NEXT GENERATION NETWORKS

VISIBILITY PLUGS & SOCKETS
WPD_NIA_029

CLOSEDOWN REPORT

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	Name	Date
Prepared by:	Jenny Woodruff	09/01/2020
Reviewed by:	Nicolas Metivier (Centrica)	23/01/2020
	Sam Wevers (Centrica)	23/01/2020
	James Atkinson(Centrica)	23/01/2020
	Yiango Mavrocostanti	28.01.2020
Approved by:	Jonathan Berry	03/04/2020

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Contents

Executive Summary

Visibility Plugs and Socket (VPaS) investigated the potential for Distribution Network Operators (DNOs) to purchase flexibility services from a third party independent platform. It was believed that having a "one-stop-shop" marketplace offering multiple services and a strong local brand could recruit different customers to those recruited under Flexible Power branded flexibility solution. The platform would also enable greater "visibility" of services being purchased.

This project was initiated in parallel to the Cornwall Local Energy Market (CLEM) project, funded by the European Regional Development Fund (ERDF) and managed by Centrica. The concept was that a market platform would be a "socket" to which a number of "plugs" (customised interfaces) could connect including DNOs, Aggregators, Electricity System Operator (ESO), Suppliers etc. While the CLEM project funded installations that would enable both industrial and domestic customers to provide flexibility services, far fewer flexibility customers were recruited than were expected, this in part may be due to the location and the lack of industrial and commercial loads that may be attracted to flexibility. This necessitated a change in trial locations and reduced the potential for learning about customer behaviour. The customers that were recruited, however, provided significant combined capacity, circa 25MW. Services were procured for transformers and circuits at 132kV and 33kV.

The project developed an engine for optimising flexibility service offers selection and showed how the specification of services can impact the complexity of the optimisation problem.

The project trialled two market mechanisms separately. Each trial demonstrated the platform's successful use for purchasing, delivery and settlement. The Quote and Tender model replicated traditional tendering using the market platform and was similar to the project ENTIRE process. The Spot Market provided services to both DNO and ESO concurrently with a sophisticated clearing algorithm to prevent trading related power flows that would exceed DNO network capacity. This was based on a fairly simplistic model of network hierarchy and capacity, but offered a view as to how conflicting use of flexibility services could be reduced. It also highlighted the requirement for DNOs to provide information about future network configurations, as well as default configuration, to ensure that services are not purchased that will be invalidated by planned switching.

The trials showed that prices under both market models centred on the £300/MWh that was used for ENTIRE for the secure service and is used under Flexible Power as a default value where an area has little liquidity. Service delivery was similar under both market mechanisms averaging 61%, however two issues were uncovered. Firstly, the delivery calculation was found to be more sensitive than expected to ramp up activities and was corrected during the trial. The second issue related to domestic customer delivery assessment which sometimes contradicted the measured response of the battery systems.

A comparison of service delivery using minute or half hour resolution data showed that half-hourly metering provided acceptable results. Comparing the baselining approaches under ENTIRE and CLEM suggests the CLEM approach has benefits but may still benefit from refinements to smooth the baseline profiles. Further analysis to assess the sensitivity to different baselining approaches is recommended, especially for domestic customers where the method gave unexpected results. Further work to automate data exchanges across a market interface will take place as part of EFFS.

1 Project Background

This project was instigated in response to the issue identified by the Smart Grid Forum Workstream 6, which was the necessity for market participants and network operators to have visibility of each other's proposed Demand Side Response (DSR) actions and requirements which was expected to become an increasingly important issue as DNOs transitioned to Distribution System Operators (DSOs). Details of how the various elements of the project contributed towards this workstream are given in Appendix 1 - Smart Grid Forum - Workstream 6 Relevance. Work on this project began before the instigation of the Open Networks project which has a number of overlapping areas of interest.

The project was designed to work in parallel with Centrica's CLEM project which had a wide range of objectives including increasing the capacity of installed renewables. As part of the CLEM, Centrica envisioned a market platform that could bring together flexibility service purchasers and providers. This would share relevant data within the system about flexibility service requests and purchases to improve co-ordination between the various parties.   The ambition for Centrica's market platform `was wider than just supporting flexibility services. As the name suggests, it was intended that it would support local energy trading, peer-to-peer trading and any other related service that could help attract the largest number of participants and therefore keep any charges to cover platform operating costs down.

An early system concept diagram is given below in Figure 1 - CLEM system concept diagram below. This shows how a common Energy Service Bus would provide the "socket" to which many specialist "plugs" could connect e.g. a plug for DNOs, another for the ESO etc.

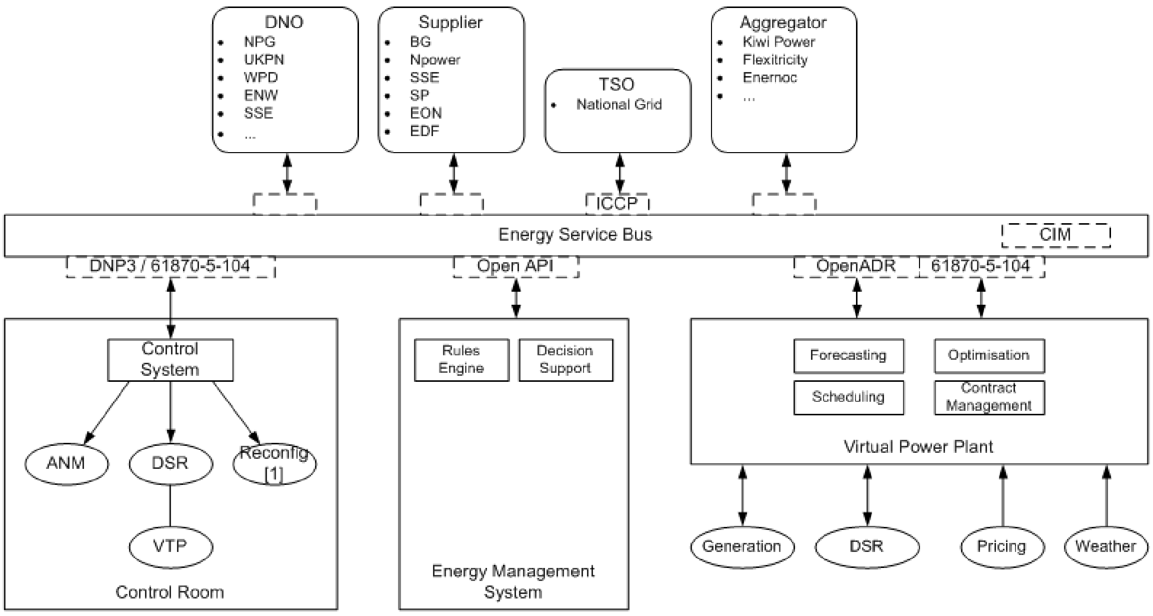


Figure 1 - CLEM system concept diagram

The expected functions of the Socket, the hub of the market platform, are given in Figure 2 - Socket capabilities.

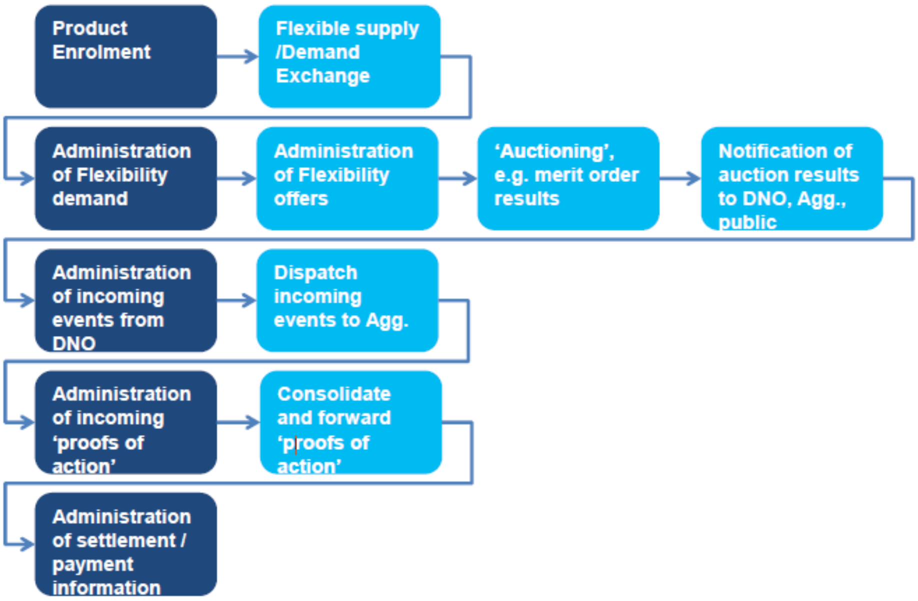


Figure 2 - Socket capabilities

The CLEM and VPaS projects have been working together in parallel but the separate projects have separate funding streams and Intellectual Property Rights (IPR) arrangements. Centrica have been responsible for recruiting flexibility service providers and developing the market platform (including the clearing engine) whereas WPD have provided supporting data and explored the options for optimisation. Work to define the two purchasing methods to be trialled and their market rules has been carried out jointly.   WPD 's involvement with CLEM will extend beyond the VPaS project with the Network Innovation Competition (NIC) project Electricity Flexibility and Forecasting Systems (EFFS) also scheduled to use CLEM during trials.

1.1 Project Learning Objectives

The learning objectives for the project mostly relate to comparing market platforms with direct recruitment and how different purchasing methods perform, as given in the following list of questions.

- How can we specify our flexibility service requirements using a trading platform?
- How can we prioritise offers and create an optimum selection to meet our requirements?
- Does this market platform increase the numbers of customers willing to sign up?
- Does this market platform increase the proportion of customers that provide services directly rather than via an aggregator?
- Is recruitment via the establishment of a market platform more cost effective than direct recruitment?
- What are the options for sharing data via the market platform?

- What are the market options (long term contract, short term contract, spot market etc.) and how do they differ in terms of reliability and cost?
- How do data exchange timings impact the use to which the data can be put?
- How can service delivery be validated and is half-hourly data sufficient to validate service delivery for longer duration services?
- What data is required to enable customers to determine their relevance to service requests, including requests that are not from WPD?
- What is the best location for functions such as load modelling and optimal service selection i.e. within the socket or the plugs?
- Establish early learning around the management of conflicted procurement at T and D levels(Phase 2)

1.2 Project Phases

The project had two main trial phases, as outlined in Table 1 below.

Feature	Phase 1	Phase 2
Purchasing method	Quote and Tender	Spot Market
Trial duration	May 2019 to August 2019	August 2019 to December 2019
Conflict resolution	None	Included in the market clearing algorithm and Transmission/Distribution coordination is also supported via the services dashboard providing visibility of services purchased by each party.
National Grid participation	No	Yes

Table 1 - Key feature comparison for VPaS Trials

2 Scope and Objectives

The project objectives reflected the need to investigate different flexibility purchasing methods and models as given in the table below.

Objective	Status
To investigate the impact of varying attributes such as market model, purchasing timing etc.	✓
To assist Centrica with the design, testing and trial of the market platform known as the Cornwall Local Energy Market.	✓
To determine the data exchanges that are required to support the platform and the practicalities of purchasing and operating flexibility services via a market platform.	✓
To determine a means of optimising the selection of services from those available, which may include other factors than price, such as reliability.	✓

3 Success Criteria

The project's success criteria are given in the following table.

Success Criteria	Status
Business processes validated and we have understanding of their practicality / limits.	✓
Data exchanges validated and can be used as a specification for future systems	✓
Process to optimise and combine offers of flexibility services trialled and refined for inclusion in future systems	✓
Service delivery validation explored and options understood, including whether half hourly metering data can provide sufficient information.	✓
Understanding of whether load modelling and optimal service selection are best placed within the "socket" of a market platform or the "plugs" of associated software.	✓

4 Details of Work Carried Out

4.1 Target area selection

The Cornwall network is characterised by having large volumes of renewable generation connected to it compared to the connected load. Cornwall has relatively low levels of larger industrial customers. Cornwall benefits from high levels of solar irradiance and in addition to a large number of 33kV connected renewable sites, both of WPD's currently 132kV connected wind farms are located here. Target areas were selected for the trials by analysing the customer numbers, types and profiles at the various Bulk Supply Points (BSPs) and primary substations within the Cornwall area. This was supplemented by discussion with the local network planners to see if there were any areas of the network where increased flexibility services would bring real benefits. While no flexibility service requirements had been identified at the time, recent assessments have identified demand turn down requirements in areas around Camborne, Hayle and Penzance. Similarly, services that could enable further generation connection would be beneficial as most sites are near their reverse power capacity.

4.2 Customer recruitment support

Customer recruitment was supported by sending a mailshot to the largest generators and load customers in the Cornwall Area. This was carried out before the GDPR legislation became active.

4.3 High level specification of the market platform

Several workshops were held to identify:

- the different user roles for the market platform;

- the market platform use cases;
- DNO flexibility service use cases;
- ESO flexibility service use cases;
- potential services that could be supported by the CLEM platform; and
- services and use cases to be prioritised in the CLEM development.

The workshops varied in the participants with some being solely between Centrica and WPD but others involving a wider range of stakeholders for the CLEM project i.e. ESO, academic partners and Ofgem.

4.3.1 Commercial Optimisation function location

There are a number of different functions that require optimisation. One example would be the optimal selection of network solutions such as reinforcement or improved voltage control vs. non-network solutions e.g. flexibility services. Another function that can be optimised is the selection of network locations for purchasing flexibility services reflecting their relative impact on a particular network issue.

Commercial optimisation was envisaged to be subsequent to optimisation stages that require understanding of network characteristics and would largely reflect price and reliability risk. Originally the CLEM was envisaged as a single source of flexibility requirements and therefore the commercial optimisation of bids to match offers for the Quote and Tender market model was seen as function of the CLEM.

However, as the project progressed the proliferation of market platforms suggested that the DNO may need to optimise the selection of flexibility services over multiple platforms and therefore the DNO will need to be able to support commercial optimisation functions within their own flexibility software.

4.4 Network hierarchy model provision

One particular aspect discussed during the design phase was how flexibility service providers would understand whether they were relevant to the services being requested. There was debate as to whether the DNO should provide a network hierarchy model to be included within the market platform so that customers-to-network association could be validated within the platform or whether the customer-to-network association should be provided to customers on request by the DNO. Centrica were originally provided with high level mappings that showed relationships between primaries, BSPs and GSPs. This was supplemented with network diagram extracts so that the relationship of 33kV or 132kV connected generator sites to WPD substations and feeders could be determined.

During the duration of the project WPD improved the data available in relation to network hierarchy which could be downloaded from the flexibility map from WPDs website. Centrica were then able to merge this data with that previously provided. Additionally the points of connection for individual MPANs have been provided by WPD on request with customer's permission.

While the limited requirements for the trial could be met in an ad-hoc way, any roll out to business as usual would need to be more robust. Incorporating MPAN to network mappings within a shared CIM model would give the most accurate results and allow for the impact of topology changes on individual customers to be best understood. However, GDPR has made using MPANs less attractive and filtering a combined dataset to take into account particular customer permissions for different users may be prohibitively complex.

One potential option, using less sensitive location information, would be to make use of the Electricity Supply Areas (ESA) using the ESA outline polygon set(s) via some suitable software utility. The ESA's are geographic areas that are electrically served by a network asset connected to WPD's 132kV or 66kV distribution networks. The ESAs are served by a BSP, typically a 132/33kV substation or a primary substation, typically 132/11kV or 66/11kV. The ESAs are produced by assessment of the electrical reach of a network asset – this is effectively done by producing polygons around distribution substations within the ESA. The ESAs were produced and are maintained by the Network Strategy team in order to support the "Strategic Investment Options – Shaping Subtransmission" reports[1], which are published every two years for each of the WPD license areas. They can also be used to provide a mapping or translation between geospatial datasets (e.g. projections of the distribution of electric vehicle adoption) and the Subtransmission network. This enables the network impact of such projections to be assessed.

[1] https://www.westernpower.co.uk/smarter-networks/network-strategy/strategic-investment-options-shaping-subtransmission

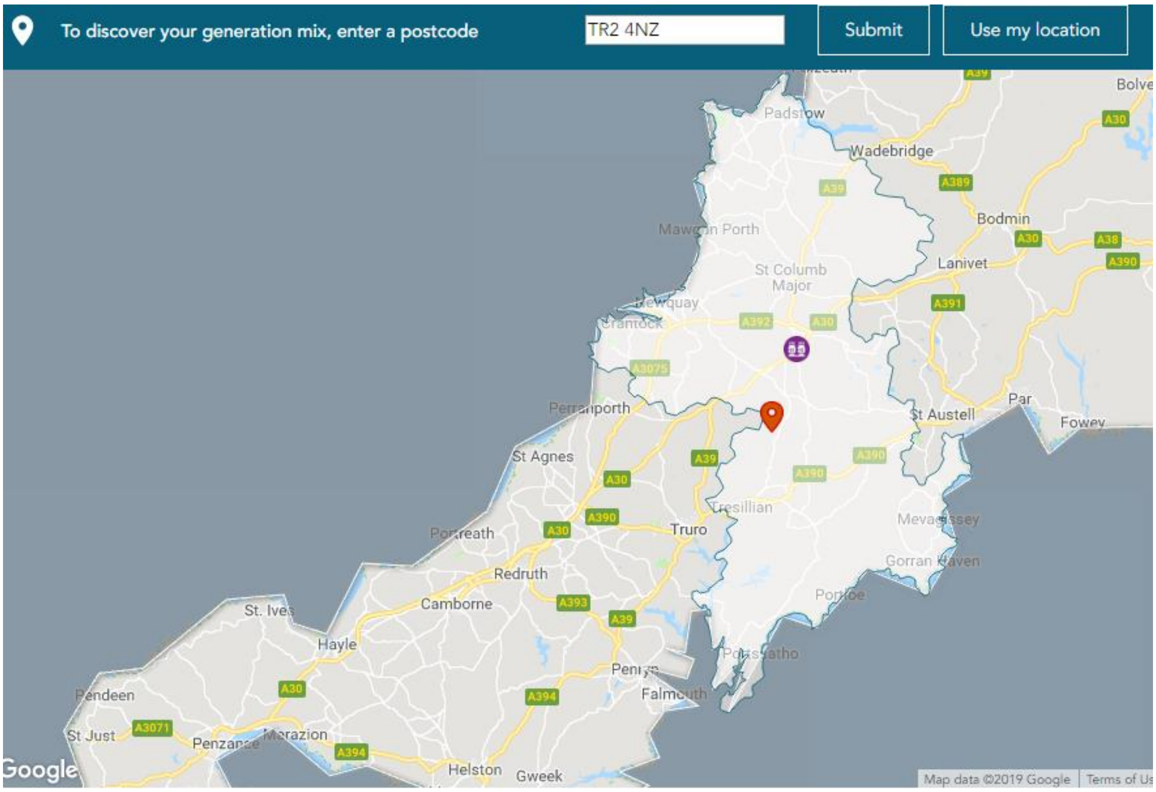


Figure 3 – Fraddon BSP Supply Area Outline (Polygon) in the Carbon Tracer App

WPD originally worked with its subcontractor Regen to create the polygon sets using the following steps.

1. The positions of all distribution substations are plotted on a map;
2. The distribution substations are colour coded by upstream substation (BSP or primary);
3. *Voronoi polygons* are then used to obtain the outline of the supply areas.

Initially, these were drawn manually (although typically in a GIS capture environment) around clusters of distribution substations of the same colour so as to form the polygons.

The available polygon sets exist at several levels, including that of the primary distribution network, the BSPs and also for certain trials zones involved in ongoing DSR pilot schemes. As ESRI shape files, these can be imported into numerous third party utilities such as Google Earth, QGIS etc. or used on application host servers to define the area boundaries to be used in conjunction with SQL Spatial queries. The ESRI shape file set includes a database .DBF file (in DBASE II format), which allows the association of a set of attributes with each shape file. This can include any available information which is required to be rendered in the top level application.

As well as internal use, in some approved cases the ESA polygon sets can therefore facilitate external use by interested third parties to perform a mapping between a geographic area and the electricity supply network – usually via some form of geospatial query able to determine whether a specific location falls inside a given supply area. Examples include: the map function within the WPD Carbon Tracer App/Website (developed for WPD by Enigma interactive) which directs the app as to the network location of the app user (who will know their geographic location but are unlikely to be aware of how they connect to the distribution network).

An analysis of postcode based hierarchy localisation vs. use of the polygon method during the testing phase of the Carbon Tracer project showed that the polygon localisation mechanism proved to give the correct result in around 96% of cases. When the incorrect cases were followed up, these were found to fall into two classes: at the boundaries of the polygons, implying a level of edge case uncertainty deriving from the method of production, and in coastal regions where the precise outline of the coast had not been fed into the polygon definition leading to a number of properties being incorrectly assessed as outside of the WPD service area boundary. In both cases, the implication is that further refinement of the polygons could result in this approach being highly accurate.

4.5 Market rules development

For the Phase 1 market model, the market rules were modelled closely on the approach being taken by Project ENTIRE. The original aim was to make it possible for the purchaser of flexibility services to be able to specify services with customised timings so that the services could have customised timings for providing offers and customised arming or triggering notification times. This was eventually rejected in favour of adopting standard timings as many of the participants in the trial were not experienced service providers and a simpler system would require less of their time.

Phase 1 trial operates as follows.

1. The purchaser of flexibility services indicates their requirements for flexibility services by creating a bid or service request.
2. The flexibility providers have a period of time to provide offers in response to the bid. This varied between one and two weeks.
3. At the end of the time period, the flexibility purchaser has the option download the set of bids as a csv file and upload this data into a separate optimisation tool.
4. The flexibility purchaser then selects the optimal selection of offers on the system as indicated by the optimisation tool to create contracts for service delivery
5. The service provider is responsible for delivering the service as required. The DNO is not responsible for providing a control signal to initiate response.
6. Validation of service delivery is carried out by the platform operator on behalf of the service purchaser.
7. A process to produce, validate and authorise invoices allows the buyer to make a single monthly payment to the platform operator, who then makes payments to the service providers.

The timeline is given in Figure 4 - Quote and Tender timing, where WPD has made bid information available a week in advance.

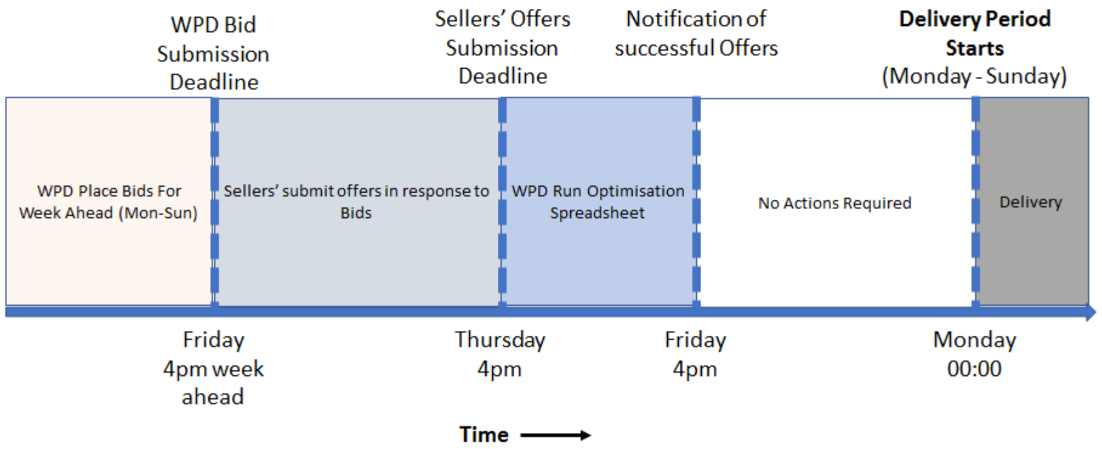


Figure 4 - Quote and Tender timing

For Phase 2 the market rules specified how the spot market, which was designed to allow for joint procurement by ESO and DNOs, would operate. There was considerably more flexibility in the advance period in which the reservation auction could take place up to three months in advance of the utilisation.

The fundamental goal of the Phase 2 market rules as defined by Centrica, WPD and NGESO was to prove the feasibility of a 3rd party, auction-based market for flexibility services, as a contrast to the tender model in Phase 1.

The Phase 2 LEM platform can be summarised as follows:

- A grid model is imported representing a static view of WPD's network topology and constraints (this could be more dynamic in future)
- Sellers register sites and assets, which are tagged to a substation
- Bids and offers for flexibility are placed on the platform
- The LEM platform runs regularly scheduled closed-gate auctions for both reserve and utilisation contracts
- Reserve auctions are run M-3, M-1, W-1
- Utilisation auctions are run day-ahead and intraday (these utilisation auctions are where buyers finalise how much reserve they wish to activate)
- A clearing engine built by N-SIDE optimises the bids and offers against each other to create contracts, maximising social welfare (i.e. finding the most efficient outcome) and ensuring the cleared results are compliant with network constraints and physical asset constraints (e.g. ramp rates).
- Users are automatically notified of these contracts
- Sellers deliver the flexibility as per their contract
- Sellers provide site-level HH metering data to the LEM platform
- The LEM platform undertakes a baselining and settlement process, issuing consolidated invoices to buyers

  Detailed market rules including timings, minimum clip size, auction clearing methods etc. are given in Appendix 3 - LEM Market Rules for Phase 2 Trial in 2019.

4.5.1 Conflict resolution

The key innovation in this spot market was to build in logic relating to the network capacity within the clearance algorithm. To support this, WPD would need to provide information about network capacity that could be used by the clearance algorithm. While this should ideally be forecast and refreshed frequently for a variety of time-horizons to match the auction time-horizons, this was not possible during the timescales of the project. Instead the values of capacity from the WPD network capacity map were used as indicative values of minimum capacity at peak times and the values were scaled down to ensure that the algorithm encountered an issue with insufficient headroom. The clearance algorithm also reflected the nature of DNO services, being more location specific and therefore having fewer service options to choose from, in conflict resolution giving DNOS priority in case of conflicts. This precedence would apply when both parties were purchasing new services concurrently but would not apply retrospectively i.e. an existing NG contract would not be overturned in favour of a new DNO requirement. It is possible that in the future a DNO could buy out NG's position in those cases where it would be cost effective however that type of trading might best be explored once "normal" trading is better established.

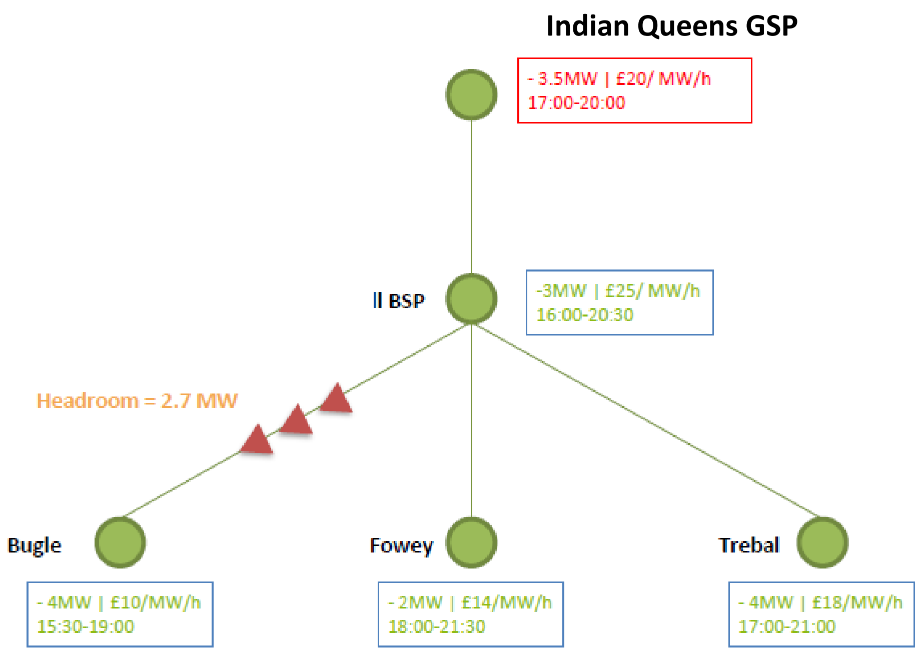


Figure 5 - Capacity check in clearance algorithm

In the example shown in

Figure 5 National Grid's requests 3.5MW downward reserve at Indian Queens GSP. The cheapest bid is at Bugle Primary at 10/MW/h and has the capacity to meet National Grid's requirement. However, due to the headroom limitation at Bugle the service is only partially cleared and the remaining requirement is partly fulfilled from Fowey, the next cheapest option, but as this does not completely match the service window required some service is also procured from Trebal to cover the 17:00 – 20:00 period. In this example the bid at St Austell BSP is out-of-the-money.

A more complex example is given in Figure 6 where both National Grid and WPD seek downward reserve to manage a summer peak.

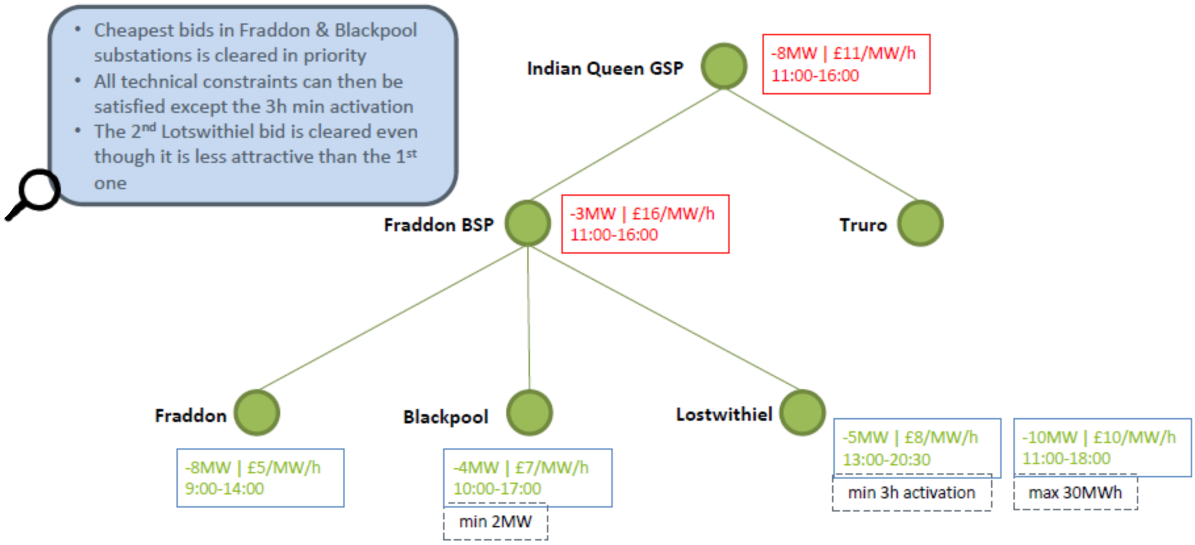


Figure 6 – Simultaneous purchasing

The algorithm was seen to prevent conflicts during the trial by reducing the capacity that could be procured for event 2a.

While these adaptions reduce the chances of the network exceeding a capacity threshold, there are some limitations to this approach currently.

Firstly, the clearance algorithm can only process the information that is available to it at the time. While the clearance algorithm takes the results of previous auctions on that platform into account there may not be a complete picture if multiple platforms were trading services in the same area. Data exchanges to support this should be technically possible. Whether these should be peer-to-peer exchanges or enabled via a central repository will reflect how the market develops.

The second limitation is that the algorithm does not perform power flow analysis to determine whether a capacity level has been breached but rather uses a simplified network hierarchy. While this is suitable for radial networks, it would not be appropriate for meshed networks. Once again it is likely that this could be overcome with additional data exchanges and further analysis is recommended to determine whether sensitivity factors could provide a workable solution to avoid full power flow analysis.

The Phase 2 platform also improved the visibility of services and the identification of potential conflicts by providing a combined service map. This highlighted the potential conflicts between purchases by NG ESO and WPD and is shown in Figure 7 and

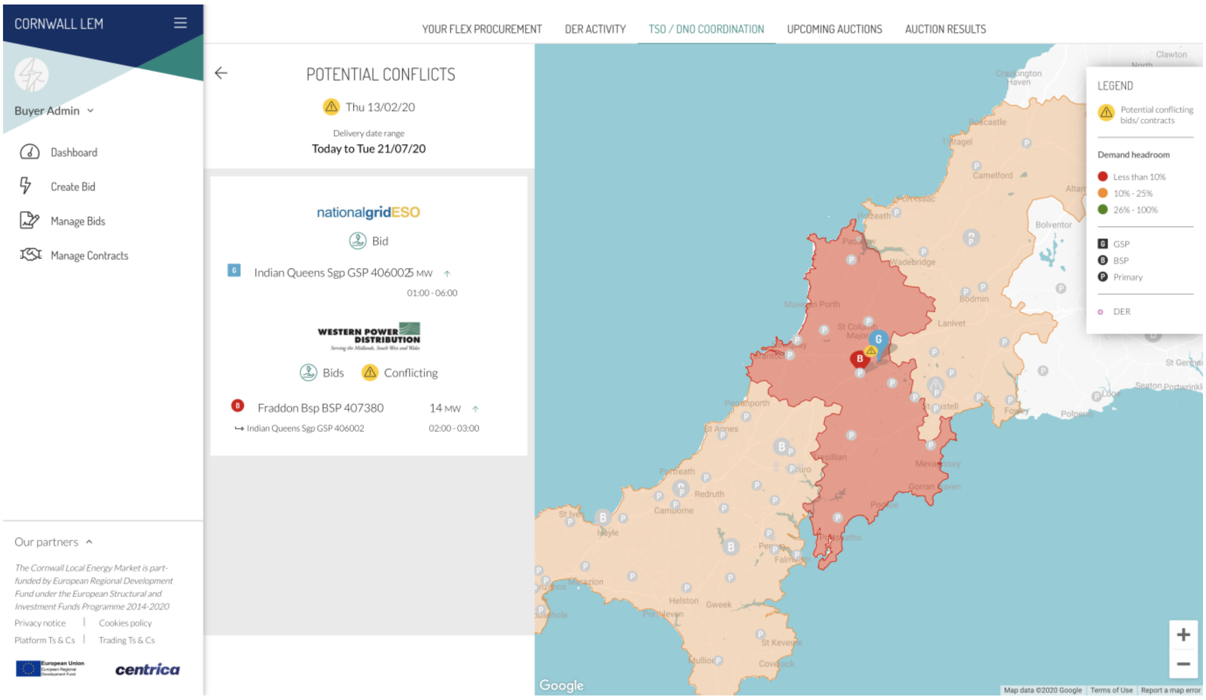


Figure 8.

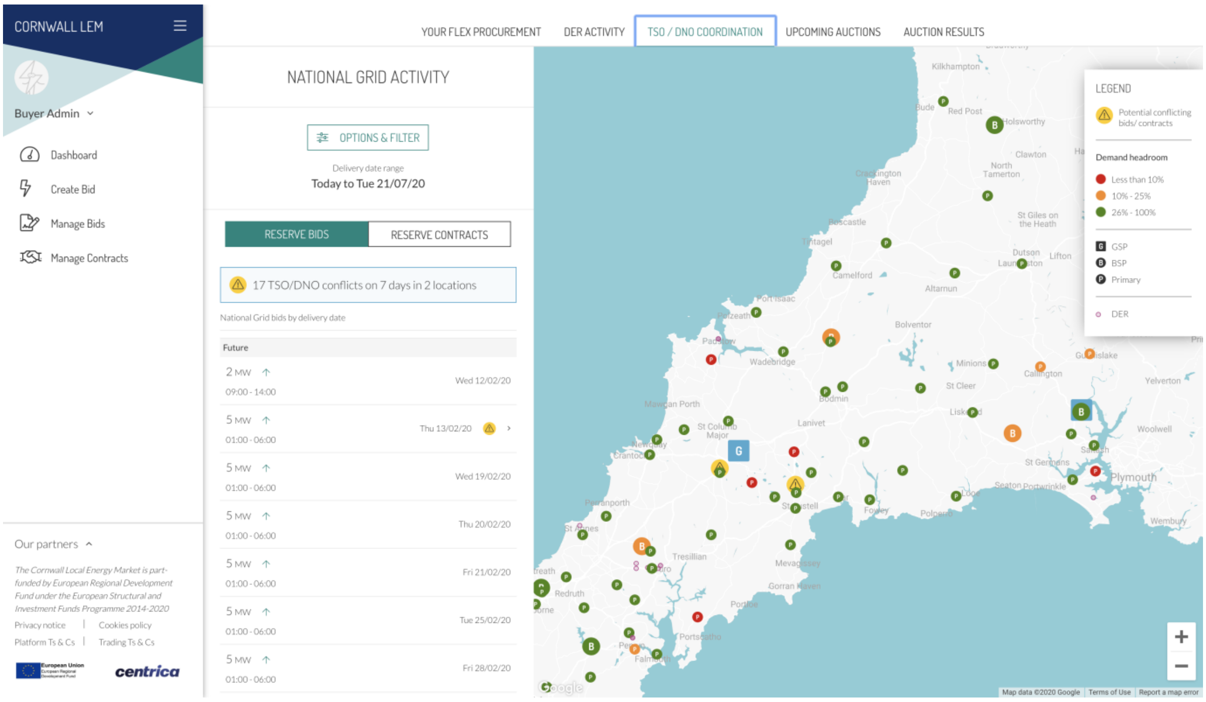


Figure 7 – Coordination screen – Overview

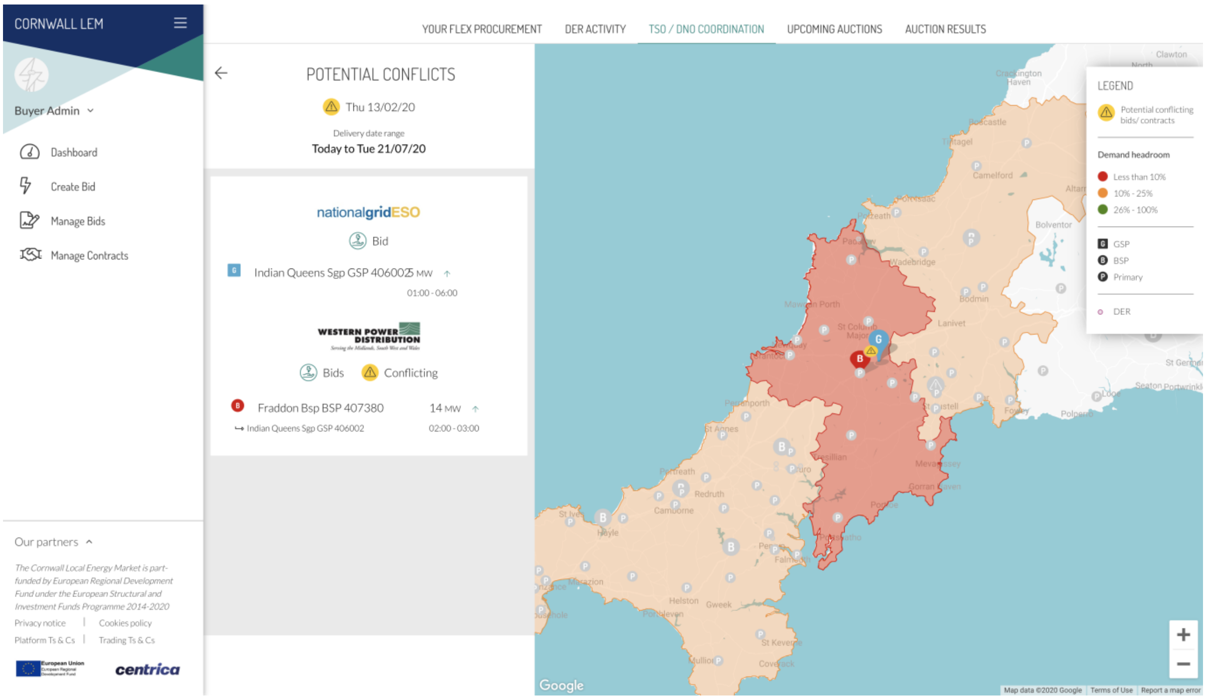


Figure 8 – Coordination screen – Detail for selected area

Since the work to develop the conflict resolution algorithms for the CLEM platform, further analysis of the potential for conflicts as part of EFFS has extended the range of potential conflicting activities.

Conflict Description	Implemented in Phase 2 Trial	Comment
Asset double booking	No	Not implemented in phase 2. Requires system wide resource register
One service negating impact of other service at a different location e.g. Load reduction required at GSP but load turn up service procured at BSP below that GSP partially/fully negates the load reduction service.	No	It would appear feasible to build this check into a market clearance algorithm so long as previously contracted services can be included in the assessment.
One service negating the impact of another service at the same Primary or BSP	Yes	Conflicting actions at the same location or the same branch of the WPD network below GSP are prevented
Service / combined services exceeding distribution network capacity	Yes	Results of previous auctions on the same platform are included, activity on other platforms in the same area is unknown.
Service / combined services exceeding Transmission network capacity	No	Could easily be incorporated given the required data

Other forms of conflict, such as reconfiguration of the DNO network to disconnect a service from its intended point of impact, or negation by the operation of an ANM scheme require another method to identify and resolve the conflict, however it may be possible to build complementary systems that work together to manage different types of conflict. Certainly embedding conflict resolution within the clearance algorithm resolves capacity issues at the earliest opportunity. This is better than a post-purchase method of resolving conflicts for markets operating on a pay-as-clear method as if trades are negated afterwards then market prices will be distorted.

4.6 Review of market platform

Several iterations of the test versions of the two market platforms were evaluated and feedback given to Centrica to improve the functionality or user experience.

4.7 Data exchange testing

Data interfaces were tested before the trial requirements were entered onto the live system. Platform cybersecurity issues were avoided by using a bespoke web interface to enter bid data and manage the inspection of offers made by the participating sites.

For the optimisation operations in the Phase 1 trial, simple CSV file transfer is required to first obtain the site offers for each event from the market platform and then post optimisation, to send direction back to the sites selected for participation via the market platform as intermediary. For the trials phase, given the small amount of test cases conducted, this could simply be achieved by using a WPD Internet connected machine (not on the main business network) to host the trial optimisation utility. For any future BAU solution however, a more integrated process would be required, and the WPD Information Resources department would need to be party to a workable solution. This could still be a standalone machine host outside the WPD business network firewalls. This aspect is likely to be explored further by the EFFS NIC project.

4.8 WPD Optimisation tool development – Supporting Phase 1

This section reflects commercial optimisation, which we consider to be the selection of flexibility services to meet requirements from a pool of potential services exceeding the required capacity. Having determined that commercial optimisation may not be a function exclusive to the market platform, a search for existing optimisation products and software for flexibility services took place. No suitable software within budget was found, but there was an investigation to determine whether DNV GL could adapt their ES grid product which had similar features. The work required, however was more complex than originally envisaged and so another solution was sought to provide learning on optimisation without involving long development timescales and high costs which would not have been consistent with the project budget and timescales. We therefore conducted an investigation of the “site generation optimisation problem” in conjunction with the WPD *Entire* project which had similar DSR event management requirements and was running at the same time. Excel with embedded VBA programming was used to model an optimisation capability and explore a number of solutions while driving out the main issues that required to be addressed to the benefit of both projects.

Given that general optimisation can be an exceedingly complex problem, it is necessary to keep sight of the overall picture. Clearly, the procurement of a complex and very expensive optimisation system is not justified if the savings that result from its use are not commensurate with the cost of deployment. In BAU running this is likely to be a totally different assessment to that which applies to this project. This highlights the need for finding the learning points in this area. It will also almost certainly be the case that for short notice emergency responses to unplanned incidents that there is insufficient time to conduct optimisation. At such times all possible offers are likely to be dispatched in order to address the problem.

Objective optimisation is a common requirement in many disciplines, and can be a particularly complex problem. The requirement can be stated as the operation to ***Solve*** a problem case by minimising or maximising an **objective value**, setting certain ***control variables*** which determine the solution while at the same time obeying a set of ***constraints*** which limit what is possible. A number of commercial solutions are available to implement "solvers" which are specifically designed to tackle such problems. For the site generation optimisation problem, the objective value will usually be to minimise the total cost of managing the event, the control variables are the run/not run selections for each possible site (taken from the list of those which have made an offer for the particular event via the market platform), and the constraints are that the whole site proposal must be selected as specified (without modification in the LEM operational model).

Generation increase and load turn down are assumed to be equivalent, and in the following we will refer mainly to "generation" (or "generators") to simplify the discussion.

4.8.1 Optimisation End-to-end Process

To successfully deploy Demand Side Response as an operational capability, constraint events are declared via the market platform in advance of their occurrence and generation offers from multiple sites which can act to mitigate the constraint are sent to the optimiser for processing (via file transfer). The sites declare their individual running configurations for a particular event as a set of value pairs of generation capacity (in MW or kW) and a price for that energy in each half hour of their offer[2]. This defines their offer and allows the optimisation utility to perform the necessary assessment of the best sites to select. Sites may also have other constraints such as total running time in a given interval (say per week).

[2] The pilot optimisation utility has been implemented assuming that the price may differ in each HH as this is the general case. In practice the business model may not permit this and may require the price per unit to be uniform over the duration of the event. We must differentiate between what is possible and what is likely, and ensure that the tools are developed so as to be able cope with either case without need of adjustment.

A constraint event is assumed to have an arbitrary length (in half hour multiples) and is defined (for the Entire and Cornwall LEM projects) by a set of contiguous half hour intervals for each of which there is a power requirement (a target in MW) to be achieved in each time interval. For DSR to be effective using generators, the sum of the power output of all the generators selected as operational in a given half hour through the constraint event must exceed the target level for the event in that half hour.

The challenge for WPD, as the buyer of the services and distributor, is to use the most effective combination of generation sites to meet (effectively to just exceed) the constraint event power requirement in each half hour while minimising the overall cost of employing the generator sites and preserving their proposed individual running schedules. This can be a complex problem unless it is approached correctly to align the business model to the optimisation system, ideally facilitating the smooth running of both.

Once the optimisation has been performed, the optimal running configuration of all the sites selected for the event is known and the optimiser can then inform the market platform which generated the offer so that it can in turn advise those sites regarding their potential involvement.

4.8.2 Core Optimisation Function

To fully define an optimisation problem and derive solutions, it is necessary to analyse the real world system being managed and then specify a conceptual "model" of the problem. This model can then be made known to a solver system and the "solver" executed to pick (in our case) the best site/cost combination from those possibilities presented in order to obtain an optimal running solution for a given event/requirement.

The problem lends itself well at small scales, to prototype implementation under Microsoft Excel as this allows the model to be laid out and visualised with the constraints, controls and objective specified using the Excel cell structure. Excel also provides a free inbuilt solver called "Solver" which has to be enabled as an ADD-IN. This Excel inbuilt utility was originally produced for Microsoft by *Frontline Systems* who also market a fully functional *Frontline Solver* offering for Excel which must be purchased as a third party plug-in. The free default supplied Excel native solver has a degraded capability, solving just 200 variables and 100 constraints, limiting the utility and only allowing for the resolution of problems with a modest size. It also has a limited set of "optimisation engines" at its core that it can invoke. Other Excel compatible Solver plug-ins are also available, a key one being OpenSolver (GNU licence openware, attractive as it is low/zero cost).

Solver utilities all have at their core a *Solver Engine* or more accurately, allow for the selection of an appropriate engine from an arsenal of such solver engines which can target a specific class of problem. The capability to select Solver Engines arises because problems offered up to solvers fall into different classes, with simple "linear" problems and the more complex "non-linear" problems which also have "smooth" and "non-smooth" cases. The various Solver Engines each target either the linear or non-linear problems and different ones can tackle smooth and non-smooth cases and offer support for a variety of possible cases. Solver engine plug-ins can be both freeware and commercial offerings and include:

GUROBI, BONMIN, NOMAD, CBC, KNITRO, NEOS and COUENNE. The engines deploy a variety of strategies when finding solutions. In some cases (NOMAD for example) there is a requirement for a starting point/seed. In general, the engines all attempt to explore the solution space to locate the optimum solution, but when dealing with complex cases they can generate a result which represents a localised rather than a global best solution within the complete solution space and/or may have to be stopped (on processing/iteration limits) before the solution search space has been exhaustively explored and the true best solution has been obtained. Some problems are also simply intractable within their existing constraint set. “Relaxation” (of constraints) can help to find a solution in such cases if this is allowable (i.e. has a real world meaning).

Non-Excel, Enterprise class solutions suitable for a BAU operational mode include such examples as IBM’s CPLEX Optimisation Suite (COS). Optimisation can be costly however and it is necessary to take a clear and informed view of the cost/benefit assessment. It may be more cost effective to simply overbuy and use a simple optimisation than to spend several hundred thousand on an optimisation engine.

4.8.3 Assumptions and Simplifications

The assumption has been made that a generator site will have their entire offer either selected or not, WPD would not attempt to modify a site proposed running configuration to attempt to select only a specific part of it or to adjust the details of the offer which should be considered as fixed. However it was realised that in the case of the site offer running time being less than the duration of a given constraint event, the position (starting offset) of the site offer within the event window forms a set of alternative permutations. Any one of such a possible set of permutations may be deployed when trying to determine the best solution, and the start and stop times would then be arbitrarily arranged within the constraint event window. Significant complexity follows from this however in the case of multiple offers of this nature being received for a particular event as the solver is required to run on and assess *each* combination of the permutations.

In the case that a site RUN PROFILE is shorter than the duration of the event, the number of multiple possibilities (permutations) of how the site can service the event is given by:

$$Np = Ne - Ns + 1$$

Where,

Np is the number of permutations for this site running profile for this event
Ne is the number of Half Hours specified for the duration of this event
Ns is the number of Half Hours in the site run profile

When assessing a series of sites therefore in the case that there is a set of running permutations available for each site, it is necessary to solve all possible combinations of these permutations across all the sites. This means that there are:

Np(tot) = Np(1) x Np(2) x Np(3) x Np(i)

Where,

Np(tot) = Total number of permutations across all sites,
Np(i) = Number of permutations for each site i,

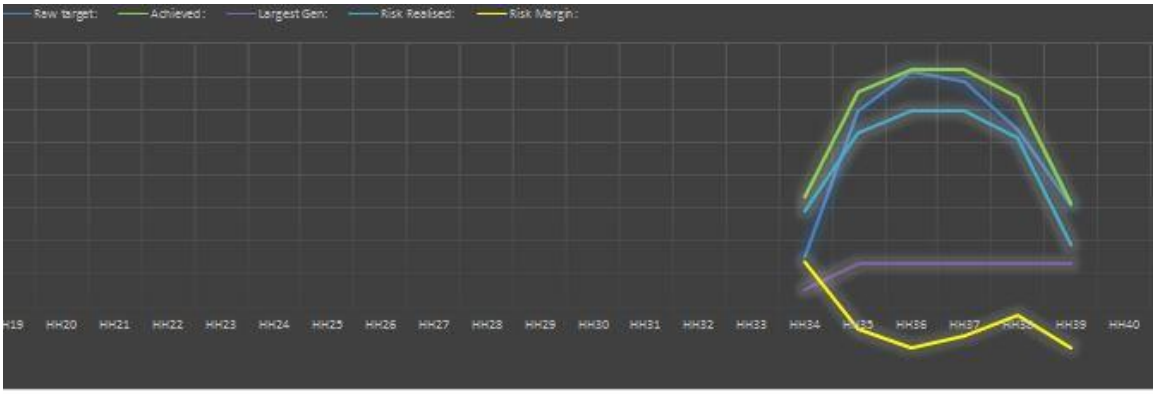
The issue that follows from this is that the total number of permutations can become astronomical in size if complete freedom is allowed over the management of permutations. For example, for 10 sites, each having 2 possible permutations, this results in there being 2^{10} or 1024 permutations – each of which must be run through the solver as a potential input case. This gets rapidly out of control as the number of permutations for each site increases, so for example for 10 sites each with 3 permutations the result is 59,049. For just 20 sites, this number is: 3,486,784,401 (three and a half billion). At around 1 second per solver run (the LEM pilot Excel optimiser utility measured performance) to address each permutation, this gives a total solve time of approximately 110 years. Care is clearly needed when setting up these problems and allowing total site freedom to run with possible permutations of start times which are offset within the event window.

A better approach may in fact be to constrain the offers to match exactly the length of the event window, or to be aligned to just the start or end of the event. If such rules create unsuitable conditions for a given site addressing a particular event, then they would clearly not need to participate.

An even further simplification would be to just request a flat delivery profile so that the same power was to be delivered in each Half Hour of the event, however this will almost certainly lead to a blocky solution profile for the overall event (see below).

4.8.4 Shaping the Response

The optimisation process will naturally tend to produce a response which follows the shape of the actual event profile itself. However the extent to which this is possible depends on the number and size of the respondent's offers which can in turn be constrained by some of the decisions discussed in the section above. It should be reasonably self-evident that close replication of the event profile is more likely in the case that there are numerous small respondents (which also means that the risk approach involving the loss of the single largest operator is minimised), while a few large generators will almost certainly yield a very blocky resulting total profile and larger attendant risk (and potentially cost which is better served by replicating the event profile). Aggregated offers may therefore be advantageous when forming the optimal response. Allowing the sites to shape their own responses is also a potential advantage.



HH19	HH20	HH21	HH22	HH23	HH24	HH25	HH26	HH27	HH28	HH29	HH30	HH31	HH32	HH33	HH34	HH35	HH36	HH37	HH38	HH39	HH40
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.065	0.065	0.065	0.065	0.065	0.065	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05	0.05	0.05	0.05	0.05	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.066	0.066	0.066	0.066	0.066	0.066	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.44	0.44	0.44	0.44	0.44	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.32	0.32	0.32	0.32	0.32	0.32	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0.21	0.21	0.21	0.21	0.21	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.22	0.22	0.22	0.22	0.22	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	1.1	1.1	1.1	1.1	1.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.22	0.22	0.22	0.22	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.254	0.254	0.254	0.254	0.254	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.22	0.22	0.22	0.22	0.22	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.22	0.4	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.15	0.17	0.17	0.17	0.07	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.15	0.15	0.15	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0.17	0.17	0.17	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.254	0.254	0.254	0.254	0.254	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.67	1.304	1.444	1.444	1.274	0.624	0

Figure 9 - Solved Optimisation Event

The question of cost again comes into the overall assessment. If the cost of a "blocky", over procured response to a particular event is only marginally more than a fully shaped optimally determined solution then the deployment of optimisation may not be justified on a case by case basis, though could still yield significant savings in an ongoing BAU scenario.

Figure 9 - Solved Optimisation Event, above illustrates a final optimal solution result output by the prototype Plugs and Socket optimisation utility. This particular run processed offers from thirty generator sites some of which had run profiles which were shorter than the duration of the event, resulting in there being 768 permutations to be processed. Figure **10** – Permutation Cost / Frequency Solution Distribution Plot presents the cost/frequency plot of the 768 independent optimiser runs which evaluated permutation 97 at a total event cost of £1780.37 as the optimal solution employing site 14 (the largest generator) along with sites 17,18,19,20,26,28 and 29 to form this result. The target required profile (by HH bin) is the dark blue plotting line in Figure 4, the achieved MW is green (as can be seen the solution, as expected, exceeds the target at each point. The other lines are associated with risk evaluation: that the largest generator (purple line) drops out leaving a cyan profile which undershoots by the amount shown by the yellow plotting line. The table below the plot shows the site offers with those selected in the solution being in the lime green or purple highlight.

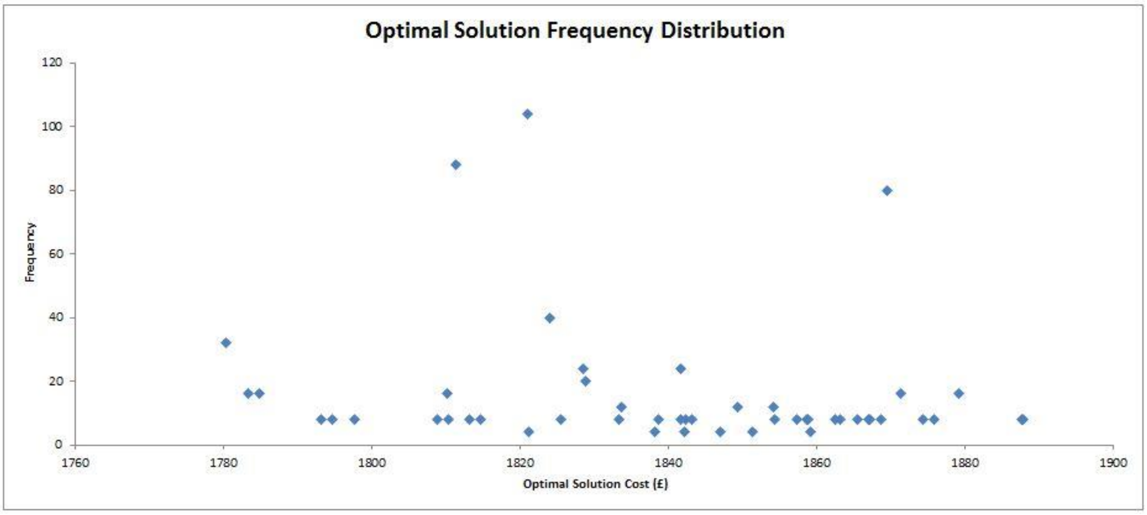


Figure 10 – Permutation Cost / Frequency Solution Distribution Plot

4.8.5 Risk Management

The project took a simplified approach to the management of risk arising from the possibility of generators dropping out either at short notice or during the event itself. The mitigation strategy envisaged is to "overbuy" to mitigate the risk by an amount which anticipates the size of the largest individual generator included in the solution. This is a recursive problem however, as specifying an inflated target requires a-priori knowledge of the solution without risk based inflation and application of the risk margin to the target will then potentially affect the combination of generators involved in this inflated solution so that the largest generator changes. A pragmatic rule of thumb approach is needed as without this the task of the optimiser is made significantly more complex (and potentially expensive).

4.8.6 Participant Reliability and Application of Fairness Principles

Linked to the approach to risk is the measurement and possible application of participant selection criteria based on past measured reliability. If the risk is based on the likelihood that a participant will either drop out or significantly underperform through an event, then such pre-selection would seem prudent. Inclusion of "reliability" within the actual optimisation process itself is not recommended as the approach should always be to reduce the number of constraints that the optimiser is asked to handle when solving the problem.

Associated with the application of any such pre-filtering of participants will be the maintenance of meaningful records based on fair and accurate assessment of the performance of generators when servicing events. Performance Analysis is another discipline in the management of DSR events and considers how well the individual generators performed against key metrics, such as:

- Percentage of requested volume that has been delivered;
- Stability of supply;
- Availability of suitable monitoring data without loss of visibility;
- Percentage of time through the event that the delivered power was above the target level. (etc.).

This assessment needs to be carried out in any case in support of the payment activity so these activities should effectively be self-supporting. The project took a conservative view on the application of pre-filtering based on performance as this could be a sensitive area.

Fairness can also be applied as a possible tie-breaker to be used when choosing between equally matched offers to ensure that the opportunity for participation is shared as widely as possible and not restricted arbitrarily. This could include taking account of such measures as:

- How early the participant signed up for the event (first come, first likely to be used);
- How long it is since the participant has been selected for active deployment in an event.

Again, this should not be a constraint or rule that is offered up to the optimiser itself, and has not already been done by the aggregators or market platform.

4.9 Centrica – Optimisation function development – Phase 2 Platform

The previous section covered the development of an optimisation tool to support WPD's use of the Phase 1 platform. For the Phase 2 platform, the optimisation was built into the market clearance algorithm. Again, the optimisation function was concerned with commercial optimisation i.e. selecting the most effective combination of services to meet the DNOs specified requirements (e.g. 0.5 MW reduction in load at St Austell Primary for three consecutive hours) while reflecting the technical constraints of the generators or batteries providing those services (e.g. maximum energy capacity and hence operating duration of batteries, generator minimum and maximum running times, individual site capacities etc.)

The LEM clearance engine is based on the commercial optimisation engine CPLEX. It is capable of supporting all the functionality of the WPD Phase 1 optimiser but has capabilities over and above those supported by Excel's Solver. This means that the need to avoid complexity is not so strong and it can therefore support partial matching of services rather than requiring all or nothing selection to simplify the optimisation process. More than that though, the additional computational abilities are essential to supporting the functions to manage conflicting services as described in section 4.5.1 Conflict resolution.

With the optimisation function located in the market platform, this centralisation offers the potential benefits compared to separate optimisation processes by each market platform user. Firstly the solution gained when optimising all solutions concurrently is likely to outperform the efficiency of separate processes. Secondly the costs of the optimisation function could be shared between all market platform users. This may be more cost effective that the parallel development of optimisation functions by many platform users.

4.10 Trial specification

For each trial phase there was a collaborative process to create and refine a trial plan. Creating a shared trial plan ensured that the trial reflected realistic scenarios but also included the widest range of participants. The plan for the Phase 2 trials ensured that conflicts were engineered between the ESO and DNO service requests but also allowed for periods of independent operation.

4.11 Contract terms development

The contract terms built on those developed from project ENTIRE. However, there were key differences reflecting the different business model. While a single contract between WPD and the flexibility provider was sufficient for ENTIRE, for CLEM, the buyer and supplier of flexibility services contract with Centrica as the platform provider and then contracts are formed between supplier and buyer through the use of the platform itself. The contracts that were developed for Phase 1 were then further refined in Phase 2 and are included in Appendix 2 Contract Terms

4.12 Service delivery validation process development

The same collective term “settlement”, is often used to refer to two distinct processes. The first process refers to calculating what is owed under a contract which reflects understanding exactly what was delivered, we are referring to this as service delivery validation. The second element of settlement is ensuring the required payments are made.

Service delivery validation requires access to the data from the service provider both for baselining and the calculation of the variance to this baseline as a measure of the service delivered. While one-minute resolution data had been used to validate service delivery for project ENTIRE, the option of using half-hourly metering data for validating service delivery was explored in this project as requiring more accurate monitoring was expected to be a barrier to entry for customers that were new to providing flexibility services. A comparison of results using minute resolution data to half-hourly resolution data is given in section 4.15.4

4.13 Phase 1 trial execution

The following section includes the key points that were reported in the Phase 1 Interim Learning Report.[3]

4.13.1 Participating Customers

Customers that participated included;

- Several clusters of residential customers
- Diesel generation sets at three different locations
- A flow battery
- A gas turbine generator

[3] Phase 1 Interim Learning report - https://www.westernpower.co.uk/downloads/75097

The recruited capacity at different network locations is given in Table 2 below. The capacity at Bulk Supply Points reflects the capacity at primary substations that are supplied by those bulk supply points and the capacity should not be double counted.

Flexibility Requirement Location	Total Capacity MW
Fraddon BSP	2.441
St. Austell BSP	8.600
St. Tudy BSP	0.062
Truro BSP	0.033
Bodmin Primary	0.010
Bugle Primary	1.600
Devoran Primary	0.015
Drinnick Primary	1.600
Fraddon Primary	0.800
Newquay Trencreek Ln Primary	0.016
Newquay Trevemper Primary	0.011
Par Harbour Primary	7.000
Penzance Causewayhead Primary *	0.450
St Agnes Primary	0.018
St Columb Major Primary	0.014
Truro Treyew Rd Primary *	2.000
Wadebridge Primary	0.052

Table 2 - Participating customer capacity

*These sites were unable to provide services for the phase 1 trials as export connection agreements were not in place. While the flow battery was able to provide services for part of the trials, it later suffered technical difficulties which prevented further participation.

4.13.2 Event Schedule and Results

While a schedule of events was agreed in advance, it was necessary to revise the schedule several times during the trial. This was partly because assets that were expected to be able to take part in the trial were unable to secure an export agreement as quickly as they had hoped.

A summary of the final schedule of events is given below in

Table 3. Events are deemed to be successful if a flexibility provider responds to the request and delivers a service, even if that service was not fully delivered.

Event	Event Date	Event Location	MWh required	MWh Offered	Price £/MWh	Comment
1	22/05/2019	Wadebridge Primary	0.12	0.04	300	Successful event, A very small requirement was used for the first event to limit the impact on the budget from any technical problems
2	29/05/2019	St Austell BSP	4.30	3.99	305-320	Successful event
3	06/06/2019	Fraddon BSP	2.88	1.34	600	No offers accepted - price unacceptably high
4	14/06/2019	Penzance Causewayhead Primary	0.59			Event did not happen - no export agreement in place
5	17/06/2019	St Austell BSP	5.16			No offers
6	25/06/2019	Fraddon BSP	3.36	2.78	300	Successful event
7	03/07/2019	St Austell BSP	3.44	2.84	300	Successful event
8	11/07/2019	Par Harbour Primary	7.00	6.66	300	Successful event
9	17/07/2019	St Austell	0.02		220	Successful event
10	23/07/2019	St Agnes Primary	0.03			No offers
11	02/08/2019	Wadebridge Primary	0.05	0.047	n/a	Although no contracts were generated via the platform, the residential battery clusters were discharged for events 11 and 12. The MWh Offered here represents the full capacity of the batteries connected at the event locations (The events were set up to target a full discharge of the battery)
12	08/08/2019	Truro BSP	0.03	0.076	n/a	As above
13	12/08/2019	Fraddon BSP	3.36	1.38	300	Successful event

Table 3 - Schedule of Phase 1 Events

4.13.3 Phase 1 Trial Execution Learning

While the trial learning is discussed more fully in the next section there are some areas of general learning.

Events without Offers.

There were many requests that were placed on the system for which no offers were received. This may reflect the relatively low number of service providers which increases the impact of one provider not participating. If there are several potential service providers then if one does not participate their impact may not be noticeable. However, if there is only one service provider at a location their participation or non-participation is critical. This highlighted the difference between the current state of the market and that for which the system is designed i.e. a mature, liquid market. In such a market, buyers would routinely receive a surplus of offers and would be able to draw conclusions as to the impact of location, notice period etc. from the degree to which the service was oversubscribed and the average price. It would be useful for future system development to allow for customers to provide feedback on why they chose not to make an offer as well as providing and offer. E.g. Asset unavailable, asset providing a service to another party at that time, service volume / duration too small/ short to be attractive, other markets expected to be more lucrative etc. This would then differentiate between the case where a service provider was unaware that there was a request in their area, or was aware of the request but unable to provide an offer, from those cases where there was a deliberate decision not to respond to the request.

Complexity vs Simplicity

Originally, the phase 1 system was designed to build on the process developed for Project ENTIRE but to allow additional flexibility which would allow the DSO to adapt the process as time went on. This additional flexibility was reflected in being able to set variable timeframes for publishing requirements, arming and dispatching services. However, in the end this flexibility was not exploited and offers were routinely submitted by the Thursday of the week before service delivery for review and selection by WPD on the Friday of the week before service delivery. While there may still be merit in having more flexible schedules, this may be better managed by flexibility service providers that could devote time and attention to managing their flexibility portfolio, rather than this being an addition to their core business.

Network Reconfiguration

The project generated additional learning around the impact of abnormal running arrangements. The default network hierarchy, based on normal running arrangements, was provided to Centrica to help associate customers with their relevant primary substation, BSP and GSP. Before the trial it had been assumed that abnormal running arrangements would be infrequent and of short duration and so could be ignored. However, during the trial it emerged that abnormal running arrangements around St Austell BSP had the effect of shifting the point of impact of flexibility services to a different BSP. Thus services procured and delivered in good faith would not have the desired impact.

This suggests that DNOs need to not only publish a default network hierarchy but also to make future network changes and any configuration related sensitivity factors available to those who may be affected by them, i.e. aggregators, market platform providers and ESO. While there would be fewer changes for primary and 132kV networks, the number of outages on HV networks is considerably higher suggesting that for both practicality and accuracy, these updates need be generated by the control room system which would hold the details of planned schedules and also the current network connectivity. The accuracy of expected future network topology will be limited by unplanned reconfiguration. However it is not known whether the inaccuracy introduced from unplanned reconfiguration outweighs the benefit from having an improved view of planned reconfiguration and further research to understand the impact at different voltages and time horizons is recommended.
Most UK DNOs use PowerOn by GE as their Distribution Management System. The most recent version of this has the ability to export network data in Common Information Model format, however it is not known whether this can export data for both the current state of the network (which will reflect the outages for that moment in time) as well as the default switch positions. There have been developments recently to support features to allow for switching operations to be replayed after the event. However, predicting *future* network states based on anticipated switching is unlikely to be as accurate. This is because as well as the planned outages, there will always be unplanned outages. Unplanned outages will also cause the network to be switched so that it is in a different configuration to the default network state, but the events causing unplanned outages cannot be predicted ahead of time. At higher voltages unplanned outages are relatively infrequent so the degree to which the benefits of a future configured network model are reduced by unplanned outages requires further investigation.

As part of the EFFS project, the ability to create future looking versions of the network will be investigated which will help determine whether this is still useful information despite not being able to take unplanned outages into account. The increasingly flexible nature of networks may result in a move away from a default topology to a number of running arrangements that are applied under different conditions. The need to exchange expected changes to network hierarchy, and whether this requires filtering to exclude changes that affect a small number of customers or have a short duration, might best be determined via the Open Networks project which has an industry wide perspective.

4.13.4 Phase 1 Post-Trial analysis

The following section summarises the key findings of the Interim Learning Report.

Prices

The Flexible Power published price of £300/MWh appears to have strongly influenced the customer's perception of the "going rate" for services. It was the most frequently occurring price by a considerable margin as shown in Figure 11 - Price variation in Phase 1. This value was also used for project ENTIRE and so a customer using a search engine to find information on flexibility prices would be likely to treat that as a reasonable starting value.

The highest price of £600/MWh was for an event where the required capacity was much smaller than the customer's actual capacity. It is believed that the customer put in a high price in order to make participation worthwhile. It is also possible that the customer perceived themselves as having a monopoly position. The £600 MWh reflects the highest price paid under Flexible Power, for the Restore service, and it is likely that this published figure was used to determine the highest value a DNO might reasonably pay.

Figure 11 - Price variation in Phase 1

Participation and Service Delivery

There were four events for which no offers were received or where prices were unacceptably high. The average delivery proportion for successful events was 60% but it can be seen that there is considerable variation between events.

Event	Service Procured (MWh)	Service Delivered (MWh)	Delivery Proportion Percentage
1	0.040	0.000	0%
2	3.990	3.990	100%
6	2.780	1.686	61%
7	2.840	2.840	100%
8	6.660	6.146	92%
9	0.032	0.008	25%
11	0.047	0.030	63%
12	0.076	0.029	39%
Average			60%

Table 4 - Service Delivery – Phase 1

While this value needs to be understood in the context of a relatively small number of events from a relatively small number of providers a high level comparison with results from project ENTIRE, which also had a small sample size suggested, the best and worst results were in line with each other.

4.14 Phase 2 Trial Execution

Table 5 – Phase 2 Events and Prices , below summarises the phase 2 trial events.

WPD event number	Event date	WPD Site location	WPD site type	Max MW	Up /down	Time	MWh	WPD Service type	Auction type	Reservation price £/MW/h	Utilisation price £/MWh
1	06/09/2019	St. Austell	BSP	1.85	up	16:30 - 19:30	5.55	Secure - evening peak1	day ahead	N/A	315
2a	10/09/2019	Fraddon	BSP	2.05	up	16:30 - 19:30	6.15	Secure - evening peak1	week ahead	17.5	330
3	13/09/2019	Fraddon	BSP	0.10	up	16:30 - 19:30	0.30	Secure - evening peak1	week ahead	30	277.5
4	05/12/2019	St. Austell	BSP	1.70	up	16:30 - 19:30	5.10	Secure - evening peak1	3 month ahead	17.5	345
5	06/12/2019	Fraddon	BSP	2.05	up	16:30 - 19:30	6.15	Secure - evening peak1	3 month ahead	17.5	345
6	01/10/2019	Truro	BSP	0.05	up	16:30 - 19:30	0.15	Secure - evening peak1	month ahead	16.5	277.5
8	20/09/2019	Drinnick	Primary	0.90	up	16:30 - 19:30	2.70	Secure - evening peak1	week ahead	17.5	315
9a	27/09/2019	Fraddon	BSP	1.40	up	08:00 - 11:30	4.90	Post Fault - morning	within day	N/A	400
9b	27/09/2019	Truro	BSP	0.05	up	08:00 - 11:31	0.18	Post Fault - evening	within day	no contract achieved	
10	01/10/2019	Bugle	Primary	1.15	up	11:30 - 15:00	4.03	Post fault - midday	within day	N/A	325
7b	03/10/2019	Newlyn	Primary	0.05	down	12:00 - 15:00	0.15	Post fault - midday	week ahead	20	315

11	03/11/2019	Truro	BSP	0.15	up	16:30 - 19:30	0.45	Secure - evening peak1	month ahead	17.5	215
2b	22/10/2019	Fraddon	BSP	1.00	up	16:30 - 19:30	3.00	Secure - evening peak1	week ahead	30	315
12	24/10/2019	Newlyn	Primary	0.05	up	16:30 - 19:30	0.15	Secure - evening peak1	week ahead	20	240
13	13/11/2019	Fraddon	BSP	1.30	up	08:00 - 10:30	4.25	Post Fault - morning	within day	no contract achieved	
14	14/11/2019	Truro	BSP	0.05	up	08:00 - 10:30	0.125	Post Fault - morning	within day	N/A	200
15	15/11/2019	Bugle	Primary	1.10	up	11:30 - 14:00	3.50	Post fault - midday	within day	N/A	300
16	28/11/2019	Fraddon	BSP	0.05	up	16:30 - 18:30	0.15	Secure - evening peak1	week ahead	10	220
17	25/11/2019	Truro	BSP	0.05	up	16:30 - 18:30	0.15	Secure - evening peak1	week ahead	10	220
18	29/11/2019	Fraddon	BSP	0.05	up	16:30 - 18:30	0.15	Post fault - evening	within day	N/A	200
19	26/11/2019	Truro	BSP	0.05	up	16:30 - 18:30	0.15	Post fault - evening	within day	N/A	220
									Average	**19**	**283**

Table 5 – Phase 2 Events and Prices

4.15 Phase 2 Post-Trial analysis

4.15.1 Price

Contracted Prices were very similar overall to those seen in Phase 1, with the total value of reservation and utilisation costs averaging £302.

Service Type / Reservation notice period	Number of events	Average Reservation Price £	Average Utilisation Price £
Within day	9		218
Week ahead	8	19	279
Month ahead	2	17	246
3 Months ahead	2	18	345
Overall Average		**19**	**283**

Table 6 – Phase 2 Prices by Service Type

The Pay-as-clear auctions introduce a difference between contracted prices and offered prices reflecting the relative levels of demand and supply.

Supply vs Demand	Price impact
Demand exceeds Supply	Clearing price = bid price i.e. maximum price the buyer was willing to pay. High prices are intended to stimulate a growth in supply
Demand equals Supply	Clearing price = average of last accepted offer and the bid price
Demand is less than Supply	Clearing price = offer price i.e. the lowest price that the supplier will provide the service for. No need to stimulate additional supply in this case.

Table 7 – Pay-as-clear price impacts

Due to the low liquidity in the trial, demand exceeded supply quite often and higher prices were used. In a more liquid market contracted prices would be expected to fall.

It appears that reserving assets with a long lead time e.g. 3 months did not result in lower utilisation prices than contracting for services at shorter lead times such as week ahead or within day. However, due to the small sample size caution needs to be applied when extrapolating from these results. If this finding is replicated by other trials, it would suggest that DSOs would only reserve further in advance at higher prices if the risk of failing to secure assets by reservation were high enough to justify the higher cost. DSOs would be incentivised to purchase on the intra-day market first before buying any residual requirements from the reserved assets if the lower prices would likely more than compensate for the lost spend on reservation payments.

Reservation prices were most frequently in the £15-£20 range.

Figure 12 – Phase 2 Reservation Prices

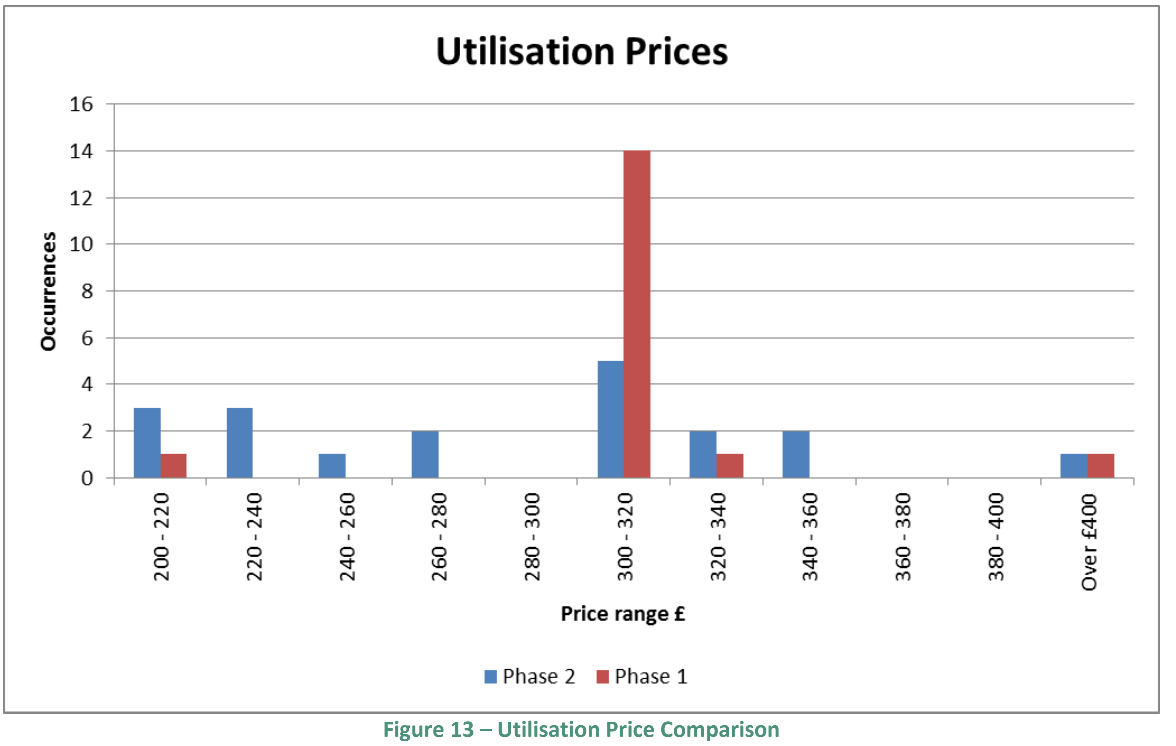


Figure 13 – Utilisation Price Comparison

Figure 13 – Utilisation Price Comparison shows that utilisation prices for Phase 2 were more evenly spread than in Phase 1 where values were predominantly in the £300 - £320 range. The highest value seen in Phase 2 was £400 MWh compared to £600 MWh in Phase 1. The lower prices tended to be offered by low volume service providers towards the end of the trial where additional events were added to assist with the analysis of domestic customer delivery. Therefore the difference in prices seems more likely to reflect the different proportions of customer types for the events rather than the impact of the purchasing method being used.

As expected, reservation and utilisation prices are higher than the recent prices for STOR.

The table below is taken from the Market Information Report published in October 2019 [4].

Table 3 Summary of accepted prices

Season number	Highest availability price accepted (£/MW/h)	Highest availability price accepted, not all or Nothing (£/MW/h)	Highest utilisation price accepted (£/MWh)	Lowest utilisation price accepted (£/MWh)
13.5	£2.98	£1.50	£170.00	£4.97
13.6	£2.98	£1.50	£170.00	£4.97
14.1	£2.10	£1.00	£207.87	£88.91
14.2	£2.10	£0.80	£195.00	£88.91
14.3	£2.10	£0.80	£195.00	£88.91
14.4	£2.10	£0.80	£195.00	£88.91
14.5	£2.10	£0.80	£195.00	£88.91
14.6	£2.10	£0.80	£195.00	£88.91

CLEM prices would be expected to be higher than STOR due to the one-off nature of the contracts compared to contracts covering monthly windows. Similarly the locational requirement for DSO services results in a very different balance of supply and demand.

4.15.2 Service Delivery

The calculation of service delivery is given by the providers' expected value of load or generation for each half hour compared to the actual load / generation value for that half hour. The expected value reflects a baseline value, generated from averaging values for similar recent days and then adjusting the baseline value to reflect conditions on the day in question. (Further details for the baselining methodology are given in Appendix 2 Contract Terms) For example, if load on the service day is higher than average then using an unadjusted baseline would result in a load reduction service being underestimated as shown in Figure 14 – Baseline Adjustment Example.

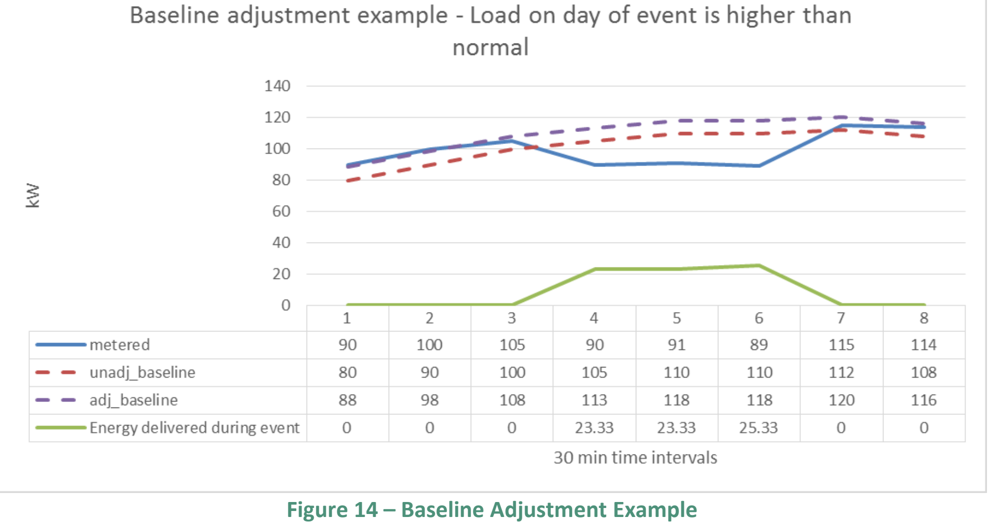


Figure 14 – Baseline Adjustment Example

[4] https://www.nationalgrideso.com/balancing-services/reserve-services/short-term-operating-reserve-stor?market-information

The calculation of the adjustment originally compared the three half hour periods immediately prior to the start of the event to the baseline values for those half hours. It had been assumed that ramping up output prior to service delivery would have a negligible effect as this would happen impact a small fraction of the time period used for comparison , perhaps ten minutes out of ninety. However, analysis of the event data showed that the ramping up period was actually impacting the adjustment values significantly and thus affecting the delivery proportion values.

The adjustment calculation was adjusted to avoid this issue by shifting the comparison period forward by half an hour so that it covered the three half hour periods starting two hours before the event, but not the half hour immediately prior to the event.

Table 8 – Phase 2 Service Delivery shows two values for delivery proportion and payment proportion reflecting the original offset calculation followed by the revised calculation.

WPD event No.	Event date	WPD Site location	Average Service Delivery proportion (original)	Average Payment Proportion (original)	Average Service Delivery proportion (revised)	Average Payment Proportion (revised)
1	06/09/2019	St. Austell BSP	59.8%	34.8%	71.2%	34.8%
2a	10/09/2019	Fraddon BSP	78.6%	59.7%	83.2%	59.7%
3	13/09/2019	Fraddon BSP	56.0%	20.0%	56.0%	20.0%
4	05/12/2019	St. Austell BSP	Data only provided in revised format		157.4%	100.0%
5	06/12/2019	Fraddon	Data only provided in revised format		18.8%	10.0%
6	01/10/2019	Truro	4.0%	0.0%	20.0%	0.0%
8	20/09/2019	Drinnick Primary	58.4%	45.4%	54.8%	45.4%
9a	27/09/2019	Fraddon BSP	67.5%	36.8%	72.3%	36.8%
9b	27/09/2019	Truro BSP	no contract achieved			
10	01/10/2019	Bugle Primary	52.5%	22.5%	81.7%	39.2%
7b	03/10/2019	Newlyn Primary	10.0%	0.0%	0.0%	0.0%
11	03/11/2019	Truro BSP	Data only provided in revised format		-13.3%	0.0%
2b	22/10/2019	Fraddon BSP	-28.3%	0.0%	-22.0%	0.0%
12	24/10/2019	Newlyn Primary	76.7%	41.7%	190.0%	100.0%
13	13/11/2019	Fraddon BSP			no contract achieved	
14	14/11/2019	Truro BSP			0.0%	0.0%

15	15/11/2019	Bugle Primary	Data only provided in revised format		224.4%	100.0%
16	28/11/2019	Fraddon BSP			Insufficient data for baseline calculation.	
17	25/11/2019	Truro BSP			Contract achieved however, resource was not dispatched.	
18	29/11/2019	Fraddon BSP	Data only provided in revised format		-10.0%	0.0%
19	26/11/2019	Truro BSP	Data only provided in revised format		10.0%	0.0%
		Average	**43.5%**	**26.1%**	**62.2%**	**34.1%**

Table 8 – Phase 2 Service Delivery

Average values for delivery proportion under the revised adjustment method are comparable with 62% overall compared to 60% for Phase 1.

This comparison is appropriate as the baseline adjustment used in the Phase 1 trial only included one half hour period which was between 90 and 60 minutes prior to the event. This would not have been affected by ramping up issues, but is likely to be a less accurate means of adjusting for daily variations as it relies on a single value.

Service delivery values were not expected to vary by reservation period as the real notification of whether service is required is achieved by the utilisation auction, which is held the day before a planned service is to be delivered.

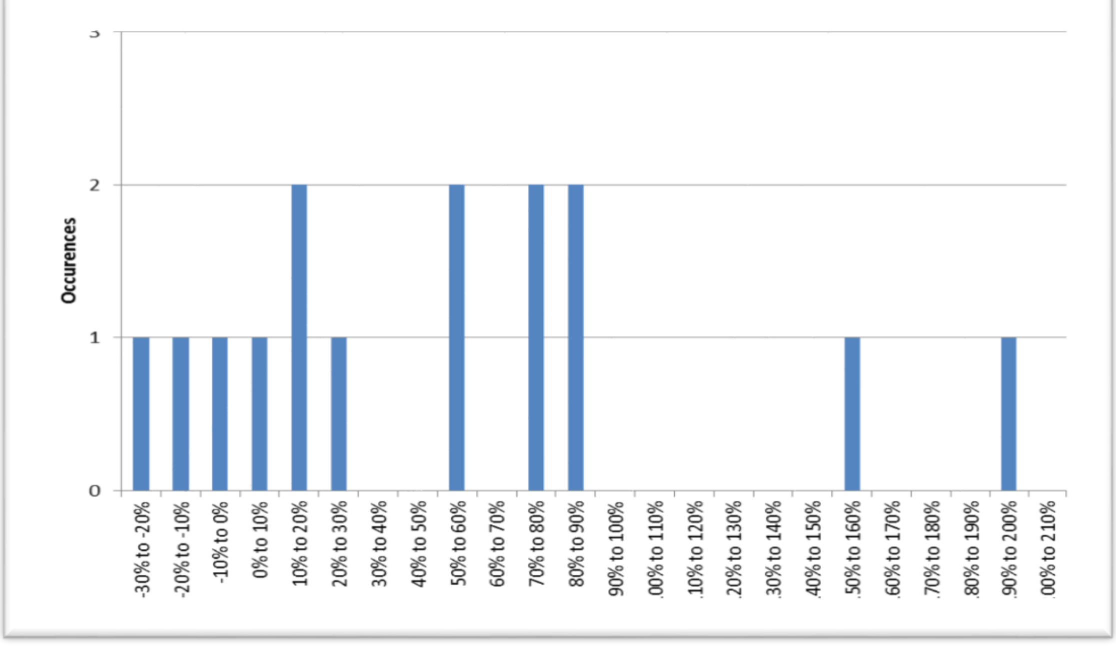


Figure 15 – Phase 2 Delivery Proportion Frequency Distribution

As seen in Figure 15 – Phase 2 Delivery Proportion Frequency Distribution, Service delivery varied widely between events with one event delivering nearly twice the required service and some negative values being reported, i.e. the customer's profile was altered in the opposite direction to that required. This prompted an investigation which showed that there was a difference between the service delivery as measured by the domestic battery system itself compared to the half-hourly meter readings. This is discussed further in the following section. The negative values related to services provided by domestic customers only. Please note - additional events were added to provide more examples for comparison so the frequency of these low/negative delivery events has been artificially increased and would not necessarily reflect delivery from a balanced portfolio of customers. The over-delivery shown in two events is not rewarded with additional payments whereas under-delivery results in deductions which is why the average payment proportion is lower than the average delivery proportion at 34% compared to 62%.

4.15.3 Domestic Customer Service Delivery Measurement

As reported in the Phase 1 Interim Learning report, there appears to be a potential issue with the delivery calculation for domestic customers where the reported negative response is contradictory to the confirmed discharge as reported by the battery management system. This did not affect all events but occurred on more than one occasion. The mismatch between battery system and smart meter data based calculations was less during the Phase 2 trial which made use of battery clusters that included a larger number of customers. The calculations for baselining and delivery assessment used aggregated data for the domestic customers which would have the benefit of averaging out some of the volatility in individual customer profiles. The improved correlation in Phase 2 suggests that using even larger clusters of domestic customers may result in even better agreement between the battery system and smart meter based calculations.

Another issue may be the relative scale of the power delivered by the battery. If battery power delivery is relatively small then concurrent increases in consumption in the home could negate the impact of the battery before it is registered at the meter. If service delivery by domestic customers is under-reported then the payments provided may be too low to encourage further development of the domestic market. Therefore further research is recommended to determine the impact of the number of customers, their aggregated capacity, the ratio of battery power to average consumption etc. on the reported delivery, but also on whether alternative benchmarking methodologies are more appropriate for domestic customers.

4.15.4 Half Hourly vs. Minute resolution settlement comparison

Minute level resolution is currently a requirement for customers providing services through the Flexible Power participant portal. However the cost and disturbance of installing more sophisticated metering may be a barrier to some customers signing up for these services. The Cornwall Local Energy Market platform opted to accept half hourly metering data for settlement specifically to maximise the chances of customers signing up for the services. For CLEM the baselining methodology has been adapted to use half-hourly metering data.

While accepting half-hourly data may help sign up more flexibility providers, there are some potential downsides. While we require a consistent and sustained adjustment of the customer's profile, averaging can mask underlying variations. If a customer started delivery 15 minutes late and then delivered at 200% of the required volume for the remaining 15 minutes, the half hourly average value would be indistinguishable from successful delivery of 100% of the service on time.

The potential for service delivery to be exaggerated for customers that are metered on a half-hourly basis rather than at minute resolution was identified during project ENTIRE as an area for further investigation. As this issue is also relevant to CLEM, the impact of metering resolution was investigated using the ENTIRE dataset to create half hourly average values and compare the calculated delivery proportion.

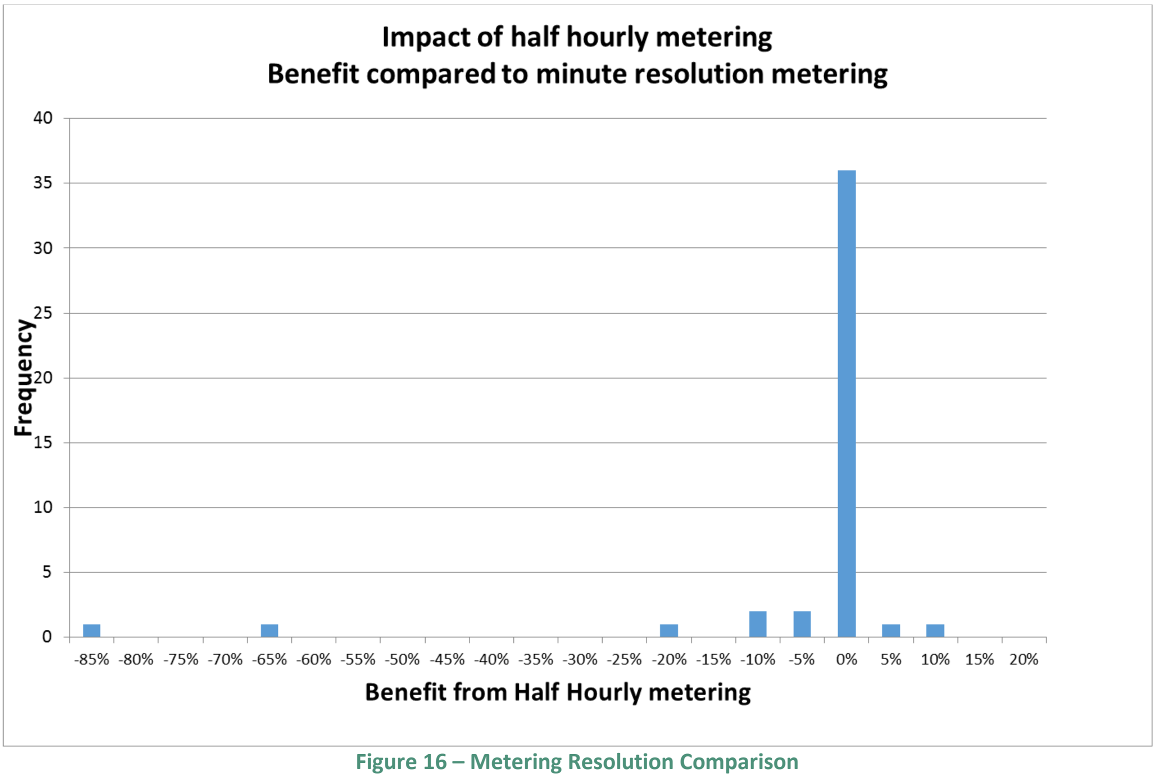


Figure 16 – Metering Resolution Comparison

While the sample size of the events is relatively small, the majority of events have very similar payments regardless of metering resolution. Once outliers are excluded there appears to be a balance between gains and losses so that one type of metering will not consistently provide an advantage. There are also practical considerations which may reduce the risk of a provider making use of half-hourly average values to mask under-delivery. Firstly, the provider would need to be aware of the under-delivery in time to take corrective action. Secondly the value of improving the calculated delivery would need to exceed any negative impacts from operating the flexibility asset in this way – i.e. a short burst of over-delivery.

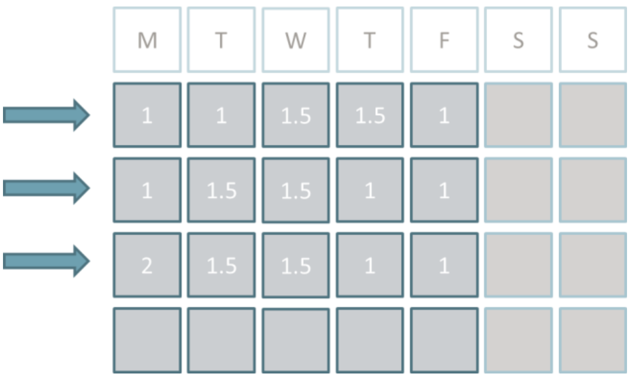
While half-hourly metering can reduce the penalties from under-delivery it can also have the opposite effect. Items with a significant difference in outcome were scarce and could be reduced further by removing the number of zeros reported by the monitoring, either by improving the monitoring and communications system or by applying data cleansing to interpolate where a zero value is surrounded by data considered to be more reliable.

Further details and examples for this analysis are given in Appendix 4 – Comparison of Minute vs Half Hour resolution on
Service delivery assessment.

4.15.5 Baselining methodology comparison

Given the sensitivity of the results to the baselining adjustment, it would be useful to compare the impact of different baselining approaches on the assessment of service delivery.

One area of significant difference between the approaches undertaken by ENTIRE and CLEM is the time-period used to create a baseline value. For ENTIRE, the time period used for comparison was selected to be a period of high load which was then averaged to create a single value for comparison. The section below is replicated from ENTIRE's Service Design report. [5]

> The system focused on establishing an average demand over a period of weeks taken from period of the day where demand is typically higher than average. This should ensure that the DD used to calculate payments should be consistently greater than if data from across the whole day were to be used. This was intended to reflect the expected running conditions at the expected times of calls whilst erring on the side of generosity towards participants.
>
> The data used for the baseline was from the first three full weeks of the month, between 3pm and 8pm, giving a sample over a total of 75 hours as shown in Figure 13.
>
> 
>
> Figure 17: Baseline example
>
> The consumption during the five-hour period for each day was totalled and divided by the 75 to establish the monthly average demand which then becomes the baseline for the following month.

Selecting the baselining time period in this way had the advantage of reducing the volumes of data that to be provided and reducing the absolute error compared to a period of low usage. However, this also reduces the accuracy of the baseline value when used for a different time period e.g. using the average value between 3pm and 8pm as a reference for a service delivered at midday may not be reasonable. Similarly, for longer services extending over several hours using a single value, rather than a value per half hour, may introduce further error.

5

The CLEM methodology, on the other hand, creates a baseline for each half hour so that a service delivered at 14:00 will be compared to the baseline value for 14:00.

Another difference is in the days that are selected to form the baseline. Both methods try to compare like with like by ensuring weekdays are compared with weekdays, Saturdays with Saturdays and Sundays with Sundays. However where CLEM includes the previous 10 weekdays, ENTIRE will include the weekdays for the first three weeks of the previous month.

Table 9 – Date selections for ENTIRE vs CLEM baselining, below shows how the methods result in very different days being selected for the first five events of the ENTIRE project.

WPD event No.	Event date	Dates used for ENTIRE baseline	Dates used for CLEM baseline
S1	22/05/2018	2-6 April, 9-13 April, 16-20 April	8-11 May, 14-18 May, 21 May
S2	24/05/2018	2-6 April, 9-13 April, 16-20 April	10-11 May, 14-18 May, 21-23 May
S3	14/06/2018	1-5 May,7-11 May,14-18 May	31 May, 1 Jun, 4-8 Jun, 11-13 Jun
S4	11/07/2018	4-8 Jun, 11-15 Jun, 18-22 Jun	27-29 Jun, 2-6 Jul, 9-10 Jul
S5	23/08/2018	2-6 Jul, 9-13 Jul, 16-20 Jul	8-10 Aug, 13-17 Aug, 20-22 Aug

Table 9 – Date selections for ENTIRE vs CLEM baselining

To provide an indicative view of how baselines may differ, the two baselining approaches were applied to half-hourly data for the first five ENTIRE events. For simplicity, the CLEM methodology excluded the baseline adjustment that reflects the difference to the baseline prior for the three half hours starting two hours before the event. Events S1, S3, S4 and S5 were at the same location and are given in Figure **18** – Baseline Comparison events S1, S3, S4 & S5. A comparison for event S2 is also given in Figure 19

It can be seen that the generator output clearly has daily pattern which outputs less during normal office hours than other times of day, so a single value baseline, reflected in the straight lines for ENTIRE baselines, is less likely to reflect the site's actual profile.

While the CLEM approach does reflect the daily profile, the resulting profile is somewhat "spiky". A trade-off is expected for the number of days included in the baselining calculation. A larger number of days may help smooth out the daily variations, providing a smoother baseline profile. However, including too many days could mask shorter term trends which would also reduce accuracy. Further study could show the impact of the number of days included in the baseline and whether smoothing the baseline profile without extending the number of days gives more accurate results. This would require accurate data for service delivered e.g. from a site with comprehensive metering.

It is evident that there is quite a bit of variation in the baselines for the events in different months under both approaches. It appears that the events that are towards the end of the month, S1 and S5, which have the biggest gap between benchmark dates and event for ENTIRE, also have the biggest difference between CLEM and ENTIRE benchmark values. Events that take place earlier in the month, S3 and S4, appear to have less difference between the baselines under the different approaches.

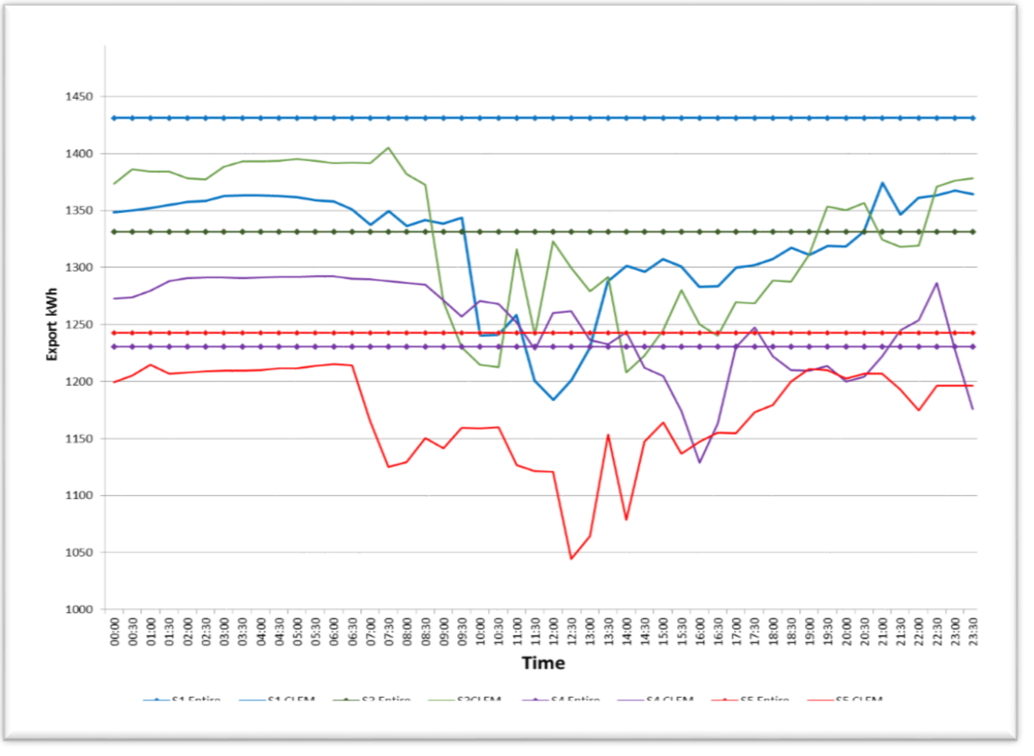


Figure 18 – Baseline Comparison events S1, S3, S4 & S5

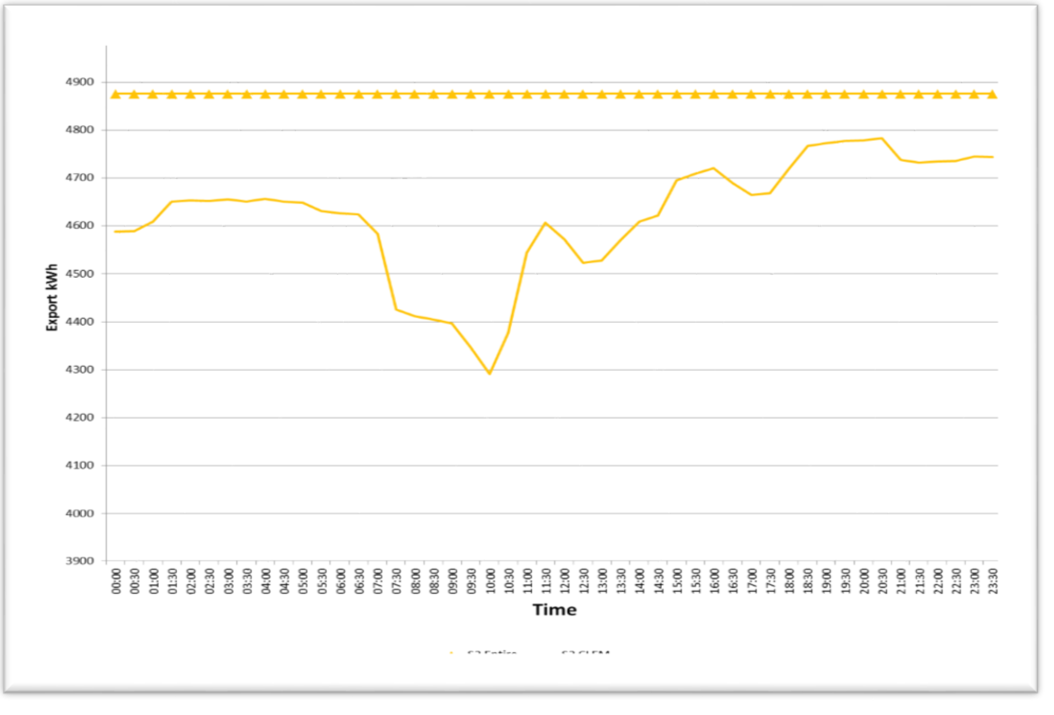


Figure 19 – Baseline Comparison Event S2

Depending on the time of day, the difference between the baseline values can be more than 15% so is potentially significant. Therefore further analysis is required.

The best source of data for this analysis is likely to be Flexible Power platform which will have all the details of the events that have been executed under Flexible Power since 2018. Not only will this be a more realistic sample, reflecting real events rather than those contrived under a trial, but there should be a larger number of events and analysis can be repeated with a growing dataset. At present extracting the data from this platform is a complex process, however a data extraction utility is currently under development. This is expected to be complete by July 2020 and would provide a means to carry out this comparative analysis.

Further analysis could also consider;

- the impact of the number of similar days used to construct the baseline assessment, and
- how to filter out "outliers" from these samples where the profile was affected by outages, or other unusual events which may distort the baseline.
- Whether it is appropriate to apply smoothing to the baseline values.

5 Performance Compared to Original Aims, Objectives and Success Criteria

5.1 Objectives

The project objectives have all been met. To avoid duplication this section provides cross-references to the sections of this report that demonstrate the objectives' successful completion.

5.1.1 Market platform design, development and trial

"To assist Centrica with the design, testing and trial of the market platform known as the Cornwall local energy market."

This objective was successfully completed as outlined in section 4, Work carried out.

5.1.2 Impact of purchasing variants

"To investigate the impact of varying attributes such as market model, purchasing timing etc."
This objective has been met. The results of this analysis are given in sections 4.13 and 4.15

In summary, there was little difference between the market models in terms of prices or reliability. Purchasing timing varied from three months in advance to within-day, however this did not provide significant changes to prices, especially for the spot market model where the reservation price is a relatively small compared to the utilisation price, which is always set using a day-ahead auction regardless of advance timing of the reservation. While this may suggest that advance planning is not beneficial in reducing prices, this trial was not designed to test whether advance reservation reduced the risk of failing to secure sufficient services. If advance reservation is no more expensive than reservation nearer to the time of delivery, then there may be benefit in reserving resources as soon as possible. This reduces the risk of failing to secure sufficient services as it allows for purchase via any of the available auctions before service delivery. While there is the potential for wasted payments in reserving more capacity than if the assessment were made nearer the time, given the relatively low cost of reservation payments compared to the high cost of alternatives if insufficient capacity is reserved (e.g. generator hire) this would still be expected to be beneficial. The optimum balance of early reservation vs. purchasing with short notice or no prior reservation requires further investigation. However, the operation of mature, liquid markets is not currently practical with sparse customer participation in trials. It may be that simulations such as agent based modelling could provide further insights.

5.1.3 Data Exchanges and platform practicalities

"To determine the data exchanges that are required to support the platform and the practicalities of purchasing and operating flexibility services via a market platform."

This objective has also been met. The data exchanges were reflected in the user interface design and the CSV output files but additionally the data required to associate customers with the network under default and other network configurations is discussed in section 4.4 while the data required to support conflict resolution is given in section 4.5.1.

Practical issues for purchasing flexibility services via the market platforms include how to optimise the selection under a quote and tender model (see section 4.8) and the impact of using half-hourly resolution data (see section 4.15.4).

5.1.4 Optimisation of service selection

"To determine a means of optimising the selection of services from those available, which may include other factors than price, such as reliability."

The optimisation process and tool developed are given in section 4.8 WPD Optimisation tool development.

5.2 Success Criteria

5.2.1 Business Process validation

"Business processes validated and we have understanding of their practicality / limits."

This Success Criterion has been met in that the business processes tested by the CLEM were validated. However, the business processes for procuring and dispatching flexibility services are still being developed as part of the Open Network project. It is likely therefore that business processes will continue to evolve beyond this project.

The practicality of the Phase 1 platform was limited by the lack of data exchange features to determine if this could be a valid method of avoiding conflicts, however the Phase 2 platform, which was enhanced during the trial, had a better user interface and was very quick to set up events. The practical issues such as how to provide customer –to-network relationship data for default and other network configurations, the limits of managing conflict through market clearance algorithms etc. are given in section 4.

5.2.2 Data Exchange Validation

"Data exchanges validated and can be used as a specification for future systems"

Most of the data exchanges are embedded within the user interfaces for both the Phase 1 and Phase 2 platforms.

Data Exchange	Comment
DNO specification of requirement via the platform UI.	Successfully validated for both Phase 1 and Phase 2
Response from the market (Phase 1)	Phase 1 offers presented via the web UI and as a downloadable CSV file for easier input into the optimisation tool
Notification of selected offers (Phase 1)	Information presented via the UI
API for suppliers to provide Bid information (Phase 1 & Phase 2)	Successfully used. While most suppliers used the UI, the API was used with the residential battery clusters. (Please note, the UI itself interfaces with the API.)
Notification of availability auction results (Phase 2)	Information presented via the UI and extended to include a notification e-mail.
Notification of utilisation auction results (Phase 2)	Information presented via the UI and extended to include a notification e-mail.
Network hierarchy for associating customers with network locations	Provided as a custom data extract with manual checking of MPANs. CIM model expected to be used in future. This will be shared via WPD's Energy Data Hub[6]
Network hierarchy for identifying conflicting actions in Phase 2 market clearance algorithm	Provided via publically available download from the WPD network capacity map.[7]
Network capacity to support Phase 2 market clearance algorithm to avoid trades that would overload assets.	As above.

Access to the data within the Phase 2 platform to enable SQL queries is being developed to support the EFFS project.

5.2.3 Optimisation process investigated

"Process to optimise and combine offers of flexibility services trialled and refined for inclusion in future systems"

The work on optimisation, as outlined in section 4.8, was used to inform not only the EFFS project, but also the TRANSFORM and FUSION projects. The optimisation tool has been provided to T.E.F project representatives.

[6] https://www.westernpower.co.uk/our-network/energy-data-hub

[7] https://www.westernpower.co.uk/our-network/network-capacity-map/

5.2.4 Service delivery validation analysis

"Service delivery validation explored and options understood, including whether half hourly metering data can provide sufficient information."

Half Hourly data was used to create baselines against which service delivery was assessed for both domestic and non-domestic customers. Analysis using the data from ENTIRE suggests that half hourly data can be used for delivery assessment. While there are occasional discrepancies with the delivery assessment calculated using minute resolution data, the vast majority of results are within a small margin of each other and there is no systematic bias.

Additionally the impact of different baselining methodologies in terms of selected days and half hourly periods used to calculate the baseline has been investigated as outlined in section 4.15.5

A potential issue around domestic customer benchmarking has been highlighted in section **Error! Reference source not found.** which suggests there may be a minimum number of customers or aggregated customer capacity that should be combined for benchmarking and service delivery purposes to benefit from the averaging effects.

Another issue may be the relative scale of the power delivered by the battery. If battery power delivery is relatively small then concurrent increases in consumption in the home could negate the impact of the battery before it is registered at the meter. If service delivery by domestic customers is under-reported then the payments provided may be too low to encourage further development of the domestic market. Therefore further research is recommended to determine the impact of the number of customers, their aggregated capacity, the ratio of battery power to average consumption etc. on the reported delivery, but also on whether alternative benchmarking methodologies are more appropriate for domestic customers.

5.2.5 Optimal functional location

"Understanding of whether load modelling and optimal service selection are best placed within the "socket" of a market platform or the "plugs" of associated software. "

The optimisation function for Phase 1 was determined to best be located on the DNO side to allow optimisation across the bids from multiple platforms. For Phase 2, however, the optimisation of selection was built into the algorithm that matched bids and offers.
Load modelling was originally expected to be located within the market platform to support local marginal pricing. A simpler form of load modelling was included in the Phase 2 clearance algorithm with full load flow analysis no longer expected within the market platform.

6 Required Modifications to the Planned Approach during the Course of the Project

The CLEM project changed and evolved considerably during the timescale of this NIA project including changes in;

- Emphasis, replacing the planned local marginal price analysis with a more comprehensive approach combining optimisation with conflict management
- the software platform used to develop the CLEM
- several key personnel
- approach to customer recruitment
- trial locations

The local marginal pricing analysis was curtailed as it became apparent that using the pricing algorithm for flexibility services without also modelling the much larger power flows associated with wholesale trading would not give reliable results. It also became clear that this modelling may not uncover the complexities of customer behaviour under different market conditions. This remains an area of interest which would help inform market design.

The changes in the software technology used for Centrica's platform reflected the ability to recruit suitably qualified staff. The platform was rebuilt using a technology that resolved staff recruitment issues.

During the project, there were several changes to key personnel. Each change introduced an element of delay as the new staff member needed time to become fully conversant with the project. While this is unavoidable, it emphasises the need for contingency in project timescales.

While the domestic customer recruitment was over-subscribed, the recruitment of non-domestic customers proved more challenging. The CLEM project included specific targets for increasing installed renewable capacity and initially it was believed that these new installations would provide trial participants. However finding untapped opportunities to increase renewables was challenging with new connections being uneconomic at locations where flexibility is required. Similarly timescales for new or upgraded connections were often too long for trial participation. Additionally some proposed use case, such as export capacity trading, were not supported by WPD. The main barrier to participation was that the financial rewards on offer were not viewed as attractive.

Customer recruitment was boosted by increasing the number of live events where customers could see a system demonstration and meet the team in person. Centrica's recruitment activities included publications via various media outlets, a media day, an aggregator event and 1-2-1 demos with several companies.

The change in trial locations reflected the locations where customers had been signed up which was a wider range than the original target areas.

The various changes in approach contributed towards delays in the Phase 1 trials. This resulted in an overlap between the Phase 1 analysis and the Phase 2 trials but did not result in loss of trial scope or delay the completion of the VPAS project.

7 Project Costs

Activity	Budget	Actual
Project Management	£125,624	£92,213
Software development	£14,000	0
Payments for flexibility services	£22,800	£9,6345
Contingency	£16,242	0
Total	**£178,667**	**£101,848**

Project management costs are lower than the budget value as this activity was originally expected to be performed via an external contractor, but resolving resourcing issues allowed this to be managed internally at a lower cost.

The software development budget was to cover the cost of developing an optimisation tool, however it was possible to make use of Excel Solver without additional cost.

Payments for flexibility services were budgeted assuming that all events would be delivered in full. Some events were not delivered at all, some were not contracted at full capacity and the cost penalties for under delivery also served to reduce the amount paid.

8 Lessons Learnt for Future Projects

The learning for the project has been documented in section 4.
However there are some additional process and project management learning points that have emerged during the project.

Creating two parallel projects resulted in a large amount of dependency from the Visibility Plugs and Socket side to the CLEM. Similarly the responsibility boundaries between the two projects were not always clear. It was often difficult to gain visibility of how the partner project was progressing, which resulted in the schedule for Phase 1 being amended to reflect delays in customer recruitment relatively late in the process.

The difference in IPR approach between the two partner projects was also problematic at times as whereas for DNO innovation projects, the normal position is to share as much as possible, Centrica had to determine what could and could not be shared on a case by case basis. Documentation could contain sharable and non-sharable elements which made it harder to obtain relevant supporting documentation.

The project highlighted some of the difficulties of operating in an evolving market. The market rules were designed with a fluid flexibility services market with plenty of liquidity in mind, however the conditions during the trials were considerably different. With a limited number of customers participating in the trial, there were few instances where there were sufficient participants for bidding behaviour to reflect a mature market. Similarly, in a mature market the way in which service providers would price their flexibility could be expected to reflect knowledge gained from many months of previous activity, but this was not possible to replicate during the relatively short trials.

Terminology needs to be stated explicitly, for example both National Grid and WPD were used to using half hourly numbers to represent the 48 half hour periods in the day. However the National Grid convention was to start the day at 11pm as is the case for balancing services whereas the WPD convention was based on settlement where the day begins at midnight.

9 The Outcomes of the Project

9.1 Platform development

Greater clarity was found over the functions that should be part of each element of the system and how these should work. The platforms was developed and tested successfully in each trial. Data was exchanged successfully using the web interfaces and APIs. Centrica will continue to develop this platform with a view to replicate it in other areas.

9.1.1 Platform learning summary

Without the additional functionality, such as peer to peer trading, it is not possible to determine whether customers prefer platforms that support multiple services to those focussed on DSO requirements. Recruitment faced very similar issues to that by other projects with the financial rewards on offer relative to the time commitment required to participate being the main barrier.

The time commitment for sellers is non-trivial as it reflects the need to familiarise themselves with the platform mechanics, market concepts, review terms and conditions, have personnel ready to respond to events, collect metering data and monitor the platform continuously for bids. Therefore the strong local brand is not expected to translate into dramatically different levels of customer sign-up. However the less onerous metering requirements may make the platform attractive to a wider range of customers.

Exeter University are investigating the potential barriers to flexibility participation in greater depth. As there is still a large degree of uncertainty as to how the market will develop, it is not yet possible to provide a reasonable estimate of likely platform operating costs.

9.2 Phase 1 trial – Quote and Tender Market Model

The outcome of the Phase 1 trial is that we have demonstrated the market platform and data interfaces in the real world. A suitable open source tool for optimisation was found and an optimisation tool created. The trial generated significant learning which is summarised below.

9.2.1 Phase 1 trial learning summary

The Phase 1 trial showed that customers generally bid at prices that were almost identical to those quoted for Flexible Power (£300/MWh). Some events did not take place due to the inability to create a contract beforehand. This was suspected to reflect participants requiring notification of service requests that were relevant to them, a feature planned but not executed on the Phase 1 platform. Events that took place typically delivered 60% of the contracted capacity. The trial highlighted the issue of the network running in a non-standard configuration impacting service delivery. The practicality of optimisation solutions depends on the complexity of service definition. Standardised services, with consistent timings for providing availability data, arming and dispatch were preferred to individually tailored services.

9.3 Phase 2 trial – Combined Spot Market Model

The main outcome of the Phase 2 trial was the demonstration of the market platform being used by multiple purchasers at the same time. This market mechanism was significantly different to the previous models that had been used and the platform performs sophisticated optimisation using complex parameters that also maintain grid security.

This generated significant learning which is summarised below.

9.3.1 Phase 2 trial learning summary

The Phase 2 platform successfully matched bids to offers for DSO and ESO services concurrently, while managing conflicts between services. The market mechanism did not affect prices or service delivery which were consistent with Phase 1. In terms of assessing service delivery analysis suggests that half hourly metering gives similar results to more granular metering for delivery proportions and does not result in consistently skewed payments. The baselining methodology and how any adjustments are applied were seen to have significant impact on measured delivery and this warrants further investigation. An issue was highlighted with domestic customers reporting negative service delivery, in contradiction to the local battery system monitoring suggesting that either the baselining is inappropriate or that service delivery can be negated by local changes in consumption.

10 Data Access Details

All non-sensitive trial data available to WPD has been provided in this report.
Data has kindly been provided by Centrica to support this project. WPD does not own the detailed customer metering data or details of the auction calculations.

www.westernpower.co.uk/Innovation/Contact-us-and-more/Project-Data.aspx)

11 Foreground IPR

Foreground IPR has been developed during the project in the form of the specification of the API for flexibility suppliers to interface with the CLEM. This is available from Centrica

The optimisation tool developed during the project, can be downloaded from the WPD innovation website using this address https://www.westernpower.co.uk/downloads/99664. Please refer to section 4.8 for the software requirements to use the optimisation tool.

12 Planned Implementation

This project has demonstrated the use of a third party operated market platform for flexibility services. Using such platforms is likely to be a requirement to demonstrate that DNOs are acting in a neutral way when managing flexibility services. The learning from this project is likely to inform any integration with third party platforms as and when they start to operate in WPD licence areas.

The EFFS software currently under development, will integrate with the CLEM platform extending the work under this project. Additionally there are plans to procure real services in the Hayle area from CLEM, though this will be managed manually via the user interface rather than via system integration.

13 Contact

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

Innovation Team
Western Power Distribution,
Pegasus Business Park,
Herald Way,
Castle Donington,
Derbyshire
DE74 2TU
Email: wpdinnovation@westernpower.co.uk

Related Documents

The following documents provide additional information relevant to this project.

Related Documents	Link
Visibility Plugs and Socket Phase 1 Interim Learning Report	https://www.westernpower.co.uk/downloads/75097
Shaping Sub-transmission report – South West Region	https://www.westernpower.co.uk/downloads/6713
EFFS design document – Market Interface	https://www.westernpower.co.uk/downloads/64096
ENTIRE closedown report	https://www.westernpower.co.uk/downloads/39682
ENTIRE service delivery report	https://www.westernpower.co.uk/downloads/39679
Policy and Regulatory Barriers to LEMs in GB (Exeter University)	https://ore.exeter.ac.uk/repository/handle/10871/33607
Unlocking-Local-Energy-Markets (Exeter University)	https://ore.exeter.ac.uk/repository/handle/10871/40135
Working Paper_ Barriers to Independent Aggregators in Europe (Exeter University)	https://ore.exeter.ac.uk/repository/handle/10871/40134

Table 10- Related documents

Glossary

Abbreviation	Term
BSP	Bulk Supply Point
CLEM	Cornwall Local Energy Market
CMZ	Constraint Managed Zone
DNO	Distribution Network Operator
DSO	Distribution System Operator
EFFS	Electricity Flexibility and Forecasting Systems (an NIC funded innovation project)
ENTIRE	An NIA funded innovation project focussing on providing flexibility services in the East Midlands.
ESA	Electricity Supply Area
ESO	Electricity System Operator
ESRI	Environmental Systems Research Institute, specifiers of the commonly used ESRI shape file standard.
GDPR	General Data Protection Regulations
MPAN	Meter Point Administration Number – a unique identifier for a customer's meter point.
MVA	Mega Volt-Amps a measure of power capacity
MWh	Mega Watt hours – a measure of power over a period of time i.e. the cumulative energy associated with a service.
VPaS	Visibility Plugs and Socket
WPD	Western Power Distribution

Appendix 1 - Smart Grid Forum - Workstream 6 Relevance

Ref	Description of Actions Recommended to be implemented by end of 2016/2017	DNO	Supplier	DECC	Ofgem
1A	Enabling value from DSR and facilitating commercial arrangements Resolve possible conflicting domestic DSR signals				X
1B	Enabling Actors offering DSR products working together to have joint contracts	X	X		
1C	Facilitating commercial agreements where more than one party shares access to a customer's DSR.	X	X		X
2A	Designing a quick and simple method for notifying relevant actors when there is a DSR action, both before and post-event.	X			X
3A	Exploration of Service contractual arrangements - (i) Continue exploration of users of flexibility services, and including DG and storage providers	X			
3B	Information provision: (i) Develop additional content that indicates location and services required. (ii) Coordinate DNO heat maps into national picture identifying constraints and possible services.	X			
3C	Potential constraints for local generation flexibility Services; facilitate the procurement of flexibility services at a local level				X
4A	Introducing a robust process for relevant flexible load / generation installations and their capacities to be notified to DNOs			X	X
5A	Challenges for community energy to be local suppliers:(ii) Explore the viability of different balancing approaches and how they could contribute to an efficient system. This should include consideration of local balancing of generation and demand for instance through the creation of a Local Balancing Unit.				X
6A	To facilitate understanding different DSR offers		X		

11A	Enabling understanding and use of energy efficiency measures: (iv) Appropriate alternatives to reinforcing the network should include energy efficiency measures. Need for increased engagement across network companies (including GDNs), local authorities, housing associations and suppliers.			X	X
15	Cost reflectivity in flexible connections: Options evaluation Market Based Mechanism	X		X	X

Appendix 2 Contract Terms

Contract terms - Seller to platform operator

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Centrica Local Energy Market Platform Terms and Conditions of use

Version: 12 July 2019

These terms of use (together with the documents referred to in them) (the "**Terms**") set out the terms which apply to your use of and access to the Cornwall Local Energy Market (the "**Project**") platform https://lemcornwall.com/ (the "**Platform**") when you are using the Platform as a registered participant (a "**Registered Participant**"). Please read these Terms carefully before using the Platform. We recommend that you print a copy of these terms for future reference. By using the Platform, you confirm that you accept these Terms and that you agree to comply with them. If you do not agree to these Terms, you must not use the Platform.

1. **Other Applicable Terms**

These Terms refer to the following additional terms, which also apply to your use of the Platform: (a) our privacy policy (available on platform) which sets out the terms on which we process any personal data that we collect from you, or that you provide to us (the "**Privacy Policy**").; and (b) our cookies policy (available on platform) which sets out information about the cookies on the Platform (the "**Cookies Policy**"), By using the Platform, you acknowledge that you have read and understood the Privacy Policy and Cookies Policy.

2. **Information about us**

We are Centrica PLC, a company registered in England and Wales with company number 03033654, and our registered office is at Millstream, Maidenhead Road, Windsor, Berkshire, SL4 5GD (referred to as 'we' or 'us' in these Terms). To contact us, please email Cornwall@centrica.com or see our contact us page here: Contact

3. **Changes to these Terms**

We may revise these Terms to reflect changes to the Platform, changes to the way the Local Energy Market is to operate, changes in our business priorities or changes in law. We will try to give you reasonable notice of any major revisions. Every time you wish to use the Platform, please check these Terms to ensure you understand the terms that apply at that time. These Terms were most recently updated on the date at the top of them. OC_UK/36115271.2

4. **Accessing the Platform**

4.1 The Platform is made available free of charge for the duration of the Project, until the end of 2020. At the end of the Project, we reserve the right to charge for using the Platform. We will notify you of such charges prior to the end of the Project.

4.2 We may, in our absolute discretion and at any time, update the Platform and change its content and the ways in which you can use it. Where possible, we will provide you with reasonable notice in advance of doing this.

4.3 We do not guarantee that the Platform, or any content on it, will always be available or will be uninterrupted, or that you will always be able to conduct transactions via the Platform.

4.4 We may suspend, withdraw, discontinue or change all or any part of the Platform at any time and at our discretion without notice. We will not be liable to you if for any reason the Platform is unavailable at any time or for any period. We may also impose limits on certain services,features or functions, or restrict access to parts of the Platform at any time without notice or liability.

4.5 You are also responsible for ensuring that all persons who access the Platform through your internet connection are aware of these Terms and other applicable terms and conditions listedabove, and that they comply with them.

5. **Eligibility and Account Registration**

5.1 To use the Platform, you must be at least 18 years of age and competent to agree to these Terms. If you are agreeing to these Terms on behalf of an organisation or entity, you represent and warrant that you are authorised to agree to these Terms on behalf of that organisation or entity, and to bind them to these Terms (in which case, the references to "you" and "your" inthese Terms, except for in this sentence, refer to that organisation or entity).

5.2 You must be a Registered Participant in order to use the Platform. To register as a Registered Participant, you must provide all the information required on the registration form, including a username and password. It is your responsibility to ensure that your password remains confidential and secure. The registration process may require you to verify the email address that you have provided to us.

5.3 Upon registration, you agree to provide us with information about yourself, your business, and your sites and assets as required by the Platform, as well as accurate, complete, and current registration information about yourself including your Meter Point Administration Number (MPAN) and meter readings (see Appendix

One “Metering data collection – format requirement”) in respect of the 3 months prior to registration (as a minimum these should be settlement valid readings which are those that are sent to your supplier). You consent to us contacting the distribution network operator to obtain your point of connection for your electricity supply.

5.4 By registering, you agree that you are fully responsible for all activities that occur under your username and password. We may assume that any communications we receive under your account have been made by you.

5.5 We have the right to disable any Registered Participant's username or password, whether chosen by you or allocated by us, at any time, if in our reasonable opinion you have failed to comply with any of the provisions of these Terms and/or if we believe that your account is being used in an unauthorised or fraudulent manner.

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5.6 If you know or suspect that anyone other than you knows your username and password you must promptly notify us at *Cornwall@centrica.com*. Following such notification, you may be required to set up a new account with a new username and/or password.

5.7 You shall be liable for any use of or access to the Platform that is undertaken using your username and password, save where such use or access occurs after we have been advised by you of any loss, misuse, or disclosure of the relevant username or password. You are responsible for notifying us at *Cornwall@centrica.com* if you become aware of any unauthorised use of or access to your account.

6. **Asset access and control**

6.1 You will provide us with the settlement data described in clause 5.3 or monitoring equipment data (i.e. any equipment installed on site used for the purpose of monitoring energy consumption) from the premises to which the transaction relates to demonstrate compliance with that transaction. Data should be provided in accordance with the instructions provided by Centrica (whether via the Platform or otherwise). Both you and Centrica will be entitled to procure independent third party data to verify compliance at any time during the trial.

6.2 You agree that:

(a) we may (but are not obliged to), at any time, either in person or remotely, monitor and check the operation of your energy assets; and

(b) you shall provide reasonable assistance including access to premises, hardware, systems and other equipment so that we may undertake such checks and monitoring.

6.3 You agree to supply us with such data from your metering devices as we may reasonably request.

7. **Trading agreements between Registered Participants**

7.1 As a Registered Participant, you are able to trade energy and capacity. Each trade between Registered Participants will be made using the standard terms of the distribution network operator, transmission network operator or such other party as applicable, and which are available to review from time to time on the Platform (a "**Contract**"). If you do not agree to the standard terms that apply to your transaction, you should not enter into a Contract through the Platform.

7.2 Where you create an offer on the Platform, you undertake to ensure that the information you submit is true and accurate and if your offer is accepted you agree you are legally bound to meet the response to which you have committed.

7.3 Each Contract is entered into directly between the selling Registered Participant and the buying Registered Participant. We will not be a party to the Contract and we are not bound by its terms. All aspects of a Contract are solely the responsibility of each Registered Participant. We will not be liable for any breach by a Registered Participant of any Contract.

7.4 The parties to a Contract must ensure that it incorporates the market rules and qualification parameters (as defined from time to time) that apply to the transaction to which that Contract relates.

7.5 By using the Platform, you accept that the Platform’s auction clearing process will match the bids and offers of Registered Participants in order to create Contracts between those Registered Participants.

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7.6 A Registered Participant will be able to view their current and past transactions using the Platform.

8. **Payments**

8.1 After the entry into a Contract between a selling Registered Participant and a buying Registered Participant, we will review and monitor the transaction to which that Contract relates.

8.2 We will notify the buying Registered Participant when we are satisfied that payment should be made to us by that buying Registered Participant, and such notice shall include the amount due and such data as is reasonably necessary (in our absolute discretion) to demonstrate to the buying Registered Participant that an obligation to pay the relevant amount has arisen.

8.3 The buying Registered Participant shall provide payment to us according the process specified in the appendix (Payment process) under clause 8.2. Following the same process, we will transfer the amount received to the selling Registered Participant.

8.4 It is your responsibility to determine what, if any, taxes apply to the payments that are made or received in respect of a transaction, and it is your responsibility to collect, report and remit the correct tax to the

appropriate tax authority. We are not responsible for determining whether taxes apply to your transaction, or for collecting, reporting or remitting any taxes arising from any transaction.
8.5 Payment to us will be by BACs, to the following account: IBAN: [ ]
8.6 Interest shall accrue from day to day (whether before or after judgment) on each amount due from a buying Registered Participant from the due date of payment of such amount at two (2) per cent above Barclays Bank plc's base rate in force from time to time.
9. **Cancelling a bid**
9.1 You may cancel a bid or offer at any time before it is matched by the Platform's auction clearing process with the bid or offer of another Registered Participant to form a Contract.
9.2 Once a Contract has been confirmed via the Platform's auction clearing process, it cannot be cancelled.
9.3 We are not responsible for and shall not be liable for any negotiations, representations made or Contracts entered into between you and any other participant on the Platform.
10. **Warranties**
By using the Platform, and each time you enter into a Contract through the Platform, you warrant and represent that:
(a) you are at least 18 years old;
(b) there are no circumstances of which you are or should reasonably be aware which would prevent a Contract from imposing binding obligations upon you;
(c) you have all requisite power, authority and approvals to enter into and perform your obligations (and/or the obligations of the person(s) on whose behalf you are acting) OC_UK/36115271.2 under these Terms and under any Contract you enter into via the Platform, and you shall not do, or omit to do, anything which is likely to invalidate such approvals;
(d) your performance pursuant to these Terms and any Contract does not and will not conflict with or breach any constitutional document, agreement or applicable law to which you are subject or by which you are bound;
(e) you are in possession of all equipment necessary for you to be able to perform your obligations under these Terms and any Contract and such equipment is in good working order and complies with all applicable laws and standards;
(f) all data you submit through the Platform is accurate and complete; and
(g) you will not question or challenge the validity or enforceability of a Contract to which you are a party on the basis of that Contract being completed on the Platform.
11. **Our Intellectual property rights**
11.1 With the exception of Participant Information (as defined in section 12.1 below), all rights, title, interest and intellectual property rights (including patents, trade-marks, design rights, copyrights, database rights, trade secrets, rights in confidential information and all rights of equivalent nature anywhere in the world, together with any applications or rights to apply for the foregoing) ("**IPR**") in the Platform are the property of us or our licensors.
11.2 We grant you a royalty-free, non-exclusive, non-transferable licence to use materials made available by us on, through or via the Platform ("**Centrica Materials**"), including but not limited to the terms and conditions used to create a Contract, solely for the purpose of entering into transactions with other Registered Participants. All other use or dissemination of Centrica Materials (by any means and in whole or in part) is prohibited without our prior written permission. You must not delete or amend any copyright notice or other notices displayed on Centrica Materials or on any copies of them.
11.3 Access to or use of the Platform does not grant you any ownership right in the Platform, Centrica Materials, or in any Participant Information not provided by you.
11.4 The Centrica and Cornwall Local Energy Market trade-marks are owned by us and nothing contained on the Platform or in these Terms shall constitute the grant of a licence to use such trade-marks.
11.5 Except as set out in this clause 11, you shall treat as confidential and shall not (other than where permitted or compelled to do so by any applicable law) use or disclose to any person (nor permit the disclosure of) any of our confidential information which shall include any information (in whatever form) which is not publicly known and which is disclosed to, or otherwise learnt by, you in connection with the Platform or these Terms, including the content of the Centrica Materials, all Participant Information not provided by you, and the terms of any Contract.
11.6 This clause 11 shall survive any termination of these Terms.
12. **Participant Information**
12.1 From time to time, participants may be required to or choose to provide information via the Platform including but not limited to your name, your company's name, your address, and your asset and metering details ("**Participant Information**"). When communicating Participant Information using the Platform, you must:
(a) ensure that the information you provide is accurate and not misleading; OC_UK/36115271.2

(b) not commit any fraudulent activity;
(c) not attempt to use the Platform for any purpose other than the buying and selling of services as well as for any purpose stated on the Platform
(d) not interfere with or jeopardise the Platform or the business of any other participant; and
(e) not promote any illegal activity.
12.2 We have the right to remove any information from the Platform if, in our opinion, it does not comply with the above.
12.3 We will not be responsible, or liable to any third party, for any Participant Information provided by you or any other participant.
12.4 You acknowledge that any interactive services or functionality provided on the Platform are not a secure means of communication and may be subject to intrusion, fraudulent use and/or modification for which we cannot and shall not guarantee the security, authenticity, completeness, content or source of the information/data sent or received. Consequently, you fully accept the risk, regardless of its nature, which could arise from the use of such interactive services or functionality.
12.5 You agree that you will take part in online surveys run by us with questions about your use of the Platform. We will conduct up to two online surveys during the Project. By taking part in this Project you also agree that we may require you to take part in an in-depth survey, interview or dissemination event (with us and/or our research and/or delivery partners) as part of a “case study”.
13. **Participant intellectual property rights**
13.1 Participant Information made available through the Platform is the sole responsibility of the Registered Participant from whom such Participant Information originated.
13.2 You grant us a worldwide, perpetual, royalty-free, irrevocable, transferable licence to use, copy, modify, reproduce, display and distribute the Participant Information provided by you for the purpose of providing or using the Platform.
13.3 All other use or dissemination of any Participant Information belonging to another Registered Participant (by any means and in whole or in part) is prohibited without the prior written permission of the applicable Registered Participant.
13.4 This clause 13 shall survive any termination of these Terms.
14. **Links**
14.1 The Platform may contain links to other websites, which in turn may contain material that has been produced by third parties not affiliated with us. We have no control over those other websites and we accept no responsibility or liability for information or content provided on such websites.
14.2 You may link to the pages on the Platform, provided you do so in a way that is fair and legal and does not damage our reputation or take advantage of it. You must not establish a link in such a way as to suggest any form of association, approval or endorsement on our part where none OC_UK/36115271.2 exists, and the Platform must not be framed on any other website. We reserve the right to withdraw linking permission without notice.
14.3 If you wish to make any use of content on the Platform other than that which is set out above, please contact *Cornwall@centrica.com*.
15. **Privacy**
15.1 We may pass on your personal information, information about your sites and assets, Contracts you have entered into via the Platform, metering information relating to those Contracts, and information about how you use electricity to our buying Registered Participants for the purposes of ensuring the functioning of the Platform and fulfilment of Contracts entered into through it. We may also use your anonymised data for research purposes, and share your anonymised data with our delivery partners for research purposes, such as to help us understand patterns of how households and businesses use electricity, the impact of energy assets (such as solar panels, diesel generators and battery storage units) on energy supply, network management and other related issues.
15.2 We may record, retain and use information on or from your access to and use of the Platform for monitoring, statistical analysis or product improvement purposes.
15.3 In the event that you terminate your agreement to these Terms, we shall delete all personal information we hold on you due to your use of the Platform, other than the information we require to keep and audit the record of transactions and Contract formation and delivery undertaken via the Platform.
15.4 If you want to know more about the personal information we have that relates to you, why we need it and what we do with it, then please see our Privacy Policy on the Platform.
16. **Viruses, hacking and other offences**
16.1 We implement a number of multi-tier cyber security policies and procedures deployed to safeguard our staff, customers and assets. These include policies and procedures for the detection of malicious software and attempts to subvert or interrupt business processes. We work on a continual basis with a range of global crime agencies and security bodies in order to eliminate threats that are detected or reported. All attempts to subvert

or interrupt our daily business is logged and investigated. It is our policy to cooperate fully at all times with government authorities that are investigating, prosecuting or otherwise seeking to prevent cyber crime.
16.2 We do not guarantee that the Platform will be secure or free from bugs or viruses. You are responsible for configuring your information technology, computer programmes and computer platform in order to access the Platform. You should use your own virus protection software. We will not be liable for any losses which you sustain as a result of any virus, trojan, worm, logic bomb, distributed denial-of-service attack, or other technologically harmful material that may infect your computer equipment, computer programs, data or other proprietary material (each a "**Virus**") due to use of the Platform.
16.3 You must not:
(a) modify, adapt, merge, translate, reverse-engineer, decompile, disassemble, hack, harm or attempt to derive the source code of any aspect of the Platform;
(b) knowingly introduce any Viruses into the Platform;
(c) attack (or instigate or facilitate the attack of) the Platform via a denial-of-service attack or a distributed denial-of-service attack; OC_UK/36115271.2
(d) attempt to gain unauthorised access to the Platform, the server on which the Platform is stored or any server, computer or database connected to the Platform; or
(e) use the Platform for any purpose which is unlawful, abusive, libellous, obscene or threatening.
16.4 By breaching the above provisions, you may commit a criminal offence under the Computer Misuse Act 1990. We will report any such breach to the relevant law enforcement authorities and we will co-operate with those authorities by disclosing your identity to them. In the event of such a breach, your right to use the Platform will cease immediately.
17. **Limitations on liability**
17.1 Nothing in these Terms excludes or limits our liability for death or personal injury arising from our negligence, our fraud or fraudulent misrepresentation, or any other liability that cannot be excluded by law.
17.2 Subject to clauses 17.3 to 17.6, our liability for losses suffered by you that are caused directly by a transaction not taking place because of a failure in the Platform shall be limited to an amount equal to the price payable under the Contract that would have been entered into had the transaction taken place.
17.3 Save to the extent prohibited by law, we exclude all conditions, warranties, representations or other terms which may apply to the Platform or any content on it, whether express or implied.
17.4 We will not be liable to any participant (whether a Registered Participant or a guest) for any loss or damage, whether in contract, tort (including negligence), breach of statutory duty, or otherwise, even if foreseeable, arising under or in connection with:
(a) the use of, or inability to use, the Platform (save as set out in clause 17.2);
(b) the accuracy of any data supplied by any other Registered Participant;
(c) any Participant Information;
(d) any acts or omissions by you, any other Registered Participants, or your or their personnel;
(e) us, or Registered Participants, acting on Participant Information or other communications which purport to have been made by or on behalf of you but which have been created or sent by (i) a third party purporting to act in your name; or (ii) a person who has lawful access to the Platform but who exceeds their authority; or
(f) the suspension or termination of your account or access to the Platform in accordance with these Terms.
17.5 Neither we nor any of our agents, licensors or delegates or its or their directors, officers or employees will be liable to any party for loss of profits, sales, business, or revenue, business
interruption, loss of anticipated savings, loss of business opportunity, loss of or damage to goodwill or reputation and/or any indirect or consequential loss or damage.
17.6 Subject to clause 17.1 of these Terms, the total aggregate liability of us to you for all losses arising out of or in connection with these Terms and the Platform (whether such losses arise in contract, tort, negligence, breach of statutory duty or otherwise) shall not exceed the total price payable under all Contracts you have entered into during any calendar year. OC_UK/36115271.2
17.7 You agree and acknowledge that the exclusions and limitations set out in these Terms are reasonable given:
(a) the nature of the Platform and the technology used to provide the Platform, and the nature of the transactions that the Platform enables;
(b) the fact that the Local Energy Market project is currently an initial trial; and
(c) that no charge is levied on participants for their use of the Platform for the duration of the Project, which shall come to an end on 31 March 2020.
18. **Indemnity**
18.1 You will indemnify us, our agents and delegates and our and their directors, officers and employees (each an "**Indemnified Person**") from and against all losses incurred by an Indemnified Person which arise directly or indirectly out of:

(a) you violating our rights or any applicable law or other rules relating to or displayed through the Platform;
(b) you or any of your agents, officers or employees failing to maintain the security and confidentiality of your username and password or otherwise losing, disclosing or misusing any such details;
(c) any claim, dispute or proceedings that you may have against another participant or that another participant may have against you; or
(d) any claim, dispute or proceedings that a participant may make against us as a result of anything that you have done or have failed to do.
18.2 The indemnity above does not apply to any Indemnified Person in so far as such losses result directly from (a) the proven negligence, wilful default or fraud of such Indemnified Person; or (b) a breach of these Terms by us.
19. **Assignment/transfer**
19.1 We may transfer all or any of our rights, liabilities and obligations under these Terms to any third party. We will notify you of any such transfer. You will be taken to have consented to such transfer if you continue to access the Platform after any such notification.
19.2 We may delegate the provision of the Platform or the performance of any obligation or function relating to the Platform and reserve the right to use any agents on such terms as we may think fit.
19.3 You shall not assign or transfer (or purport to assign or transfer) or otherwise deal with (including through the declaration of a trust) in whole or in part, your rights or obligations under these
Terms without our prior written consent.
20. **Termination**
20.1 You may terminate your agreement to these Terms at any time by emailing us at *Cornwall@centrica.com*.
20.2 We reserve the right to suspend, block or close your account in the event of any breach or suspected breach of these Terms at our sole discretion.
20.3 On any termination of these Terms:
OC_UK/36115271.2
(a) your right to use the Platform shall cease and you shall not make (or attempt to make) any further use of it; and
(b) we may terminate your access to and use of the Platform and invalidate any relevant participant accounts.
20.4 Termination for whatever reason of these Terms shall not affect:
(a) any rights, liabilities or obligations which accrued before such termination;
(b) any right to payment of fees (if applicable);
(c) the validity of any executed Contract;
(d) the application of these Terms and the applicable; or
(e) any of these Terms that are intended to continue to have effect after such termination.
21. **Matters outside our control**
We are not be liable to you or in breach of any of these Terms for any delay or failure to perform that is due to a cause beyond our reasonable control.
22. **Entire Agreement**
22.1 These Terms and our Privacy Policy and Cookies Policy constitute the entire agreement between you and us relating to your use of the Platform and supersede all prior agreements, understandings or arrangements (both oral and written), in relation to the Platform.
22.2 You acknowledge that you have entered into these Terms in reliance only on the representations, promises and terms contained in these Terms and, save as expressly set out in these Terms, neither party shall have any liability in respect of any other representation, warranty or promise made prior to these Terms unless it was made fraudulently.
23. **Third party rights**
23.1 All rights expressed in these Terms to be owed to us shall be construed as owed also to all other participants of the Platform, as exist from time to time. This means that other participants may be able to sue you directly for loss or damage caused to them by your failure to meet specific obligations to them arising and enforceable under these Terms.
23.2 Except as provided for immediately above, these Terms shall not be enforceable by any third party under the Contracts (Rights of Third Parties) Act 1999 or otherwise. You may not transfer any of the rights we give you under these Terms unless we expressly agree in writing.
24. **General provisions**
24.1 No failure or delay by a party to enforce or exercise any right or remedy under these Terms or by law shall be deemed to be a waiver or abandonment of that or any other right or remedy, nor shall it operate so as to bar the enforcement or exercise of that or any other right or remedy at any subsequent time. Any waiver of a breach or default of any of these Terms by us shall not be deemed to be a waiver of any subsequent breach or default and shall in no way affect any other provisions of these Terms.

24.2 If the whole or any part of any provision of these Terms is invalid, that invalidity shall not affect the validity of the remainder of the affected provision, or of any other provision.
OC_UK/36115271.2
24.3 You acknowledge that these Terms will not create any partnership, joint venture or trust relationship between you and us.
25. **Governing law and jurisdiction**
25.1 These Terms shall be governed by, construed and take effect in accordance with, the laws of England.
25.2 The courts of England and Wales shall have exclusive jurisdiction to settle any claim, dispute or matter of difference that may arise out of or in connection with these Terms or the Platform.
26. **Contact us**
If you have any questions about these Terms or the Platform, please email *Cornwall@centrica.com*.
OC_UK/36115271.2
Appendices
1. **Metering data collection – format requirement**
All sellers will be required to provide energy data from the boundary meter at least at ½ hourly resolution for the purpose of baselining and to verify performance during an event, for 30 days of history and up to 1 hour after the event For business customers, this energy data should be available by requesting it from their energy supplier or meter operator The data will need to be uploaded to a safe SFTP site, where it will be analysed and evaluated. Sellers should provide MPAN numbers for site boundary Import and Export meters (where existing). Some sites may be twin-fed. Both of these MPANs will be required
OC_UK/36115271.2
2. **Payment process**
2.1 Attributes to be communicated
• Name
• Address
• Email Address
• Phone Number
• Legal Business Name
• Company Number
• VAT number (if registered)
• IBAN (preferred)
• Bank Account Name (as alternative to IBAN)
• Bank Sort Code (as alternative to IBAN)
• Bank account Number (as alternative to IBAN)
OC_UK/36115271.2
2.2 Sequence diagram

OC_UK/34925755.8

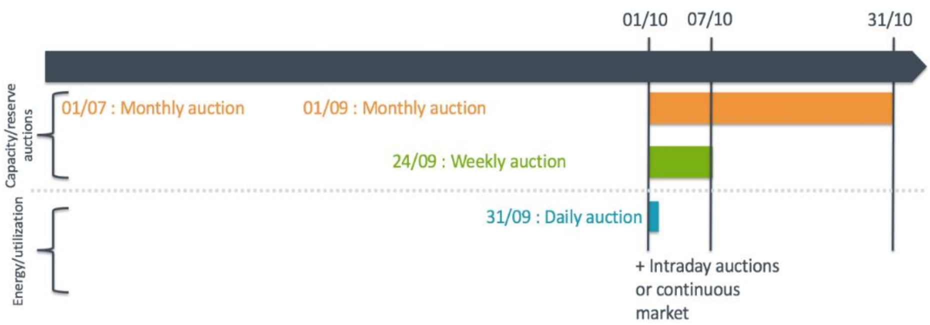
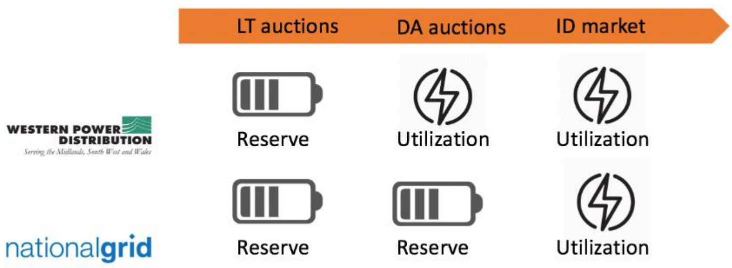
Contract terms - Buyer to platform operator - https://s3.eu-west-2.amazonaws.com/system-data.cornwalllem.co.uk/dev/LEMTradingTC_311019.pdf

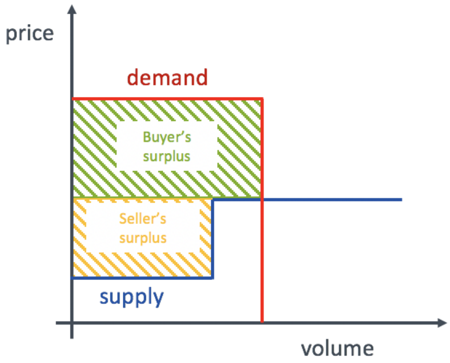
Appendix 3 - LEM Market Rules for Phase 2 Trial in 2019

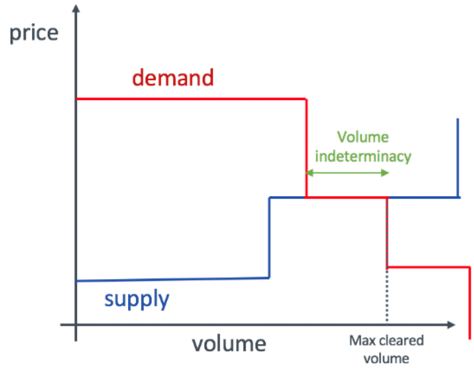
LEM Market Rules – Approval for Trial in 2019

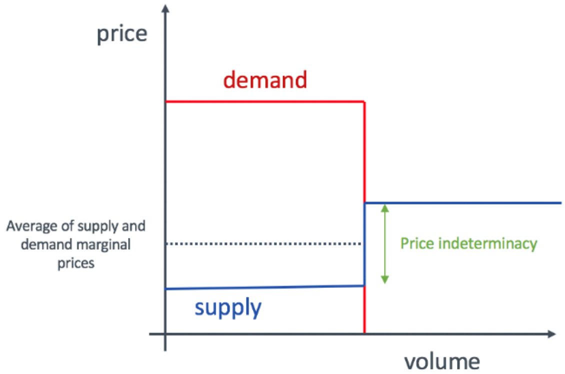
European Union
European Regional
Development Fund

Cornwall Local Energy Market

Issue	Description
Market sequencing	M-3: NG + WPD (reserve) M-1: NG + WPD (reserve) W-1: NG + WPD (reserve) Day ahead utilisation (DAU): WPD only Day ahead reserve (DAR): NG can procure reserves from any non-reserved sellers Intraday (ID): NG + WPD (utilisation only)   Both NG and WPD will have access to the Intraday market
Auction format	Closed gate, pay as cleared auction: enables more complex parameters to be taken into account to meet buyer needs, focuses liquidity, provides transparent and uniform pricing at locations, encourages efficient pricing at marginal cost / tends against sub-optimal bidding and gaming. Optimisation function: maximise welfare between buyer and seller surplus

<table>
<tr><td></td><td>


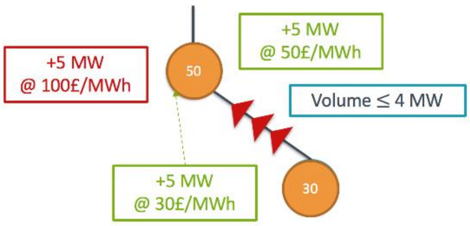
Resolving volume indeterminacy: maximise matched volume


Resolving price indeterminacy: clearing price will be average of marginal price of demand and supply curves


</td></tr>
<tr><td>Market timings</td><td>M-3: 1st of each month at midday
M-1: 1st of each month at midday
W-1: Wednesday each week at midday
DAU: Daily at midday
DAR: Daily at 12:30pm
Intraday auctions: Every half hour for delivery starting from 1 hour later
NB: no auctions on/for delivery on weekends or bank holidays</td></tr>
<tr><td>Intraday auctions</td><td>Half hourly, closed-gate, utilisation only auctions. Each auction will cover delivery starting from 1 hour later until the end of the current day (e.g. Auction occurring at 10:00 will cover all half hour periods between 11:00 to 24:00). Whilst the GB electricity market runs from 23.00-22.59, for the sake</td></tr>
</table>

	of this trial we will run according to a normal 24hr clock (i.e. no bids/offers across midnight). Delivery in half hour blocks (orders must cover a minimum of one half hour block)
Price cap	Propose no price cap initially and then implement price cap if initial results indicate needed
Product description	Reserve and energy products have been simplified to create one bid/offer pair for LEM reserve and one bid/offer pair for LEM utilisation, described below and documented as part of the attached API specification: bidsoffersapi_apispec_0.0.2.yml **<u>Reserve</u>** *LEM Reserve bid, accessible to WPD and NG* - Time - Volume (MW) - Location - Price (£/MW/h) - (optional) Min acceptance volume (MW) - (optional) Time block (Boolean) *LEM Reserve offer, accessible to flexible assets* - Time - Volume (MW) - Location - Price (£/MW/h) - (optional) Max energy (MWh) - (optional) Max energy over a particular time span (MWh) - (optional) Min activation time - (optional) Max activation time - (optional) Min recovery time - (optional) Min acceptance volume (MW) - (optional) Time block (Boolean) - (optional): ramping rate (kW/min) (up and down) **<u>Utilisation</u>** *LEM utilisation bid, accessible to WPD and NG* - Time - Volume (MW) - Location - Price (£/MWh) - (optional) Min acceptance volume (MW) - (optional) Time block (Boolean) *LEM utilisation offer accessible to flexible assets*

	- Time - Volume (MW) - Location - Price (£/MWh) - (optional) Max energy (MWh) - (optional) Max energy over a particular time span (MWh) - (optional) Min activation time - (optional) Max activation time - (optional) Min recovery time - (optional) Min acceptance volume (MW) - (optional) Time block (Boolean) - (optional): ramping rate (kW/min) (up and down) In addition, assets can offer into the energy-only market with the same LEM utilisation product.
Technical and size parameters	Time: 30 min settlement periods (a single bid/offer can comprise single block of 2.5 hours etc.). Response time to full output: 20 min maximum Min duration per seller: 30 minutes Seller min clip: 50kW WPD: 50kW clip size, 50kW minimal acceptance amount National Grid: 50kW clip size, 500kW minimal acceptance amount Clearing engine will only clear reserve contracts that can be utilised for the duration of the contract: e.g. a battery with a maximum duration of 1 hour will only be cleared for a 1-hour reserve contract.
Conflict rules	If WPD and NG have bids that conflict in the same reserve auction, WPD's bid will take precedence. WPD and NG cannot have reserve contracts in opposite directions at the same time if they conflict (i.e. the NG-contracted asset would potentially be in conflict with WPD's action). If WPD has a pre-existing reserve contract, NG cannot win a reserve contract in a subsequent reserve auction from an asset that would conflict with WPD activating its reserve. If NG wins a reserve contract through auction (and therefore is not prevented by the above scenarios), then WPD cannot win a reserve contract or free bid in conflict with NG's existing reserve contract. Once WPD has made day-ahead utilisation decision, NG undertakes a DA reserve auction taking WPD actions into account. WPD and NG will be able to see that the other has submitted bids in advance of auctions closing, and will be able to see reserve contracts, but will only see location, direction, and volume (no pricing).

Bid allocation	LEM platform will tell sellers which buyer has reserved them and for what hours, so they can submit utilisation offer with best information. Engine first determines what volumes are accepted or rejected so as to maximize the welfare, and then allocates capacity offers from the sellers to bids from the buyers as a post-processing step. For this trial, given limited liquidity and NG's larger minimum buy size, larger volumes are allocated to NG first, with remaining volumes going to WPD. As reserve is pay as clear, this allocation process does not affect pricing. We expect that with increasing liquidity, this allocation mechanism will change.
Metering	1 minute power metering is preference, with 30 minute energy metering as a minimum. No live pulse of metering is required.
Baselining and Settlement	Utilisation payments based on delivery percentage, to be calculated based on Half Hourly metered volumes. Availability payments to be paid to sellers unless average utilisation delivery percentage falls below a particular threshold (reconciled on monthly basis).
Contract and payment model	Sellers, NG and WPD have contracts with LEM for use of platform The legal relationship for flex service delivery exist between buyer and seller directly, but buyers are invoiced by LEM for the aggregated service. Buyers pay this total amount to LEM, which then disburses to sellers.
Network representation and headroom	Engine to clear economic bids/offers based on consideration of basic network model with headroom data derived from WPD information. Any bids/offers that if activated would not comply with the headroom data are to be rejected in closed gate auctions.
Congestion rent	Due to congestion, it is possible to have a capacity or energy transfer from one location to another with different prices at each location. This generates a financial surplus called "congestion rent". This is illustrated in the following example.  **Figure 20 : Example illustrating the concept of congestion rent** Current proposal is that LEM keeps congestion rent during trial and distributes it between participants at the end of the trial pro rata.

Appendix 4 – Comparison of Minute vs Half Hour resolution on Service delivery assessment.

As outlined in section 4.15.4, a potential issue with the over-reporting of service delivery for half-hourly metered customers was identified by project ENTIRE as an area for further investigation. As this issue is also relevant to CLEM, the ENTIRE dataset has been used to examine the impact of assessing delivery using half-hourly metering data rather than at minute resolution.

In Figure 21 – below, it can be seen that there is a period of under-delivery near the start of the event. The service dips below the 95% limit, where penalties begin and even drops under the 63% limit for a few minutes where payments fall to zero. However the half-hourly average value only drops to the 95% limit thanks to higher delivery values later in the period, so no penalty would apply if this customer only had half hourly metering.

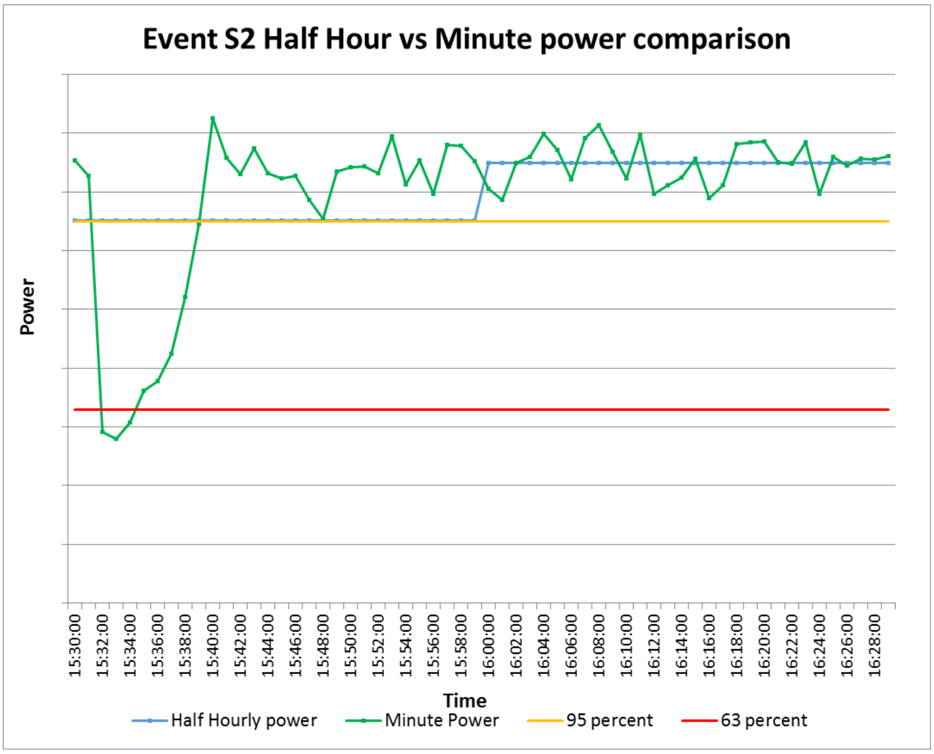


Figure 21 – Event S2 Power Comparison

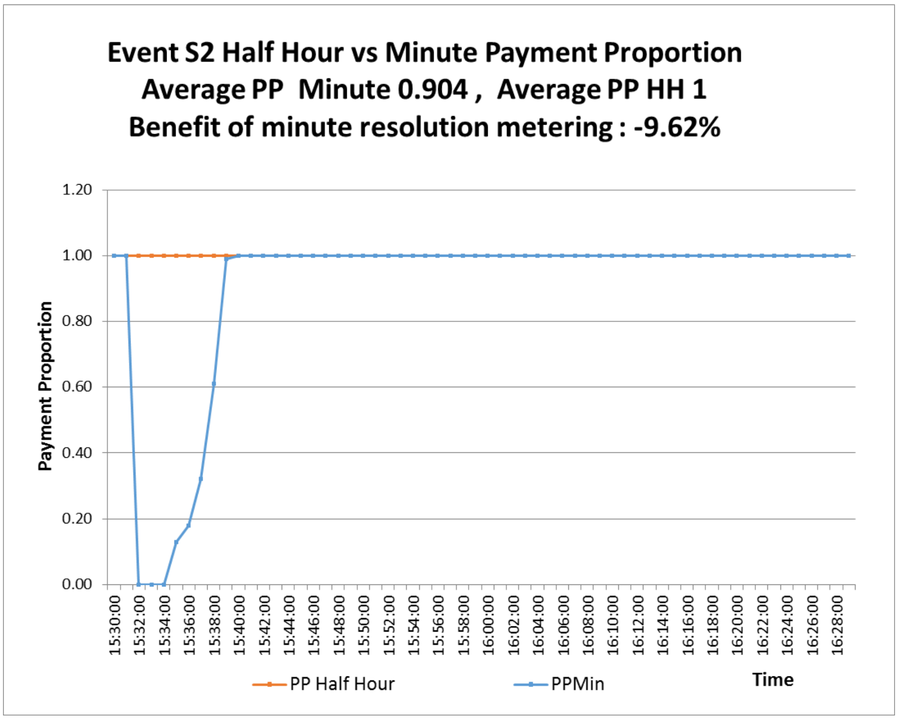


Figure 22 – Event S2 Payment Proportion Comparison

Events 13 and 20 have a similar effect with under-delivery at the start of the event resulting in a lower payment proportion under minute resolution metering, but to a lesser extent.

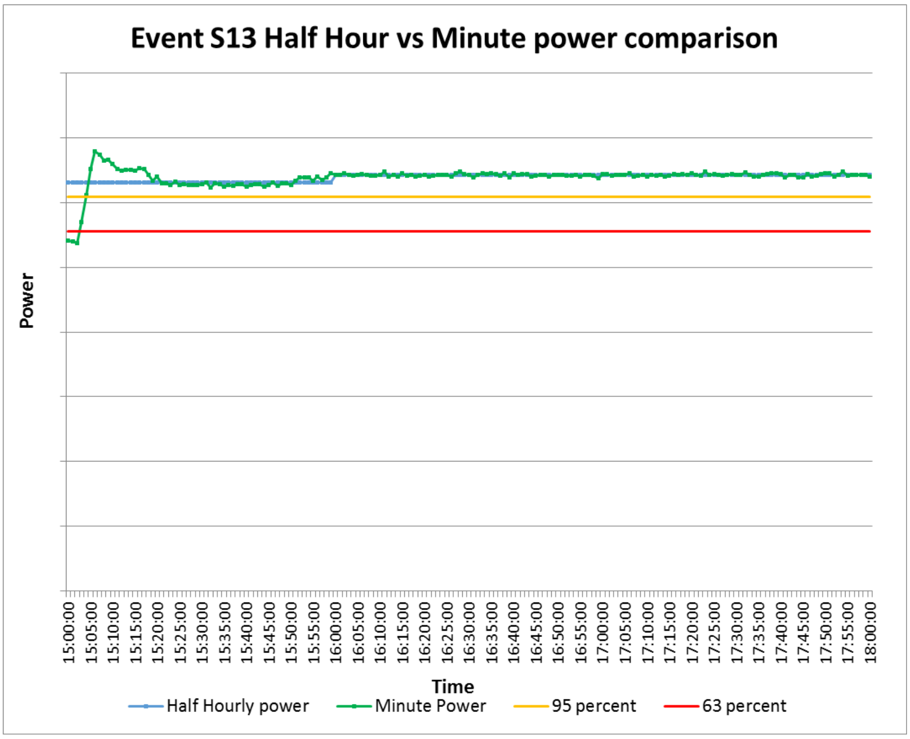


Figure 23 – Event S13 Power Comparison

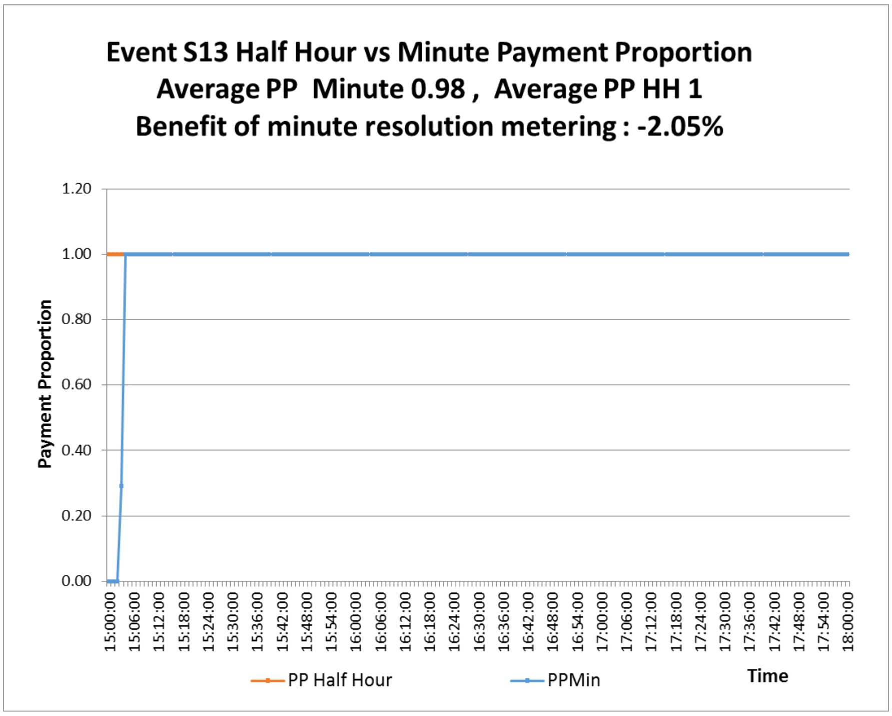


Figure 24 – Event S13 Payment Proportion Comparison

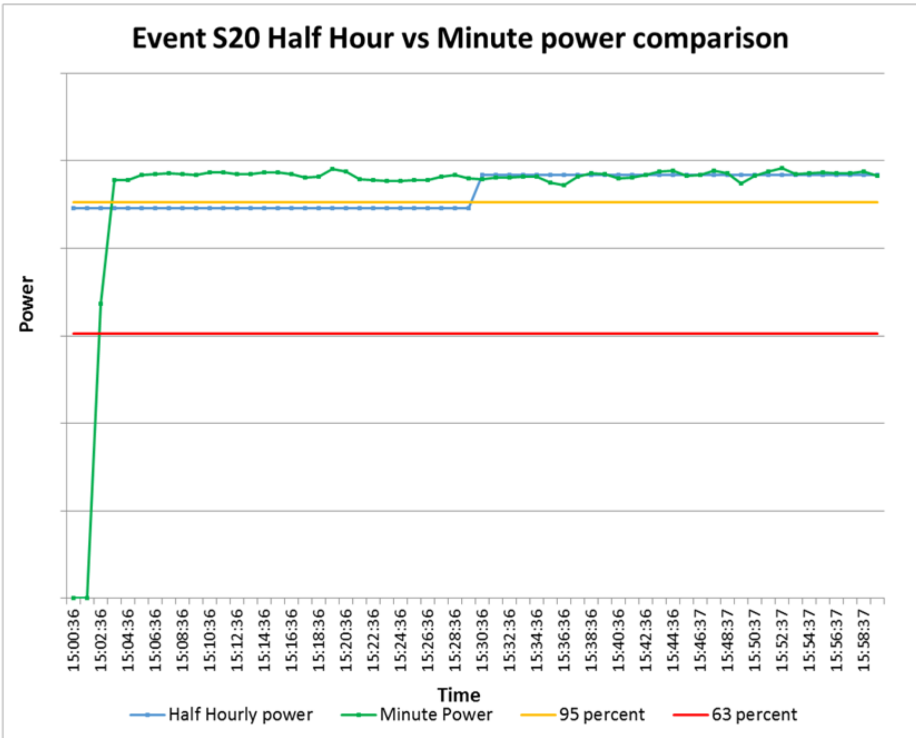


Figure 25 – Event S20 Power Comparison

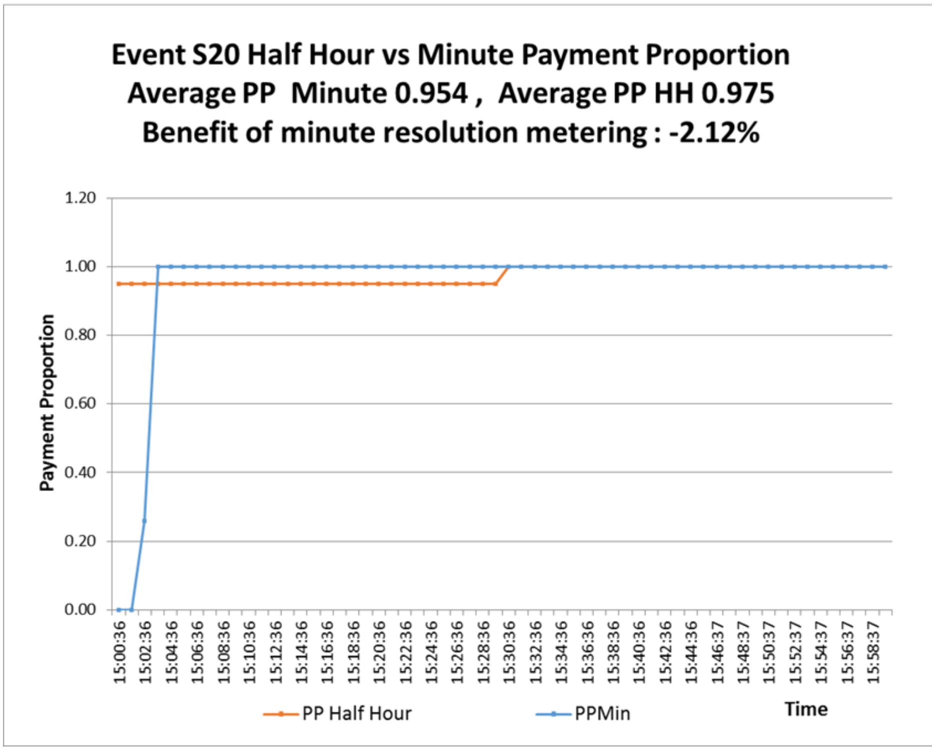


Figure 26 – Event S20 Payment Proportion Comparison

In Event 16, dips below the 95% threshold are distributed throughout the period rather than concentrated together. This helps to reduce the difference between the half hourly average and the average of the minute resolution data.

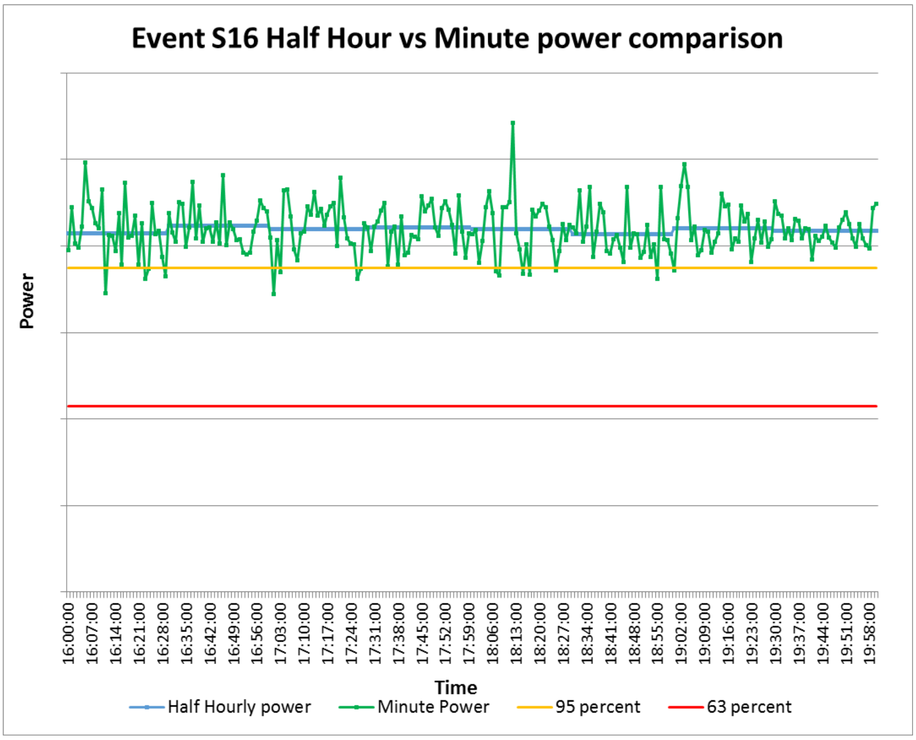


Figure 27 – Event S16 Power Comparison

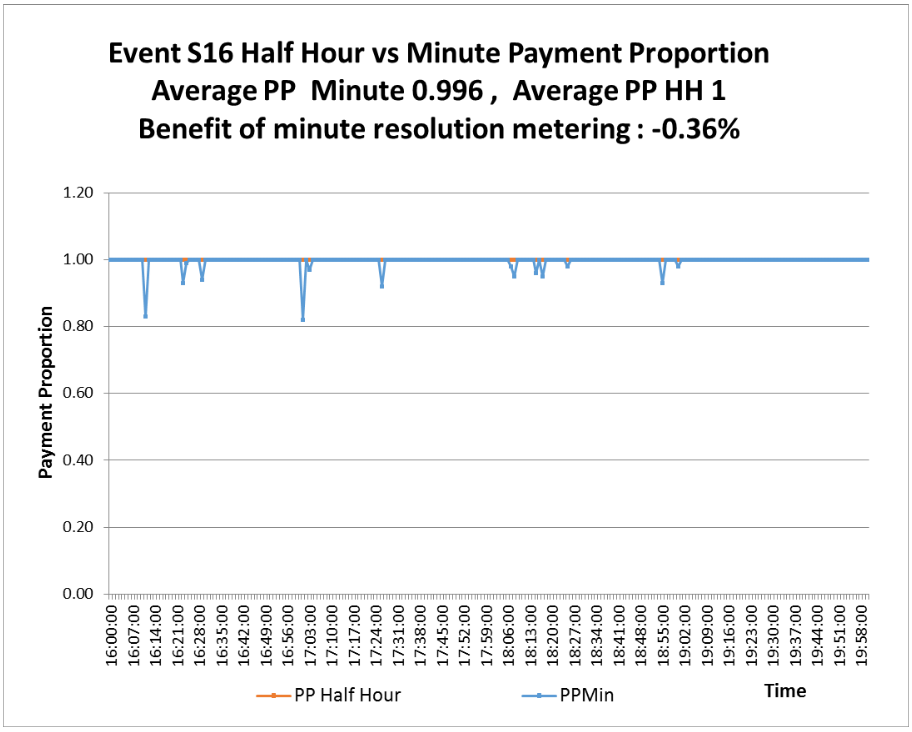


Figure 28 – Event S16 Payment Proportion Comparison

Event 22 shows the impact of the payment curve. The average delivery is on target resulting in a payment proportion under half hourly metering of 100%, However as there is no reward for over-delivery, the payment proportion under a minute resolution metering is lower.

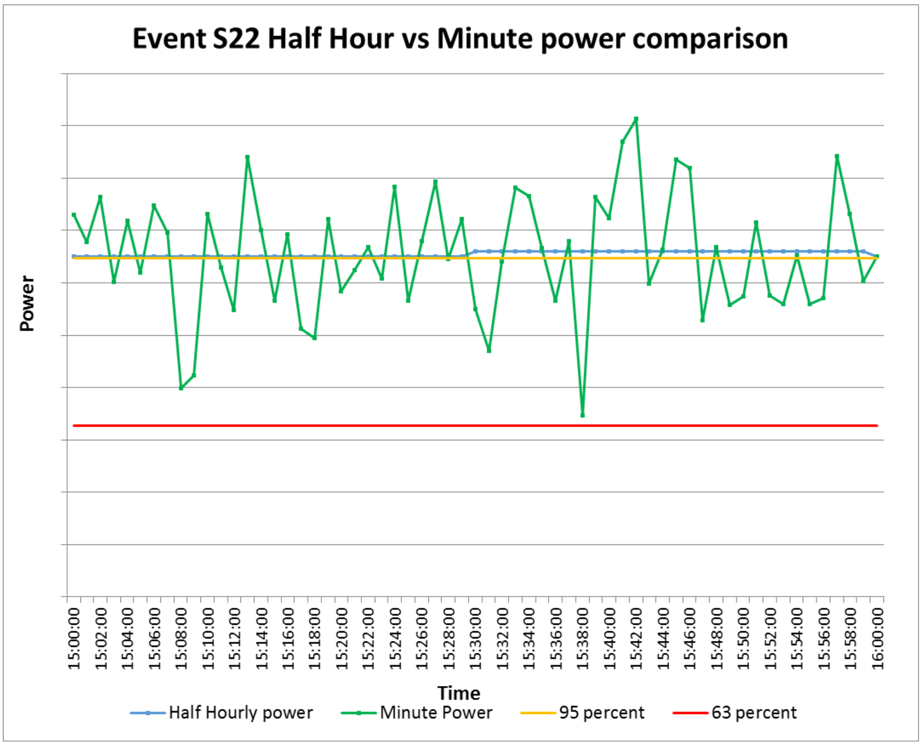


Figure 29 – Event S22 Power Comparison

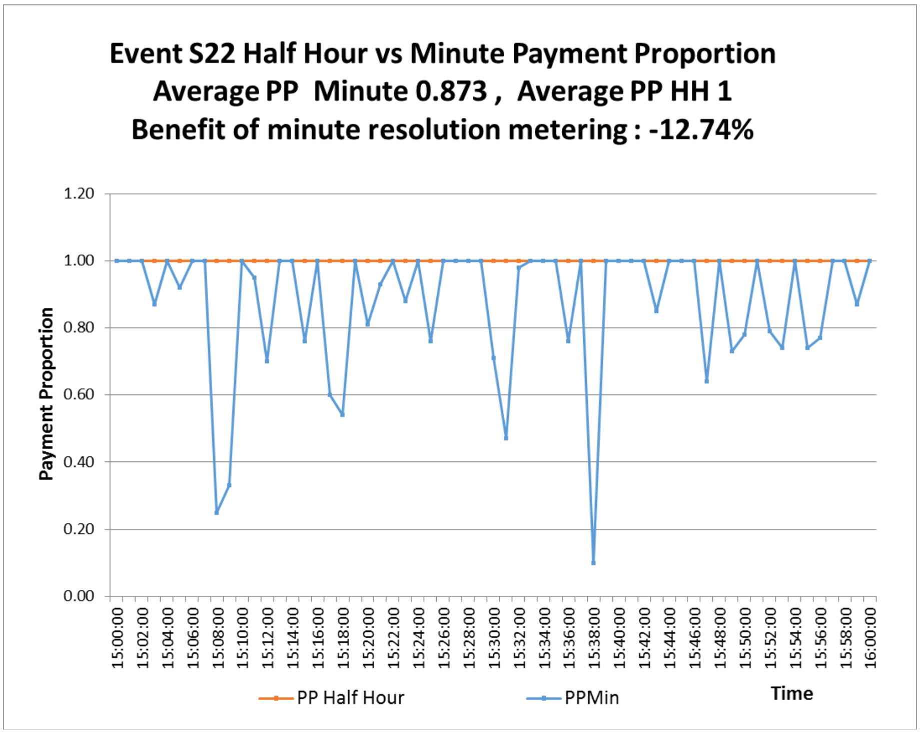


Figure 30 – Event S22 Payment Proportion Comparison

While all the previous examples showed a benefit from half hourly metering, Event 4 gives an example of where half hourly metering is not beneficial compared to minute by minute metering.

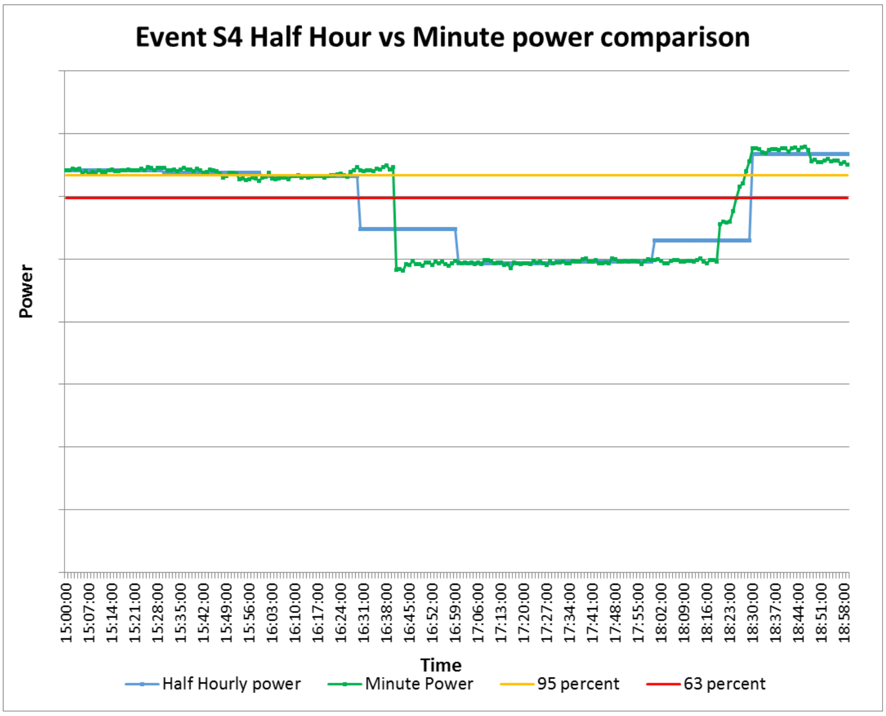


Figure 31 – Event S4 Power Comparison

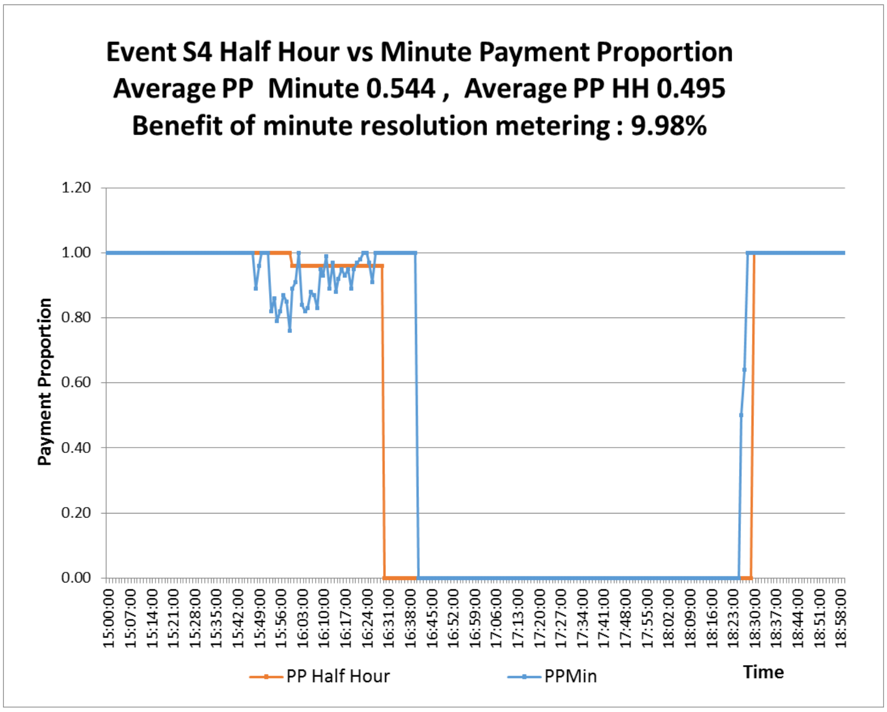


Figure 32 – Event S4 Payment Proportion Comparison

Event 24 also shows a significantly lower payment under half houlry metering. In this case the apparent lack of delivery for four minutes may reflect a loss of data as the rates at which the power ramps down and up again is suspicious.

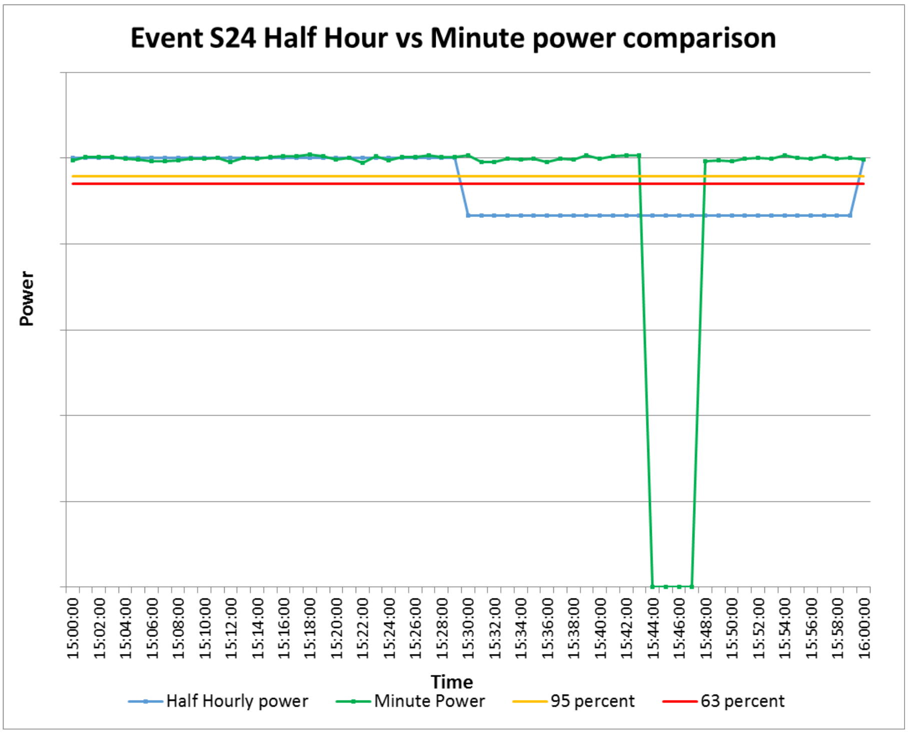


Figure 33 – Event S24 Power Comparison

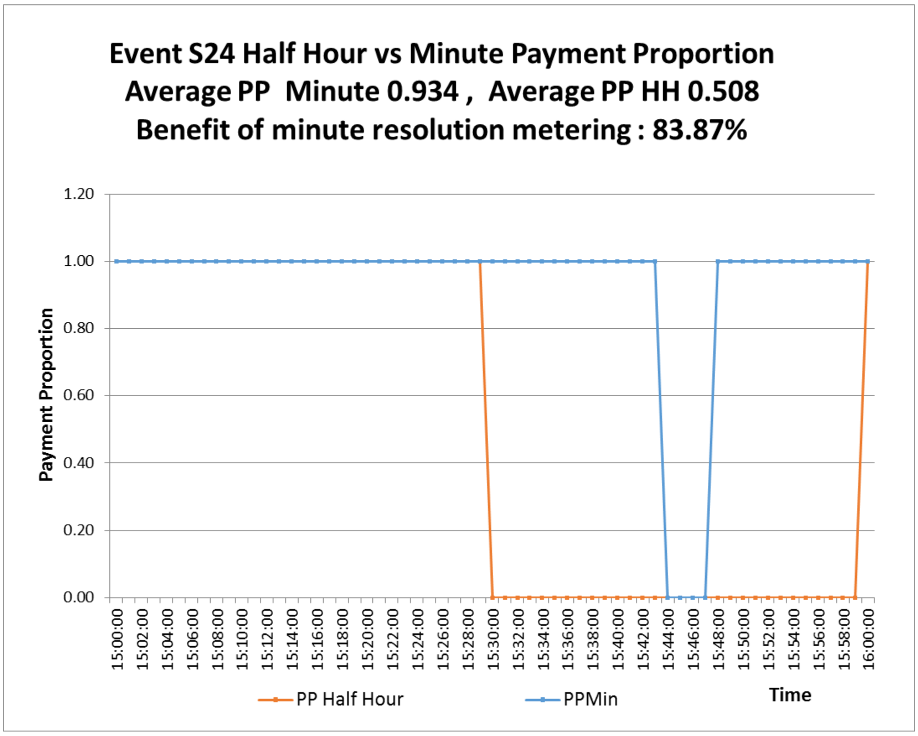


Figure 34 – Event S24 Payment Proportion Comparison

Event s38 also shows a benefit from using minute resolution metering but this does not appear to reflect data issues but rather slow ramp up. Given that slow ramp up can result in either better or worse results for customers that have half hourly metering, this would reduce the incentive to try to game the outcome.

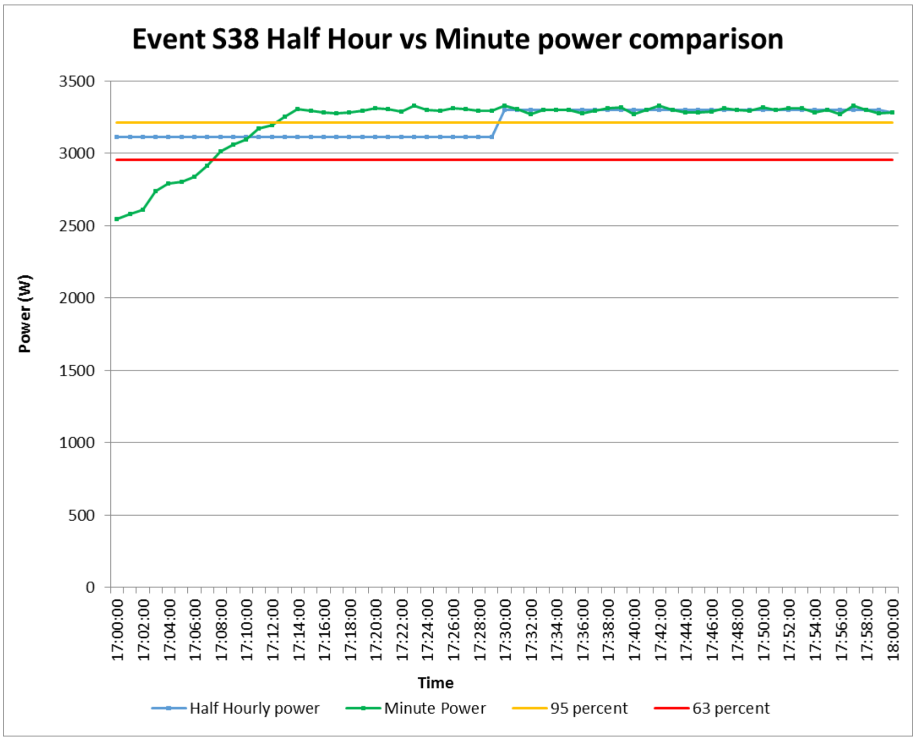


Figure 35 – Event S38 Power Comparison

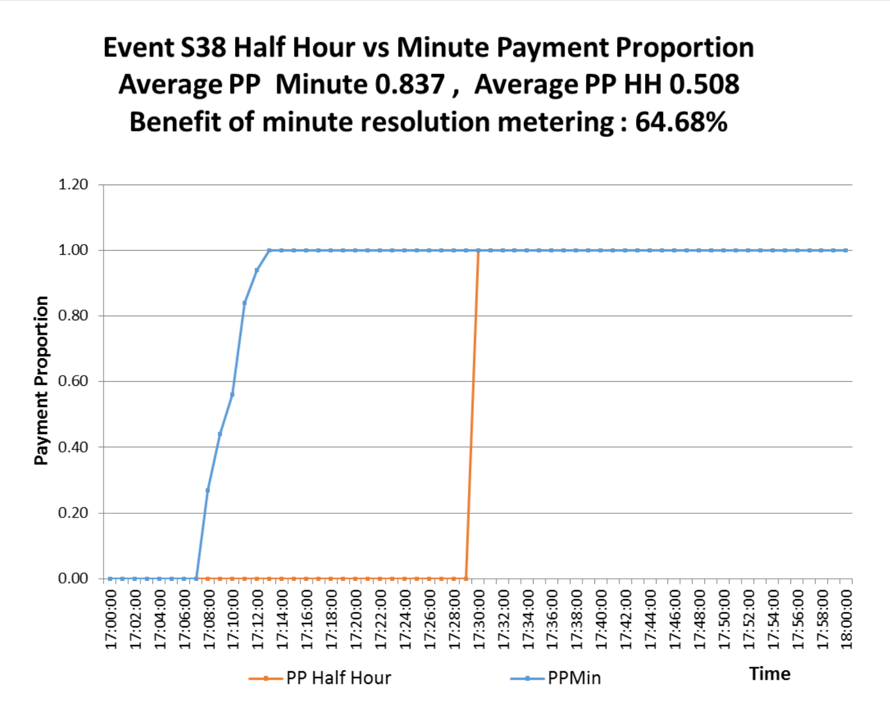


Figure 36 – Event S38 Payment Proportion Comparison

Finally, where results are consistently above or below the thresholds, as seen in event S6, there is no difference between the results for half hourly or minute resolution metering.

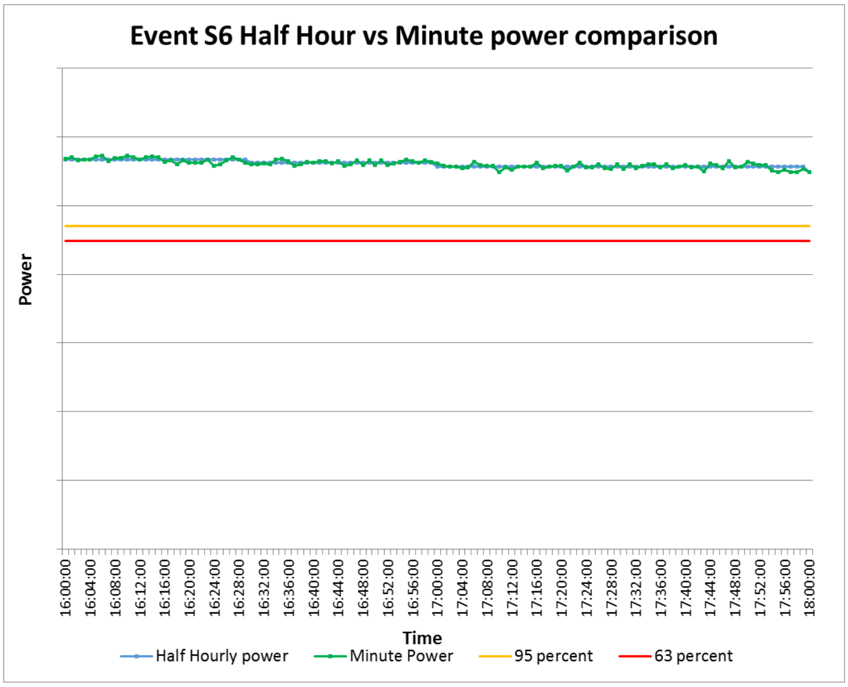


Figure 37 – Event S6 Power Comparison

While half-hourly metering can reduce the penalties from under-delivery it can also have the opposite effect. For the vast majority of the events examined there was no benefit or only a small value either way. Items with a significant difference in outcome were scarce and could be reduced further by removing the number of zeros reported by the monitoring, either by improving the monitoring and communications system or by applying data cleansing to interpolate where a zero value is surrounded by data considered to be more reliable.

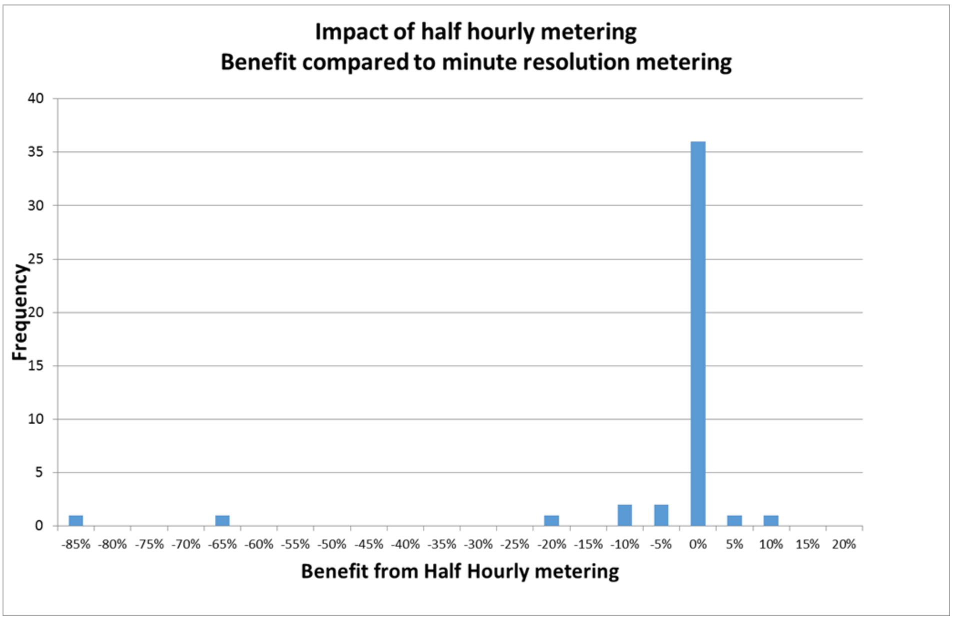


Figure 38 – Benefit frequency distribution