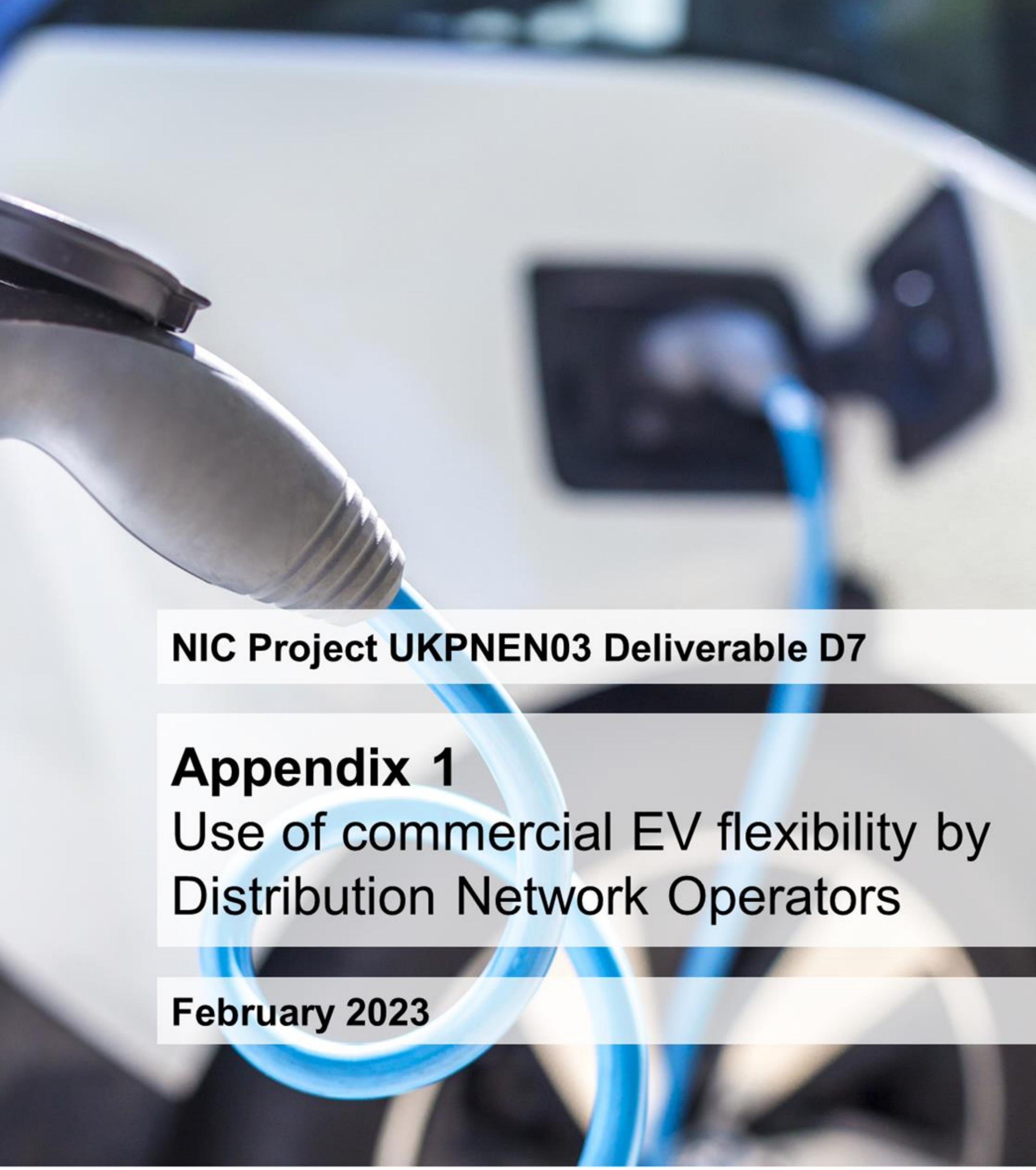


NIC Project UKPNEN03 Deliverable D7

Appendix 1
Use of commercial EV flexibility by Distribution Network Operators

February 2023

Optimise Prime

HITACHI Inspire the Next | Uber | Scottish & Southern Electricity Networks | centrica | Royal Mail | UK Power Networks

Contents

Use of Commercial EV flexibility by Distribution Network Operators (DNOs)

Flexibility services and new connections products have the potential to reduce load on the network at peak times, allowing DNOs to avoid or defer the need to upgrade elements of network infrastructure, and provide the capacity needed for more customers to electrify more quickly. This appendix explores in greater detail the results from Optimise Prime's trials of flexibility from commercial vehicles, and should be read together with Section 2 of the main D7 deliverable.

Optimise Prime proposed two methods to allow more flexibility from commercial fleets to be utilised by DNOs:

1. Flexibility services to DNOs from commercial EVs on domestic connections, detailed in section 1

2. Planning tools for depot energy modelling optimisation with profiled network connections, detailed in section 4

In addition to these two core methods, Optimise Prime also trialled the provision of demand-response flexibility services from depots, applying some of the processes from Method 1 to the depots in Method 2 – this is detailed in section 2. The practicalities of providing flexibility from the mixed trial PHVs is considered in section 3.

The aim of the trials was to analyse how these methods can be implemented, and to quantify the benefits that they may bring both to the DNO and to the customer offering flexibility. Across all flexibility products trialled, the following seven key metrics were used to help judge the value of the flexibility being offered:

1. **Cost**: At what value (£/kW/h) is it economical for fleets and PHV operators to provide flexibility services? How does the response quantity/quality vary with price?
2. **Magnitude**: What is the aggregated total amount of load (kW) that can provide flexibility services for a given type or number of EVs?
3. **Duration**: How long (hours) can this flexibility service be sustained for?
4. **Responsiveness**: How quickly (days, hours, minutes) can commercial EVs respond to take part in flexibility activities?
5. **Proximity**: How does the response or cost vary with the length of notice given to the fleet or PHV operator?
6. **Make-up**: Is there a variation between availability and utilisation payment values that delivers the lowest service cost?
7. **Predictability**: How predictable is the flexibility from commercial fleets and PHV operators? Can it be relied upon to deliver when requested by the DNO?

Based on the analysis of the trial outcomes, the key recommendations for the implementation of flexibility serviced made by the project are:

- The month (or more) ahead product should allow fleets to re-forecast their baseline in the run up to delivery to improve predictability/reliability of outcome
- Pricing incentives should be based on performance probability depending on certainty of delivery in order to reward good performance without disincentivising participation by some fleets
- Automation is required in the tender, bidding, dispatch and settlement calculation processes to make provision by smaller assets cost effective

- Where baselining is needed it should be simple and tailored to the fleet. A validation method, such as automating a comparison of baselines against past performance may be needed to avoid gaming.
- Incentives should be used to prevent the occurrence of secondary peaks

The following recommendations are made based on the trials of profiled connections:

- A process to model the expected load flow (such as using UK Power Networks' LV utilisation modelled data), as a proxy for the substation data may be required if no monitoring is available, supplemented with half-hourly data and/or diversity modelling
- Connection planning systems need to offer profiled connections with a 48 half-hour period granularity
- The range of contracts should allow for dynamic profiled connections, that can be changed or activated at the request of DNOs to act as flexibility products
- A process to revise profiled connections is needed to allow changes in fleet operations
- Integrated monitoring is required to provide the DNO with visibility of breaches, a method of communicating alerts to the provider is also required
- A method to police the profile, either through physical disconnection, economic penalties, or a combination of the two, must be agreed in the contract and implemented

The following sections discuss the findings from each of the flexibility and profiled connection trials in turn.

1 Method 1 – Flexibility services to DNOs from commercial EVs on domestic connections

1.1 Explanation of the method

Method 1 involved the trial of flexibility services delivered by controlling the charging of commercial vans located at domestic properties in response to signals from the DNO.

The aim of this method is to reduce the additional load on domestic connections at peak times in order to avoid or defer the need to upgrade parts of the network supplying residential properties. The DNO is responsible for the full cost of reinforcing connections to domestic properties, therefore deferral of upgrades can result in savings for electricity bill payers.

Two flexibility products were tested as part of these trials:

Product B – A day-ahead spot auction flexibility product
Spot auctions are competitive auctions run close to delivery, in this case day-ahead. Near-term forecasts should be more accurate than longer-term forecasts, so the energy volumes required can be scheduled at auction award rather than dispatched at the time of need via a signal from the DNO. This product was included in the trial because it is the standard structure for the day-ahead energy markets in GB.

Timescale	Procurement	Market Clearing	Dispatch	Baseline	Payment
Day ahead spot	Auction, standardised bids	Pay as clear	Scheduled at auction award – day ahead	Forward schedule	Utilisation

To prevent gaming of the market a schedule is submitted for a full 24 hours (in 48 half-hour periods) as part of the bid. A schedule accuracy factor is calculated based on the accuracy of this baseline at times when flexibility is not being provided within a specified window. This is then applied to the utilisation payment due to the flexibility provider.

Product C – An intraday balancing market flexibility product
In a balancing market, the flexibility providers submit an expected forward schedule of their electricity demand and an offer of the amount they are willing to reduce their demand by during a specific time window before a cut-off (gate closure) time (minimum 30 minutes before start of Settlement Period). The DNO was then able to accept offers as required after gate closure. This product was included in the trial because it is the structure used for balancing mechanism market in GB.

Timescale	Procurement	Market Clearing	Dispatch	Baseline	Payment
Post gate closure	Continuous market	Pay as bid	Operational	Forward schedule	Utilisation

Product B was common to both the WS1 (at-home charging) and WS2 (depot) trials, while product C was unique to WS1.

1.2 How the method was implemented

Centrica utilised their Centrica Business Services flexibility solution to control flexibility from home charge points (CPs). The system connects to each CP via a cellular connection, allowing the collection of meter data and the imposition of charging profiles.

In both of the products the flexibility from charge at home vehicles is aggregated into a group which forms a flexible unit (FU). A minimum of 300 home CPs took part in Product B and 300 home CPs in product C, each forming an FU.

The system was configured to be able to send bids to UK Power Networks' ANM system via an Application Programming Interface (API) and to receive dispatch signals in return in the form of demand schedules.

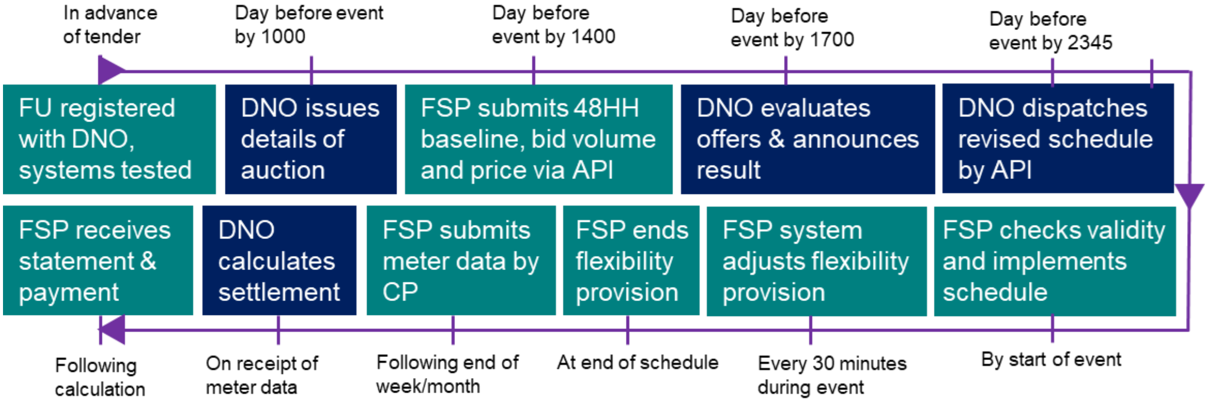
Detailed explanation of lessons learnt from the implementation of Method 1 within WS1 can be found in Deliverables D2 and D3.

Product B method

The process for providing product B flexibility included the following steps, as shown in Figure 1:

- The Flexibility Service Provider (FSP) registers the FUs with the DNO
- DNO issues tender by 10:00 day ahead. UK Power Networks and Scottish and Southern Electricity Networks alternately took responsibility for issuing tenders.
- The FSP responds to the tender by 14:00 day ahead, issuing a schedule/baseline for the following 24-hour day (consisting of 48 half hourly power levels in kW), the flexibility available (turn down in kW) in each half hour flexibility is being offered and a utilisation price per MW per hour
- The DNO decides the successful bids, taking into account the volume required, the prices received and the maximum bid that will be accepted
- The DNO sends a revised schedule to the FSP by 23:45 day ahead, reflecting the accepted flexibility
- The FSP enacts the schedule, controlling EV demand in line with the agreed flexibility provision
- At the week or month end, the FSP submits meter data to the DNO for settlement
- The DNO calculates the payment to the FSP based on the settlement methodology for Product B and sends a statement and payment to the FSP.

Figure 1 – Product B bid and dispatch process



Product C method

The method used in product C followed that of product B, with the following exceptions:

- Each half hour of the day can be bid for, accepted and dispatched separately (as opposed for the full day being bid at once in Product B)
- The gate closure time for each market period is 30 minutes before the market period starts (although bids can be placed in advance in batches), and the award/dispatch is 15 minutes before the market period starts.

1.3 Learnings from trialling the method

The following sections evaluate the ability of the British Gas fleet to respond to flexibility requests against the relevant metrics described in the introduction. The analysis in this section focuses on performance on weekdays, unless otherwise stated, given the reduced charging demands at weekends.

1.3.1 Magnitude:

Figure 2 shows the average magnitude of the flexibility response from the British Gas fleet (orange) against a baseline of normal uncontrolled charging (blue). The vehicles in the trial have a maximum aggregated charging load at peak times of ~0.9MW. The provision of flexibility services can, on average, reduce this demand by approximately 0.5MW to 0.4MW. This reduction results in a peak load of over 1MW when vehicles return to full power charging (approximately 20% higher than in the base case) and higher charging demand throughout the night. This new peak needs to be considered when procuring flexibility so that it does not create further constraints.

Figure 2 – Average response to a flexibility request from the British Gas fleet

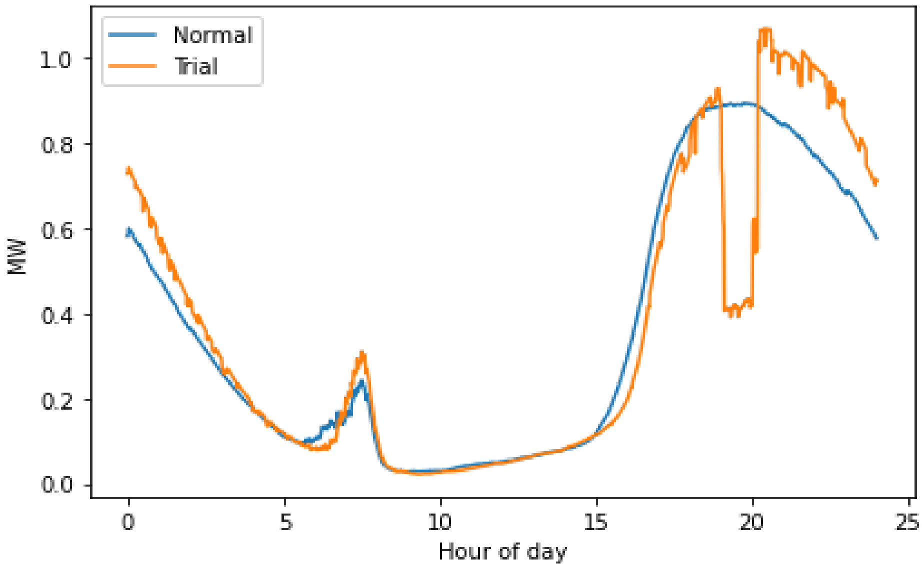
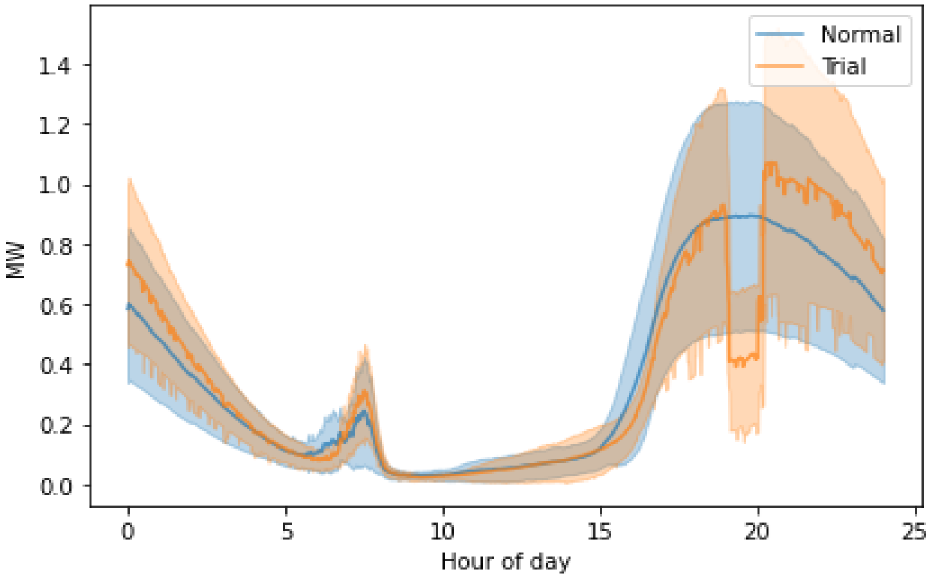


Figure 3 shows that there can be a significant variation in the load presented by EVs at peak times. This is due to a number of factors, such as daily and seasonal variations in routines and workloads, which are described further in Appendix 2. Flexibility delivered generally varies in line with load, though the magnitude of the variation is smaller, due to the greater control that can be exercised over CPs providing flexibility.

Figure 3 – Range of baseline and flexibility responses from the British Gas fleet



1.3.2 Duration

The British Gas vehicles generally operate on a plug and charge basis – the vans begin charging as soon as they are plugged in. As a result, the number of vehicles actively charging that can be curtailed varies over time, as shown in Figure 4. For flexibility events earlier in the day this is limited by the plug-in times of the vehicles, since EVs cannot provide flexibility before they plug-in in the evening. Later in the evening some vehicles will become fully charged, and as a result fewer vehicles will be able to provide flexibility services. Both the length and timing of flexibility events therefore have an impact on their magnitude.

Figure 4 – Proportion of British Gas EVs plugged in across the week

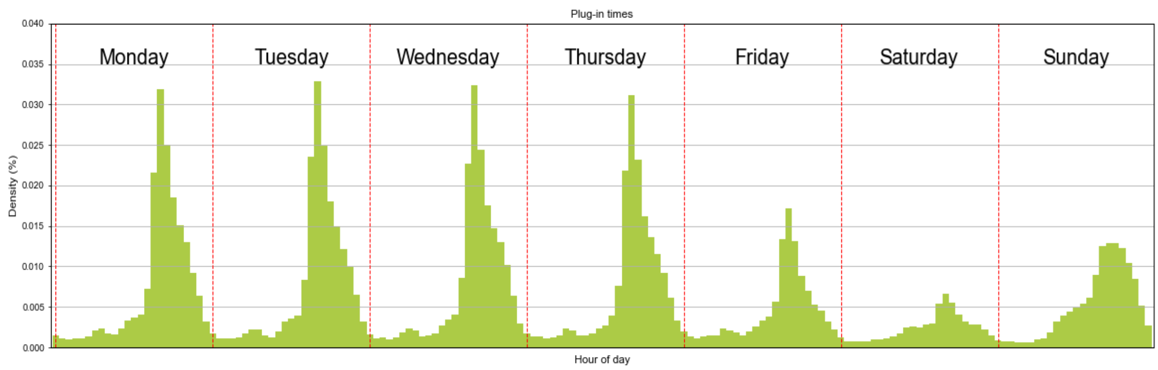
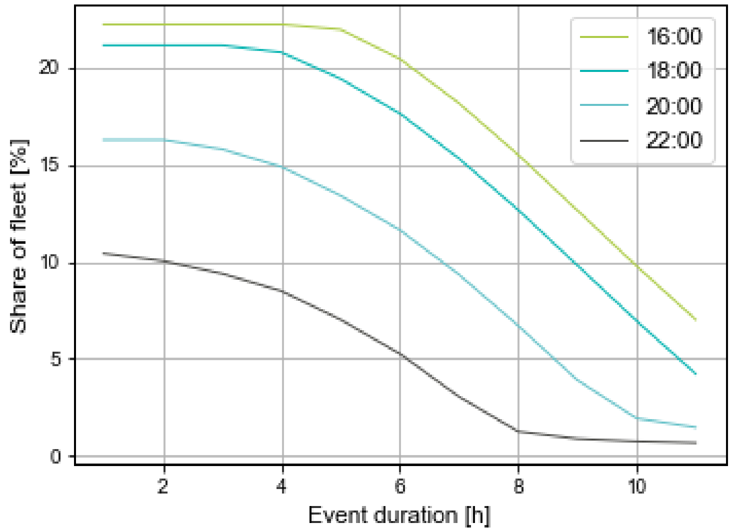


Figure 5 illustrates the percentage of the nominal fleet charging power that can be curtailed reliably on a weekday, by the time of the flexibility request, and the duration that flexibility services can be maintained without impacting the operation of the vehicles.

For an event starting at 16:00, up to 22% of the nominal fleet charging power can be curtailed for events up to four hours.

As the EVs typically plug in between 16:00-18:00, some EVs will already be fully charged later in the evening. So later charging windows will have a reduced amount of power that can be curtailed reliably, and this can be maintained for a shorter duration.

Figure 5 – Share of fleet able to provide flexibility services, by time of request

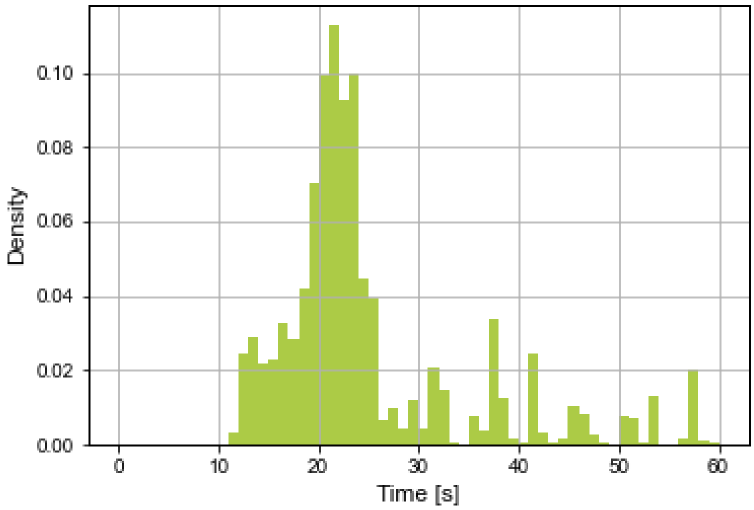


1.3.3 Responsiveness:

Responsiveness describes how quickly and reliably CPs can react to control signals. This information helps the DNO decide what purpose the flexibility can be used for and when dispatch messages have to be sent. The CPs in the WS1 trials can be fully controlled – when a CP is curtailed, it should respond immediately, reducing the charge rate to zero.

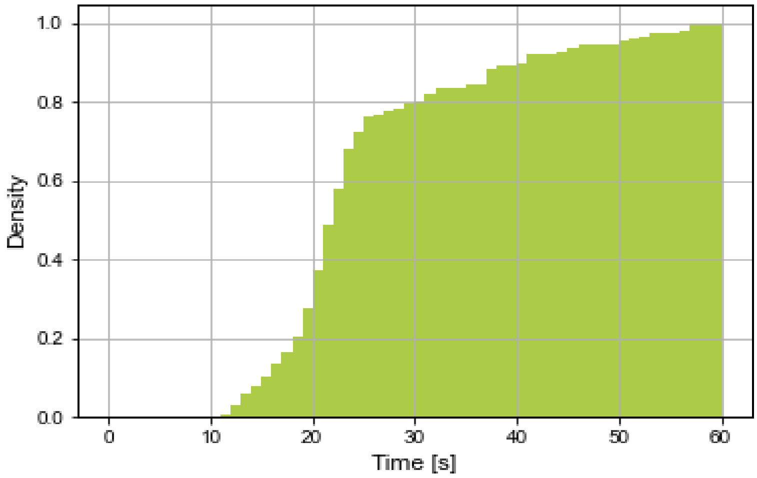
On an individual level, the CPs started reacting to a command 10 seconds after the command was sent out as shown in Figure 6. The bulk of the CPs reacted to a command between 10-25 seconds after the command was sent from the cloud.

Figure 6 – Response of CPs to off command



Across the whole pool of CPs, the average response time was 25.1 seconds. Figure 7 shows the cumulative response rate of British Gas CPs to a request - 99.1% of commands had started executing within one minute of sending the command.

Figure 7 – Response of Centrica pool to flexibility request



Almost all CPs reported zero power directly after being turned off. A small subset (4.8% of measurements) were non-zero. This is mostly due to transient effects (for example controls arriving after the report had been generated).

Centrica consider that this response could potentially be sped up by further optimising internal software architecture and/or using ethernet connected CPs instead of 4G connections.

1.3.4 Proximity and Predictability

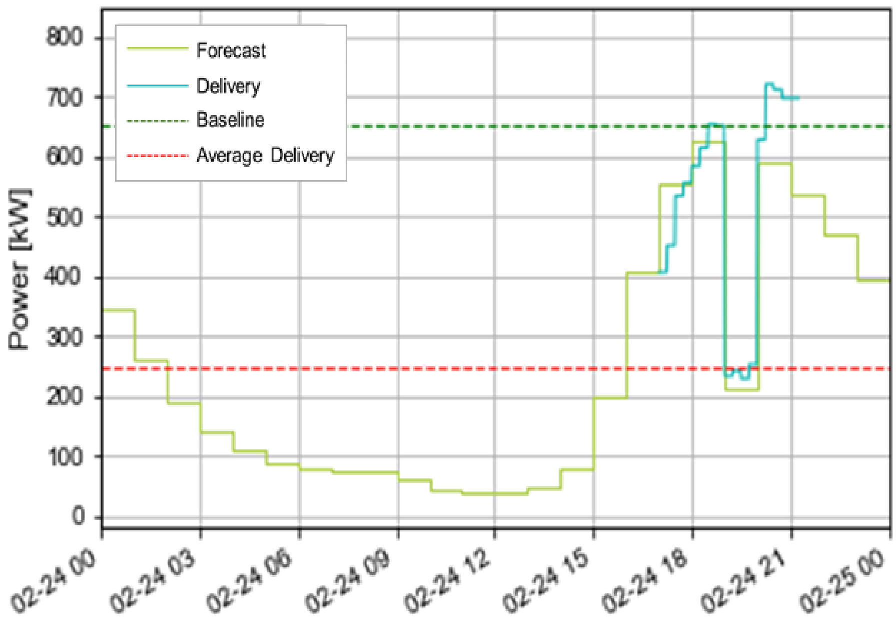
Two flexibility products with differing notice periods were trialled with the British Gas fleet:

- Product B – bid and dispatched day ahead
- Product C – an intraday product bid and dispatched around an hour before use

The products offered by the British Gas fleet require a baseline schedule to be submitted, representing predicted load, and a deviation from that baseline, representing the bid. The DNO then responds with an amended schedule including the deviation where the bid was successful. This process therefore requires accurate forecasting of both the EV load and the potential to turn down at any time.

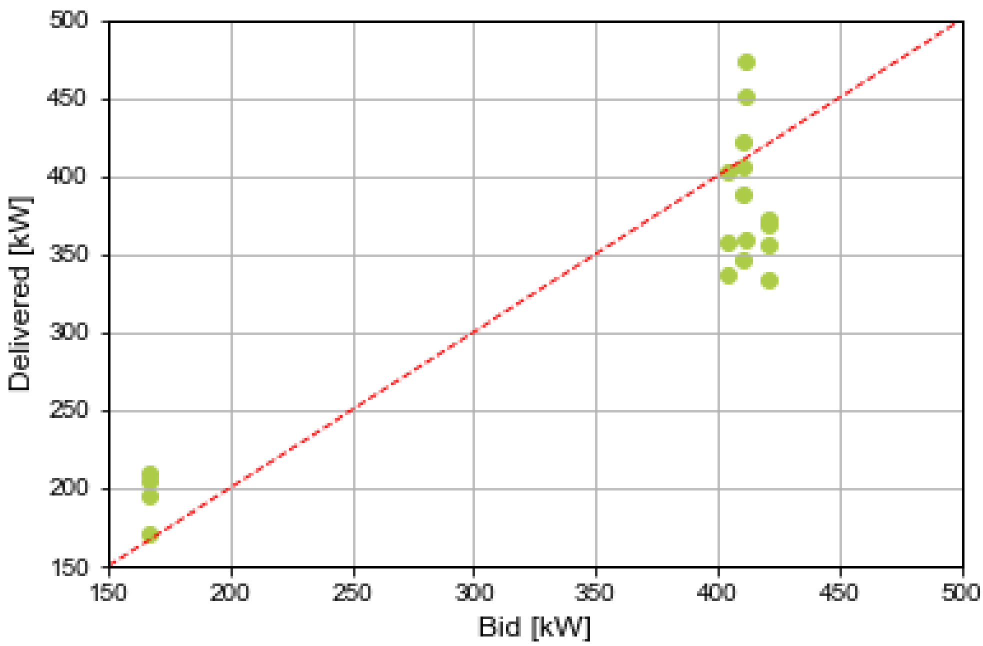
Figure 8 shows an example of performance of flexibility vs. forecast in Product B, where flexibility is delivered for an hour period between 19:00 and 20:00 by a pool of vehicles. The reduction in load in this instance is in line with the volume of the bid, though the actual load varies slightly from forecast.

Figure 8 – Example of Product B flexibility forecast vs. delivery



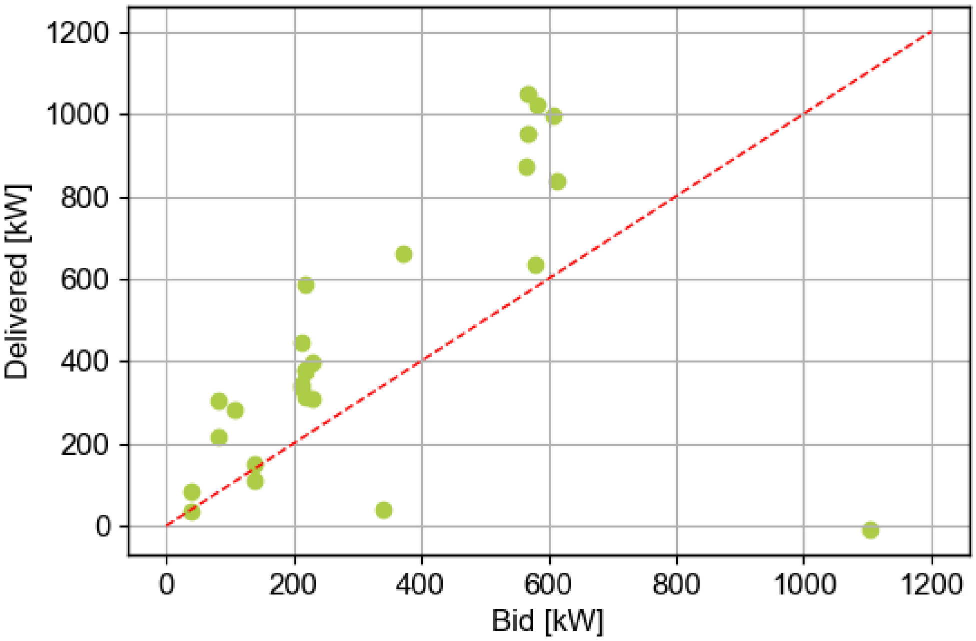
Exactly delivering the bid amount is challenging with EVs, where the number of vehicles available to offer flexibility at any time cannot be controlled. Figure 9 shows the results of a set of product B bids vs the delivered volume of flexibility. There are two distinct volume levels, representing Monday to Thursday and Friday, where less controllable capacity is available. Across the dates the divergence from the bid ranged from 83.3% of the bid amount to 125.4%.

Figure 9 – Product B bids vs delivery



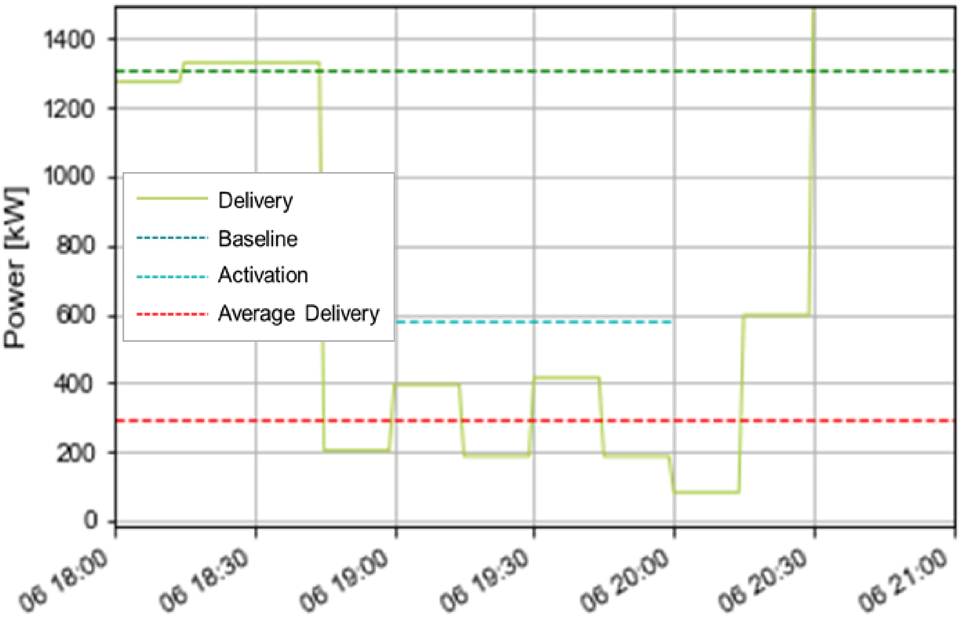
In product C, the shorter time period before delivery enabled higher bids to be placed with more certainty as shown in Figure 10. Bids could also be varied more to reflect expected load.

Figure 10 – Product C bids vs delivery



The load curve from a specific Product C event can be seen in
Figure 11. Load was successfully reduced from the baseline (green dashed line) to below the requested flexibility activation (blue dashed line). To ensure the bid was met, a conservative approach was taken to flexibility dispatch, resulting in delivery that exceeded the required activation. As trials and prediction confidence progressed, the over delivery could be reduced.

Figure 11 – Example of Product C event



Initially, weekends were found to be more difficult to predict, as demand could be lower than forecast in the baseline. This could result in failure to deliver actual change in the load during the flexibility period, as shown in Figure 12.

Figure 12 – Weekend activation of Product C

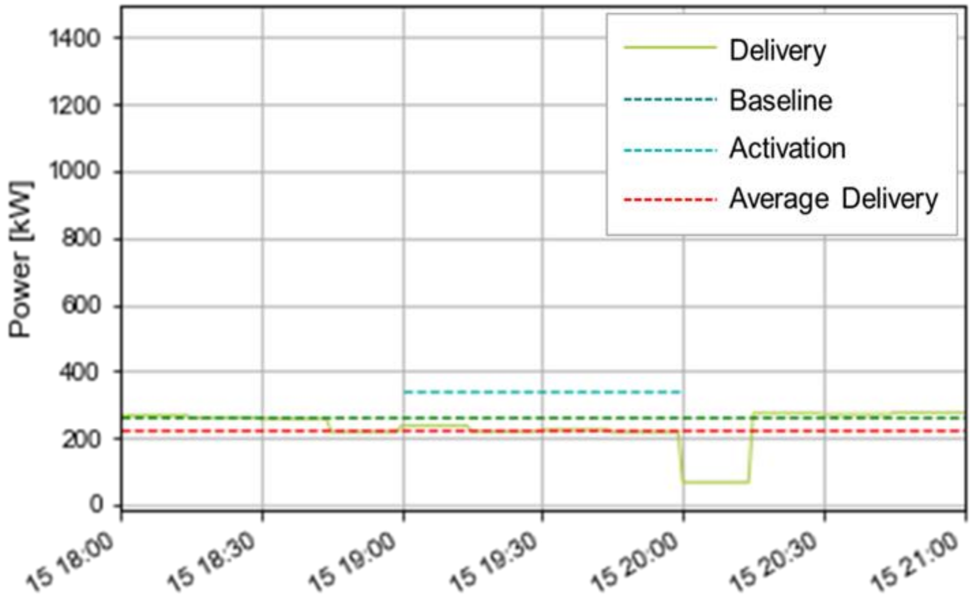


Figure 13 shows the accuracy of the forecasts before the service window, while Figure 14 shows the accuracy of the forecasts for the period immediately after the service window. The pattern of before-delivery baseline accuracy was slightly wider than the variance in delivery accuracy, ranging from -25% to +50%. Because CPs can be turned down to zero in a flexibility event, the load being higher than forecast had a limited impact on the ability to deliver the required volume of flexibility.

Figure 13 – Forecast accuracy before service window

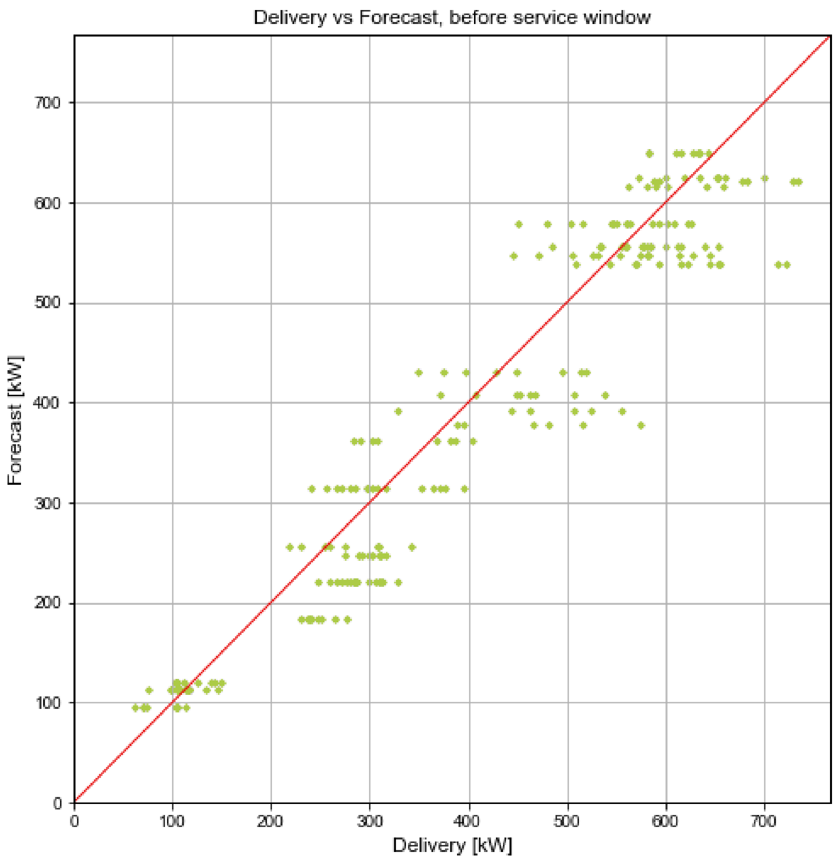
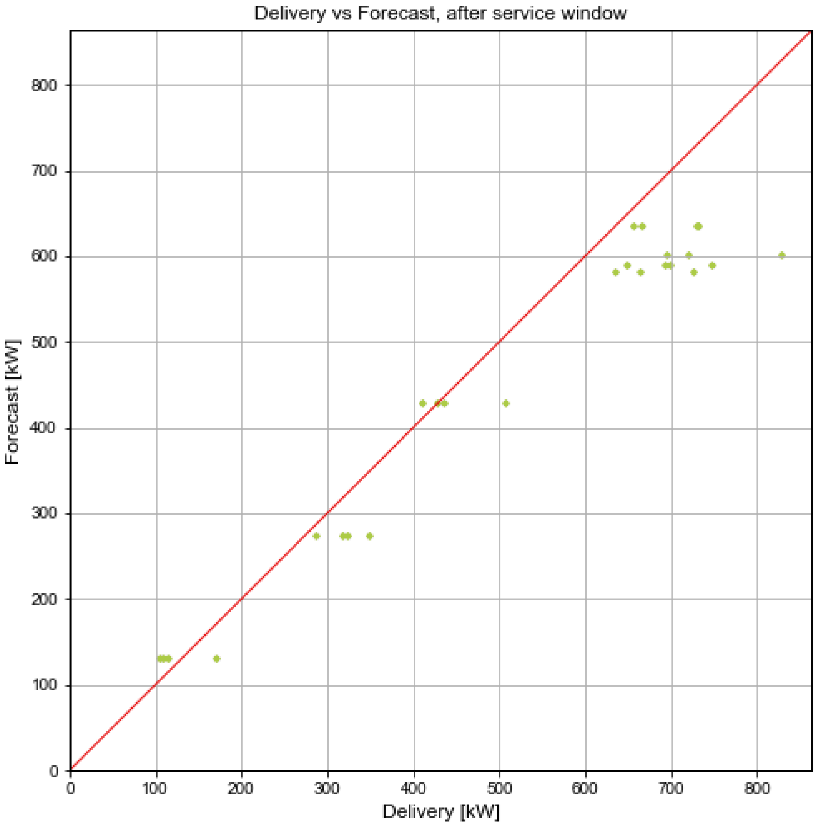


Figure 14 – Forecast accuracy after service window



2 Results from trialling demand response services at depots

As an extension to Method 1, flexibility services were also trialled in Royal Mail depots. The initial results of this trial were introduced in Deliverable D3. Two demand response products were tested at depots in Optimise Prime:

Product A – A firm forward option flexibility product

A firm option is agreed well in advance of need (year or months ahead) via a competitive tender. Availability payments are made for accepted tenders. The option is then enacted during operational timescales through a dispatch instruction from the DNO to the Hitachi control system for which utilisation payments are made. This product was included in the trial because it is the standard type of product for longer-term flexibility services contracts.

Timescale	Procurement	Market Clearing	Dispatch	Baseline	Payment
Forward (in the trials 1 month ahead)	Tender	Pay as bid	Operational timescales, partial dispatch	Recent history or last observation	Availability or utilisation

The utilisation payment was made for any turndown achieved, however the availability payment is not paid if the flexible unit does not achieve a minimum of 60% of the required turndown in a period.

Product B – A day-ahead spot auction flexibility product

Spot auctions are competitive auctions run closer to delivery, in this case Day-Ahead, based on forecasted network needs. Near-term forecasts should be more accurate than longer-term forecasts, so the energy volumes required can be scheduled at auction award rather than dispatched at the time of need via a signal from the DNO. This product is included in the trial because it is the standard structure for the day-ahead energy markets in GB.

Timescale	Procurement	Market Clearing	Dispatch	Baseline	Payment
Day ahead spot	Auction, standardised bids	Pay as clear	Scheduled at auction award	Forward schedule	Utilisation

To prevent gaming of the market a schedule is submitted for a full 24 hours (in 48 half-hour periods) as part of the bid. A schedule accuracy factor is calculated based on the accuracy of this baseline at times when flexibility is not being provided within a specified window and this is then applied to the utilisation payment due to the flexibility provider.

Product B is common across WS1 and WS2, with both homes and depots responding to the same events. In both trials, flexibility services are offered based on the EV load, and not the whole load of the site, as the project did not have control over any other assets. This section covers the results from each product in turn, before comparing the approaches and making observations and recommendations based on the findings.

2.1 The Optimise Prime Depots

The flexibility products were implemented across the nine depots taking part in the Optimise Prime trials in and around London, as shown in Table 1. Throughout the analysis the depots are grouped by size in order to simplify presentation.

Table 1 – The Optimise Prime depots

Category	Depot Name	Number of sockets	Number of vehicles	CP socket to vehicle ratio	Maximum installed capacity kW	Schedule Type
Large	Mount Pleasant	87	125	1:1.4	643.8	Deliveries & Collections
Medium	Premier Park	51	49	1:1	377.4	Deliveries & Collections
	Whitechapel	33	37	1:1.1	244.2	Deliveries & Collections
	Dartford	22	35	1:1.6	162.8	Deliveries & Collections
	Islington	24	24	1:1	177.6	Deliveries only
Small	Camden	6	12	1:2	44.4	Deliveries & Collections
	Victoria	6	22	1:3.6	44.4	Deliveries & Collections
	Orpington	6	18	1:3	44.4	Deliveries & Collections
	Bexleyheath	6	18	1:3	44.4	Deliveries only

As can be seen from the table above, the depots in the trial feature a range of sizes both in terms of number of EVs and number of CPs, resulting in a range of CP to EV ratios. The maximum installed capacity reflects the maximum power the site's CPs could draw, if they were all charging at their rated capacity simultaneously. The schedule type indicates the routines of EVs at each depot. Delivery-only routes typically end earlier in the day, while delivery and collection vehicles may return in the middle of the day and go out again later to collect mail.

The numbers in this table reflect the EV fleet at the end of the trial; around 40 EVs were added to the fleet as the trial progressed.

Throughout this section, the following terms are used to refer to the capacity and load of depots in the trials:

Table 2 – Definitions used in flexibility analysis

Term	Definition
Maximum Installed Capacity (kW)	Maximum power that can be drawn from all CPs at the depot
Maximum Required Capacity (kW)	Maximum power that drawn from depot CPs, given the capability of the EVs present at each depot
Average Unmanaged Load (kW)	Average power that would be drawn by EVs on site without external control
Uncontrollable Load (kW)	Load from charging EVs that are not under control e.g. using an unknown CP token (RFID) at the CP

The following sections outline the results from trialling the flexibility products.

2.1.1 Factors influencing the feasibility of flexibility from the trial depots

The majority of depot-based trials involved reducing CP power, rather than turning them off completely. This was done to reduce operational risk by ensuring EVs were always charging to some extent, and reduce technical risk as some CP's and/or vehicles would not wake-up to charge again after being switched off.

This can at times mean the vans may become fully charged before or during the flexibility period, reducing actual delivery.

Key features of the depots identified through the operational analysis includes:

- Morning and afternoon shifts exist – it varies whether EVs are charged between shifts
- The number of CPs to EVs varies from 1:1 to 1:4
- As a result, some depots do not charge each EV every day, and the timing of load can be unpredictable
- The CP to EV ratio is almost 1:1 at some depots, which reduces utilisation of the CPs. This needs to be considered when forecasting turndown.

2.2 Product A

2.2.1 Introduction

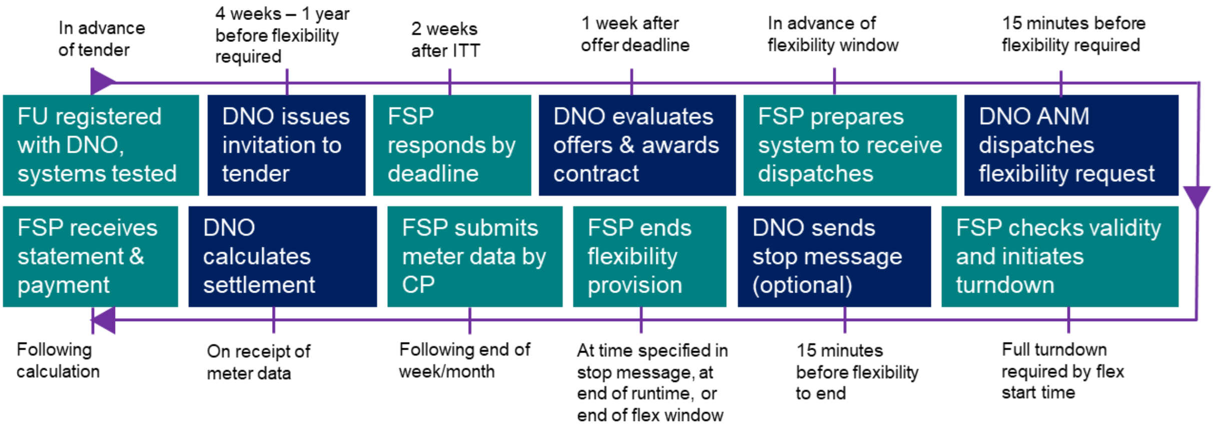
Product A was only used in the WS2 trials. The product is procured ahead of time (in these trials approximately one month before first delivery) and dispatched in near real time. It is intended as a longer-term firm flexibility contract, similar to those available in the market today, and offers both availability and utilisation payments to participants. Each depot is a separate FU and makes its own bid.

Eight depots took part in flexibility Product A at some point during the trials, with 305 turn-down events taking place in total across six flexibility trial periods. Flexibility was generally provided for two to three hours.

2.2.2 Product A process

The process and timescale followed for Product A flexibility provision is shown in Figure 15.

Figure 15 – Product A flexibility process flow



In product A the DNO started the process around six weeks prior to delivery by issuing a tender for a specific time and maximum quantity of turndown on each day of the week for a defined period.

The FSP responded to the tender with a volume of turn down (which must be maintained for the full period offered), a maximum run time, a price for availability and a price for utilisation.

The DNO dispatched the flexibility in near real-time (15-minutes ahead of when it's needed) by API message and the FSP reduced site load in response. Once turn-down was no longer needed the DNO sent a stop command.

At the end of the period, the FSP submits meter data to the DNO for settlement.

2.2.3 Product A bidding methodology

In order to make a bid, load has to be predicted based on past performance. In the trials, the offers were calculated using the following process:

1. The average EV load in each half-hour period of the specific day of the week is calculated
2. The average number of EVs charging in each time period is calculated
3. The minimum demand of each EV (6A/1.4kW) is multiplied by the forecast number of EVs for each period to give the site's minimum EV load
4. The minimum load is deducted from the average load to give the maximum turn down in each period
5. The lowest maximum turn down out of all of the 30-minute periods in the requested availability period is bid as the available turn down.

2.2.4 Product A settlement methodology

Product A offered payment for availability and utilisation.

- Utilisation payment was made based on the amount of turndown actually delivered. There was no penalty for under-delivery and no payment for over-delivery.
- Availability payment was weighted by a performance factor, based on the turndown performance of all events during the settlement period. An average performance of over 90% resulted in full payment, while there was no payment for performance below 60%.

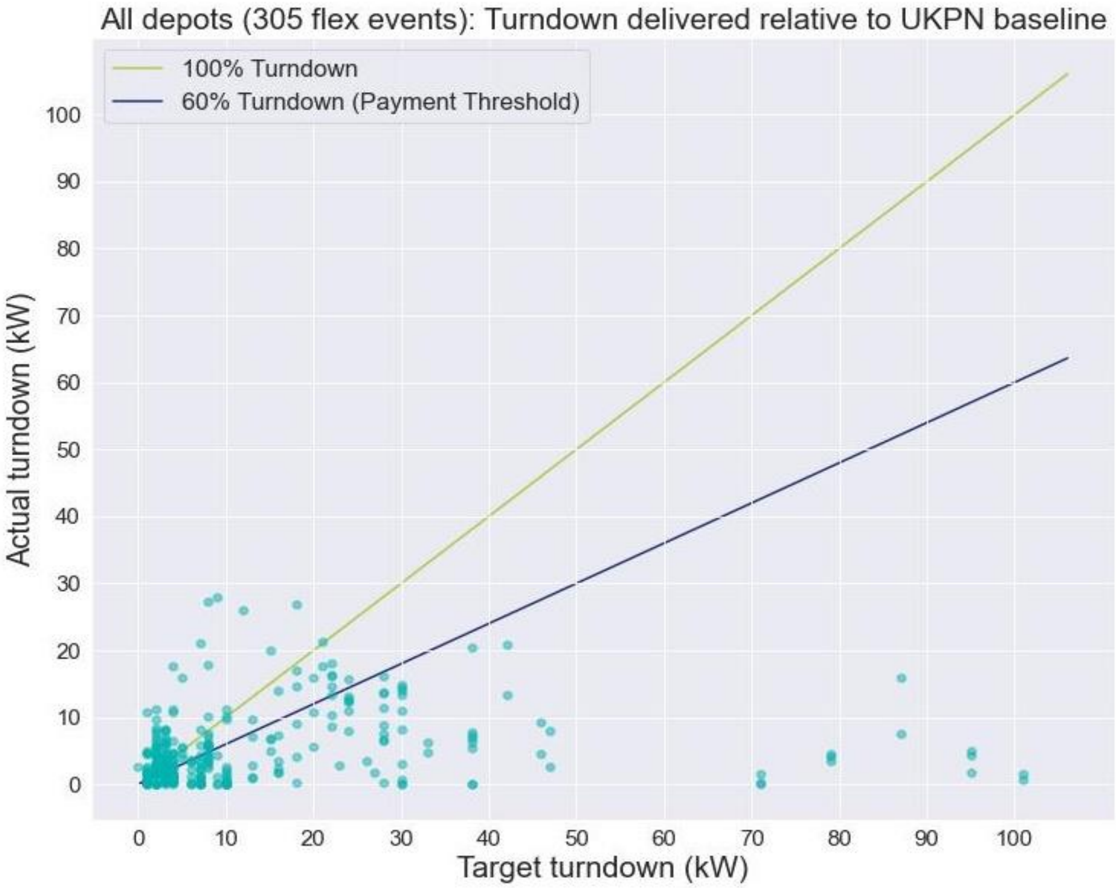
The DNO calculated a baseline against which delivery performance is delivered. This baseline was based on the average load for each half-hour period over the previous five qualifying days, meaning five most recent weekdays or weekend, excluding periods where flexibility was being provided.

2.2.5 Product A results

2.2.5.1 Overall Result

The diagram in Figure 16 summarises the results of all events with Product A. As can be seen, there was mixed performance – 82 of the trials achieved or exceeded 100% of their target turndown and 48 missed the target but exceeded the threshold of 60% which impacts availability payments. 175 events failed to meet the threshold required for turndown, although the majority of these were as a result of very small bids (<10kW) that could not be accurately delivered.

Figure 16 – Overview of performance of Product A events

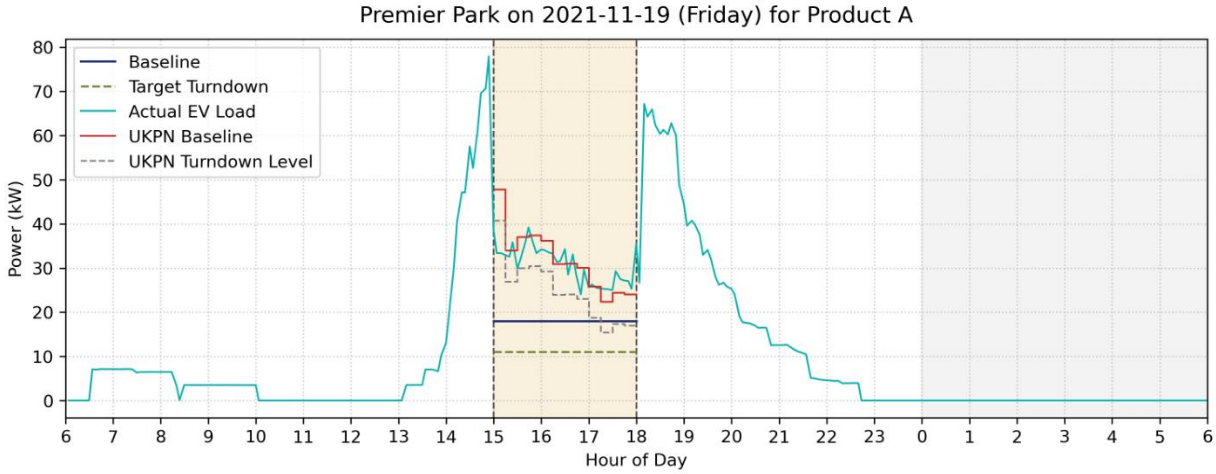


2.2.5.2 Assessing success: Baselining and Settlement

As described in Sections 2.2.3 and 2.2.4 above, there are different methodologies used to decide how much flexibility can be offered ahead of time and evaluating how much flexibility was provided. With a fully predictable and controllable source of flexibility the result of the methods would be similar. However, the project has found that these two methods can result in quite different outcomes, and this impacts the evaluation of the success of a flexibility event. These two methods, based on past comparisons, can in turn differ substantially from the instantaneous change in load that is observed on a particular day.

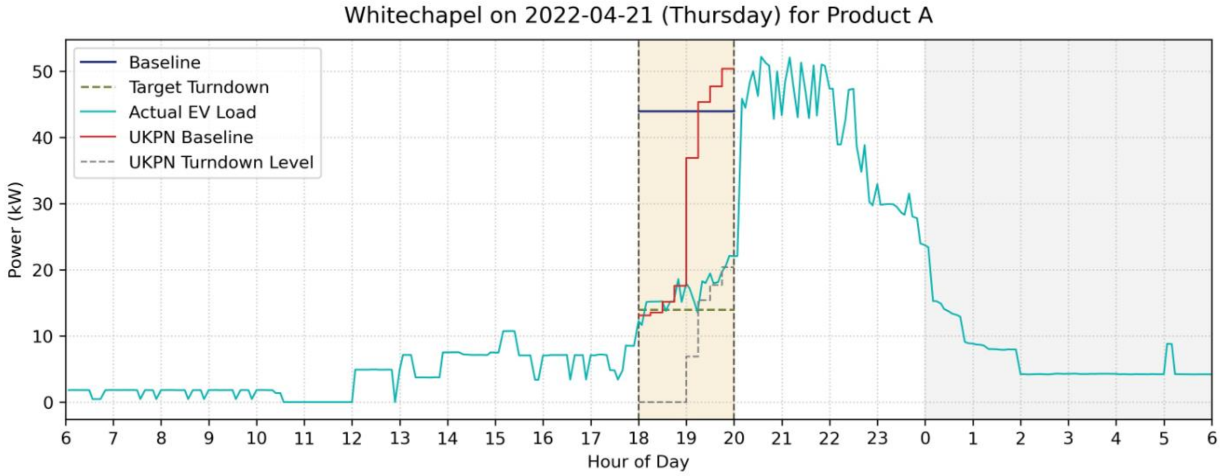
Ability to accurately predict how much flexibility is available at a site at a specific time is key to making a bid that can successfully be delivered. This is particularly an issue for Product A, as the prediction has to be made over a month before delivery, based on data from an even earlier period. An example of this can be seen in Figure 17, on a day with unusually high load. An instantaneous drop in load of 40kW was achieved at 15:00 (light blue line), however, this is above both the target based on the bid baseline (the green dashed line) and the target based on the settlement baseline (the grey dashed line) so will be regarded as a failure to provide the contracted turndown of 8kW.

Figure 17 – Example of a Product A flexibility response



An alternative settlement method could therefore be to measure success based on instantaneous change in load, however this methodology can also create inaccuracies. Figure 18, for example, shows that the load is being suppressed significantly below the forecast and settlement baselines. However, if compared to the time immediately before the flexibility event, the load will appear to have increased, due to the natural peak in EV demand coinciding with the flexibility period.

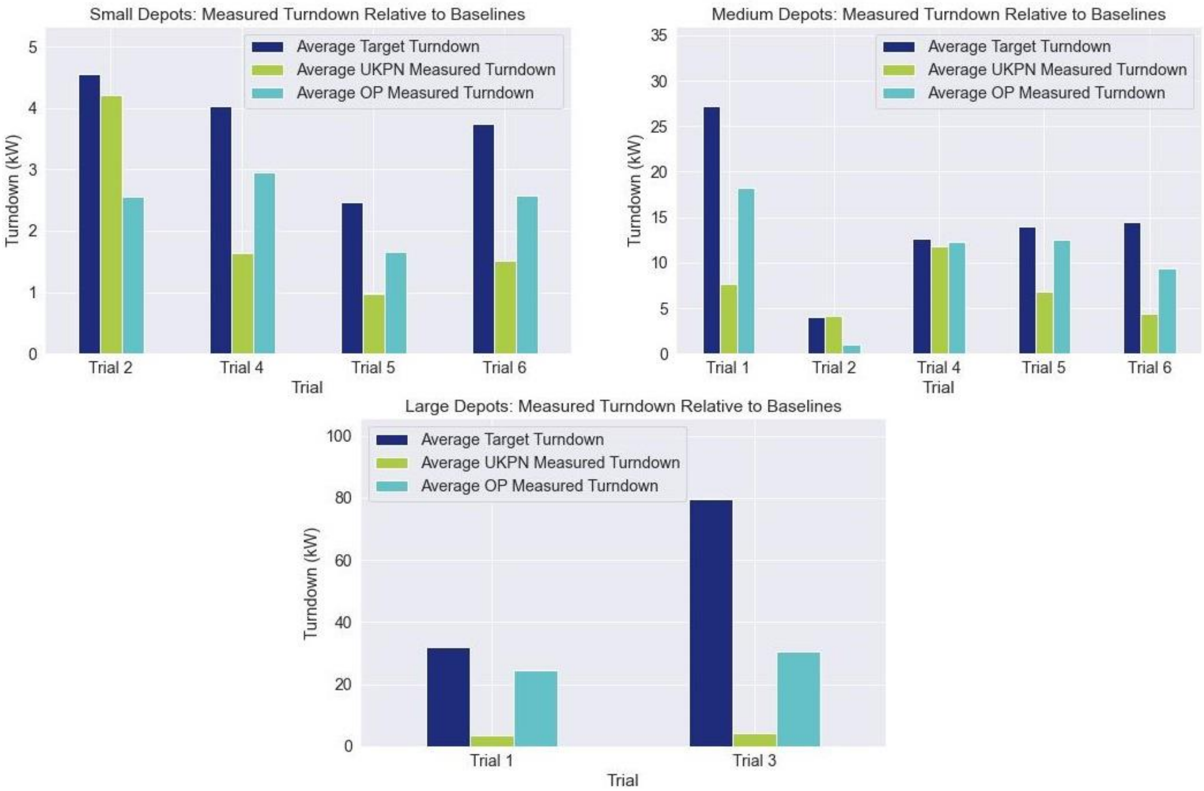
Figure 18 – Example of a Product A flexibility response



In this section UK Power Networks Baseline and Optimise Prime Baseline will be used to refer to the settlement and bid baselines respectively.

The graphs in Figure 19 give some examples of how the two different calculation methods can result in very different calculations of whether a site has achieved a turn down and by how much. The dark blue line represents the average bid made, based on a calculation of the controllable load on the same day in previous weeks at the time of bid. The green bar shows the measured turndown based on the settlement methodology and the teal bar shows the measured turndown recalculated after the event using the bid methodology.

Figure 19 – Turndown relative to baselines



The settlement methodology must take into account variations between days

The DNO baseline methodology could produce some anomalous results due to the way that an average of all weekdays or all weekend days are used in the calculation. Load patterns at the depots can vary significantly across the days of the week, in line with variations in operational requirements. This was especially the case at weekends, where load on Saturdays was significantly higher than load on Sundays. The average weekend load used in settlement calculations therefore under rewarded delivery on Saturdays but could over-reward delivery on Sundays. Comparing a day based on the same day in the past, rather than all days, is likely to give a more accurate result.

Figure 20 highlights key considerations and recommendations for setting a baseline, based on experience in the trials.

Figure 20 – Key recommendations for setting the baseline

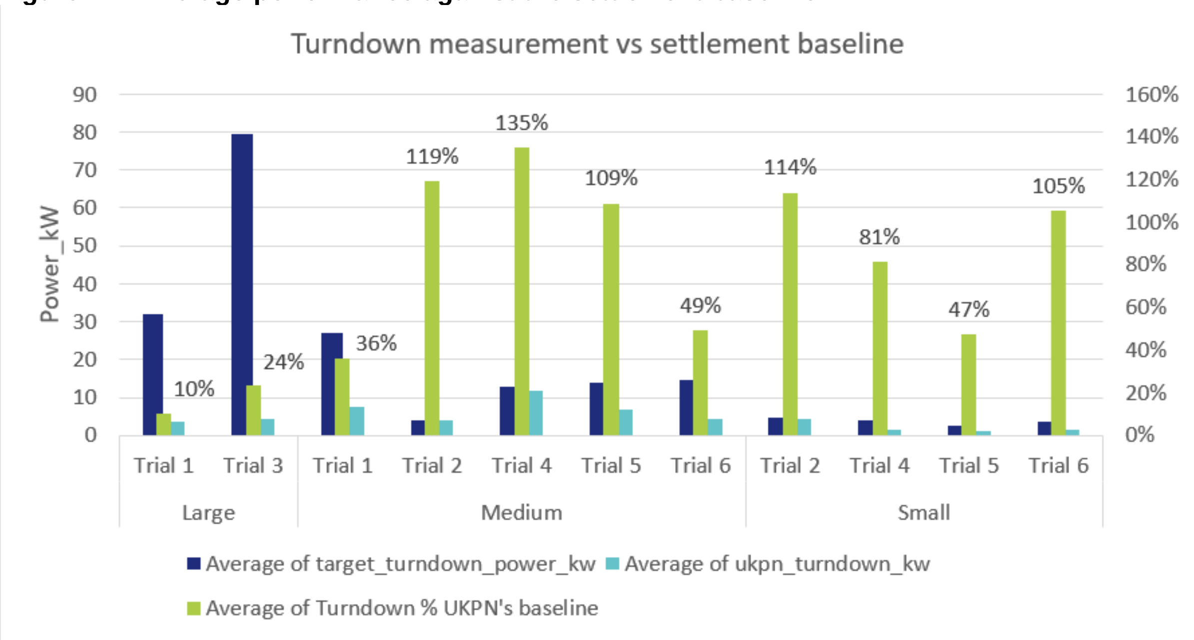
- It is important for DNOs and flex providers to use the baseline processes that are **most suitable** for their load shapes in order to produce accurate results. Fleets with consistent load may need a different process to loads that ramp up and down during the flex period.
- Data used to evaluate the success of flex events should be used **as close to the event as possible** so that settlements are not impacted by seasonal variations or changes in operations.
- Evaluation periods should have the **same characteristics** that are expected during the event. Days where flexibility or other similar services were being provided should be excluded from the settlement calculation.
- Since there is variation between weekdays and weekends, as well as individual days, **each day of the week should be treated separately**.
- **Two or more occurrences of each day** of the week are recommended to ensure accuracy and limit the impact of unusual changes in demand.

The impact of using different settlement methodologies will be discussed further regarding Product B.

2.2.5.3 Predictability and proximity

Making accurate predictions is especially important in Product A, due to the need to make bids far ahead of delivery. Figure 21 shows the average targeted turndown of Product A events (the dark blue bars), the calculated actual turndown based on the settlement methodology (the teal bars) and the delivery performance as a percentage of the bid (the green bars).

Figure 21 - Average performance against the settlement baseline

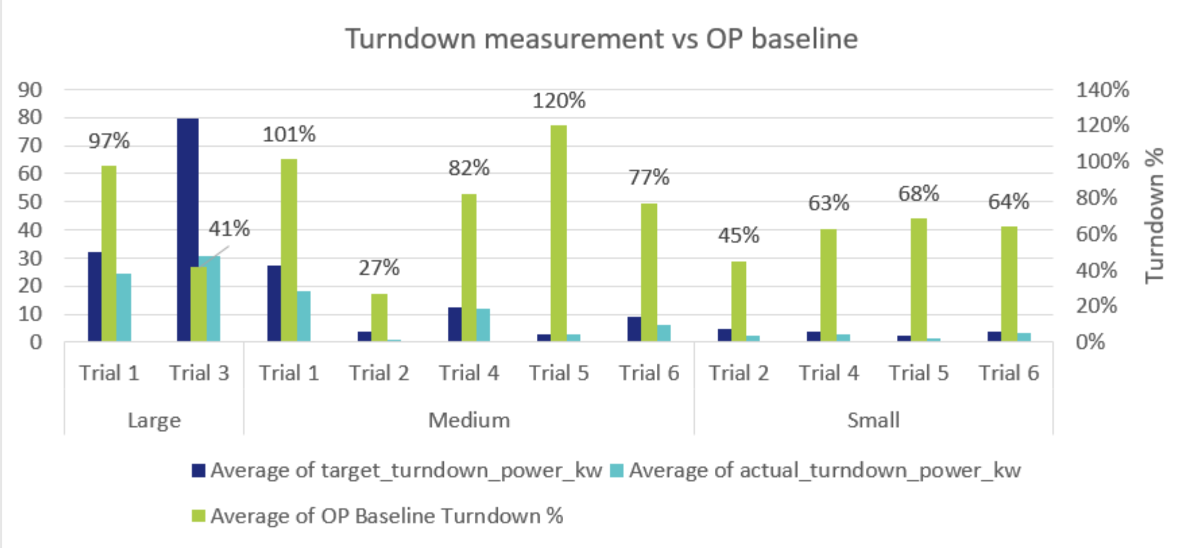


As can be seen, there is a significant variation in performance across the events, with both under and over delivery. The following observations can be made:

- The large site performed poorly. However, this result is based on a very small sample from December 2022, as the single large site was usually used in Product B. The timing of the trial, in Royal Mail's busy Christmas period, may have resulted in higher-than-normal load, impacting how delivery is calculated.
- The medium depots were the most consistently successful at providing the required turndown. Often, they would significantly exceed the required turndown. This is partly because bids needed to be set relatively conservatively to provide a consistent turndown throughout the period of the flexibility window.
- Performance at small depots was highly variable. The bids that could be offered were often very small due to the variation in load during the bid windows. Relatively small variations in operations, such as a single vehicle changing its routine could result in a significant impact on both load and available flexibility.

Figure 22 shows the same results with performance compared against the baseline that was predicted at the time of the bid. It can be seen that there is quite a significant difference between the two methodologies and, other than large depots performing better, there is not a clear pattern.

Figure 22 – Average performance vs the bid baseline



Sites with very small amounts of load are particularly difficult to predict accurately and it can be challenging to offer a meaningful amount of turndown

At the small sites (which generally had six charge sockets) very small changes in operations can result in large percentage changes in EV load. This high degree of variability can limit the amount of turn-down that can be offered reliably, and the site can often under or over perform significantly nevertheless, depending on the vehicles in the depot at the time.

The time between offer and delivery means forecasts of load and flexibility may not be accurate

Load analysis at the sites has shown that there can be significant seasonal variation in the timing of load at sites. Bids may need to be informed by a large amount of data for accuracy, the DNO may need to allow more lenience in judging performance, or the provider will need to reduce their bid. Longer flexibility periods (e.g. if they were to cover multiple months) may be less reliable as the timing of the controllable load shifts.

2.2.5.4 Duration and timing

Periods of two and three hours were tested in the Product A trials, with a relatively even split between the two durations. Three-hour events usually began at 15:00 and two hour events at 18:00.

No clear pattern in success of the flexibility events was observed based on duration in this trial.

Timing of the flexibility window was found to have much more impact on the amount of flexibility that can be provided.

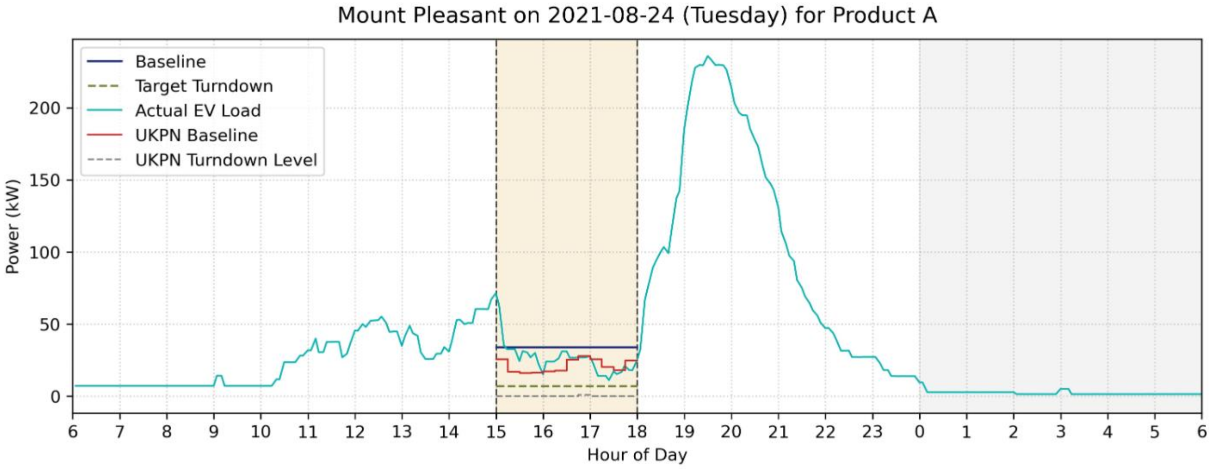
Sites should only offer flexibility if the period coincides with when they normally have load

While the different Royal Mail depots carry out similar tasks, the timing of their charging load varies significantly. For example, in some of the more suburban depots most vehicles return at around 13:00-15:00, whereas the central London vehicles often do not plug in until 19:00-20:00 as they collect more post from businesses in the city at the end of the day. Some depots also see two daily spikes in demand due to separate delivery and collection rounds with a break in between.

Because of this, responding to the same event across all of the depots is not always feasible, as there is minimum controllable load at certain times of day and low levels of load (and shoulders of the peak period) are generally more difficult to predict. The shape of a particular depot's load needs to be considered when deciding whether to offer flexibility services.

The graph in Figure 23 shows an example of this at the trials' largest depot, Mount Pleasant. Flexibility was offered between 15:00 and 18:00, when demand is usually low. The blue line represents the expected minimum load at the time of the bid and the green line represents the predicted minimum that load could be turned down to. The red line represents the baseline for this period based on the settlement methodology. To turn down the offered flexibility from this baseline would require a load of less than zero. As can be seen from the actual demand line (light blue) a significant turndown was achieved at the start of the period, and charging resumed at the end, however as the load was higher than forecast, the utilisation payment was not paid.

Figure 23 – Example of a flexibility event that does not coincide with peak load



In this situation, measuring turndown vs the previous period would have resulted in a very different result, with the FU likely overperforming what was offered.

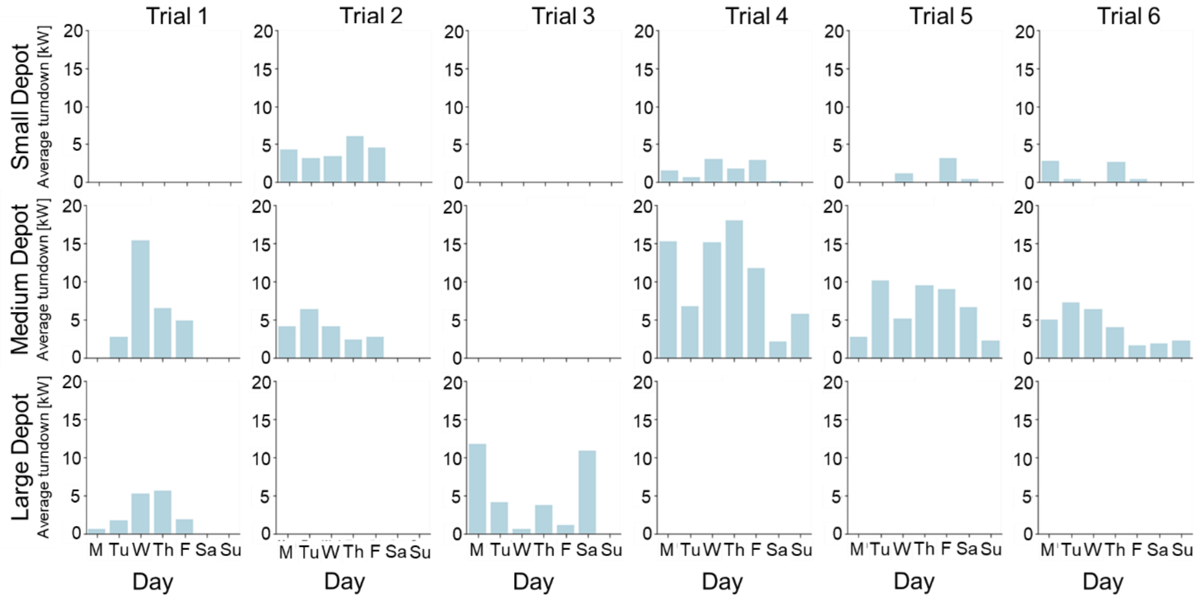
The recent history/previous period approach will not, however, always benefit the FSP. If the flexibility window began as vehicles were plugging in and the flexibility system stopped the load increasing, rather than decreasing it, the FSP might not be rewarded.

2.2.5.5 Magnitude

The magnitude of turndown available varies based on a range of factors: the size of the depot, the capacity of the vehicles and principally the number of vehicles plugged in and charging during the flexibility window.

Figure 24 shows the average magnitude of flexibility achieved in each of the Product A trials. Although small depots theoretically had a maximum load of ~30kW, variation in load across the flexibility window meant that the size of bids and the level of the resultant flexibility provision was very low, generally below 5kW. Medium depots could provide more flexibility, up to 15kW, though magnitude was still limited by the lack of predictable controllable load across the flexibility period. The large site only participated in Product A trials on a very limited number of days, so the figures from this trial may not be fully representative of the site's capability.

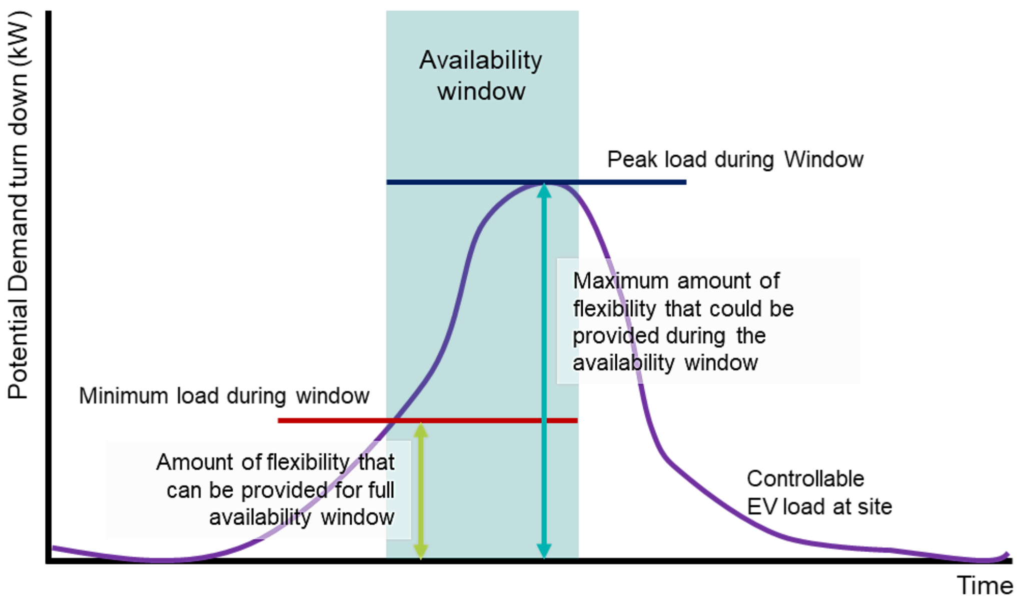
Figure 24 - Average flexibility turndown in each trial



A requirement for a flat baseline for a long period may result in lower bids from groups of assets with peaks in demand

To be successful in flexibility delivery the FSP must be able to offer a consistent amount of flexibility for the full availability period. As a result, the half hour which offers the least amount of flexible capacity will limit what can be provided across the whole availability period, as illustrated in Figure 25. Allowing bids by half-hour or rewarding over-delivery may allow more flexibility to be delivered if controllable load varies within the availability period.

Figure 25 – Impact of availability window on flexibility provision



The same issue occurs with days of the week. A flexibility product that requires provision of the same quantity of flexibility each day will limit the magnitude of flexibility that can be offered and delivered due to the variability in load between days.

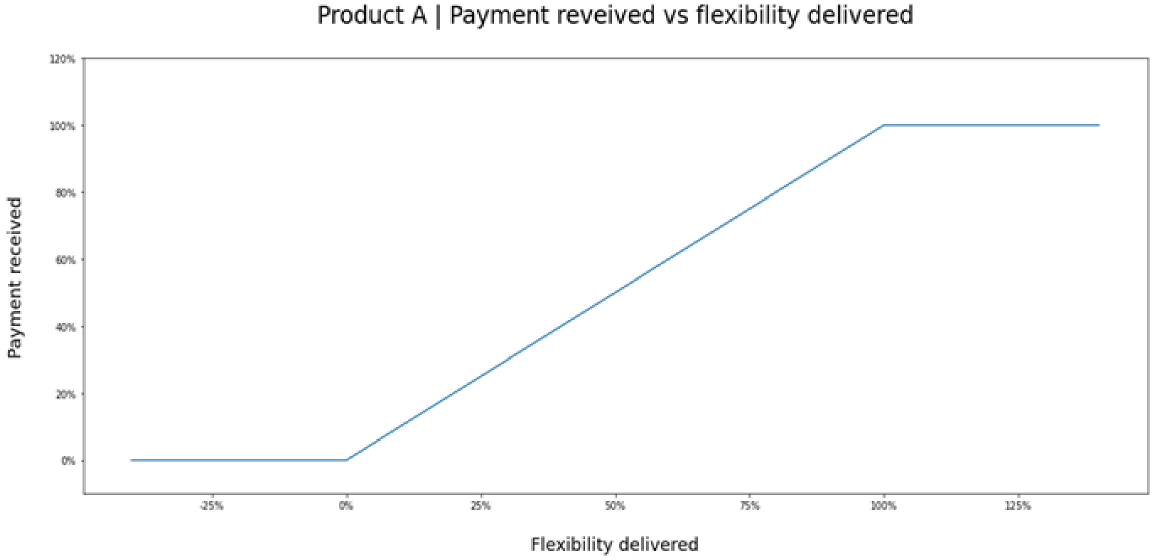
Invitations to tender need to consider the variations in available flexibility over time

In the first round of trials, a tender was prepared covering all days in the period. This proved to limit the available flexibility that could be offered, as the day with the lowest load (typically Sunday) dictated the maximum that could be bid. In subsequent rounds a bid was made per day of the week for each flexible unit, allowing more flexibility to be unlocked.

2.2.5.6 Cost

Product A was settled based on both utilisation and availability, prices for each of these form part of the bid. Utilisation was paid for based on the flexibility delivered regardless of performance against target, though it is capped at 100% of the contracted amount, as shown in Figure 26.

Figure 26 – Utilisation payment received for Product A



Availability was only payable when the average delivery performance over a period exceeds 60%, and a performance factor is applied to average delivery of over 60% as shown in Table 3.

Table 3 – Product A Performance Factors

Performance against target turndown	Performance Factor
≥ 90%	1
< 90% and ≥ 80%	0.8
< 80% and ≥ 70%	0.7
< 70% and ≥ 60%	0.6
< 60%	0

The delivery performance was calculated by UK Power Networks on a baseline of historical load. This baseline was based on the average load for each half-hour period over the previous five qualifying days, (either weekdays or weekends, excluding periods where flexibility was being provided (or as many days of data as possible if five days of data was not available)).

While bids were made with prices, the lack of a market means that the prices cannot be used for analysing the value, or cost, of flexibility services. Instead, a market benchmark price was applied, based on UK Power Networks' previous flexibility events.

- Based on the real-life turndown measured combined with market benchmarked price (Utilisation £326.33 and Availability £120.70) the potential revenue is shown in Table 4.

- Prices for Utilisation and Availability are very dependent on the time of day/day of the week/location and volume of flexibility required by the DNO, so prices may vary significantly.
- The Small Depot example shows that even when kWh delivered in trial 2A was lower than the results in 4A, the monetary benefit is similar due to the 80% delivery performance which unlocked availability payment.

Table 4 – Value of flexibility delivered in trials of Product A

Flexibility Period	Depot	Flexibility delivered (kWh)	Delivery Performance	Performance Factor	Utilisation Payment [Trial Prices]	Availability Payment	Total Payment	Utilisation Payment [Benchmark Price 326.33 £/MWh]	Availability Payment [Benchmark Prices 120.70 £/MWh]	Total Payment [Benchmark Prices]	Average Target Turndown v Average Unmanaged Load	Target turndown vs Max Required Capacity (kW)
2A [Oct -Nov '21]	Small	81.3	79.9%	0.7	£6.75	£6.90	£13.65	£26.53	£8.59	£35.12	18%	8%
	Med	146	86.5%	0.9	£12.13	£13.08	£25.21	£47.64	£18.35	£65.99	29%	2%
4A [Jan -Feb '22]	Small	110.8	44.0%	0	£13.61	£0.00	£13.61	£36.15	£0.00	£36.15	40%	9%
	Med	717.8	37.0%	0	£124.89	£0.00	£124.89	£234.23	£0.00	£234.23	39%	10%

In a situation where flexibility is being provided by only partially predictable assets, such as EVs, reduced payments for inconsistent deliveries can result in providers offering much less flexibility than may be available, in order to ensure it is delivered.

2.2.5.7 Responsiveness

Responsiveness refers to how quickly and reliably the CPs at a depot can react to requests for turn down. As the control system is the same for both products, responsiveness does not vary between products A and B.

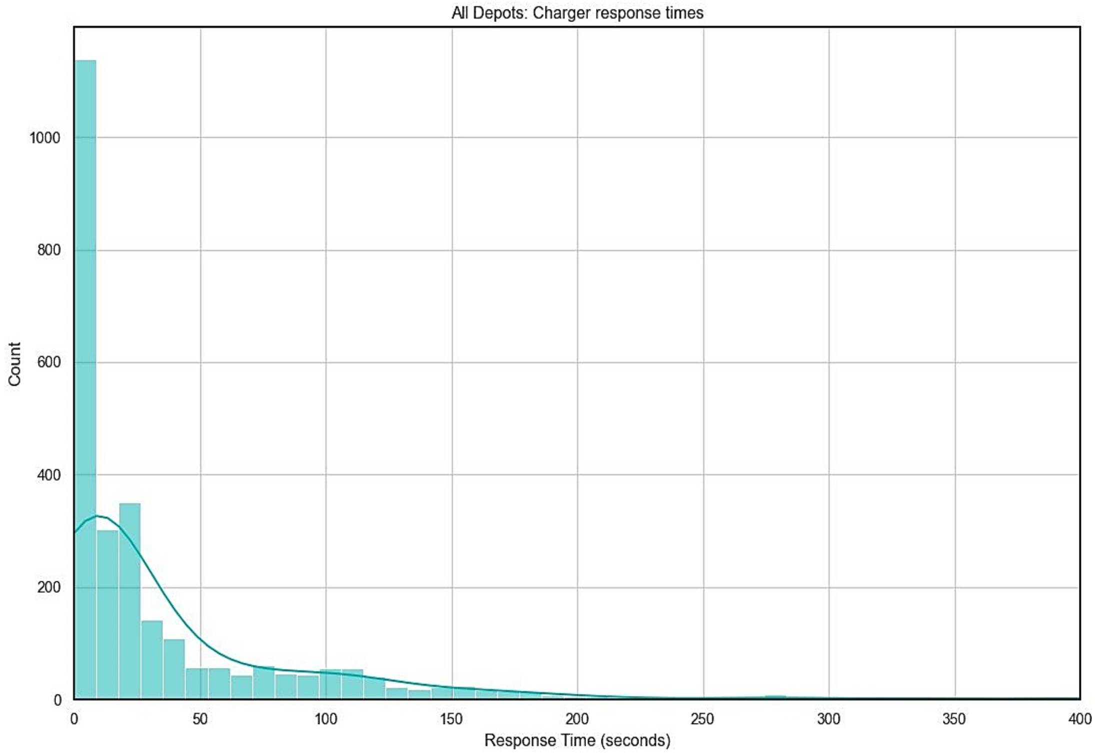
Across the trials 90% of the time CPs responded to the setpoint sent within two minutes.

50% of the time CPs responded in less than 16 seconds, as shown in Figure 27. Of those CPs that responded within 30 seconds the majority responded to the setpoint in less than five seconds. The average response time was 46.39 seconds.

This response rate must be considered in context with the limitations in CP setpoint control at depots outlined in Appendix 9, where it was necessary to stagger the sending of setpoint changes in order to ensure that they were correctly applied by the CPs. This required sending of setpoints to be spread out, adding up to 174 seconds to the response time at the largest depots.

This response rate is sufficient for the products trialled within Optimise Prime, which all required a response within 15 minutes. It shows that it would be possible to provide a five-minute response to a dispatch signal reliably, though shorter response times than this would be impacted by the ability of the depot infrastructure to enact the change. This is slightly different from the result in the WS1 trial, where each socket is controlled independently, and depot controllers and dual socket CPs do not create a bottleneck impacting responsiveness.

Figure 27 – CP response times at Royal Mail depots



2.2.6 Product A learnings

Royal Mail depots showed a good availability to turn down their load in response to flexibility request signals, however the following findings were made in respect to Product A:

- Due to changing load patterns over time, baselining to make an achievable bid can be challenging and can lead to underbidding or overpromising. To be successful, bidders need to be conservative with their bids, offering a smaller quantum of flexibility
- The volume of flexibility provided varies depending on the number of vehicles plugged in during the flexibility window. This can be problematic at smaller depots, where each vehicle makes up a larger proportion of the controllable load and small operational changes can result in significant under performance
- Longer flexibility periods made it more difficult to maintain/be able to guarantee flexibility turndown against a baseline of past demand, due to the peaks in demand that occur in EV depots. This results in customers having to offer less flexible capacity in order to ensure reliable turndown
- Different baselining methodologies can potentially result in variances in payment to the provider – an analysis of several potential methodologies can be found in Section 2.1.4.2 of Deliverable D7.

2.3 Product B

2.3.1 Introduction

Product B was common to both the WS1 and WS2 trials, with both fleets bidding to provide flexibility in the same auctions. While WS1 aggregated dispersed vehicles over a wide area to create an FU, WS2 treated each depot as an FU – with depots containing between six and 87 CPs.

Throughout the trials Product B flexibility events were run 404 times across seven depots, involving 303 EVs in WS2.

2.3.2 Product B process

The process for providing product B flexibility is the same as in WS1, as described in Section 1.2 and Figure 1.

2.3.3 Product B bidding methodology

Bids for Product B at Royal Mail sites were calculated based on past load at the depot in a similar way to Product A. Key differences between the products included:

- As a day ahead product, Product B's bids could take in more recent data when making a bid
- In Product B, a baseline was submitted by the FSP that is subsequently used in settlement
- Although a single bid was sent to the DNO each day, different values were bid for each half hour within the flexibility window, rather than a single bid for the whole period.

It should be noted that in the trials, due to the frequency of flexibility events and other interventions, there were relatively few unmanaged days on which to base forecasts. As a result, forecast baselines may have been based on less information, or older information than would be the case in a business-as-usual scenario.

2.3.4 Product B settlement methodology

Product B was settled using the baseline provided as part of the bid. Utilisation payments were made on flexibility delivered, limited by the size of the bid.

In order to prevent gaming of the baselining process a baseline reliability factor (Schedule Accuracy) was applied to the outcome of the bids. This schedule accuracy factor was calculated based on how closely load followed the baseline between 15:00 and 21:00 each day during the week of the enacted event.

2.3.5 Product B results

2.3.5.1 Overall result

Product B was tested through several rounds of flexibility provision, each consisting of approximately four weeks, between October 2021 and July 2022.

Product B requires that the load at a site follows a schedule of predicted demand that was set in the bid, reduced as required by a deviation for which a utilisation payment is paid. Due to the variation in load at the depots, accurately following a specific baseline can be challenging.

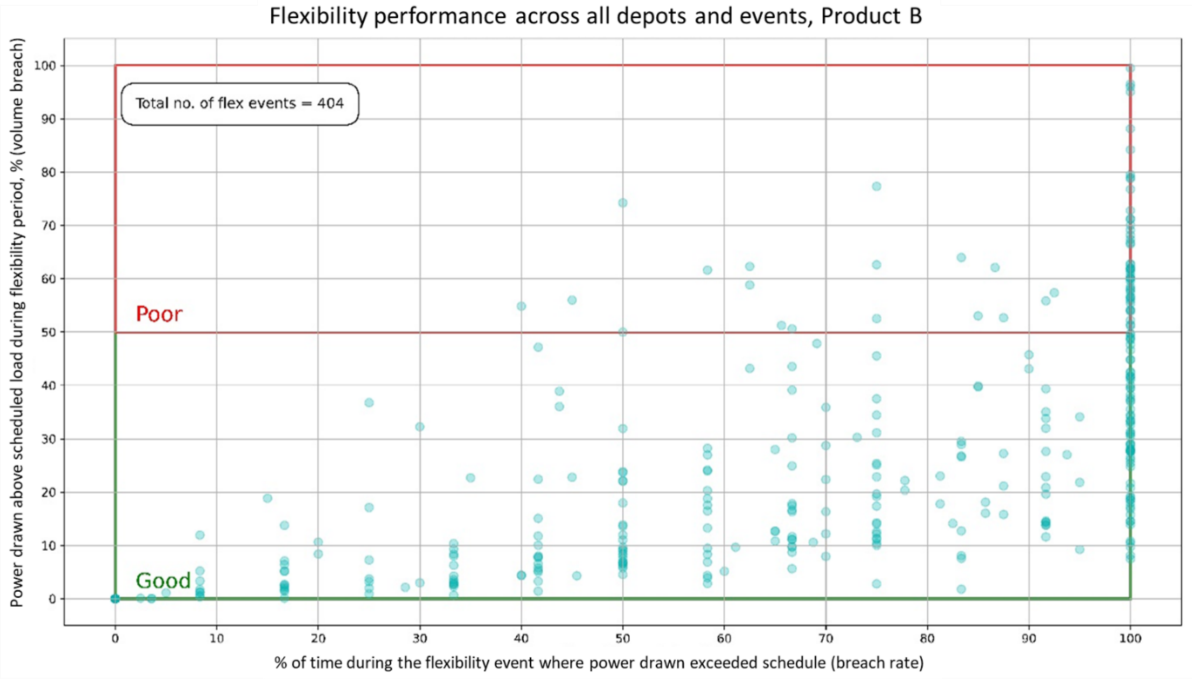
In order to categorise the results of Product B events, the following terms are used to describe the performance relative to the baseline:

- **Breach Rate** measured in 15-minute intervals of time with load above the scheduled power, as a % of the total length of the flexibility event
- **Volume Breach** is the amount of power drawn above the scheduled load during the flexibility event, as a % of the scheduled load.

Across the trials there was a wide range of results in terms of compliance with the set schedule. Figure 28 maps each flexibility event against the two metrics described above.

As can be seen, most events delivered 80% or more of the requested flexibility, however relatively few events delivered the full amount for the required timeframe.

Figure 28 – Overall performance of product B - WS2



In total:

- 76 events were rated excellent and met or exceeded the bid amount at all times
- 272 events provided more than 60% of the flexibility that was bid for
- 48 events had a poor result, with less than 50% of the promised power delivered.

There are several reasons for this:

- The schedule is based on a predicted load at the site, and each vehicle being able to reduce demand to a minimum load of 6A (1.4kW). The number of vehicles at a site at a particular time cannot be predicted to 100% accuracy.
- Very small changes in routine, such as vehicles plugging in slightly late or more vehicles than usual plugging in, can cause quite significant breaches, especially at smaller sites.
- The approach taken to bids was to minimise load as far as possible, leaving little margin for error, in order to produce larger bids. At smaller sites adding margin may have made bid volume very small or zero due to the potential variation in load.

The following sections describe the performance of the Product B flexibility trials in more detail.

2.3.5.2 Predictability and proximity

The predictability of load and ability to deliver turndown requested is key in successfully responding to a flexibility event. The load pattern of the depot can vary over time – from day to day and seasonally. Operational events, such as delivery rounds taking longer than usual, can be unpredictable and can result in under or over delivery of flexibility, or failure to follow the load schedule.

Figure 29 – Performance of the large depot across trial B

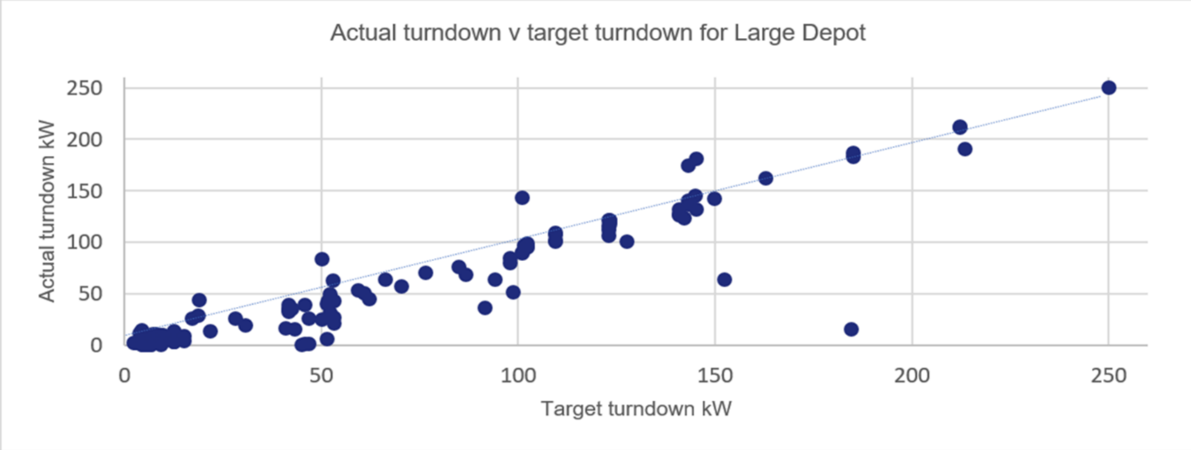


Figure 30 – Performance of the medium depots across trial B

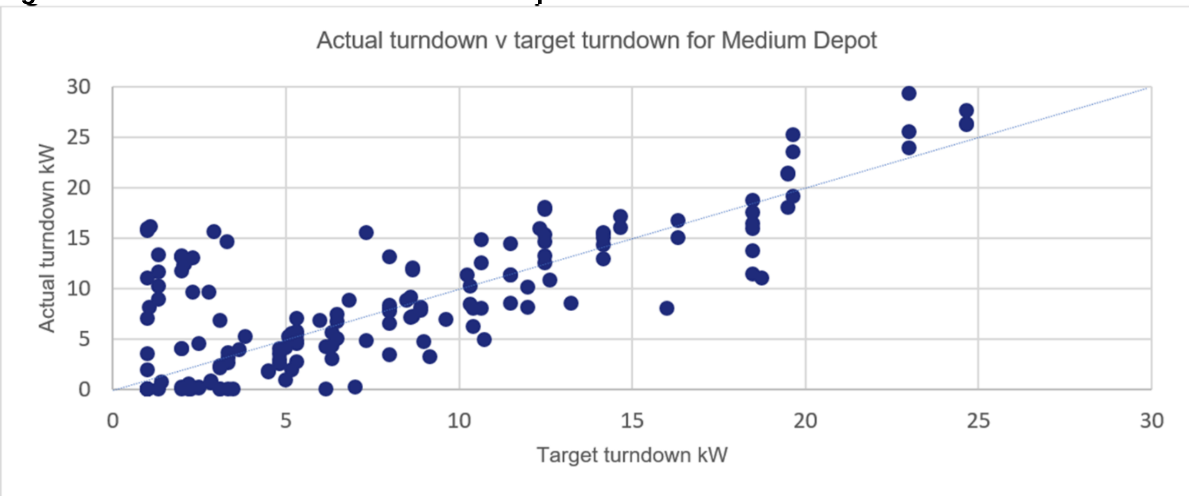


Figure 31 – Performance of the small depots across Trial B

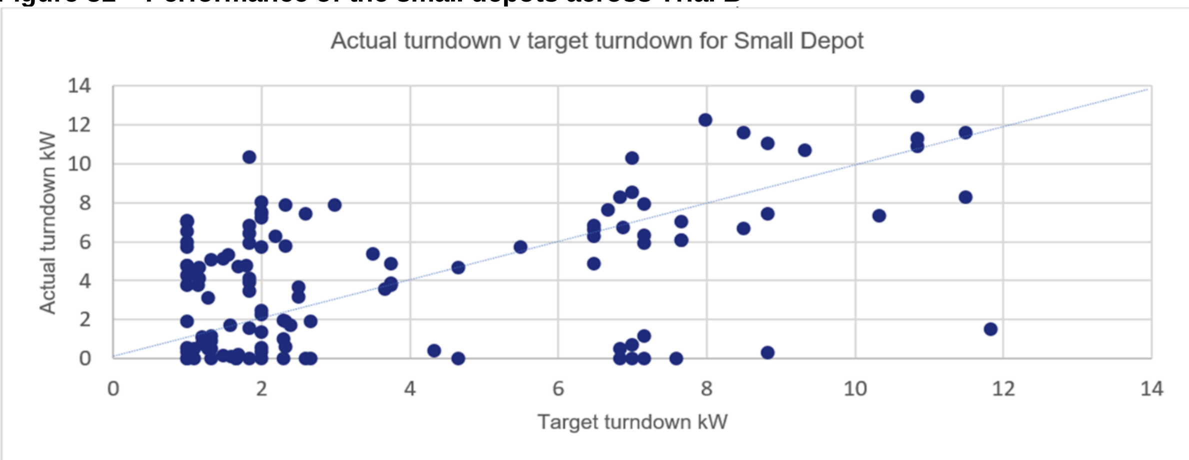


Figure 29, Figure 30 and
Figure 31 provide an overview of performance against bid at the large, medium and small depots respectively. Each dot represents an event – dots above the diagonal line represent over delivery of flexibility while dots below the line represent underperformance.

This demonstrates that the size of the depot (and, due to that, the bid) clearly impacts upon the predictability of the delivery. With the exception of occasional outliers, the large depot's results generally follow the line, while the bids of the small depot consistently under and over deliver. Very small bids, below 5kW are particularly unpredictable.

Improving predictability
In the early trials there were a number of factors that impacted the accuracy of the forecasts of available flexibility. These included:

- Technical issues that prevented flexibility from being dispatched, such as failure of elements of the control and communications systems
- The inability to control charging behaviour of vehicles that were not recognised in the system
- Accurate modelling of how the minimum setpoint of vehicles impacted the amount of flexibility that could be delivered
- Attempts to bid at times where load was expected to be exceptionally low, such as overnight and on Sundays
- Availability of past information to inform the bid.

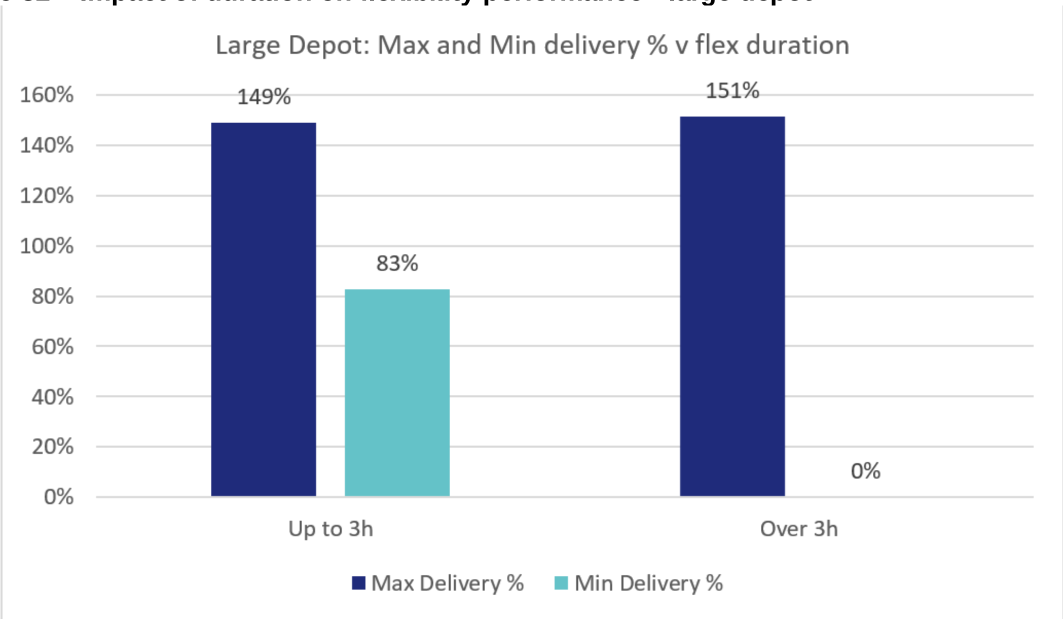
As the trial progressed, improvements could be made to address these issues, and this generally resulted in greater accuracy over time.

2.3.5.3 Duration and timing

Each day up to four flexibility windows of varying length could be bid into. Some of these windows stood alone, while others followed directly after another window, allowing a longer flexibility event. Several combinations of flexibility event length and number of events bid for and delivered during a day were trialled. As the most successful times became clearer these were increasingly prioritised to maximise the flexibility being delivered.

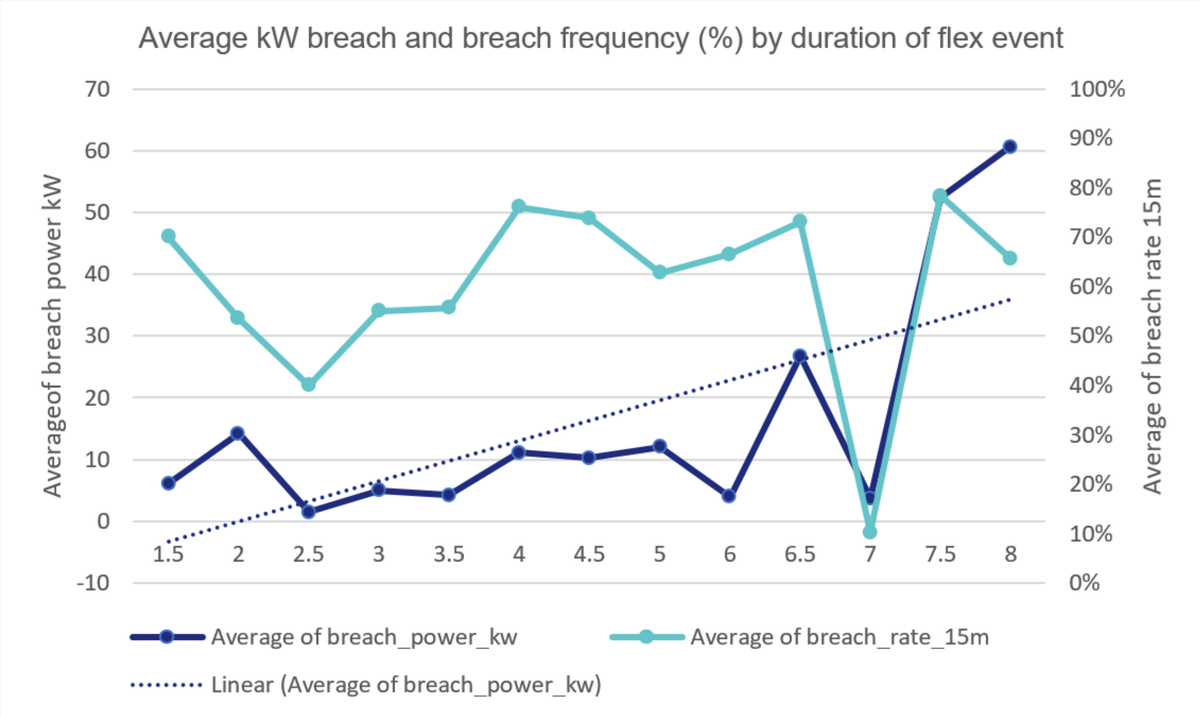
Analysis across all the events shows a clear pattern of longer and multiple events being less successful (or less predictable) in flexibility delivery than shorter events and one event in a day. Figure 32 shows a comparison of the delivery performance of different event lengths. The variation in performance of events exceeding three hours significantly exceeded that of shorter events. On average, shorter events provided 105% of requested turndown, while events over three hours only provided 70% of requested turndown.

Figure 32 – Impact of duration on flexibility performance - large depot



As shown in Figure 33 events of over six hours became particularly unpredictable.

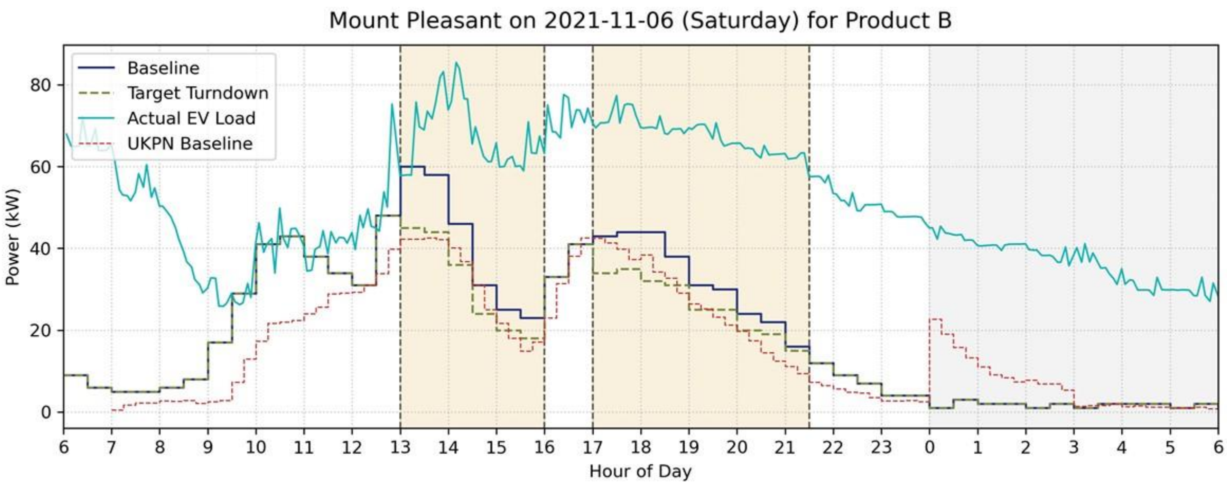
Figure 33 – Average breach vs. event length



A similar result can be seen when multiple events are offered during the same day.

Due to variations in operational patterns, load at weekends proved both lower and less predictable than on weekdays. At times, bids could not be made at the times flexibility was required as vehicles would not be predicted to charge. Weekend load could also vary very significantly from past baselines, as shown in Figure 34. This resulted in poorer flexibility performance at weekends, with 19% of events resulting in a ‘poor’ result, vs 9% on a typical weekday.

Figure 34 – Unusually high weekend charging load at the large depot

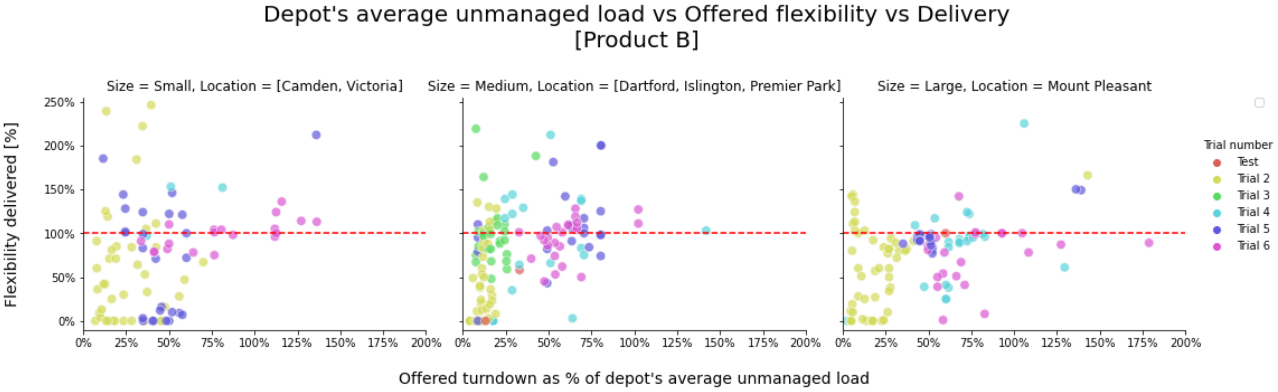


2.3.5.4 *Magnitude*

The magnitude of flexibility available at Royal Mail depots varied significantly across the day, throughout the week and between depots.

The trials found that the depots were able to deliver up to 75% of offered turndown as % of its average unmanaged EV load (kW). As shown in Figure 35, the large depot more regularly achieved close to 100% committed flexibility, whereas in small and medium depot results are much more varied.

Figure 35 – Average unmanaged load vs offered and delivered

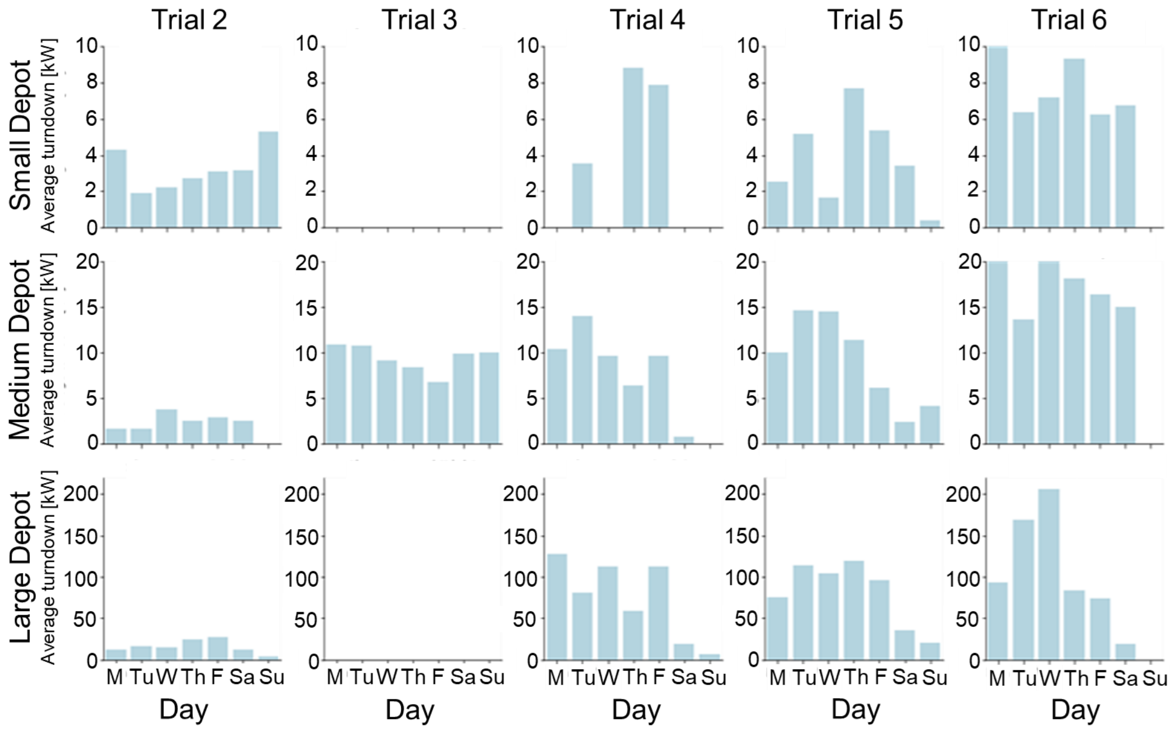


This level of magnitude comes as a result of a number of factors, including:

- The size of the depot and number of vehicles and CPs
- How well the flexibility period aligns with the peak in demand at the depot, largely dictated by the vehicles' return to depot time
- Other control methods in operation such as time of use tariff optimisation or profiled connections.

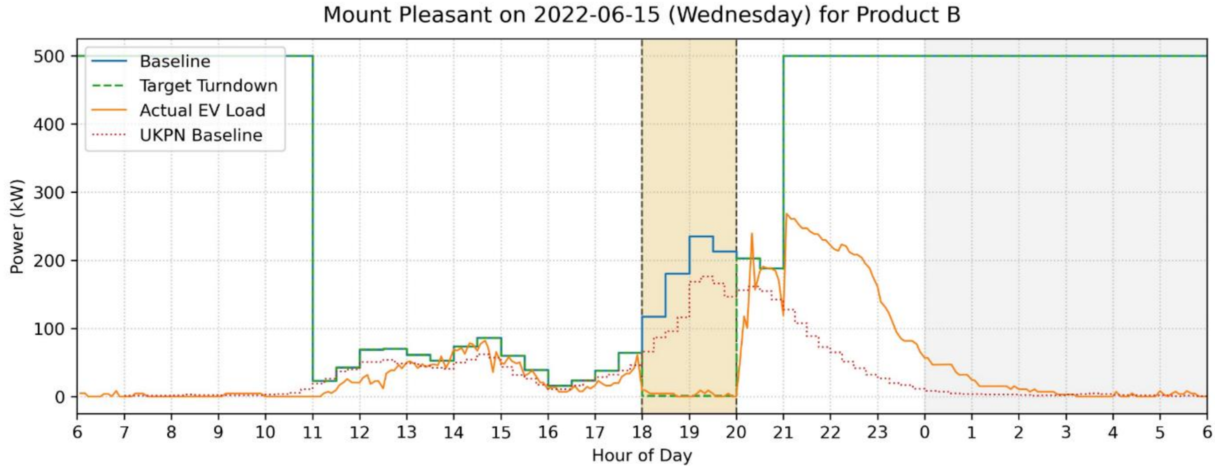
On weekday evenings, the large depot was able to deliver 130kW of turndown, as shown in Figure 36. The medium and large depots were able to deliver flexible capacity more consistently across the trials.

Figure 36 – Average flexibility turndown by trial, Product B



In trial six, the reduction of charging to zero amps (as discussed in Appendix 9) was implemented – this was successful in reducing load to zero during the flexibility window, achieving a turndown in excess of 200kW at peak, as shown in Figure 37.

Figure 37 – Example of flexibility turndown with 0-Amp control



2.3.5.5 Cost

While the Optimise Prime flexibility products allowed the creation of realistic bids in order to test the end-to-end settlement process, the prices bid were based on covering the costs involved in making a bid only. With only two bidders, the auctions did not have the liquidity or competition needed to establish a market price for flexibility.

Due to this, the project has looked at flexibility prices achieved in active markets (using achieved and/or guideline prices from UK Power Networks flexibility events), in addition to the results of settlement, to determine the cost of flexibility to the DNO and the potential revenues for depot operators.

Theoretically, Product A has a higher revenue potential than Product B, due to there being both a utilisation and an availability payment. However, the performance requirements, and the frequency of utilisation will have a significant impact on what can be achieved. Figure 38 shows an example of the revenues that could be obtained at the large site in a situation where flexibility was requested on 10% of days.

Figure 38 – Example of revenues from Product A and B flexibility services

Delivery Performance % Best Case scenario	Delivery Performance % Worst Case scenario	Flex B Utilisation Piclo Price	Flex A Utilisation Piclo Price	Flex A Availability Piclo Price
100%	60%	£549.45/MWh	£326.33/MWh	£120.70/MWh

Site	Available kW	Duration h	Working days	Available MWh	DNO Requests	MWh for Payment	MWh for availability Payment
Large	130	3	260	101.4	10%	10.14	101.4

Product B	Best Case Scenario	Best Case Scenario With Aggregator's cost 20%	Worst Case Scenario	Worst Case Scenario With Aggregator's cost 20%
Utilisation Payment	£5.571.42	£4.457.14	£3.342.85	£2.674.28

Product A	Best Case Scenario	Best Case Scenario With Aggregator's cost 20%	Worst Case Scenario	Worst Case Scenario With Aggregator's cost 20%
Utilisation Payment	£3,308.99	£2,647.19	£1,985.39	£1,588.31
Availability Payment	£12,238.98	£9,791.18	£7,343.39	£5,874.71
Total	£15,547.97	£12,438.37	£9,328.78	£7,463.02

Although Product A offers a higher revenue potential, achieving 100% delivery of target turndown is much more challenging due to lag between bid and delivery. The availability payment reduces with underperformance, and is not paid at all if a provider cannot consistently deliver at least 60% of turndown offered.

The day ahead product may need a significantly higher utilisation payment then the firm product if it is not going to be called frequently, otherwise the revenue available to the fleet for this product may not be competitive and may not attract sufficient bids to meet the needs of the DNO.

2.3.6 Product B learnings

Accurate baselining is key to creating successful bids

Accurate baselining was a key driver of the ability to deliver flexibility successfully, and accuracy of baselines increased throughout the trials as more data became available.

Baseline load at different depots could be predicted with varying levels of accuracy, for a number of reasons including:

- The size of the depot/number of EVs
- The ratio of EVs to CPs
- Seasonal and other variations in operations

Bids need to be focused on shorter periods when significant load is predicted

The tenders for Product B allowed the depots to bid for up to 4 different flexibility periods within a day, each consisting of three to four hours. Some of these periods were continuous.

Through different trials, bids were made for one or more of these periods. Results have shown that attempting to deliver more than one period of flexibility resulted in less accurate provision of flexibility. There are two key reasons for this:

1. At most depots load is concentrated at a specific and short time. At other times of day load is lower and less predictable – offering flexibility at these times is less reliable as a result.
2. Longer and continuous periods of flexibility were also more difficult to deliver. Each flexibility period pushes load into subsequent periods, and impacts upon the baseline and the minimum load in subsequent periods.

Secondary peaks can occur at the end of flexibility events

Once a flexibility event is over, power will ramp up immediately unless there are other constraints on the site. This can create secondary demand peaks – sudden surges in demand which are greater than would happen in an unmanaged scenario. If the site is being controlled to a baseline, this can be managed, but the baseline needs to be set or updated to take account for this displaced charging. If the DNO were to want to limit the impact of these new peaks, they would have to put in place procedures to limit how quickly sites are able to return charging to its maximum after the event.

Even day before, ability to predict a baseline can be limited. Controlling to a baseline for a long period of time can cause operational issues

In product B a 48-half hour schedule of load is sent by the DNO via API, for implementation by the flexible unit. This consists of the offered baseline, altered by accepted flexibility.

This method of control works well for fully predictable/controllable load, but may not be fully suited to groups of EVs. When the schedule is requested, it must be decided whether this is used to actively control the charging or not. In the Optimise Prime system used for the control of Royal Mail the optimisation system attempted to control charging to follow the baseline – this helped improve baseline accuracy, which is one of the inputs to the settlement process. This did however create a number of issues within an operational depot. While on average the load at a depot occurs overnight, in reality there will be some need for ad-hoc charging at other times (such as in the morning before a shift). There is potential that this type of charging is restricted if the baseline control is very strict.

If charging is not controlled in line with the schedule, it will likely roughly follow the schedule if the baselining is accurate but will likely deviate due to the unpredictability of the load, potentially impacting schedule reliability.

A method is needed to judge the accuracy of the baseline submitted to prevent gaming. The predictability of load needs to be considered when setting this method.

Settlement for product B is based on the FU's ability to follow the schedule, which includes the promised flexibility during the flexibility event.

While this is a simpler solution than the baselining used in method A, relying on a baseline from the flexibility provider creates the possibility of gaming. To combat this, a reliability factor, based on ability to follow the baseline between 15:00 and 21:00 hours throughout the week, is applied to the result to prevent flexible units from over-predicting baseline in order to appear to over deliver flexibility.

The period that schedule reliability is calculated on needs to be considered and clearly communicated, so that it allows for natural variation in load while acting to ensure the baseline and turndown is accurate and is not gamed by market participants.

2.4 Comparison of different flexibility sources available to DNOs

Flexibility from EVs will be one of a number of sources of flexibility available to DNOs in the future, and decisions will need to be made about what products are offered in order to maximise participation in the market.

2.4.1 Flexibility product effectiveness

Flexibility Product B was trialled across WS1 and WS2 and was generally successful for both fleets.

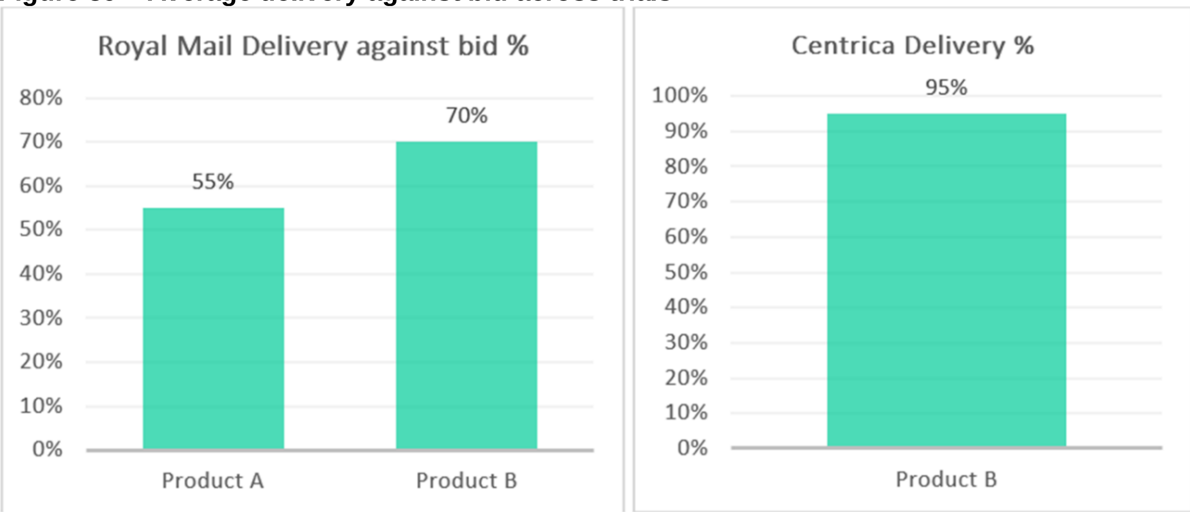
On average the Royal Mail EV fleet delivers target turndown power more successfully with Product B than Product A, as shown in Figure 39.

The main driver for this difference between the products is because it is possible to forecast turndown more accurately day ahead, rather than month ahead.

The delivery in the home trial was more successful still. There are several reasons for this difference:

- The CP to EV ratio is 1:1 in Centrica's home-based fleet, with most EVs plugging in when they return home each day, whereas in Royal Mail depot CPs were shared and EVs charged less frequently and consistently.
- Different approaches were used to reduce impact on fleet operations. British Gas CPs were completely turned off for the duration of the flexibility event, but were generally only turned down for an hour, while Royal Mail CPs were generally kept at a minimum charge rate but were flexed down for longer. The shorter full turndowns could be forecasted more accurately.
- Royal Mail FUs consisted of a single depot with between six and 87 CPs, whereas Centrica CPs were dispersed and aggregated into a group of 300 CPs. The larger aggregated group means that behaviour of individual vehicles has less impact on the flexibility result and allows a greater margin of error to be built into the bid without unduly impacting magnitude of flexibility provided.

Figure 39 – Average delivery against bid across trials



2.4.2 Comparative benefits to the DNO

The key difference between the flexibility products trialled in the project is the length of time in advance that they can be procured.

The day ahead product B appears most valuable, as procurement close to real-time means that UK Power Networks can be confident about network requirements, and can therefore send sharper price signals, whilst FSPs are more likely to commit to greater flexibility due to more accurate forecasting and are more likely to deliver in line with the bid. Product B also provides FSPs with the opportunity of participating in ESO services, as flexible capacity is not tied up in a long-term product.

However, because the volume and cost of flexibility available is not known until the day ahead the DNO cannot use this flexibility to avoid or defer network reinforcement. A DNO may also want wish to ensure that sufficient flexible capacity is available ahead of time, rather than risk insufficient capacity is bid day ahead, favouring a longer-term product. Figure 40 gives a summary of the positives and negatives of the three products.

Figure 40 – Comparison of flexibility products

Product A: Month-ahead

- ✓ Product A's long-term auction payments provide confidence that flexibility will be delivered when it is needed
- ? But, month-ahead is too late to inform reinforcement go/no-go gate and too early for accurate network or FSP availability forecasts
- ? Dispatch after gate-closure means market participants exposed to imbalance prices and unable to participate in other services
- ? *Opportunity to refine baselines?*

Product A uses a similar process to the existing Secure product, however it was trialled with a one-month ahead auction due to the limited length of the trial. In order to be used to replace reinforcement flexibility may need to be procured a year or more ahead.

Product B: Day-ahead

- ✓ DNO has good forecasts of network requirements day-ahead
- ✓ A greater amount of flexibility can be committed by FSPs
- ✓ Would allow DSO services to be procured in advance of ESO ancillary services (done intraday)
- ? Technology enhancement required to enable automation of FSP and DSO process
- ? Need to consider how to encourage accuracy in FSP-provided baselines
- ? Not certain on how Product B works with Product A yet

Product C: Intraday

- ✓ Highest clarity on current network needs
- ✓ Could be suitable for unplanned outages
- ? Has the highest requirements for operational capability and automation
- ? Might be questionable participation rate after day-ahead wholesale and ESO ancillary service auctions
- ? Hard to coordinate with ESO Balancing Market activity
- ? Need to consider how to encourage accuracy in FSP-provided baselines
- ? Not certain on how Product C works with Product A & B

The project recommends that a range of products are needed, as discussed in the recommendations in Section 2.1.4.3 of Deliverable D7, allowing use of flexible services to be maximised by allowing more fleets to participate while providing reliable and cost-effective response to the DNO.

2.5 Conclusions

The flexibility trials have shown that depots are able to provide flexibility to network operators, but have also highlighted a number of aspects of EV flexibility that need to be considered carefully in product design in order to optimise the amount of demand response that the vehicles can provide. Key considerations when designing a product include:

- It can be challenging for EV fleets to make accurate predictions for month (or further) ahead products. Such products should allow fleets to re-forecast their baseline in the run up to delivery to improve predictability/reliability of outcome
- Pricing incentives should be based on performance probability depending on certainty of delivery in order to reward good performance without disincentivising participation by some fleets
- Where baselining is needed it should be simple and tailored to the fleet. A validation method, such as automating a comparison of baselines against past performance may be needed to avoid gaming
- Incentives should be used to prevent the occurrence of secondary peaks
- Automation is required in the tender, bidding, dispatch and settlement calculation processes to make provision by smaller assets cost effective.

The key learnings from the flexibility trials are summarised in the main document of Deliverable D7.

3 Flexibility for the mixed use case

The mixed trial, WS3, only involved the analysis of data from Uber's platform and was not directly involved in the Optimise Prime methods. As a result, flexibility services could not be directly trialled. However, the project has considered whether elements of the methods may be applicable to PHVs in order to provide additional benefits to the distribution network.

Electric PHV fleet operators are unlikely to be significant flexibility providers

The operators themselves are unlikely to be flexibility providers as they do not generally own the vehicles and are not responsible for charging them – drivers would have to choose to offer flexibility. Operators could promote such services if it were commercially viable.

The value available from flexibility provision is insufficient to alter driver behaviour

There is a clear distinction between off-shift and on-shift charging and the potential for flexibility.

On shift, there is a very clear opportunity cost for charging, as drivers could be earning around £25 per hour by taking trips. Flexibility services that prevent drivers taking trips (e.g. by prolonging charging sessions or pushing them into busy periods) would need to offset this opportunity cost. As an hour of opportunity cost is equivalent to the cost of charging with a rapid CP on a per minute basis it is unlikely that a flexibility payment of sufficient value could be offered.

Off shift, there is potentially greater opportunity for flexible charging, with Uber vehicles at home acting in a manner closer to Centrica's home-based fleet. However, there are certain key differences:

- Uber charging is predicted to start later than Centrica charging, due to different shift patterns, with relatively low charging load at the time of network peak
- Fewer Uber drivers are likely to have facilities for off street charging in Greater London, with many relying on local on street infrastructure, so a smaller proportion will be able to take part in flexibility services.

4 Method 2 – Planning tools for depot energy modelling, optimisation with profiled network connections

4.1 Explanation of the method

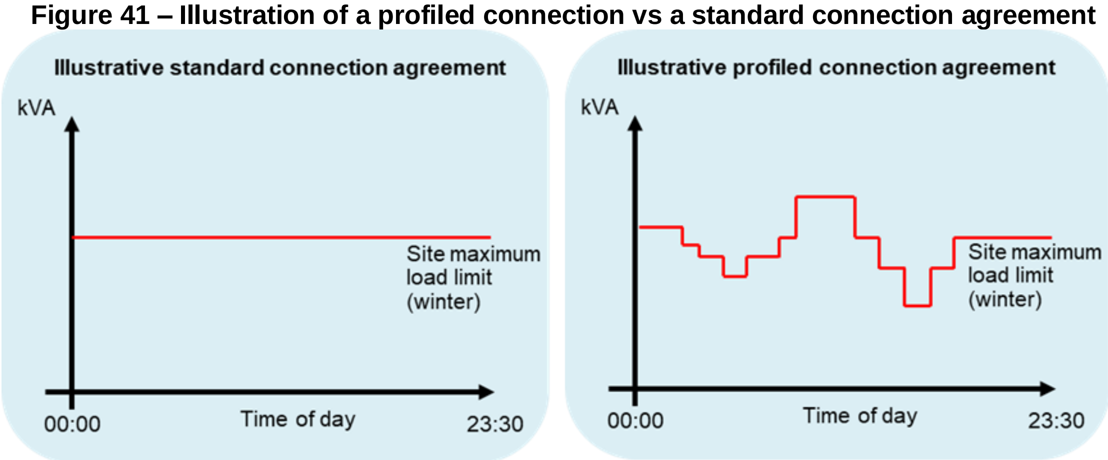
The electrification of vehicles that charge at depots, such as Royal Mail's delivery fleet, can potentially cause a significant increase in electricity demand. Many depots currently have relatively low connection capacities which may need to be upgraded, potentially causing impacts further up the network. The cost of this is currently shared between the DNO and the connecting customer. This potential cost and the time required to upgrade the network may impact upon the customer's decision to electrify a site.

For the purposes of Optimise Prime, a profiled connection agreement is defined for a given supply at a given site as follows:

A connection agreement where the applicable maximum demand limit (in kVA) varies according to the time of day and the season, up to 48 half-hourly time slots per day, with adherence to the profile actively managed through behind-the-meter smart systems and monitored by the DNO.

An illustration of the maximum load profile for a day at a site with a profiled connection agreement is shown in Figure 41.

Figure 41 – Illustration of a profiled connection vs a standard connection agreement



The aim of the method is to enable more customers to electrify their depots within the constraints of the existing network capacity. This is achieved by providing the DNO with a more accurate view on future load profiles through the use of the Site Planning Tool, offering profiled network connections which can provide more capacity to the customer when the network is less congested, and the use of smart charging and optimisation in order to achieve compliance with the profiled connection (or the existing firm connection if it has sufficient capacity).

4.2 How the method was implemented

Method 2 consists of several inter-related capabilities:

- A Site Planning Tool to help fleets understand their connection needs (further details of this tool can be found in Appendix 7), outputting a peak load minimising demand profile
- Updates to UK Power Networks' connection planning tools to analyse and offer connections profiled by up to 48 half-hourly periods
- Implementation of a control system that limits demand at a depot to the profiled connection through the control of EV charging

- Implementation of monitoring by the DNO to provide alerts when profiled connection agreements are breached.

4.3 Results from trialling Profiled Connections

Deliverable D5, Section 5, presented the initial findings from the trial of profiled connections. The key conclusions were that, due to the variability of background load at sites:

- Determining an accurate profile is key to being able to adhere to the profile
- Actual load data is required in order to accurately set an achievable yet tight profile, as load does not always follow predicted schedules – profiled connections may need to be refined as charging data becomes available, or in response to changes in depot operations
- The EV load must be equal to at least the variability of the background load in order to manage the connection through flexible EV load, plus a small buffer – expressed as $$\boldsymbol{EV\ load} > (\boldsymbol{Max}(\boldsymbol{BL}) * \mathbf{1.1}) - \boldsymbol{Min}(\boldsymbol{BL})$$

Since this initial analysis, trialling of profiled connections focussed on the two sites of Premier Park and Mount Pleasant, where the EV load is more considerable. The results of this work can be found in the following sections.

4.3.1 Further development of the Profiled Connection

As discussed in Deliverable D5, the profiled connection was originally set based on expected demand from EVs derived from telematics. In order to improve compliance with the profile it was re-planned based on actual load data from the site and this profile was run over the January to April period.

When considering adherence to the profile, success is quantified as a breach rate – both in kW terms and as a percentage of the profile in place at the time. Table 5 shows how the breach rate has reduced over time as the connection has been revised.

Table 5 – Results of profiled connection trials at Premier Park

Month	Maximum breach rate	Breach rate
January	26.7%	9.6%
February	35.5%	8.1%
March	55.5%	5.6%
April	59.6%	4.6%
Overall	59.6%	6.6%

Table 6 details the timing and length of the highest observed breaches in each month. It can be seen that in most cases the breach is at a time of low EV load (generally late on a Sunday or early on a weekday morning) demonstrating that the background load is the cause of most breaches and there is limited possibility of the EV load offsetting them.

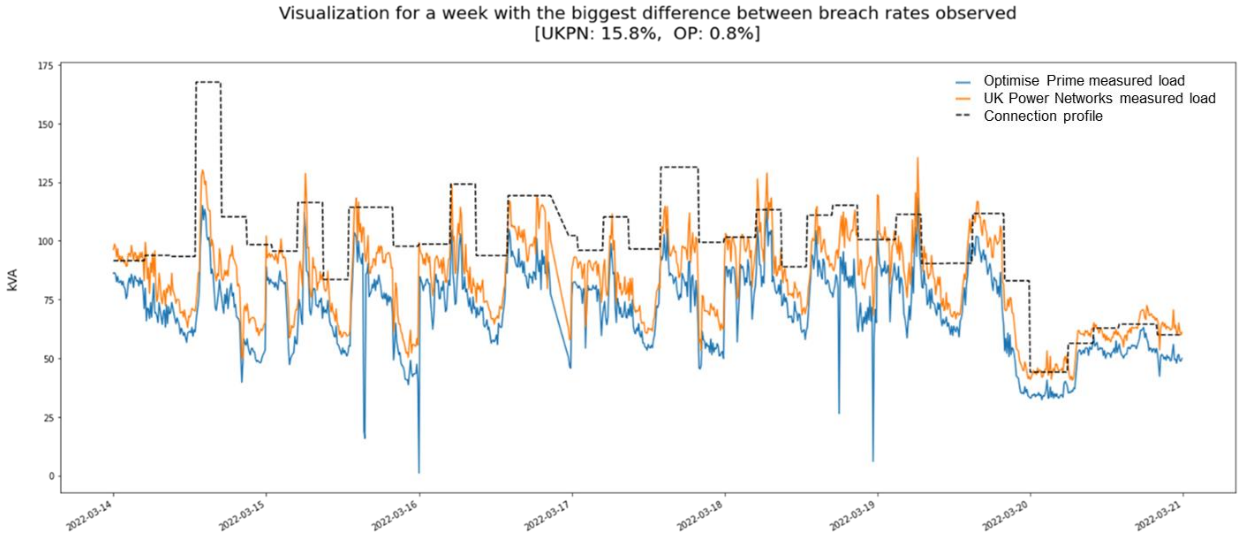
Table 6 – Maximum breached observed in flexibility trials

Month	Maximum absolute breach rate (kW)	Maximum breach rate relative to the profile (%)
January	29.0 kW (for 4 mins) (reading: 145.3 kW, profile: 116.3 kW) Tuesday, 06:10	26.7% (reading: 71.3 kW, profile: 56.3 kW) Sunday, 07:01
February	40.9 kW (for 1h 26mins) (reading: 160.1 kW, profile: 119.2 kW) Wednesday, 15:02	35.5% (reading: 122.5 kW, profile: 90.4 kW) Saturday, 14:26

Month	Maximum absolute breach rate (kW)	Maximum breach rate relative to the profile (%)
March	38.1 kW (for 26 mins) (reading: 131.8 kW, profile: 93.8 kW) Monday, 05:16	55.5% (reading: 93.2 kW, profile: 59.9 kW), Sunday, 23:52
April	35.7 kW (57 mins) (reading: 95.6 kW, profile: 59.9 kW) Sunday, 23:07	59.6% (reading: 95.6 kW, profile: 59.9kW), Sunday, 23:07

Following the update to the profiled connection it was noted that the site still generated a high number of breach notifications from UK Power Networks' monitoring systems, exceeding the expectations of the Project's monitoring. An example week of monitoring data is shown in Figure 42, highlighting the discrepancy between the site load considered for managing the EV charging in accordance with the profile (blue line), and the total site load as monitored by UK Power Networks (orange line). Part of the reason for these breaches occurring was found to be that an element of the site load was not being fully monitored. Difficulty was encountered at a number of sites ensuring all load was monitored due to the complexity of the electrical installations on the sites. Given that the difference in readings was relatively consistent, the difference was factored into the profiled connection set, reducing the number of breaches in the May trials.

Figure 42 – Monitoring of site load at Premier Park Depot



Where breaches of the connection did occur, they were generally short in duration, as shown in Figure 43 and Figure 44:

- 50% breaches last for no longer than two minutes
- 75% breaches last for no longer than four minutes
- There were very few breaches lasting longer than 10 minutes

When setting the profiled connection, the DNO needs to consider whether there is a maximum size, frequency or length of breach that can be tolerated without causing disruption to other customers.

Figure 43 – Distribution of breach durations

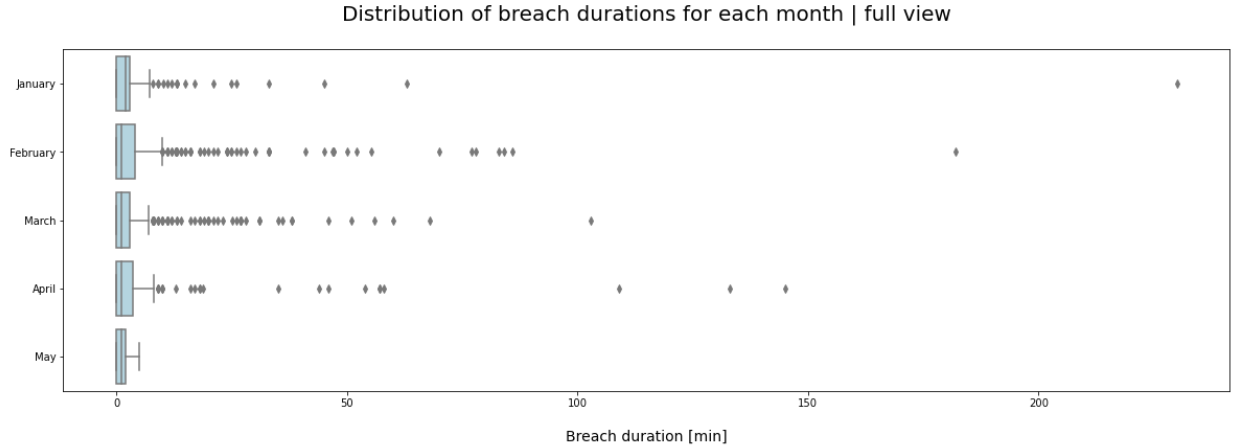
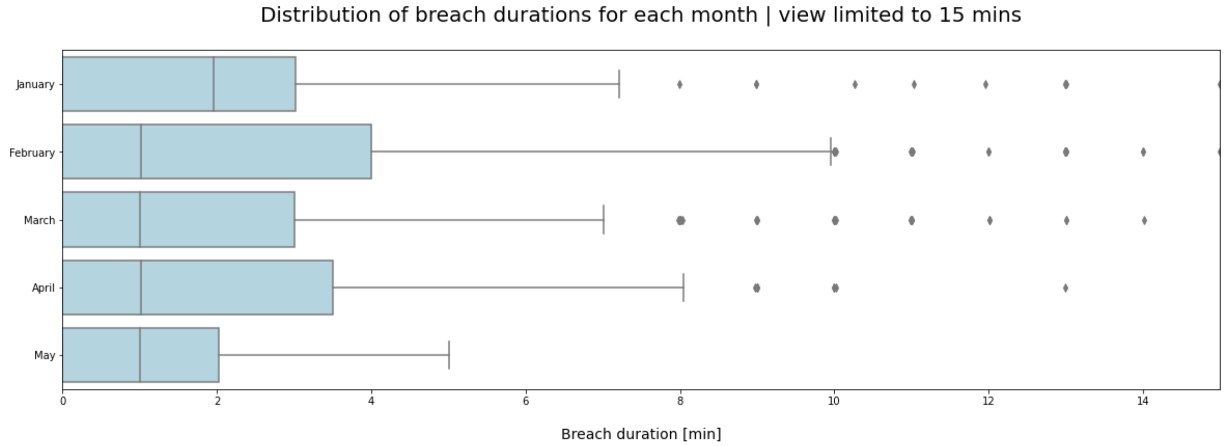


Figure 44 – Distribution of breach durations – 15-minute view



4.3.2 Analysis of the drivers of load variability

As described above, background load was often the cause of profile breaches. It was found to be variable across many of the sites, across days, within months and throughout the year.

At the Premier Park depot, as shown in Figure 45, there were months with background load peaking at 80 kVA over the typical background load observed in August 2021 (illustrated by the blue area) Even within the month there was significant variability, as shown by the red area. This signals that:

- The ability to create a profiled connection based on a short 'training period' for some depots may be limited
- Background load can be highly volatile – the better its variations are understood, the better the profile that can be created
- Where there is not sufficient data to create an accurate profile, a more generous buffer may be needed at first to take account of this variability.

Figure 46 shows a similar pattern at the Mount Pleasant Mail Centre, with a greater variability in load within the month, and several significant peaks highlighted that could impact compliance with a profile.

Figure 45 – Variability of background load at Premier Park - day vs month vs year

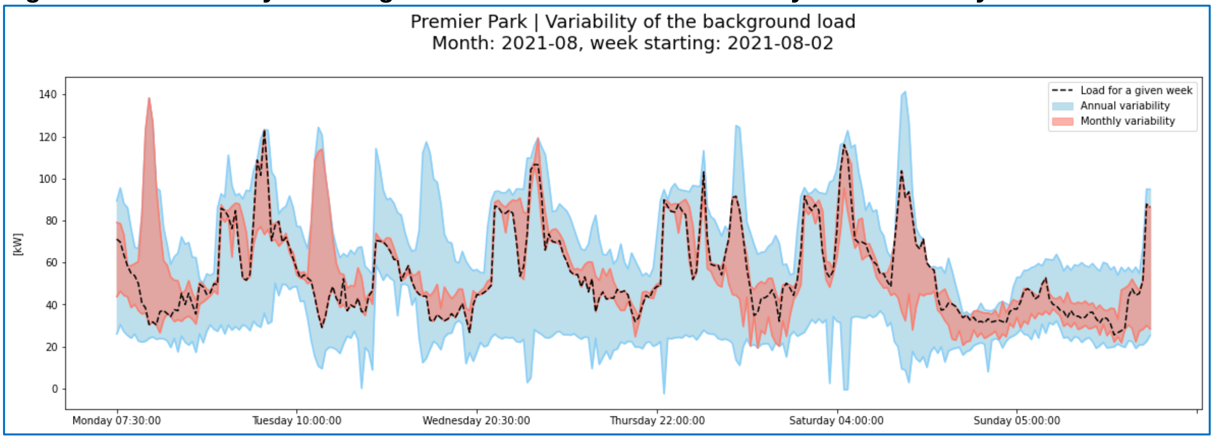
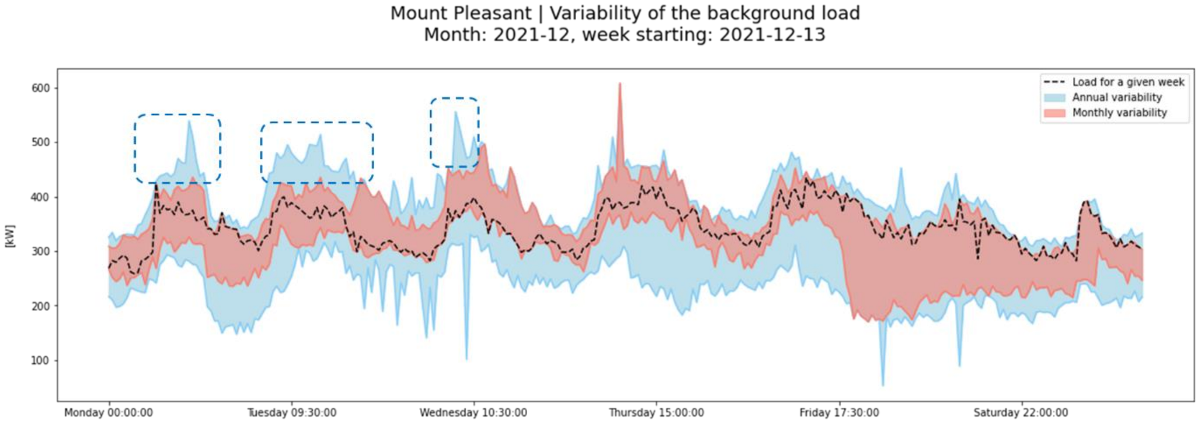
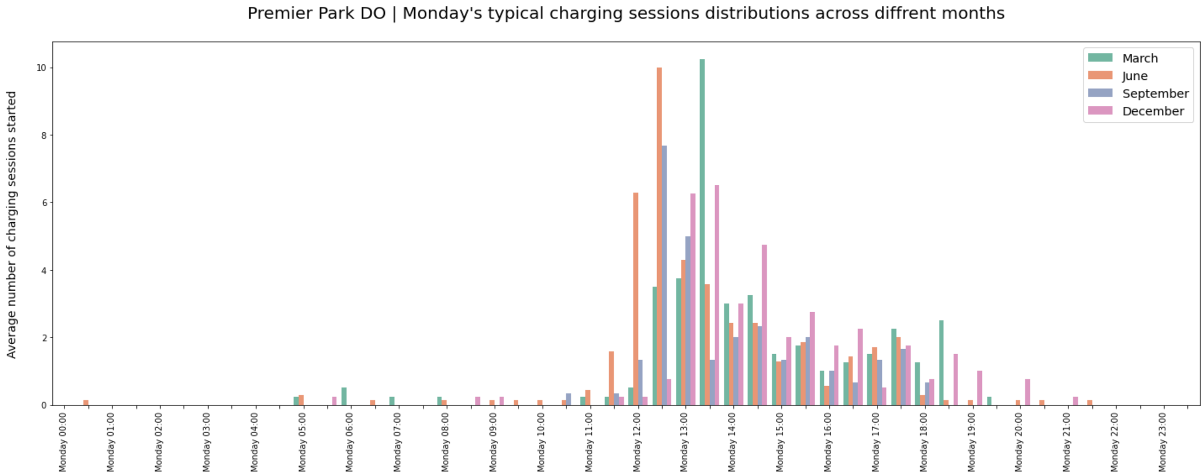


Figure 46 – Variability of background load at Mount Pleasant - day vs month vs year



In addition to the variability in the background load, EV load also changed throughout the year. The plug-in time of vehicles had a strong seasonal component, with winter plug-in times being one to two hours later than in the summer, as shown in Figure 47. At Royal Mail, this behavioural change is understood to be due to the higher parcel delivery workload in winter months.

Figure 47 – Shifting EV load at Premier Park



In May 2022, the profile was re-run, considering the differences between UK Power Networks and the project's monitoring. The result of this is shown in Table 7, below. The white rows show the actual maximum breaches with the revised trial and the green rows show the maximum breach that would have occurred if the shift in EV charging load had been taken into account.

Table 7 – Profiled connection results, May 2022

Week	Breach rate (%)	Maximum absolute breach (kW)	Maximum relative breach (%)
9th-15th May	0.19%	4.9 kW (reading: 119.4 kW, profile: 114.5 kW) Wednesday, 12:57, duration: 2 mins	4.33% (reading: 102.6 kW, profile: 98.4 kW) Monday, 23:03, duration: 2 mins
9th-15th May	0.00%	-	-
16th-22nd May	0.23%	6.1 kW (reading: 101.7 kW, profile: 95.6 kW) Sunday, 23:12, duration: 5 mins	6.29% (reading: 101.7 kW, profile: 95.6 kW) Sunday, 23:12, duration: 5 mins
16th-22nd May	0.13%	6.1 kW (reading: 101.7 kW, profile: 95.6 kW) Sunday, 23:12, duration: 5 mins	6.29% (reading: 101.7 kW, profile: 95.6 kW) Sunday, 23:12, duration: 5 mins

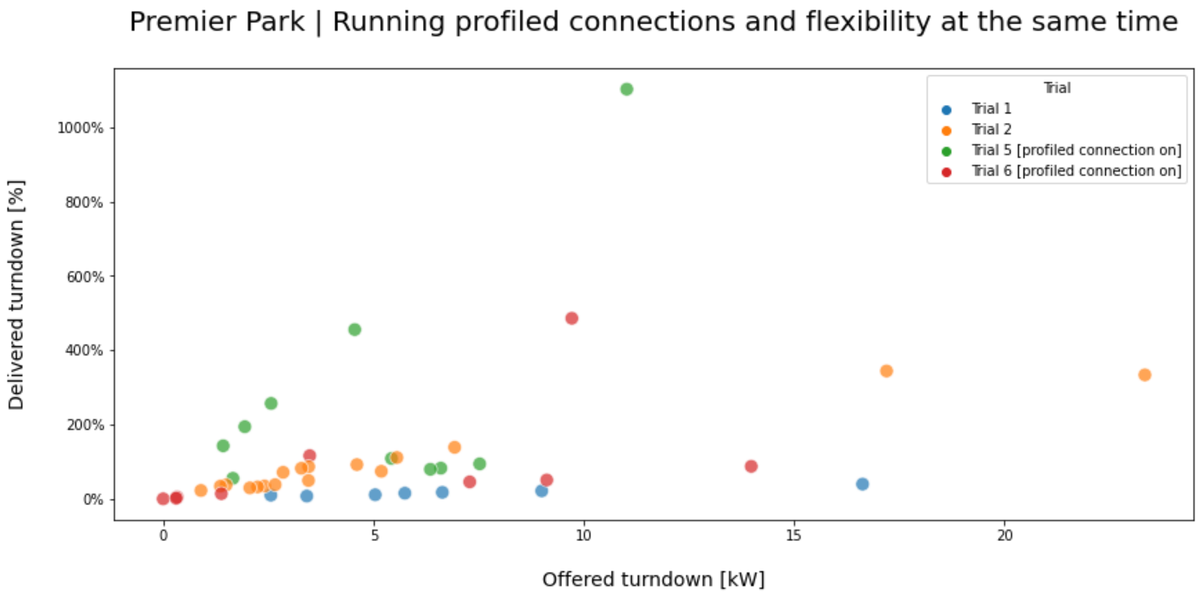
4.3.3 Combining profiled connections with other flexibility products

Flexibility services were offered at Premier Park with and without a profiled connection being enabled. Figure 48 shows the result from these trials.

For the trials where flexibility was offered on top of profiled connections, performance against the bid amount was not significantly worse than in trials without profiled connections.

The presence of a profiled connection can reduce the size of the bid that can be made, either because of properties of the site's load, the profile supressing load at the time flexibility is required or there being insufficient space in the profile to shift the load. This example does however show that there are scenarios when stacking the methods is possible.

Figure 48 – Flexibility results with profiled connections



4.4 Desktop study of the connection requirements of additional Royal Mail depots

In order to test the potential process for requesting profiled connections (or connections relying on smart charging to minimise load) and quantify the potential value for fleets, eight further Royal Mail depots were assessed with the project's Site Planning Tool. The depots, located across UK Power Networks' licence areas, were chosen as sites where Royal Mail was planning to electrify and it was perceived that the existing connection capacity would be insufficient.

The sites presented a complex use case for the site planning tool, as Royal Mail specify a 2:1 EV to CP relationship with alternate day charging in use. Sites also needed to be modelled with additional visitor and workshop CPs which were not being constrained by smart charging.

Of the eight depots analysed, six would have required reinforcement works in a base case scenario, considering just the rated capacity of the CPs and existing site load. When actual predicted load was taken into account, four of these sites would need upgrades, and when managed smart charging was implemented only two sites would need an upgrade, as shown in Table 8. All costs and time to connect were estimates, based on a desktop analysis by network planners.

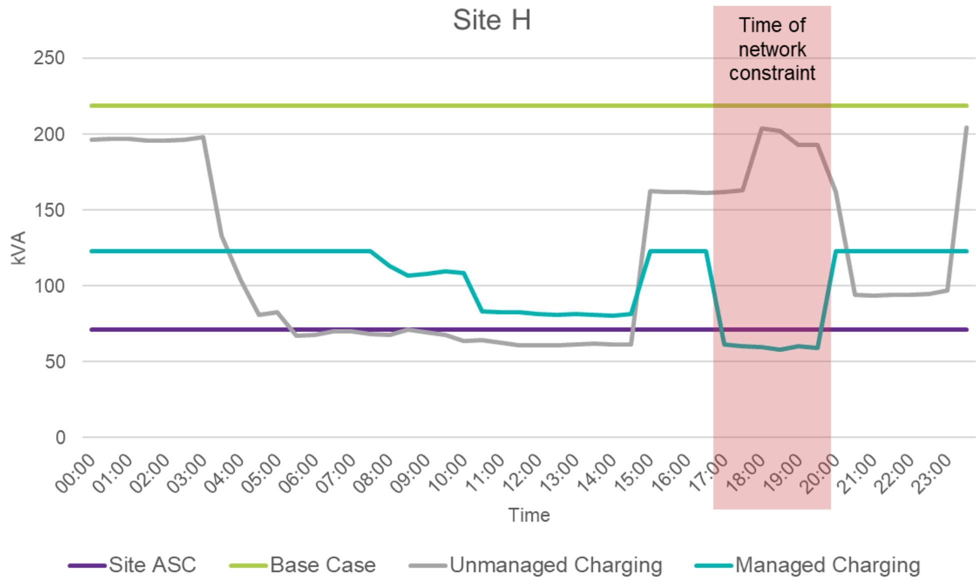
Table 8 – Connection cost estimates for depot electrification scenarios

Site	Managed charging scenario	Unmanaged charging scenario	Base case scenario
A	Within ASC	£50,000 - £75,000	£50,000 - £75,000
B	£21,000	£21,000	£21,000
C	£0	£0	£95,000
D	£0	£0	£8,000
E	Within ASC	Within ASC	Within ASC
F	£0	£0	£0
G	£0	£10,000	£10,000
H	£20,000	£115,000	£115,000

Potential savings of up to £95,000 per depot were identified, compared with the base case scenario. Time to connect could also be reduced, with many depots not requiring works in the managed charging case, rather than 5-16 weeks. The main driver for reinforcement cost was sole-use asset replacement (service cables, cut-outs, etc.) rather than a need to upgrade shared network assets.

The peak demand of the unmanaged scenarios is similar to the base case scenario, though lower, so reinforcement requirements are often similar. At three of the sites, constraints existed on the wider network in the 17:00-20:00 period, so the site planning tool was utilised to test the feasibility of reducing load during this period while still fully charging the vehicles. Figure 49 shows the difference in load achieved by minimising charging during this period at one of the depots.

Figure 49 – Managed charging profiled to avoid peak network load



4.5 Conclusions from the profiled connections trial

Profiled connections can be implemented successfully

The trials have found that shift of EV load can be used successfully to adhere to a profiled connection, provided there is some allowance for iterations

To use EVs to manage compliance with a connection a minimum volume of EV load is needed

EV load should be greater than the difference between max and min building load (EV load > (Max(BL) x1.1) – Min(BL)). If it is not, then the EV load will not be able to be used to manage the profile

Profiled connections may need to be re-profiled regularly to reflect seasonal changes and the time needed to gather sufficient load data

There is a high variability in background load for all depots, resulting from seasonality and events (e.g. public holidays) which causes schedule changes. Therefore, a profiled connection should be updated over time:

- 1st profile (based on schedules and meter data) – a buffer to the requested profile is recommended depending on the time of the day and day of the week with and one hour buffer either side of the peak profiles requested
- 2nd profile (based on feedback from DNO and EV charging data/building load monitoring) after 12 months of data collecting. A year of data is the recommended 'training' period for setting a profile. However, a three month data set could be used to start with and then iterated every three months with each season
- 3rd profile (based on seasonality, schedule changes picked up from the EV charging data/ building load monitoring) – every three months

Profiled connections can be used alongside flexibility services

Profiled connections do not necessarily conflict with participation in flexibility markets, depending on timing and provided there is enough profile headroom for recovery. Depending on local requirements, offering profiles with sufficient capacity overnight to allow a depot to shift load and benefit from participation in the peak hours flexibility markets.

Non-EV profiles should be considered

Consideration should be given to offer profiled connections to non-EV customers that simply take into account the variability in background load, or other types of controllable loads. This would potentially make more capacity available to customers connecting EVs and other LCTs as they may be able to take up unused capacity from other organisations.

4.5.1 Recommendations for the implementation of profiled connections

Based on the analysis of the profiled connection trials, the project has made a number of recommendations for the future development and implementation of the product:

- **Fleet demand changes**: products are needed to accommodate changes in demand by the fleet – this could include periodic or on-demand reviews to revise the connection agreement, or offering top up/sell back capacity products when capacity is required on a shorter term basis
- **Network demand changes**: consider what products and prices UK Power Networks could offer to a fleet to accommodate forecasts of capacity constraints (outside of the flexibility markets), such as a dynamic connections product
- **Contractual**: consider what contractual products, operational processes and penalties would be required to police the profile, and to encourage non-EV customers to adopt profiled connections. There is potential for a spectrum of products existing in profile connections and the flexibility markets.

These recommendations are discussed further in Section 2.2.3 of the main Deliverable D7 report.