated) and included an override option. The Kaluza platform itself, runs a fully automated algorithm that manages customer charging on a minute-by-minute basis against a combined price signal.

**Table 3** Optimisation Data for Kaluza Trial

Automated optimised charging	Yes
Optimisation granularity	Minute-by-minute
Charging session data collected	Yes
HH household meter data collected	No

The average price signal is shown in Figure 5 and Figure 6 for the two different ToU DUoS profiles included in the trial.

#### 4.2.3. Recruitment

Kaluza originally targeted 368 customers, with 311 customers accepting the trial. They passed the minimum threshold of 300 customers on the 14<sup>th</sup> of January 2020 and of the 311 trial customers, 228 were located across UK Power Networks'. Of the customers, 155 were exposed to the red peak DUoS price (Group 1) and 156 were exposed to the shoulder pricing DUoS (Group 2).

#### 4.2.4. Overview of trial customers

Kaluza undertook a customer survey amongst their trial customers to better understand their motivations to smart charge, perceptions of smart charging and the drivers of customer behaviour. The research included 122 survey responses, representing 39% of the customers enrolled in the Shift Trial, with surveys collected between 21<sup>st</sup> August and 22<sup>nd</sup> September 2020.

Across these four categories, the survey results revealed the following key insights across the Shift trialists surveyed:

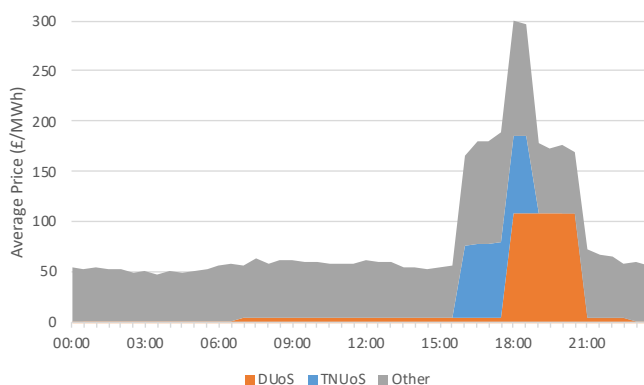
- Motivations to smart charge: customers were primarily driven by cost savings (43%) and secondly by environmental reasons (34%).
- Perceptions of smart charging: 70% of responses were deemed to understand the core functionalities of the smart charging algorithm; 76% of customers understood how the 'boost' function worked; 78% of customers were able to correctly identify times of peak grid constraint.
- Drivers of customer behaviour: most customers surveyed rely on home charging - it is a necessity, not a luxury. For 96% of respondents, their EV is the car they use the most, 84% fully rely on their EV for transport, and 78% almost always charge at home.

Table 4 provides an overview of the customers involved in the trial.

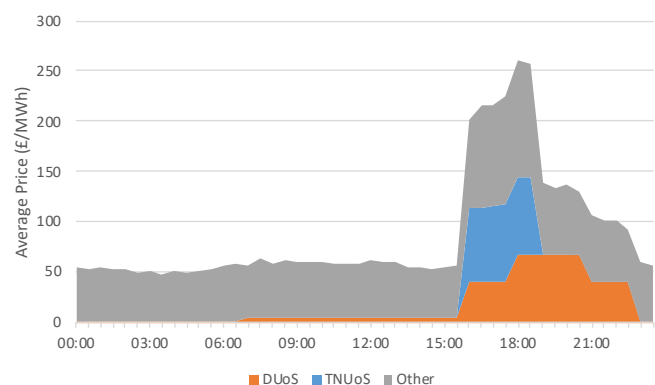
**Table 4** Customer characteristics from the Kaluza trial

Tariff type	163 single rate 74 multi-rate 74 unknown
Vehicle type	59% BEV 41% PHEV
Average EV battery capacity	38 kWh
Charging point rating	7 kW for BEV 3.6 kW for PHEV

**Figure 5** Average weekday price for Kaluza Red Peak DUoS trial (16/11/2019 - 11/05/2020)



**Figure 6** Average weekday price for Kaluza Shoulder Pricing DUoS trial (16/11/2019 - 11/05/2020)





## 4.3. Results

### 4.3.1. Charging behaviour

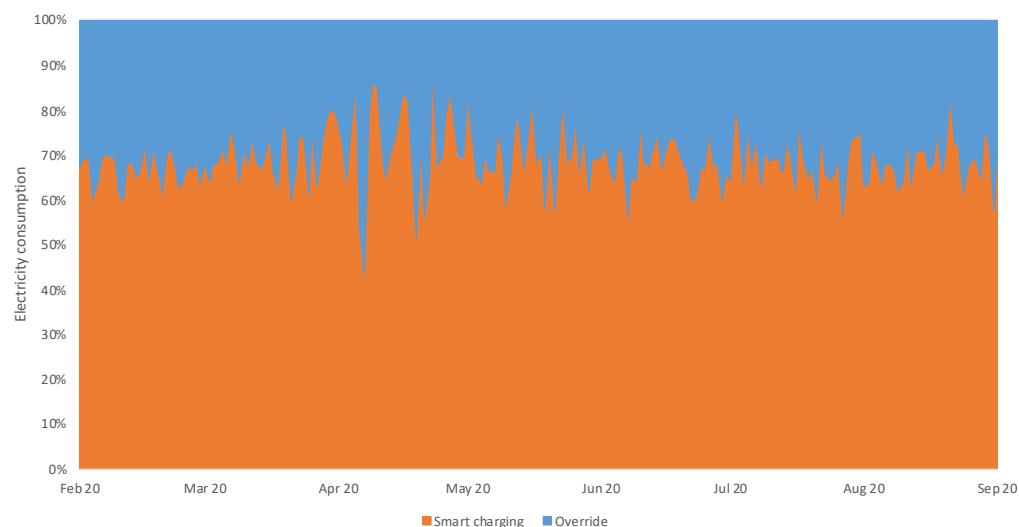
As of the 20<sup>th</sup> October 2020, the Kaluza ToU DUoS trial has been in operation for 11 months. Over this period, the trial delivered 384 MWh of energy, of which 56% (215 MWh) was shifted, and delivered a total of 6.2 tonnes of CO<sub>2</sub> savings<sup>5</sup>. Over the duration of the trial, no customers dropped out, although 35 devices remained offline for extended periods of time. These were offline as a result of the customer choosing to operate their charger as a “dumb”, unmanaged charger. Table 5 provides an overview of customer charging session characteristics.

**Table 5** Charging session data from the Kaluza trial (06/02/20 - 20/10/20)

Most common plug-in time	17:30
Most common plug-out time	07:30
Average duration of plug-in time	17.8 h
Average duration of charging session	3.4 h
Average consumption per charging session	11.2 kWh
Average weekly consumption per EV	36.5 kWh
Average number of charging sessions per week	3.3

Early analysis within the Kaluza trial has shown on average 31% of energy was consumed in override mode. Daily fluctuations in total hours boosted have been observed in Figure 7, although there is no clear correlation to a particular day in the week. Similarly, early insights have shown that, to date, there has been no clear correlation between the extent of customer overriding and the vehicle type (BEV/PHEV) or battery size.

**Figure 7** Daily variation in smart charging override across Kaluza the red peak and shoulder pricing trial customers (07/02/20 – 26/09/20)



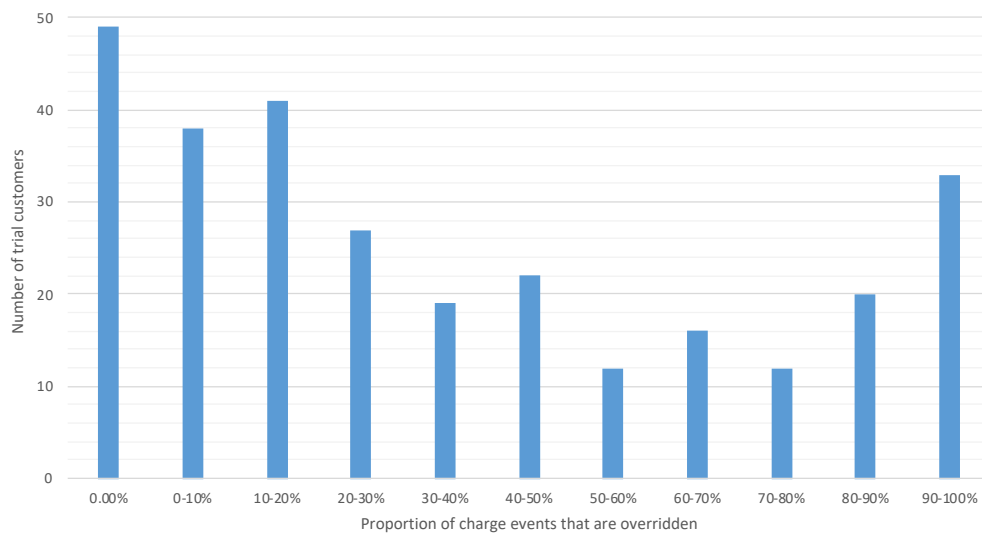
<sup>5</sup> CO<sub>2</sub> savings are calculated based on the carbon intensity of the grid (in g CO<sub>2</sub>/kWh), as reported by NG ESO, the University of Oxford, Environmental Defense Fund Europe, and the WWF. The carbon savings created per charging session are calculated from the difference in carbon emissions of the optimised smart charging profile, and the baseline unmanaged profile



The distributions in Figure 8 illustrates how not all customers override charging sessions to the same extent – a small minority use this function most times they plug in to charge, whilst the majority have done so less frequently.

In addition to this analysis, Kaluza's Shift trial customer survey investigated what was driving customer overriding behaviour. This found that 66% of customers chose to override only when their EV needed to charge ahead of schedule, whilst 31% override even if their EV is not needed right away. Factors that a flexibility provider can impact were present in 33% of responses (such as product teething issues, customer education, or improving features). This suggests that the number of customer overrides could fall over time, as intelligent charging features and customer propositions evolve.

**Figure 8** Distribution of charging events that are overridden, across the Kaluza trial customers (07/02/20 - 22/03/20)



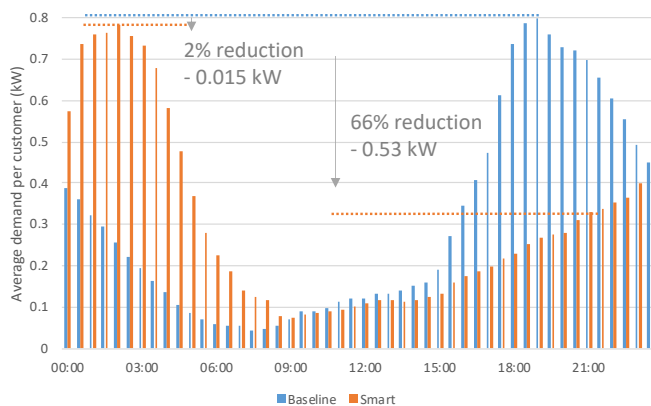
### 4.3.2. Level of response

The demand reduction at peak time was determined by comparing the peak EV demand between the baseline and smart profiles between 6 - 9pm. The impact on peak EV demand was compared between the unmanaged baseline and the smart profiles.

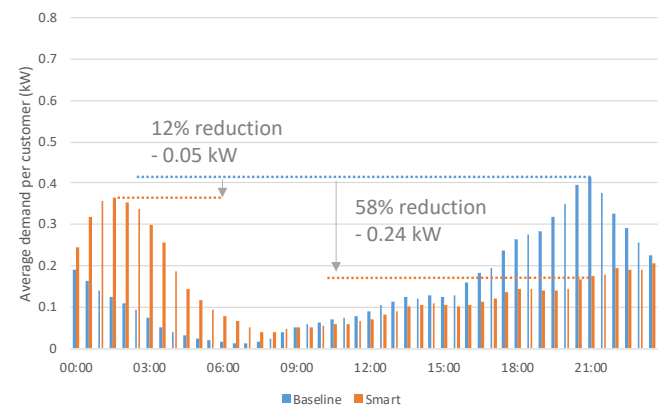
The Kaluza baseline was calculated retrospectively from the total energy delivered during the charging session, the recorded plug-in time and charger power to determine the demand profile if the energy was delivered at full power from the plug-in time.

Figures 9 - 12 compare the baseline (unmanaged EV charging) and managed charging profiles for each average device per average 24-hour period. The data is shown separately for both groups of the trial (Group 1 Red peak, Group 2 Shoulder peak), and over two distinct timeframes; pre-COVID restrictions (winter) and during COVID restrictions (spring - autumn).

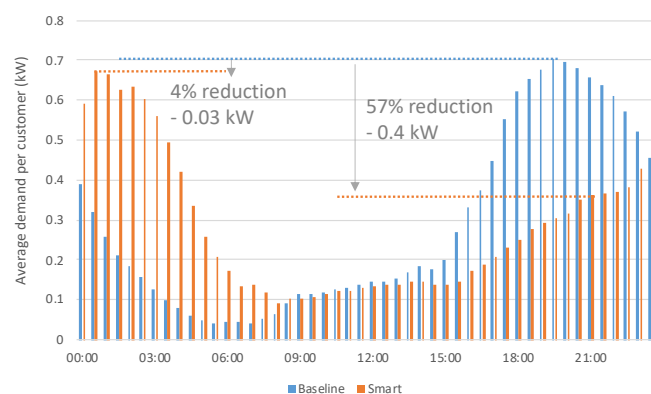
**Figure 9** Group One (Red Peak): Average baseline demand and smart EV charging demand pre-COVID (09/12/19 - 22/03/20)



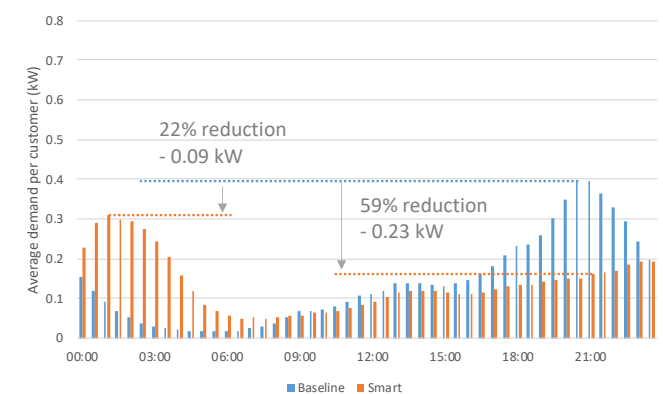
**Figure 10** Group One (Red Peak): Average baseline and smart EV charging demand during COVID restrictions (23/03/20 - 06/09/20)



**Figure 11** Group Two (Shoulder Pricing): Average baseline and smart EV charging demand pre-COVID (09/12/19 - 22/03/20)



**Figure 12** Group Two (Shoulder pricing): Average baseline and smart EV charging demand during COVID restrictions (23/03/20 - 06/09/20)

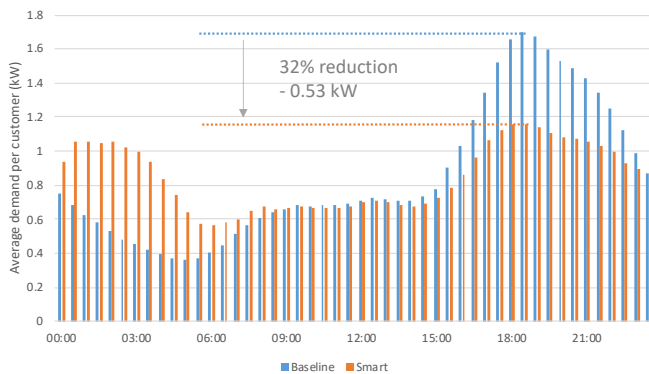


A reasonable amount of demand was shifted from peak time to the overnight period. Demand which was not shifted resulted from overridden charging sessions or charging which was required to meet the customers ready-by-time. Due to the level of demand which was not shifted, overall charging diversity increased across both groups.

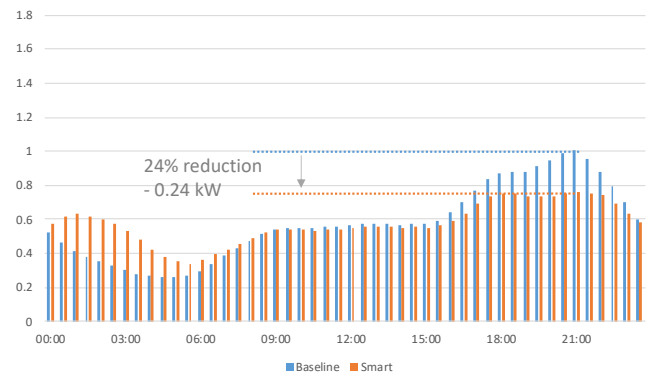
The level of demand reduction over the peak period was similar across both groups, despite the different DUOS signal. This is likely because of the interaction with the wholesale price and TNUOS which are generally higher over the LV peak period and will be explored further.

Figures 13 - 16 illustrate that the average total household load profile (house load + EV load) in both the baseline unmanaged EV scenario, and the managed charging scenario, for each average device per average 24-hour period. The data is shown separately for both groups of the trial (Group 1 Red peak, Group 2 Shoulder peak), with the data presented for two distinct timeframes – pre-COVID restrictions and during COVID restrictions. The household load profiles are based on the Elexon PC1 profiles; winter for pre-COVID and an average of the spring/autumn profile for during COVID restrictions.

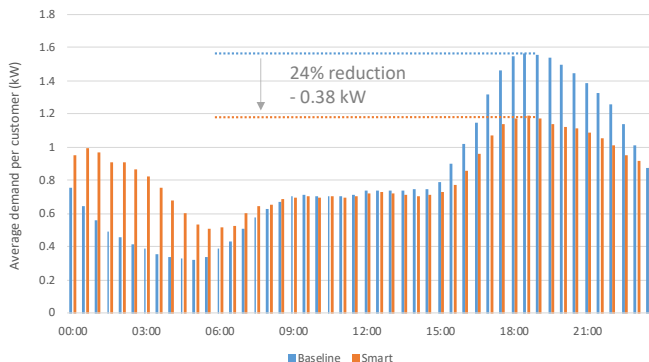
**Figure 13** Group One (Red Peak): Average baseline and smart EV charging demand pre-COVID restrictions combined with typical winter household demand (09/12/19 - 22/03/20)



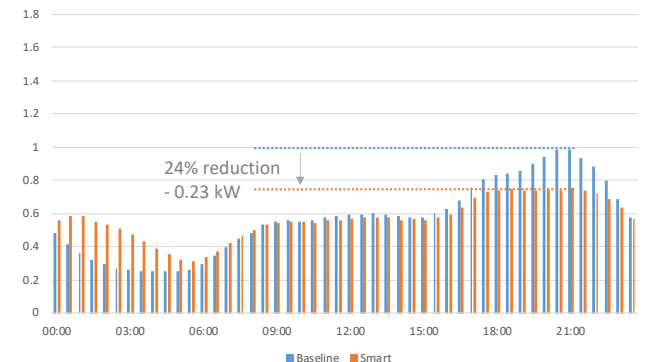
**Figure 14** Group One (Red Peak): Average baseline and smart EV charging demand during COVID restrictions combined with typical spring/autumn household demand (23/03/20 - 06/09/20)



**Figure 15** Group Two (Shoulder Pricing): Average baseline and smart EV charging demand pre-COVID restrictions combined with typical winter household demand (09/12/19 - 22/03/20)



**Figure 16** Group Two (Shoulder Pricing): Average baseline and smart EV charging demand during COVID restrictions combined with typical spring/autumn household demand (23/03/20 - 06/09/20)





On average, the effect at household level is a reduction of 24 - 26% in peak demand across the overall profile. The secondary peak is marginally higher than the evening peak pre-COVID and lower than the evening peak since COVID.

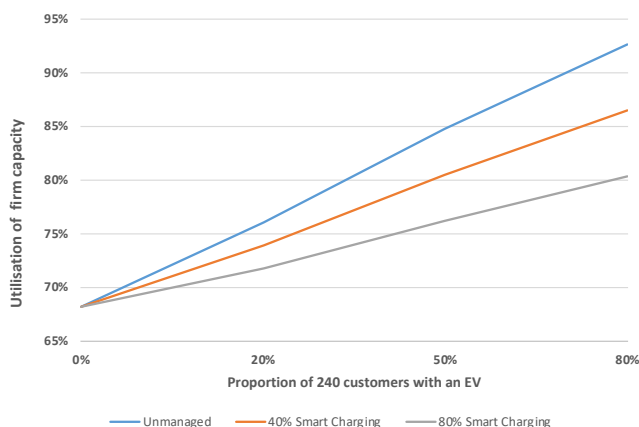
To illustrate the impact of smart charging at LV substation level, we added the average EV demand observed through the trial to the average winter demand measured through LV monitoring. To reflect the level of EV uptake, demand was applied to different proportions of customers supplied by the substation. At each level of EV uptake, we also assessed the impact of varying degrees of smart charging adoption by using a blend of unmanaged and smart charging demand profiles. Figures 17 and 18 show the peak demand in each of the scenarios above as a proportion of the firm substation capacity.

This analysis was carried out on two residential LV substations with different underlying demand profiles. This was done to highlight the impact of location specific factors such as baseload profiles and capacity on the value of smart charging to the network at LV substation level.

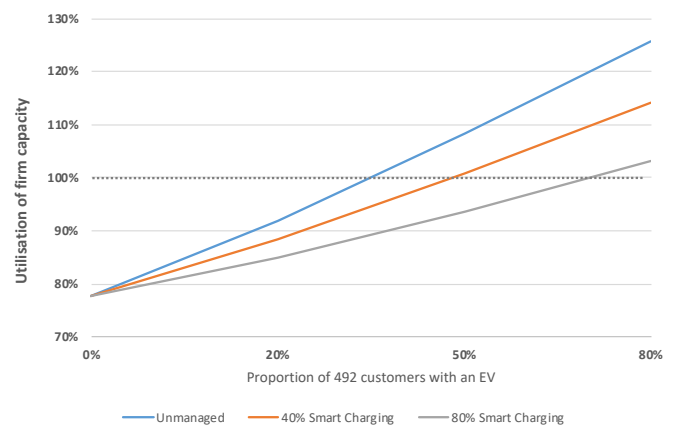
Due to the marginal difference between the secondary peak and the evening peak in the smart charging scenario, the secondary peak does not become the main driver of constraints on the LV substations assessed until very high levels of EV uptake and adoption of smart charging propositions occurs. This is particularly highlighted when considering the total household load, where the smart charging secondary peak fills the trough created by low household demand.

An important consideration in these analyses is the impact of customer overrides. As discussed in Figure 7, the presence of customer overrides has led to increased diversity relative to unmanaged charging. However, it is expected that with a reduced number of customer overrides, the ToU DUoS mechanism could elicit a stronger response and reduce charging diversity. One factor which could impact overriding is financial incentives – for example, in the Kaluza trial many customers were not exposed to ongoing financial incentives to smart charge, as they were on single rate tariffs. A change in tariff or proposition could incentivise more smart charging behaviour.

**Figure 17** Modelled utilisation of firm capacity at Glengall Road Substation (0.5MVA, 240 customers) at different levels of Kaluza smart charging (Kaluza response)



**Figure 18** Modelled utilisation of firm capacity at Park Parade Willows Substation (0.5MVA, 492 customers) at different levels of Kaluza smart charging (Kaluza response)



## 5. Capacity Based DUoS Pricing Trial





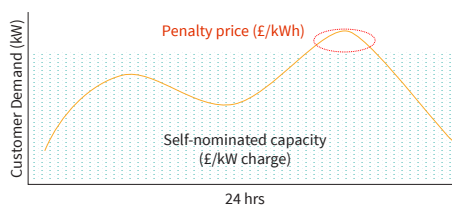
## 5.1. Market Design

### 5.1.1. Product overview

This product is based on payment for access to network capacity, with suppliers charged for the total aggregate maximum demand for their customers (kW), rather than via a volumetric charge. The primary objective of a capacity-based price signal is to incentivise service providers to spread load throughout the day, thus ‘flattening’ the demand curve, rather than simply shifting it to another time band as per the ToU DUoS signal.

In the conceptual design of this mechanism, suppliers would be required to book a nominated capacity level for their customers, with a charge per kW, and would be subject to additional peak pricing for any volume of demand that breaches the booked capacity level, as illustrated below.

**Figure 19** Indicative view of capacity-based pricing mechanism



### 5.1.2. Product design

For the trial, the nominated capacity price has been calculated to determine the capacity price that recovers the same net revenue per customer group as the existing DUoS charges, based on the LV Network Domestic tariff for the EPN region. This tariff is used for consistency with the ToU DUoS pricing mechanism, which is also based on recovering the costs under this tariff.

The capacity price assumes that if suppliers take a risk-averse approach and book the maximum capacity per customer, aggregated for their group of customers (i.e. the ADMD per customer) then the DNO will still recover the same costs as under the current charging regime. However, if the supplier can reduce the capacity booking with minimal usage in the penalty zone then they can reduce their DUoS bill.

The penalty price imposes additional costs on a supplier if the aggregate consumption of their customers rises above the booked capacity for that group of customers (for the trial, a group of customers is expected to be the supplier’s customers under a feeder). This is intended to incentivise a flattening of the supplier’s aggregate load profile for that group, and booking of a capacity level that is highly utilised, with minimum consumption above that booking.

In the trial design, prices for nominated capacity would be set regionally (i.e. per licence area), to reflect the long-run cost of reinforcement and follow a similar approach to the current DUoS regime. Penalty prices could then be varied locally to provide sharper signals in areas facing higher constraints.



Nominated capacity would be booked by suppliers for their customers at a local level (i.e. feeder level) and would therefore provide a valuable and granular forward view of capacity requirements to the DNO. The service provider would be responsible for understanding their customer needs and coordinating EV charging in order to minimise its costs whilst delivering the customers' mobility needs.

The prices for the trial were determined based on EPN DUoS and are shown in Table 6.

**Table 6** Capacity-based trial prices

Nominated capacity price	71 £/kW
Penalty prices	2-40 £/kWh

### 5.1.3. Implementation considerations

A key challenge for this mechanism is that it would require an entirely new way of setting DUoS charges for customers, involving a two-way process between suppliers and the DNO. In setting up this trial we have attempted to determine an approach that is implementable, whilst gathering learning that will help to inform how practical this approach is.

To implement such a capacity booking regime at LV level, DNOs would need to share the connectivity of customers to the local network with suppliers and publish capacity and penalty prices at this level. Suppliers would need the ability to consume this data, and generate their optimal capacity nominations based on an understanding of the diversity they can create within the local customer groups. Changes to settlement would be required to settle based on applying a peak (kWh) price, once a capacity threshold is breached at an aggregate customer portfolio level on a given feeder, and would therefore require a new data flow to capture and provide visibility on the access levels nominated for each customer or portfolio.

In addition to technical challenges, a key implementation consideration for this mechanism from a regulatory perspective, is the impact of diversity. This leads to several challenges:

- 1 To recover the required revenue, the capacity price must be set based on an ADMD per customer, which will vary according to the number of customers and their typical energy consumption. This could lead to an additional implementation challenge if the nominated capacity price was required to also vary by LV feeder, adding to the data challenge in implementing this approach;
- 2 Setting a capacity price based on an ADMD per customer could also lead to winners and losers created by the way that customers are categorised, and as a result careful consideration is required as to how customers would be grouped;
- 3 Barriers to entry for suppliers might be created, driven by the fact that it will be easier for a supplier with a large number of customers on a feeder to offer lower prices, than one with fewer (or no) customers.

Ofgem have signalled in their Access & Charging review that they are not minded to take forward this mechanism in the near term. However, we will set out high level considerations for how this mechanism could be implemented and report on its effectiveness to further inform industry developments.



## 5.2. Product delivery and customer adoption

### 5.2.1. Customer proposition

Octopus Energy designed a new tariff (Octopus Go Faster) based on their Octopus Go EV tariff and offered it to their existing customers, marketed as a research project. Customers were offered £5 off their overall bill for each month that they participated in the trial. Octopus Energy continued to offer the Go Faster tariff to customers not involved in the trial without the £5 credit.

Octopus Energy customers selected both a duration for the reduced rate and a start time for that rate to apply to. Customers could select a start time of 20.30, 21.30, 22.30, 23.30 or 00.30 and a tariff choice of:

- 3-hour Go period at a reduced rate of 4.5p/kWh
- 4-hour Go period at a reduced rate of 5p/kWh
- 5-hour Go period at a reduced rate of 5.5p/kWh

During the trial, there were several periods with low wholesale energy prices over the summer and negative plunge prices for charging. This led to a number of customers moving between the Octopus Go Faster tariff being trialled and the Octopus' Agile Tariff to take advantage of the best offering. It is important to acknowledge that this switching is in part due to the current market context, which would be different under a capacity based pricing DUoS mechanism which incentivises smoothing of demand.

### 5.2.2. Charging Optimisation

The control approach was customer managed and therefore the level of automation was dependent on any devices that the customer chose to use, such as built in timers or a smart cable.

Table 7 provides an overview of the optimisation data used by Octopus Energy in their capacity based DUoS pricing trial:

**Table 7** Overview of data from Octopus Energy trial

Tariff type	HHS
Automated charging	Combination
Charging session data collected	No
HH household meter data collected	Yes

### 5.2.3. Recruitment

Octopus Energy targeted 565 customers, with 458 accepting the trial, reaching the 300 participant milestone on the 2nd February 2020. As at the 14th July 2020, 143 customers had moved to another tariff and therefore dropped out of the trial.

### 5.2.4. Overview of trial customers

Octopus Energy undertook a survey with their customers, receiving 194 responses. The majority of those surveyed (70%) were two driver households and 39% had solar PV installed at their home. The most common EVs were the Nissan Leaf and the Tesla Model 3 both representing 23% of those surveyed and a minimum of 95% had a full EV (opposed to a plug-in hybrid) with only 5% selecting 'other' when describing their EV (these could have been full EVs too).



Using electricity when it is cheapest was by far the most important reason for smart charging (69%), with 25% citing using electricity when it is cleanest to minimise the carbon intensity of running an EV and only 5% referring to using electricity when the local electricity network has capacity to minimise reinforcement works. Most charging appears to be undertaken at home, with 20% stating they only charge at home and 38% stating that they only charge away from home 1 - 2 times a month.

Table 8 provides an overview of the customers involved in the trial.

**Table 8** Customer characteristics from Octopus Energy trial (based on survey respondents)

Vehicle type	BEV 183 PHEV 0 Unknown 11
Average EV battery capacity	54kWh
Charging point rating	Various

## 5.3. Results

### 5.3.1. Customer behaviour

When asked the reason for selecting the 3, 4 or 5-hour version of the tariff, 50% of survey respondents on the trial referred to their car taking a long time to charge and therefore wanting the longest option available. The main reason for selecting a particular start time was due to the desire to use other household appliances during the Go Faster period (46%).

Of the survey respondents, 83% indicated that they moved the demand of other devices in addition to their EV to take advantage of low electricity rates. The most common devices were dishwashers and washing machines which were both noted by 61% of respondents. Just under half (49%) of respondents noted that this was mostly done manually. Further analytic techniques will be used alongside information from customer surveys to understand the impact of this.

When asked how they ensure that their car charges at the cheapest times, a large majority (81%) referred to manually scheduling their charging (45% manually schedule the same window for all charges and 36% manually schedule the best time for each charge). Only 12% referred to either their car's app or charger's app integrating automatically with their Octopus tariff.

After the trial had been running for several months, Octopus Energy reviewed the overall allocation across the portfolio of Shift customers and asked customers to accept new start times in order to flatten the demand profile across the trial customers. When asked whether they had any issues being moved to a different start time to the one requested, 46% stated they had no issues with this. However, 27% did not want to be moved and preferred the time they requested and 19% indicated this would be difficult, as they would need to change settings on devices and chargers.

Despite this, a large majority of those surveyed would be willing to try a more dynamic version of Go Faster, like Octopus' Agile tariff (76%) although this would depend on the frequency at which the start time would change. Circa 28% would be willing if the start changed once a month, 29% if it changed once a week and 19% if it was different every day.

### 5.3.2. Level of response

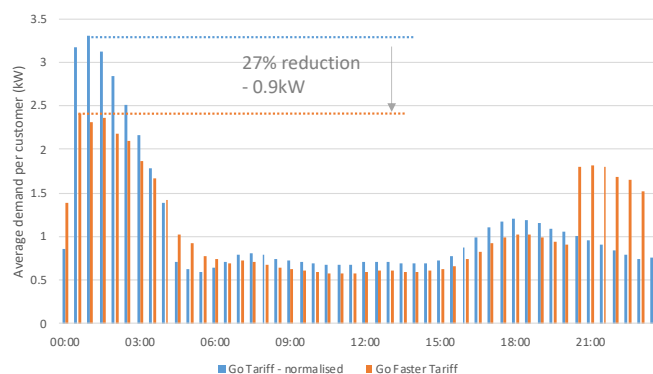
Smart meter data is collected for the Octopus Energy trial, which includes household load for the customers involved in the trial; therefore, this was used directly for the capacity-based trial analysis. As a result, the response includes flexibility from other household appliances or variation in household demand.

Figures 20 and 21 compare Shift customers on the Octopus Go Faster data with a baseline from the Octopus Go tariff. However, Octopus Go customers already have an incentive to move their demand.

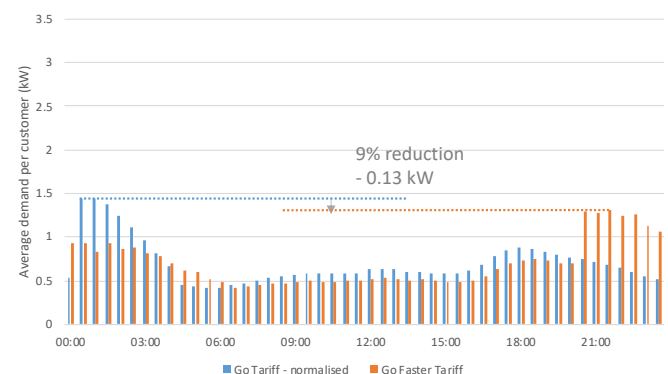
The Octopus Energy Go Faster data from the trial was also compared to a baseline profile from EV customers who do not have an incentive (unlike Octopus Agile or Octopus Go). This profile is based on the unmanaged demand profile from the Kaluza trial (average between both groups), together with the household load profile used for the Kaluza analysis in Figures 22 and 23. This total average household load has then been scaled up so that the energy consumption is the same as the Octopus Energy customers.

The level of response observed in comparison to the unmanaged baseline is positive during the evening peak prior to COVID-19. However, at average household level, the overall peak demand increases. During the summer/COVID period, the peak demand increased over the LV peak window, with a notable increase in demand at 8.30, which is the earliest and most popular tariff time. Further analysis will be done to assess the impact on the demand profile if tariff times were more evenly balanced and factors which would impact a customers' willingness to change start time.

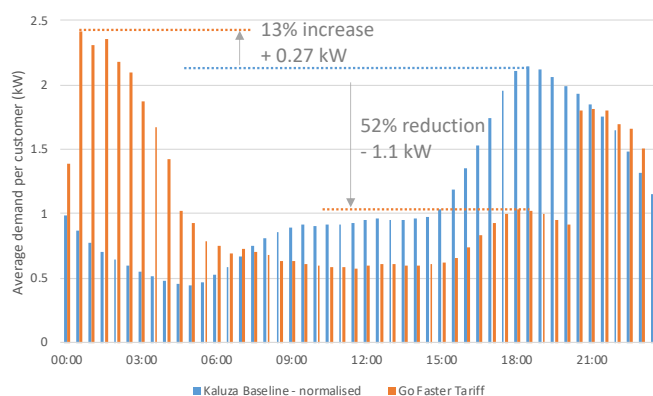
**Figure 20** Average Octopus Go Faster demand from the Shift trial compared with a baseline from the Octopus Go tariff pre-COVID (16/12/2020 - 22/03/2020)



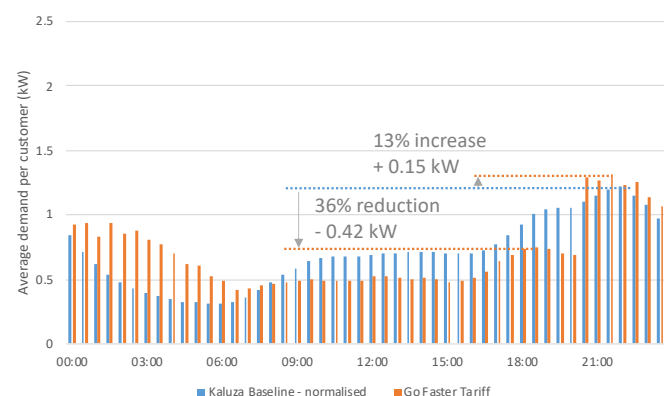
**Figure 21** Average Octopus Go Faster demand from the Shift trial compared with a baseline from the Octopus Go tariff during COVID restrictions (23/03/2020 - 06/09/2020)



**Figure 22** Average Octopus Go Faster demand from the Shift trial compared with scaled Kaluza baseline pre-COVID (16/12/2020 - 22/03/2020)



**Figure 23** Average Octopus Go Faster demand from the Shift trial compared with scaled Kaluza baseline during COVID restrictions (23/03/2020 - 06/09/2020)



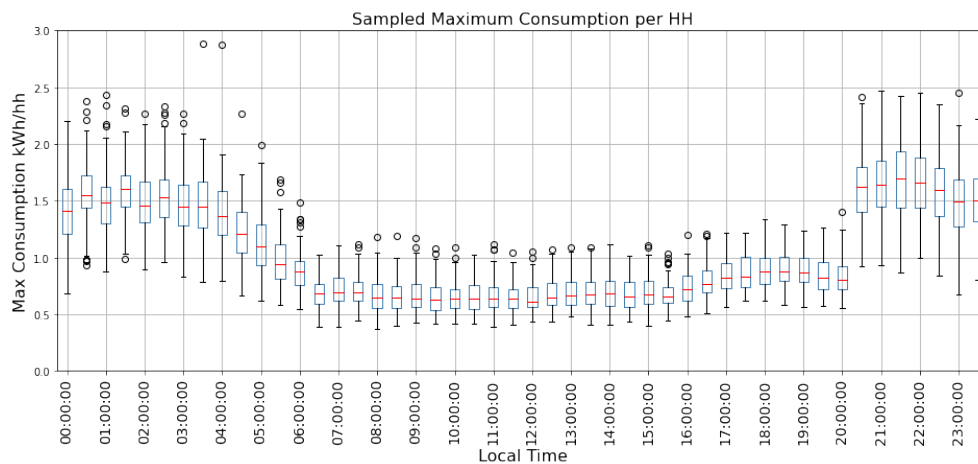


Whilst changes to the customer proposition may be able to improve the flattening effect across the overall profile, the ability to implement this practically at LV level needs to be considered. We have started exploring this by randomly sampling different size groups of customers to observe the impact on the demand profile at a more granular level, without further optimising which tariff start time or duration they have.

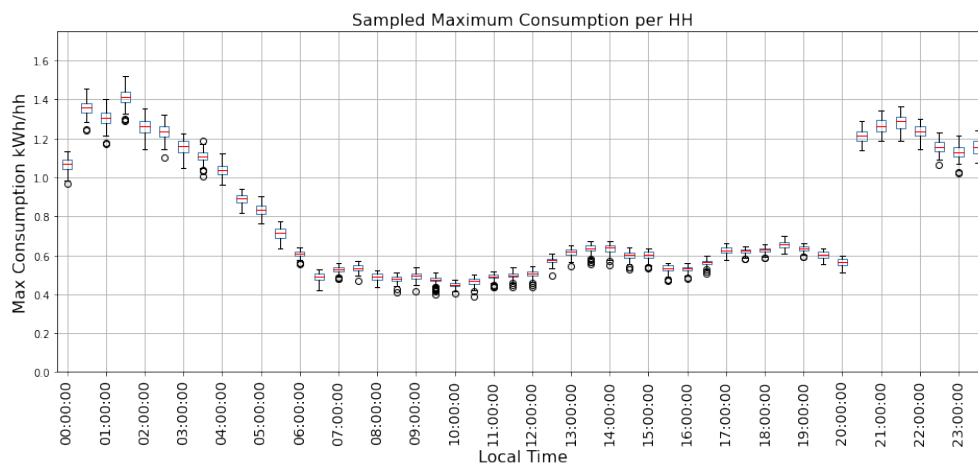
This analysis is shown for two different sized groups, 20 customers in Figure 24 and 150 customers in Figure 25. Trial data was randomly sampled to make up the customers in each group, assuming 100% EV uptake, and repeated 100 times. The maximum consumption in each half hour period was then plotted to show the level of variation and how this varied between the different size groups.

As the customer numbers increase, the maximum consumption in each half hour window converges due to the averaging effect over a larger pool of customers. As a result, it is easier to decrease the capacity booked per customer for higher customer numbers. If this mechanism was applied at granular levels, this could either result in suppliers overbooking capacity to account for the variation or being charged penalty prices due to spikes in demand over a group of customers. The practical implications of this need to be considered further to understand what solutions could be applied on less populated LV networks or for suppliers with fewer customers. This is required to ensure chargers remain fair, despite the lack of diversity that limits the ability to reduce capacity booked per customer if this methodology is applied at granular levels.

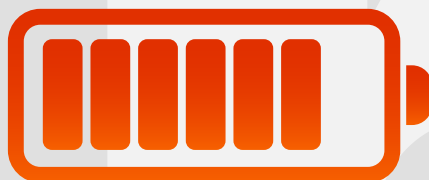
**Figure 24** Profile of maximum consumption for 20 customers (100 samples)



**Figure 25** Profile of maximum consumption for 150 customers (100 samples)



## 6. LV Flexibility Procurement trial





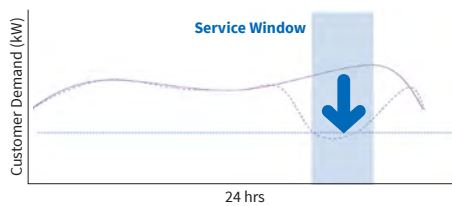
## 6.1. Market Design

### 6.1.1. Overview

As the transition to DSO progresses, more networks have been incorporating flexibility procurement into their operations. The LV flexibility product developed for Shift was developed in line with existing approaches for HV and EHV flexibility.

In this product design, ‘service windows’ are defined at times of the day that correspond to real network constraints, and within these windows the product requests that a service provider limit the aggregate load of their EVs to a pre-defined level, as illustrated in Figure 26.

**Figure 26** Illustrative flexibility procurement product



### 6.1.2. Product design

The value of the service per kW of turn-down response is defined by the avoided cost of reinforcing the network. Typically, this is set by calculating the cost of capital saving generated by deferring reinforcement for a defined number of years, and then dividing this by the number of kW required per year to defer the need for reinforcement.

The value of the service is therefore highly location-dependent, and driven by a number of factors specific to each substation and constraint, such as the expected costs of reinforcement for a given site and the number of hours per year the service is required for.

In the market, values are revealed through tenders, which establish the price at which a service provider can offer the service. If this offered price is less than the value of the service at that location, then this is an economic option for customers. If the offered price is higher, then reinforcement is the right option for customers.

The product design for this trial requests a ‘guaranteed load limit’ from the service provider in the service windows – i.e. the maximum demand level that a group of EVs can exhibit – with the service provider incentivised to manage customer load into other time periods.

The amount of load reduction provided is measured against a baseline determined by a ‘default load factor’, which is a diversity-adjusted level of charging per EV. This attempts to account for the fact that it is unlikely that all EVs in the service providers’ portfolio will be charging at the time of the service window, and that we would likely be over-rewarding the service provider if we assumed all EVs were plugged in and charging ahead of the window. This approach to baselining will be investigated during the trial.

### 6.1.3. Implementation considerations

A key advantage of this mechanism is that it is tried and tested, and similar to existing flexibility procurement products. The learning gathered from this trial has indeed already been used to secure our first flexibility contract at LV level from aggregated EVs.<sup>6</sup>

In the second stage of the trial we will set out our learnings and how we have incorporated them into our business-as-usual products.



## 6.2. Product delivery and customer adoption

### 6.2.1. Customer proposition

ev.energy are testing a range of propositions, including rewards for every 20 charging sessions and offers powered by partner energy suppliers. ev.energy offered a range of incentives to customers to sign up to the trial and were looking to incentivize customers around type of use rather than time of use (e.g. plug in more often for longer periods) to increase the amount of flexibility available.

The control approach was third party managed where customers who signed up to the smart agreement allowed ev.energy to manage their charging, although an override option was available to the customer. ev.energy then automate the load of their customers within the service window and optimise their usage against other market services, cost and carbon intensity of electricity.

The choice of incentives available to customers on the trial has received great feedback and these incentives have correlated to higher levels of smart charging.

By having a rewards scheme ev.energy have been able to get flat rate users to engage in smart charging as they now have an incentive to charge this way.

Since introducing the choice of smart charging rewards in April 2020, most customers have opted for financial incentives over green credentials, the most popular are Amazon vouchers (80%), coffee vouchers (12%) and carbon credits (8%).

### 6.2.2. Charging Optimisation

Table 9 provides an overview of the optimisation data used by Octopus Energy in their capacity based DUoS pricing trial:

**Table 9** Overview of data from ev.energy trial

Automated optimised charging	All customers
Optimisation granularity	Half hourly
Charging session data collected	Yes
HH household meter data collected	No



### 6.2.3. Recruitment

ev.energy targeted 3,264 customers as part of the trial, these customers were targeted through an initial email campaign, with continuous recruitment via the smart charging rewards page in the app. By Q2 2020, 445 customers were recruited, with a further 269 customers starting the trial since then, bringing the total number of trial customers to 714. Of this, approximately 30% fall within the UK Power Networks.

As the customer proposition for ev.energy is based on the number of smart charging sessions, the customer rewards were sufficient to accommodate a greater number of customers. This was in part due to the decreased number of charging sessions due to the COVID-19 lockdown measures and changes in customer behaviour. The number of customers and point at which they joined the trial will be considered in the analysis.

### 6.2.4. Overview of trial customers

Table 10 provides an overview of the customers involved in the trial:

**Table 10** Customer characteristics from ev.energy trial

Tariff type	41% ToU 11% on a dynamic tariff 48% on a flat rate tariff
Vehicle type	410 BEVs (92.1%) 35 PHEVs (7.9%)
Average EV battery capacity	ww 55 kWh
Charging point rating	7.2 kW

## 6.3. Results

### 6.3.1. Charging behaviour

So far in the trial, ev.energy have managed over 48,000 charging sessions, delivering 900,000 kWh of smart energy and saving more than 20 tonnes of CO<sub>2</sub> emissions<sup>7</sup>. Over the course of the trial 45 users have stopped smart charging. The main reason for this was their charger point dropping offline.

Table 11 provides an overview of customer charging session characteristics.

**Table 11** Charging session data from the ev.energy trial (06/02/2020 - 20/10/2020)

Most common plug-in time	18:00
Most common plug-out time	08:00
Average duration of plug-in time	14 h
Average duration of charging session	~1-3h
Average consumption per charging session	18 kWh
Average weekly consumption per EV	59 kWh
Average number of charging sessions per week	3

Customers using optimisation apps to set smart charging preferences can override scheduled charging events, also known as boosting. This can be done via the platform provider's app or on the physical charge point. When a session is overridden, the EV will charge at the maximum rate until the battery is full or the customer stops the session.

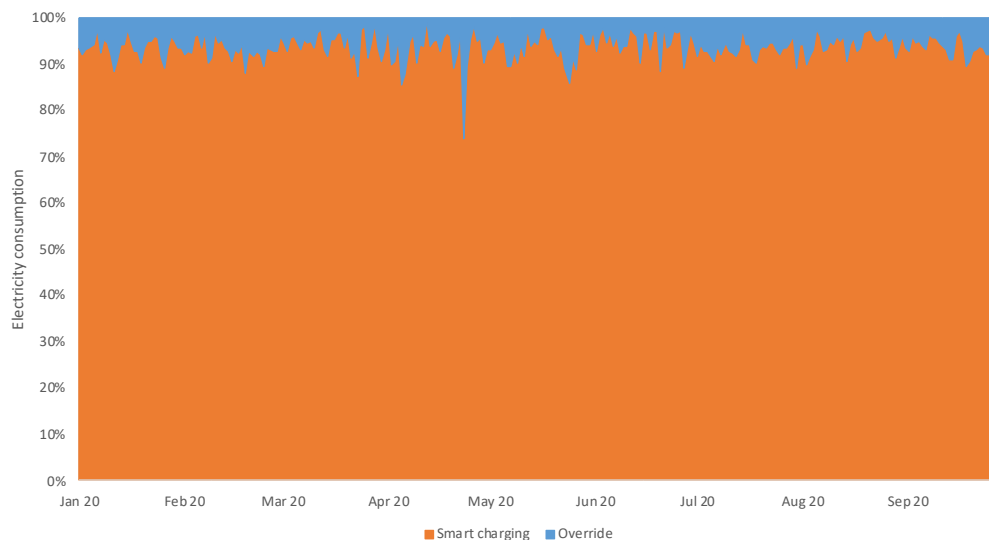
<sup>7</sup>

Emissions are calculated based on the national grid data on emissions associated with generation in a given UK GSP Group at a given time. Carbon savings are calculated as the difference between: the grid carbon intensity at the time the car would have charged if there was no smart charging intervention, and when the car did charge as instructed by ev.energy



Figure 27 below shows the percentage of energy use for EV charging per day, where a via the smart charging function compared to the customer overriding. On average, overriding accounted for 6% of energy.

**Figure 27** Daily variation in ev.energy smart charging hours overridden (06/02/20 - 20/10/20)



### 6.3.2. Level of response

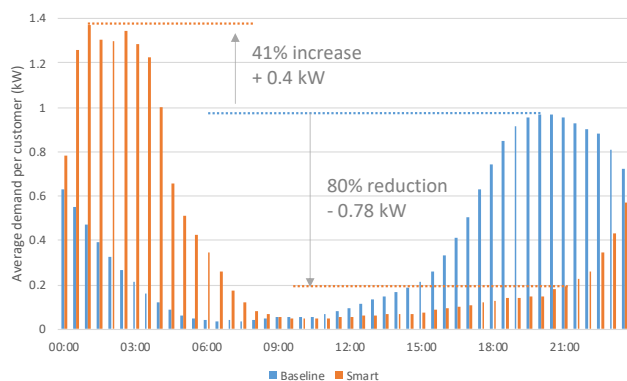
The demand reduction at peak time was determined by comparing the peak EV demand between the baseline and smart profiles between 6 - 9pm. The impact on peak EV demand was compared between the unmanaged baseline and the smart profiles.

The ev.energy baseline was calculated retrospectively from the total energy delivered during the charging session, the recorded plug-in time and charger power to determine the demand profile if the energy was delivered at full power from the plug-in time.

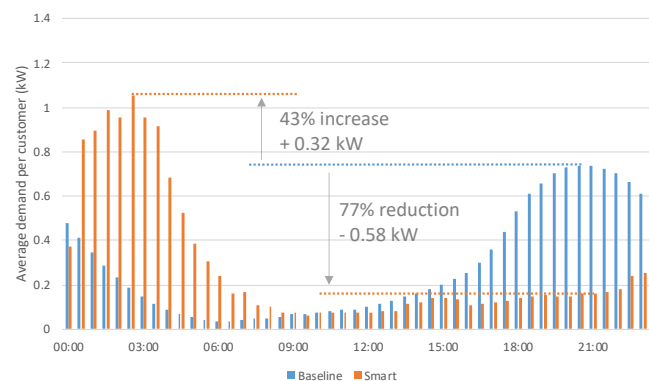
Figures 28 and 29 compare the baseline (unmanaged EV charging) and average managed charging profiles for each device per average 24-hour period. The data is presented for two distinct timeframes – pre-COVID restrictions and during COVID restrictions.

On average, the EV demand was significantly reduced over the LV peak period. However, the strong response, paired with optimised charging, resulted in less diversity between charging sessions as shown by the secondary peak which exceeds the unmanaged charging demand. The impact of this was greater during the summer/COVID period as a proportion but lower overall than in the winter period.

**Figure 28** Average ev.energy baseline and smart EV charging demand pre-COVID restrictions (01/01/20 - 22/03/20)



**Figure 29** Average ev.energy baseline and smart EV charging demand during COVID restrictions (23/03/20 - 06/09/20)



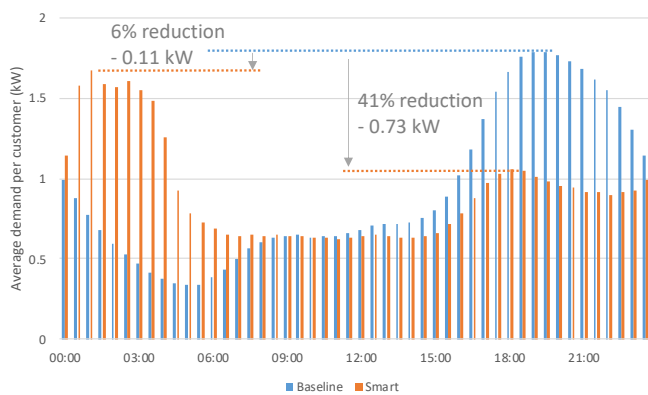


When considered alongside a typical household load profile (profile class 1), the impact of the secondary peak was reduced due to low household load during the overnight period where the EV charging demand was shifted. However, the secondary peak was still relatively similar to the unmanaged peak at individual household level.

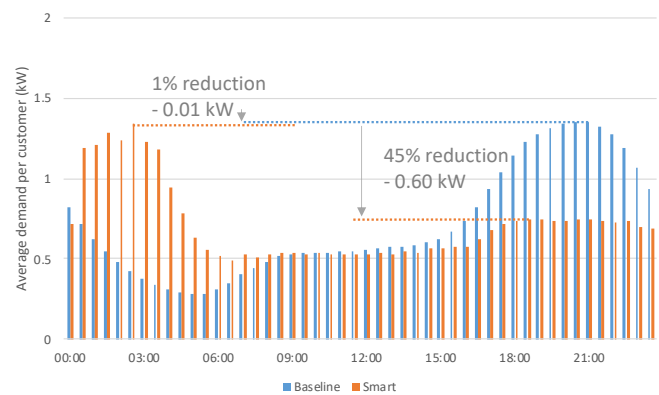
Figures 32 and 33 show the effectiveness of the smart charging response observed in the ev.energy trial at varying levels of EV uptake (% of households with an EV on the substation). It also shows how the proportion of customers who are signed up to the ev.energy smart charging proposition would impact the effectiveness of the response.

The crossing over between the 40% and 80% smart charging curves is a result of the secondary peak. This illustrates that shifting EV demand in the same way beyond this point does not deliver more value to the network. This reinforces the need to monitor demand over time and ensure network price signals are adjusted to reflect network conditions as they change.

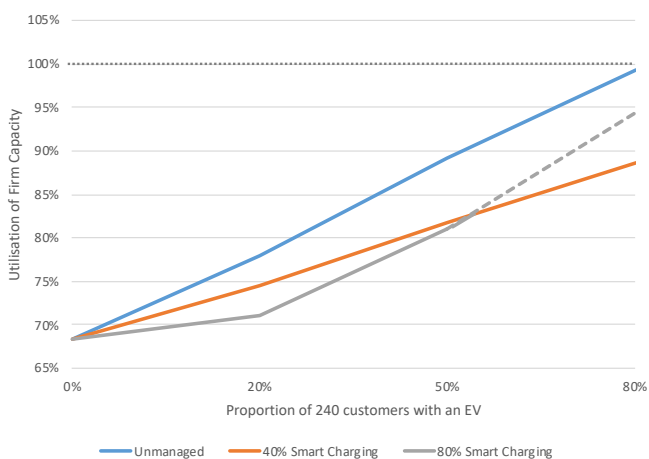
**Figure 30** Average ev.energy baseline and smart EV charging demand pre-COVID restrictions combined with typical winter household demand (01/01/20 - 22/03/20)



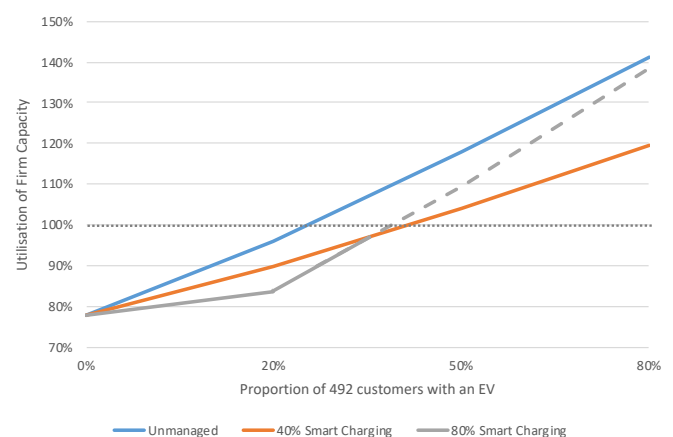
**Figure 31** Average ev.energy baseline and smart EV charging demand during COVID restrictions combined with typical spring/autumn household demand (23/03/20 - 06/09/20)



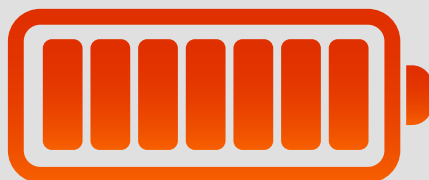
**Figure 32** Modelled utilisation of firm capacity at Glengall Road Substation (0.5MVA, 240 customers) at different levels of ev.energy smart charging



**Figure 33** Modelled utilisation of firm capacity at Park Parade Willows Substation (0.5MVA, 492 customers) at different levels of ev.energy smart charging



## 7. Early insights and next steps





## Early insights and next steps

### 7.1. Market Design

#### Early insights

Through the design of the commercial mechanisms, and subsequent discussions with trials partners, we have learned about the potential benefits of each mechanism, as well as the technical and regulatory challenges that would be associated with implementing them.

An advantage of LV flexibility procurement is that it can be targeted, both in terms of the specific locations in which it can be applied, and the value that can be attributed to any given constraint. It also provides certainty, as the provider is contracted to deliver a response. Given similarities to existing approaches that are in use today, it is perhaps the easiest to put into practice in the short term.

Indeed, the development of the LV Flexibility Procurement product for Shift has allowed us to accelerate the implementation of a business as usual product, and in June 2020 we became the first DNO in the UK to award flexibility contracts to an electric vehicle smart charging provider, and the first network in the world to contract flexibility on the LV network.

Whilst the flexibility procurement product can be more targeted at specific locations, running individual procurement processes extensively at LV may have practical limitations. Participating in tenders has associated administrative costs to networks and service providers and value can only generated by customers located in constrained zones.

Price mechanisms, such as ToU DUoS and capacity based DuoS pricing, are accessible to all customers, and not dependent on a customer being located under a specific constraint, as with flexibility procurement. However, the granularity prices are set at and the need for visibility of the LV network to facilitate this must be considered.

Whilst static ToU DUoS is familiar to market participants at a DNO level, generating price shapes reflective of constraints at LV substations in the same way would be more complex. This is due to the volume of secondary substations (>80,000) and different price signals which suppliers would need to consume along with the connectivity of customers to these networks. Alternatively, prices could be set based on network archetypes, which would compromise cost reflectivity for fairer allocation of costs and more simple implementation.

The capacity-based pricing mechanism has the benefit (by design) of avoiding a time of use incentive on the third party, and encouraging a smoothing of demand, which would serve to manage the risk of secondary peaks – though this is yet to be demonstrated in the trial. Provision of capacity booking data to the DNO would provide a useful signal regarding the need and willingness to pay for more network capacity.

Capacity-based charging is a novel new approach, and so is not familiar to market participants. Whilst the capacity-based charge in theory provides a means to incentivise a smoothing of demand, to be effective on the LV network it may require a feeder-level capacity booking approach. This could be complex to administer in terms of setting prices at this level of granularity and the booking approach. New data flows would also be required to facilitate the settlement process. The mechanisms also favours a larger number of customers per feeder (or under management of any given provider) due to the diversity, allowing suppliers or service to providers to drive down the capacity booked per customer. To manage this adds complexities in capacity budgeting and allowances per provider that would need to be taken into account.

**Next steps**

Working with the trial partners we will further investigate the advantages and disadvantages of each mechanism, and put forward conclusions regarding how these mechanisms might play a role in incentivising market-led smart charging at scale. We will set out approaches through which the trials commercial mechanisms could be practically implemented, setting out enablers required, such as LV monitoring or access to smart meter data; identify limitations and consider the impacts on customers (accessibility, fairness and protecting customers in vulnerable situations).

## 7.2. Product delivery and customer adoption

**Early insights**

A key objective of the Shift trials is to understand the extent to which market participants are able to develop and deploy propositions that engage customers to participate in smart charging, and to do so in a way that mitigates impacts to the network. We received a good degree of interest from market participants looking to partner on the trials during the expression of interest.

Subsequently, the project partners have all successfully deployed smart charging propositions, and have done so based on their existing technology without significant further investment on behalf of either the participant nor the DNO. The range of approaches have been utilised with differing hardware requirements and employed a mix of fully automated and more manually scheduled approaches, implying differing levels of required customer engagement on a daily basis.

Furthermore, as can be seen in this interim report, these propositions have been able to attract customers (from within participants' existing customer base in some instances). However, due to challenges recruiting trial customers solely within the UK Power Networks area within the period required for the trial, this criterion was relaxed.

Overall, retention of customers to the trial was reasonable; however, a large number of customers on the Octopus Energy trial moved between the Go Faster and Agile tariff to take advantage of the best offering over the trial period. These are likely to be very energy savvy and engaged customers and this behaviour may not be representative. However, it highlighted the importance of considering the risk of customers switching when considering reliability of response.

These successes are an encouraging sign that market-led smart charging will be possible, subject to proving that the response provided is sufficiently sizable and consistent, and that the enabling mechanisms are scalable from a technical and regulatory perspective. Both the customer surveys and pre-trial customer research indicated environmental benefit and financial gain are the main motivation for smart charging.

It should be noted that each Shift trial uses one proposition (with small variations) under each mechanism. There are a number of ways in which customer propositions could be offered by market participants under each commercial mechanism, which can influence customer behaviour.

**Next steps**

The successful adoption of smart charging propositions is encouraging but more insight is needed to understand the behaviour of the customers involved in the trial. A high level of engagement might be expected at this stage, as many of the customers may be early adopters who are more prone to engaging than mass market customers.



In addition, further insight is required as to how the level of engagement changes over time and within different regulatory frameworks. For instance, the movement of Octopus Energy's trial customers between Octopus Go Faster and Octopus Agile, which may not be exhibited in a market setting where capacity based pricing is applied. We will consider this further in our assessment of how each mechanism would be implemented.

The attitudes and motivations of customers as part of the trial will be investigated further through analysis of customer surveys being conducted as part of the trial. We will also conduct further analysis and research into the role of automation in driving engagement and delivering a reliable smart charging response.

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## 7.3. Level of response

### 7.3.1. Charging behaviour

#### Early insights

The majority of customers on the trial have responded well in response to the incentives, which reflect realistic network constraints (in both the form and value of the incentive). As set out in sections 4, 5 and 6, each of the propositions and incentives have so far been able to elicit a useful smart charging response from customers.

The ev.energy trial produced the strongest response, of up to 80% reduction in EV demand over the system peak. This compared to between 57 - 60% reduction across the Kaluza trial, where the discrepancy in reduction is attributed to higher levels of customer overrides of smart charging sessions. For the Kaluza trial no substantial difference has been observed in the response of the two DUoS price shapes trialled. The level of overriding behaviour has been markedly different between the Kaluza and ev.energy trial which are both fully-automated, suggesting that the proposition design may be able to reduce overriding.

At a household level, each of the trials has observed a secondary peak in the overnight period, with two of the approaches reducing diversity of charging (i.e. leading to a higher overall household peak, but in the overnight period), and one increasing diversity (i.e. leading to a lower household peak).

Due to the impact of smart charging response on diversity, at high levels of EV uptake and participation in market-led smart charging, this behaviour could result in secondary peaks on the network. However, this is due to the strong response over the LV network peak (6-9pm) in response to price signals.

Secondary peaks are unlikely to create issues in areas with low EV penetration, as many residential LV networks have capacity at off-peak times to accommodate the shifted electric vehicle charging. This will change in the future as the penetration of electric vehicles (and other low carbon technologies such as heat pumps) change the load profile and increase demand, or when demand becomes sufficiently flexible that the underlying demand profile begins to change in response to price signals.

In the case of flexibility procurement, the mechanism was not designed to mitigate the risk of secondary peaks, but rather to elicit a targeted response is required to deal with sharp and localised peaks. In the case of the static ToU DUoS, a secondary peak was expected, and useful insight is being gained regarding the extent of that challenge.



The capacity-based price attempted to mitigate this secondary peak risk by design, and through the proposition design process with Octopus Energy, interesting insight was gained into the challenges designing such a tariff to apply to a single customer, which ultimately led to a customer proposition expressed as a ToU tariff. This has led to a sharper secondary peak when compared to the static ToU trial, which is in part due to the greater proportion of customers on the 20:30 start time. Octopus Energy have explored how to ‘nudge’ customers onto different time bands to attempt to smooth out the overall charging profile which will be assessed in more detail in the next phase of analysis.

The Octopus Trial demonstrated that customers were receptive to the concept of booking a time slot and that this successfully moved customer load. Further customer insight is required to better understand customer behaviour and how to make better use of availability across the entire day, through proposition development.

The survey of customers on the Octopus Energy trial indicated customers using manual scheduling are more reluctant to frequently change their schedule. Ensuring customers have access to devices with the ability to respond to timers/tariffs or third party signals will remove barriers to more dynamic propositions which people would be more willing to take up if they don’t have to make manual changes.

#### Next steps

Once a full dataset has been gained from each trial, we will conduct a full analysis of the delivered response, the reliability of response, and the factors described which affect this response. This will include a detailed assessment of:

- financial factors such as customer propositions and tariff type;
- physical factors such as car battery size and charge point rating; and
- behavioural factors such as charging habits, level of automation and customer views.

We will also review the detailed learnings that can be drawn regarding the design of the mechanisms. This will involve calculating settlement to understand the impact on cost recovery and customer bills, as well as investigating conflicts and synergies with wider system needs and price signals.

### 7.3.2. Impact on the LV network

#### Early insights

Insights gained to date from each of the mechanisms has helped to demonstrate that customers are prepared to shift their charging demand profiles. However, whilst we have aggregated results over a large number of customers, we do not have a clear view of how this impact might manifest at the lowest levels of the network – i.e. on an individual low voltage feeder. When viewed over a larger number of customers, the demand profile might be a smoother shape, whilst small sub-groups of those customers might be exhibiting a more coordinated peak demand that could impact local networks.

In addition, the benefit that smart charging could have in any given location will depend on a number of specific local factors, such as the local demand profile and capability of existing assets; the rate of demand growth (particularly in the number of electric vehicles or other low carbon technologies such as heat pumps); the local network asset ‘archetypes’ (e.g. urban/rural, overhead/underground, feeder length, transformer type, configurability of the local network, etc.); the number of customers on a feeder; and other local factors.



In order to recruit sufficient numbers of customers to enable statistically significant results, we did not restrict the trials partners to targeting recruitment in small areas, and instead, the customers participating in the trials are spread over a wide area. As a result, we were not able to explicitly demonstrate the aggregate effectiveness of these mechanisms on a specific low voltage network and instead this was done theoretically using LV monitoring data.

#### Next steps

Investigating the potential for a market-led approach to managing low-voltage level constraints is a key objective of Shift. To investigate this, we will conduct an analysis of data gathered through the trial to simulate the effect that each approach could have at the low voltage level. Trial data under a range of EV penetration and smart charging scenarios will be applied to data collected from LV monitoring sites across. This will build on the analysis carried out to date and assess the effectiveness in the mechanisms over a range of network archetypes.

Similar to EVs, electric heating has the potential to significantly change the demand profile of a household. As outlined in our Heat Strategy<sup>8</sup> we are investigating the impact and potential flexibility associated with electric heating. We will consider these insights when assessing the network impacts of smart charging in areas that may have higher adoption of electric heating. Whilst these findings will inform inputs to our internal investment tools, network-wide studies are out of the scope of this trial.

## 7.4. Moving smart charging forwards

Approximately 85% of the total cost of upgrading low voltage cables relates to digging up the street<sup>9</sup> and in areas, there may be a need there may be a need for networks to invest in infrastructure. However, flexibility is the first solution networks must look to in order to reduce investment and keep costs low to consumers and meet their customers' needs.

Through close collaboration with Kaluza, Octopus Energy and ev.energy, we have incentivised over 1,400 domestic customers to smart charge over the course of the trial. This has produced an extensive dataset, which coupled with customer research has generated new insights into the impact of price signals, customer behaviour, and the impact of this on the LV network. Shift will support the industry to understand how and when market-led smart charging can be deployed to optimise network capacity and unlock value to customers.

#### Contributions from our partners

We would like to recognise the valuable partnerships with Kaluza, ev.energy and Octopus Energy on the project and insights that collaboration with them has enabled. Their contributions to the project have enabled us to develop a richer understanding of market-led smart charging, and the motivations and perceptions of customers involved.

#### Share your feedback

As we approach the end of the trials, we are moving into the analysis phase where we will draw insights from the data and survey responses collected. We recognise the pace of change in the industry and want to build on the engagement during the trial development by providing an opportunity to inform our analysis. Let us know what sparked your interest or what you would like to see next at [innovation@ukpowernetworks.co.uk](mailto:innovation@ukpowernetworks.co.uk)

8 <https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2020/03/UK-Power-Networks-Heat-Strategy-11-March-2020.pdf>  
9 <https://www.theccc.org.uk/wp-content/uploads/2019/05/20200418-CCC-Accelerated-Electrification-final-report.pdf>