Project FUSION

Report on the implementation & analysis of USEF trials rev. 1

SP ENERGY NETWORKS

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Internal Use

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Executive Summary

INTRODUCTION

Project FUSION has prepared this document to report on the progress and the learnings the FUSION trial, as well as to communicate the project's next steps. Although the main focus of this report is phase 2 of the trial, learnings from phase 1 are also included where relevant.

This document should be read in conjunction with other FUSION publications and particularly the FUSION' Interim Trial Learnings Report #1, published in October 2021, FUSION' Interim Trial Learnings Report #2, published in May 2022 and FUSION' Interim Trial Learnings Report #3, published in December 2022; found in the FUSION Project page of the SP Energy Network's webpage[1].

OVERALL TRIAL LEARNINGS [2]

The FUSION trial has been operational since September 2021, and flexibility is being dispatched in both St. Andrews and the Leuchars areas. In Phase 1 and 2 of the trial, the network congestion events were simulated almost daily to allow the trials to respond to those events using flexibility.

Phase 2 of the FUSION trial started in April 2022 and saw the addition of three 11kV feeders as congestion points in the trial to add to the two primary substations. The following statistics provide a snapshot of progress in Phase 2 and across the full trial period (at the time of writing):

- 632 FlexRequests were issued by the DSO throughout the trial across all congestion points (211 in Phase 1 and 421 in Phase 2)
- During Phase 2, the DSO requested a larger range of flexible power compared with Phase 1, including FlexRequests of 1000 kW.
- 825 FlexOffers responded to these requests including 557 in Phase 2 and 268 in Phase 1,
- The average offer price was £0.66/kWh in Phase 2 compared with £0.46/kWh in Phase 1;
- 55.2 MWh of flexible energy was ordered and 45.5 MWh was delivered; and
- Total utilisation payments amounted to £28,625 including £21,616 in Phase 2.

The trial showed that:

- Aggregators were able to respond to FlexRequests with at least one offer in 94% of cases, which demonstrates the reliability of aggregators to offer flexibility when the DSO requests it.
- The reliability of the flexibility delivery in Phase 2 was 77%.
- In Phase 2, the aggregators continued, in general, to overdeliver on the volume of flexibility that is ordered despite changes to the FSA to reduce the penalties for underdelivery.
- On average, aggregators over delivered the ordered power. Aggregators advised that they were still conservatively approaching the delivery of flexibility by dispatching more assets than are needed to cover the FlexOrder power.

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1 https://www.spenergynetworks.co.uk/pages/fusion.aspx#tablist1-tab4
2 Please refer to Section 3 for further detail

- The aggregators acted more conservatively when dispatching a smaller number of assets at the 11kV feeders. This conservatism was to ensure that they achieve at least the ordered flexibility and was demonstrated most clearly at the 11kV "18612", which had the highest over-delivery of all congestion points
- The accuracy of the aggregators' baselines impacted the results for the reliability of delivery particularly for one of the aggregators at St Andrews. This was evidenced by large negative deliveries (i.e. increasing demand or reducing generation). The aggregator addressed this problem in October 2022 and the results have considerably improved since then.

TRIAL LEARNINGS PER OBJECTIVE [3]

Project FUSION partners agreed on a set of learning objectives for the FUSION trial. The following provides a status update on the progress to date against each objective:

Free Bids

USEF defines free bids as flex offers which aggregators send in response to a flex request from the SO, that are either outside of their contracted availability window or above their contracted power capacity. This trial objective aims to analyse aggregators' experiences with this mechanism; and whether the use of free bids would save costs for DSO and benefit the aggregator by allowing them to bring additional non-firm capacity to the market (e.g., residential).

- Free bidding is, according to the aggregators, a mechanism that could contribute to making more flexibility available and positively impact their business case by enabling additional revenue on non-firm capacity and value stacking in the future.
- Raising the free bids price cap in phase 2 had a positive effect in raising public interest (from aggregators' customers) on flexibility and was a good incentive to encourage participation.
- The current contractual arrangements and payment structures did not make free bids of primary importance for aggregators. While aggregators appreciate the mechanism as an extra revenue source, their focus was to fulfil their obligations on availability and get the payment through the availability contract.
- To participate in free bids, the aggregator needs to have short-term flexibility monitoring capabilities.
- The DSO saved 64% of the contracted capacity thanks to the extra capacity made available by the aggregator outside the availability contract (i.e., free bids).
- Even considering the potential savings, the DSO would only consider relying on free bids if there is sufficient market liquidity to make that approach statistically reliable, which is highly dependent on the location for congestion management services.
- Since October 2022, aggregators have not sent free bids. The results were updated to compare the performance of free-bids (sent before October 2022) and normal bids for which more data was extracted from the trials in 2023. The average offered power for free bids was greater than the power for normal bids at all congestion points.
- Ultimately, the trial has shown that the free bidding concept works but the current market and system is not mature enough yet to fully leverage this mechanism.

Refer to Section 4.1.1 of this report for full analysis of this objective.

3 Please refer to Section 4 for further detail

Baseline design

In this report, we have analysed the effectiveness of D-programmes in satisfying the baseline use cases through quantitative analysis and insights from FUSION trial participants and the DSO.

Regarding the use of D-programmes as aggregator baselines:

- In Phase 2, aggregators capitalised on the opportunity that nomination baselines offer to trial different baseline methodologies to improve the accuracy of their forecasting.
- The accuracy shown by the D-programmes varied per portfolio type. The accuracy of one of the aggregators improved from Phase 1 into Phase 2 while the other aggregator experienced challenges moving into Phase 2. The overall accuracy of the D-programmes was still poor when compared to what the literature defines as "good" or "acceptable" baseline methodologies. It is worth noting that the portfolios were relatively small, which created more difficulties in forecasting than bigger portfolios.
- The accuracy and bias of the baselines in the trial were compared with the ENA's online historical baseline tool. The comparison showed that ENA's tool was more accurate and had less bias. Nevertheless, the historical baseline is still also not able to achieve a baseline accuracy that is considered "acceptable" at all congestion points except one. All parties involved recognise the need to monitor the baseline as a key first step to identify potential improvements.

It is worth mentioning that as part of this objective, Project FUSION representatives held a workshop with representatives from the TRANSITON project. The workshop was held on the 31st of January 2023 to share experiences of baselining. The workshop included an overview of each trial and a summary of the main learnings related to how baselines are produced and used in local flexibility markets.

Following the workshop, a webinar will be held on 25th April 2023 with relevant stakeholders in order to discuss workshop's findings and recommendations on baselining.

In addition, a combined FUSION – TRANSITION short report will be published to reflect and address feedback which will be acquired during April's webinar.

Refer to Section 4.1.2 of this report for full analysis of this objective.

Market Co-ordination Mechanism (MCM)

The USEF MCM facilitates flexibility trading and consists of five phases – contract, plan, validate, operate and settle. During the trial, the contract phase was populated at the procurement stage whereas the phases from 'plan' to 'operate' were conducted day-ahead and intraday. This report analyses aggregators' experience using the MCM features, the impact of the MCM on reliability and efficiency linked to the DSO forecast accuracy.

Aggregators consider the MCM useful, clear and well structured, as they benefit from the whole process being defined in a single system, avoiding the need to use several systems across different phases. Improvements were suggested by trial participants regarding the contract timing (week-ahead availability contracts) and bid selection (inclusion of carbon emission information).

The MCM had a positive impact on reliability - between 1-28% increase - compared to other DSO flexibility trials. It also had a positive impact on efficiency linked to DSO forecast accuracy. With its shorter procurement and dispatch timeframes, USEF allowed a 1-3% reduction in need of DSO flexibility to account for forecast inaccuracy.

Project FUSION has calculated a theoretical rebound impact that a future representative portfolio would have in East Fife congestion points. The results indicate that ~20% more flexibility needs to be activated to counteract the negative impact of rebound. For future research, project FUSION recommends making an empirical analysis on rebound effect.

Refer to Section 4.1.3 of this report for full analysis of this objective.

DSO procurement mechanism cost drivers

The trial results suggest that the different cost drivers considered would have a significant impact on the volume of flexibility required by the DSO to ensure that the required flexibility is delivered. In particular, the baseline accuracy had a large impact on the volume of flexibility, for both FUSION and BaU.

An even split in the risk of reliability of delivery (and baselining implications) between the DSO and aggregators was assumed, however, it is important to have a better understanding on how to split the risks between DSO and aggregator and understand how different measures would impact each stakeholder. For example, if a certain level of baseline accuracy is required, some flexible technologies might be excluded, leaving more expensive technologies incurring a higher cost for the DSO.

The final stage of the project will explore how the risk distribution affects 1. the cost of flexibility, 2. the entry of flexibility into the market and 3. the DSO decision process. It will also explore if the reliability and baseline quality should be included in the tendering process and the effect of including of other baseline methodologies to the DSO.

The comparison between the trial results and a hypothetical business-as-usual case has indicated that the FUSION trial required less additional flexibility at four of the seven congestion points. This shows that the USEF framework can reduce uncertainty in the drivers that affect flexibility procurement costs and therefore reduce DSO costs compared with BaU flexibility markets.

Refer to Section 4.1.4 of this report for full analysis of this objective.

USEF Flexibility Trading Protocol (UFTP)

In the FUSION trial the interaction between SP Energy Networks (DSO) and the aggregators was formalised through the USEF Flexibility Trading Protocol (UFTP). The scope of this learning objective is to analyse the experience of aggregators and DSO while using the protocol; to identify potential improvements; and to capture the contributions from Project FUSION to the protocol.

Aggregators and SP Energy Networks found the experience with the UFTP smooth and positive. Aggregators perceive that the complexity of the protocol is on par with other protocols that cover similar processes.

The FUSION Project is continuously interacting with SHAPESHIFTER TSC to discuss potential improvements to the UFTP protocol. Previous change requests described in ITLR#2[4] and feedback given by Project FUSION was implemented in version 3 of the protocol. The change request regarding the congestion point hierarchy was submitted, approved, and implemented in the UFTP specification 3.0.1.

Refer to Section 4.1.5 of this report for full analysis of this objective.

Business case of USEF-based flexibility market

The scope of this objective is to demonstrate the proof of concept, and evidence the business case, of commoditised flexibility (locally and for GB) through a USEF-based flexibility market covering the following aspects:

- Are there changes to USEF required for adoption by the GB energy market?
- Demonstrate the commoditization of all technologies and that USEF creates a level playing field
- Are the network needs / service needs covered by the level of procured flexibility?

The learnings from the previous studies conducted under Project FUSION as well as the FUSION trial suggest that:

- The FUSION trial has proven that USEF framework is largely applicable to the GB DSO flexibility services. Project FUSION has collaborated in making modifications to increase the compatibility and has identified two different areas that could be considered in the future to improve the fit of USEF with the DSO standardised products.

- The FUSION trial has proven that USEF created a level playing field for the participating aggregators and technologies, which included a high participation of residential assets.

Next steps for this objective is to answer the final sub-objective: Are the network needs / service needs covered by the level of procured flexibility? The answer to this will be the result of integrating the learnings of ICL's report on the Role and value of FUSION concept in supporting cost effective electricity system decarbonisation with further analysis on the final trial data.

Refer to **Section 4.1.6** of this report for full analysis of this objective.

DSO potential and Efficient DNO Network Management

The scope of this learning is to explore 1. the potential for localised demand-side flexibility (DSF) utilisation to accelerate new demand connections to the network that otherwise would require traditional reinforcement and 2. the potential use and value of flexibility within geographically local regions to further enhance efficient DNO network management.

Regarding the assessment on the potential for localised DSF to accelerate connections, the analysis suggests that:

- Flexibility services can be used to sufficiently control demand on the network and mitigate constraints.
- The level of confidence in delivery of flexibility from demand groups *is suitable* to satisfy DNO/ network risk management requirements.
- Flexibility service contracts *do hold suitable assurance* on the provision of flexibility over the long term where network reinforcement would otherwise be required.
- The levels of flexibility available *are sufficient* to enable new connections without reinforcement.

Regarding the assessment on the potential use and value of flexibility for efficient network management, the analysis concludes that:

- Local flexibility can deliver the range of flexibility services which are available to regional (and national) markets.
- Local flexibility *can* provide suitable flexibility to all parts of the network (i.e., secondary primary, BSP (England), GSP and Transmission System.
- The delivery of flexibility services at two local boundaries can provide an additive or complimentary flexibility support to the common network (i.e., two substations).
- The value of flexibility will be wider in a low carbon world since there will be a wider role for flexibility beyond the existing roles of DSO constraint management services, ESO system management services and wholesale trading. This role will include the support to self-managing communities on smart energy use, the trading of flexibility in peer-to-peer services, among others.

Refer to **Section 4.1.7** of this report for a complete summary of this objective.

The full analysis of this objective can be found in the report 'FUSION ITLR4 – Report on Origami Actions'

Common Reference Operator

The Common Reference Operator (CRO) is responsible for operating the common reference (CR), the repository that contains detailed information on network congestion points, associated connections, and active aggregators in those connection points. The CR enhances transparency by allowing aggregators to get the information on the congestion points where they are active (and only those for confidentiality and privacy reasons). It also allows DSOs to get visibility on the aggregators operational at their congestion points.

The experience of both SP Energy Networks, fulfilling the Common Reference Operator role, as of the aggregators as users has been positive, as it facilitates access to the information. Aggregators highly appreciate the security of the platform and encryption. In addition, maintaining the CR at DSO level was considered beneficial, further coordinating with ESO requests potentially unlocking value stacking opportunities.

Refer to Section 4.2.1 of this report for full analysis of this objective.

DSO Data Transparency

The FUSION project explored the data transparency of the processes and the experience of the trial participants. It was confirmed that aggregators and the DSO did not have notable issues accessing or sharing data in the FUSION trial.

Furthermore, the FUSION trial participants did not face data privacy concerns. Nonetheless, if the CRO role were to be transferred from SP Energy Networks to a separate entity, a thorough due diligence process would have to take place to ensure the data is stored, handled and processed appropriately.

From the two competitive processes with which aggregators can offer flexibility to the DSO, aggregators found availability contracts transparent, however, had questions regarding the selection of utilisation bids for certain lesser common cases that will be clarified for the next phase of the project.

Refer to Section 4.2.2 of this report for full analysis of this objective.

Commercial Mechanisms

One of the aims of Project FUSION is to explore the commercial mechanisms that USEF offers to encourage consumer participation. The key conclusions of related to this objective to date based on reflections on the trial and feedback from participating aggregators are the following.

- One aggregator experienced challenges in bringing on additional flexible assets in Phase 2 of the trial to meet their contracted availability volume. They noted that the technical challenges associated with enabling new assets and dealing with businesses with multiple subcontractors increased the lead time of new connections.
- It was also noted that the requirement to state the available capacity six month ahead of delivery created more challenges in bringing on new customers due to uncertainty in revenue, penalties, sub-optimised flexibility use. Short term markets allow aggregators to be more certain about the availability of flexibility and makes it easier to onboard new assets that are considered non-firm capacity into the market, which in turn would enable more efficient use of flexibility and more revenue to their customers. (Note that this section does not refer to contract duration between aggregator and customer but rather between DSO and aggregator).
- Aggregators recommended that the balance between utilisation and availability incentives could be improved by rewarding delivery over availability.
- Notification time between FlexOrder and delivery is important to customers. Ordering day ahead provides customer with more visibility of when their assets will be utilised and is therefore more appealing to them.
- While it is recognised that USEF's free bids mechanism provides more opportunities for revenue through enabling additional income outside of long-term contracts, FUSION's free bid system is not mature enough yet to fully leverage this mechanism. Therefore its ability to attract new customers is not clear at this stage but will continue studied as the trial develops.

Refer to Section 4.2.3 of this report for full analysis of this objective.

D-programmes

USEF designed D-programmes for two purposes – 1) serving as baseline to quantify flexibility delivery and 2) providing visibility to the DSO for their own forecast as well as having the visibility on the flexibility amount that they could request from aggregators. This objective aimed to analyse the effectiveness of D-programmes in improving the DSO forecast through quantitative analysis and insights from FUSION trial participants and the DSO.

- FUSION has identified a way in which the DSO could conceivably integrate D-programmes into substation load forecasting to improve accuracy. To test this, however, the aggregator would need to communicate real time sub-meter data, which could be costly.
- The current DSO substation forecast is very accurate (estimated 2-3% of error) and therefore further reducing the error would have a small impact on the flexibility activations day-ahead. However, the D-programmes and other type of information (such as asset type, capacity, etc) could add significant benefit by improving the accuracy of lower-voltage forecasts, especially those below 11 kV, which are outside of the scope of the FUSION trial.
- Given the low accuracy that were observed in D-programmes, the project decided to investigate further the impact of flex trading timing in the accuracy of the DSO forecast. This is further explained and analysed under the Market Coordination Mechanism objective.

Refer to Section 4.2.4 of this report for full analysis of this objective.

Sub-metering arrangements

This objective aimed to compare and contrast the use of MPAN data versus the use of sub-meter data for service delivery validation and settlement purposes. Due to lack of access to MPAN data during the trial, this assessment focussed on qualitative insights from the aggregators.

In the FUSION trial, flexibility validation was performed exclusively using sub-meter data for all congestion points and participating aggregators. Some of the assets, such as CHPs and EVs, had an integrated sub-meter. Whereas for other residential assets the sub-meter was installed by the aggregators. Based on aggregators' experience with sub-metering arrangements, both aggregators suggest that they prefer the use of sub-metering versus connection point meters in flexibility services:

- Sub-metering offers better resolution and visibility of asset behaviour
- Sub-metering allows for more informed control of assets
- Forecasting at asset sub-meter level is more straightforward because aggregators do not have visibility of the rest of assets behind the main meter.
- Access to MPAN data for residential connections is not available to non-supplier aggregators.

Refer to Section 4.2.5 of this report for full analysis of this objective.

Additional learning – Demand turn-up

During phase 2 trial, SP Energy Networks explored the possibility of engaging with another aggregator to trial a demand turn-up service. Although USEF supports this concept, the FFP was not designed to place orders for demand turn-up, nonetheless, the test was conducted to prove that it could be used to do so. This trial demonstrated that, whilst the FFP and the AGR-stub were not designed for this purpose and do not offer the same quality of user experience in this configuration, they can be configured to trade demand turn-up services.

This is positive news because it means that:

1. Not only can the AGR-stub provide a means for aggregators to participate in a USEF flex market (like FUSION) without having to implement any IT development of their own, but also;
2. They can use this configuration to trade both demand turn-down and demand turn-up.

Refer to Section 4.2.6 of this report for full analysis of this objective.

NEXT STEPS

The next steps for project FUSION are summarised below:

- Following the workshop with project TRANSITION in January 2023, a webinar will be held towards the end of April 2023 with relevant stakeholders in order to discuss workshop's findings and recommendations on baselining.
- A combined FUSION – TRANSITION short report will be published to reflect and address feedback which will be acquired during April's webinar.
- Project FUSION will publish a closedown report on or before November 2^{nd} 2023 as per the requirements of the NIC Governance document.

1. Introduction

1.1. OVERVIEW OF PROJECT FUSION

Project FUSION is funded under Ofgem's 2017 Network Innovation Competition (NIC), to be delivered by SP Energy Networks in partnership with the following project partners: DNV (formerly: DNV GL), Origami Energy recently acquired by Baringa, Imperial College London (academic partner), SAC Consulting, The University of St. Andrews, and Fife Council.

Project FUSION represents a key element of SP Energy Network's transition to becoming a Distribution System Operator, taking a step towards a clean, smart and efficient energy system. As the electricity system changes from a centralised to decentralised model, it enables the functioning of a smarter and more flexible network. Project FUSION is trialling the use of commoditised local demand-side flexibility through a structured and competitive market, based on a universal, standardised market-based framework; the Universal Smart Energy Framework (USEF). USEF provides a standardised framework that defines products, market roles, processes and agreements, as well as specifying data exchange, interfaces and control features. The purpose of USEF is to accelerate the transition to a smart, flexible energy system to maximise benefits for current and future customers.

FUSION will also inform wider policy developments around flexibility markets and the DNO-DSO transition through the development and testing of standardised industry specifications, processes, and requirements for transparent information exchange between market participants accessing market-based flexibility services. Ultimately, FUSION will contribute to Distribution Network Operators and all market actors unlocking potential and value of local network flexibility in a competitive and transparent manner. In doing so, FUSION aims to contribute to addressing the energy trilemma by making the energy system more secure, affordable and sustainable.

1.2. USEF OVERVIEW

The USEF framework aims to facilitate effective coordination across all the different actors involved in the electricity market by providing a common standardised role models and market design while describing communication requirements and interactions between market roles. USEF turns flexible energy use into a tradeable commodity available for all energy market participants, separated from (but in coordination with) the traditional electricity supply chain, to optimise the use of resources. USEF focuses on explicit demand-side flexibility, in which prosumers are contracted by the aggregator to provide specific flexibility services using Active Demand and Supply (ADS) assets. USEF acknowledges but does not provide detailed considerations for implicit demand-side flexibility or peer-to-peer energy trading.

To facilitate the transition towards a cost-effective and scalable model, the framework provides the essential tools and mechanisms which redefine existing energy market roles, add new roles and specify interactions and communications between them. In addition, the USEF standard ensures that all technologies and projects will be compatible and connectable to the energy system, facilitating project interconnection, hence fostering innovation and accelerating the smart energy transition. By delivering a common standard to build on, USEF connects people, technologies, projects and energy markets in a cost-effective manner. Its market-based mechanism defines the rules required to optimise the whole system, ensuring that energy is produced, delivered and managed at lowest cost for the whole system and effectively for the end-user. The USEF framework provides:

- a standardised common framework designed to be implemented on top of current energy markets such as wholesale, retail and capacity markets.

- A description of the flexibility value chain (FVC) involving new and existing market players and giving a central role to the aggregator in facilitating flexibility transactions.
- A roles model and interaction model to enable the implementation of different business models and interactions between actors
- A market design described by the Market Coordination Mechanism (MCM) which sets out the phases and interaction requirements for flexibility transactions. The MCM provides all stakeholders with equal access to a smart energy system. To this end, it facilitates the delivery of value propositions (i.e. marketable services) to various market parties without imposing limitations on the diversity and customisation of those propositions.
- Detailed communication and markets access requirements taking into considerations privacy and cybersecurity issues.

The USEF framework was initially developed by the USEF Foundation. In 2014, the USEF Foundation was inaugurated to accelerate the establishment of an integrated smart energy market which benefited all stakeholders, from energy companies to consumers. USEF was an early mover, a combined force of parties and professionals with a shared goal. Together they explored new territories to help unlock and structure the future market and, as a result, many elements of USEF can now be found in standardisation and harmonisation policies at both national and European level.

In 2021, 7 years later, the work of the USEF Foundation was therefore considered complete and USEF Foundation had ceased to exist by 1 July. To safeguard the legacy of the USEF foundation, the USEF framework, including the UFTP protocol (recently rebranded to Shapeshifter) is being maintained by the GOPACS organisation. The SHAPESHIFTER protocol has also been adopted by the Linux Energy Foundation, offering a platform for the maintenance and support of the protocol.

1.3. BACKGROUND TO THIS DOCUMENT

Project FUSION commenced in September 2018. Since then, a number of milestones and activities have been completed, including the flexibility market evaluation, the USEF implementation plan and USEF process implementation, whilst stakeholder engagement and coordination with ENA Open Networks are ongoing over the lifespan of the project. All these activities have culminated in the commencement, in September 2021, of the live FUSION trials, which marked the first deployment in GB of a USEF-compliant flexibility market. This document represents the final instalment of a series of Learnings Reports which have been published bi-annually since October 2021.

1.4. PURPOSE OF THIS DOCUMENT

Project FUSION has prepared this document to report upon the implementation and analysis of the FUSION trial which commenced in September 2021 and concluded March 2023, as well as to outline the planned next steps for the project. This document represents the completion of Delivery milestone 5 in Ofgem's project direction letter in 2018.

The focus of this document is the analysis and learnings of USEF trials, therefore the document is of a factual nature and includes statistics and a detailed analysis for each trial learning objective. This is a separate document from the closedown report that project FUSION will deliver at the end of the project as per the requirements of the NIC Governance document. The closedown report will include a distillation, a higher-level interpretation and a wider stakeholder view of the analysis presented in this report and the various reports that the project has produced throughout its duration.

This document provides an overview of:

1. The background of the trial design and its operation to date, including an overview of flexibility providers and flexibility assets that have been participating in the trial, the detailed service requirements and the trial cases that have been simulated.
2. The analysis of the trial operation, key statistics on delivered flexibility, prices, flexibility offers and orders;
3. Assessment of delivery against agreed objectives for the FUSION trial;
4. Learnings from stakeholders and participants in the FUSION trial;
5. FUSION's progress with stakeholder engagement and
6. Next steps, which are planned to commence in April 2023.

2. Trial implementation & operation – Phase 2

FUSION's phase 2 trial started in April 2022. In comparison to phase 1, the design of the second phase of the FUSION trial was adapted to test the effectiveness of real time forecasts from the DSO, instead of the simulated forecasts that were used in phase 1. For more information on phase 1 learnings please refer to FUSION's Interim Trial Learnings Report #2 (ITLR#2) which was published in May 2022.[4]

This section describes the main characteristics of the trial design and operation. Section 2.1 describes the roles and the parties responsible for those roles in the FUSION trial. Then, Section 2.2 describes the flexibility characteristics, namely the services that were provided, their location, the detailed service requirements as set in the Fusion Service Requirement documentation (FSR), and the description of the flexible assets. Finally, Section 2.3 describes the three flexibility use cases, and the relevant test cases for each, adapted to incorporate the real time element of the phase 2 trials.

2.1. TRIAL ROLES AND RESPONSIBILITIES

FUSION partners agreed on the FUSION USEF Implementation Plan, covering the flexibility services and the USEF roles that the trial seeks to test. Table 1 sets out the roles included in the trial and the market parties responsible for performing them.

Table 1 USEF roles in the FUSION trial

USEF Role	Inclusion in FUSION trial	Performed by	Comments
Distribution System Operator (DSO)	Yes	SP ENERGY NETWORKS	
Electricity System Operator (ESO)	No	n/a	
Prosumer	Yes	DERs owners contracted by participating aggregators	
Active Demand Supply (ADS)	Yes	DERs managed by participating aggregators	

4 https://www.spenergynetworks.co.uk/pages/fusion.aspx#tablist1-tab4

Aggregator	Yes	Flexibility providers: Engie and Orange Power	Selected Through industry engagement and tendering process
Supplier	No	n/a	
Capacity Service Provider (CSP)	No	n/a	The aggregator can also be active in the capacity market, but the trial did not test the interactions with this role
Constraint Management Service Provider (CMSP)	Yes	Flexibility providers: Engie and Orange Power	Through industry engagement and tendering process
Balancing Services Provider (BSP)	No	n/a	The aggregator can also be active in balancing products, but trial did not test interactions with this role yet
Balance Responsible Party (BRP)	No	n/a	The aggregator can also be active in wholesale trading, but the trial did not test interactions with this role
Common Reference Operators (CRO)	Yes	SP ENERGY NETWORKS	
Meter Data Company (MDC)	Yes	SP ENERGY NETWORKS	SP ENERGY NETWORKS took this role by default
Allocation Responsible Party (ARP)	No	n/a	Wholesale settlement is out of scope

2.2. FLEXIBILITY CHARACTERISTICS

This section provides a high-level description of the available DSO flexibility services, their locations and requirements for each of the DSO congestion management zones.

2.2.1 DSO Flexibility Services

Three DSO Services were procured in the two selected primary substation and three feeder locations for trial phase 2:

- Sustain Peak Management: A service to provide the DSO with a planned reduction in demand or increase in generation in advance of a forecast capacity constraint at peak time, e.g. reducing the loading on a transformer during tea-time peak.

- Secure DSO Constraint Management (pre-fault): A service to provide the DSO with an immediate reduction in demand or increase in generation during a planned outage of one or more critical assets on in the event of network disturbances to maintain security standards and avoid any customer minutes lost.
- Dynamic DSO Constraint Management (post-fault): A service to provide the DSO with an immediate reduction in demand or increase in generation following an unplanned outage of one or more critical assets to maintain security standards and avoid any customer minutes lost.

2.2.2 Location of Flexibility

The project trial area of East Fife is defined as the network area supplied by the primary substations at St Andrews and Leuchars. This area was selected because both recent load growth and the integration of distributed generation can lead to localised network constraints which FUSION could alleviate.

In phase 1 of the FUSION trial, all flexible units including distributed energy resources (DERs) and flexible assets, had to be located within the area that is normally supplied by Leuchars primary substation and St. Andrews primary substation. In phase 2, DER and flexible assets participating in the trial could also be in areas normally supplied by St. Andrews 11 KV Feeders 18612, 18614 and 18616. A map showing the FUSION trial location can be found in Figure 1Figure 1.

More information on the postcodes served by the St. Andrews and Leuchars can be found in the FUSION Flexibility Services Requisition (FSR) for each location. [5] [6] [7] [8] [9]

[5] FSR Leuchars: FUSION_Flexibility_Services_Requisition_Leuchars_SP ENERGY NETWORKS.pdf (SP Energy Networksergynetworks.co.uk)
[6] FSR St. Andrews: FUSION_Flexibility_Services_Requisition_St_Andrews_SP ENERGY NETWORKS.pdf (SP Energy Networksergynetworks.co.uk)
[7] *FSR St. Andrews 11 KV Feeder 18612: FUSION Service Request (FSR) - St-Andrews 11 kV_SP ENERGY NETWORKS.pdf*
[8] *FSR St. Andrews 11 KV Feeder 18614: FUSION Service Request (FSR) – St-Andrews 11 kV_SP ENERGY NETWORKS.pdf*
[9] *FSR St. Andrews 11 KV Feeder 18616: FUSION Service Request (FSR) – St-Andrews 11 kV_SP ENERGY NETWORKS.pdf*

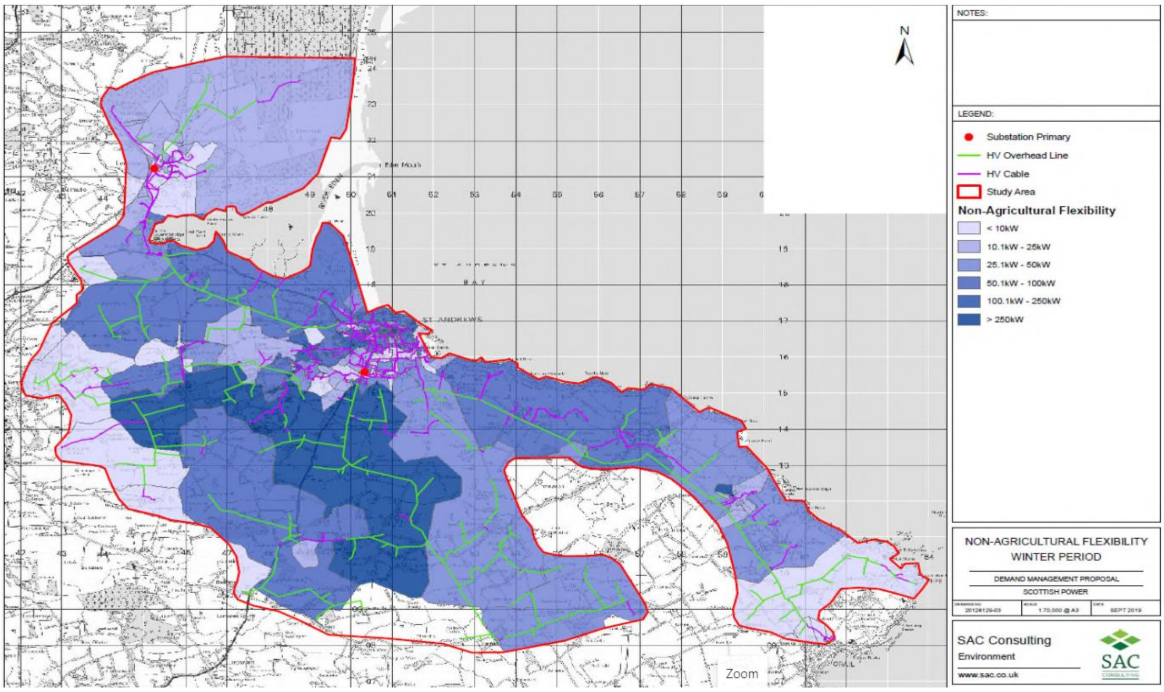


Figure 1 FUSION project trial location.

2.2.3 Detailed service requirements

There were two events for which the trial anticipated having to provide standby capacity:

- To de-risk the N-1 event from planned maintenance scheduled at the St Andrews Primary.
- To accommodate the peak loads on the Primary Substation associated with the St. Andrews open

Nonetheless, as there was no urgent or imminent need for flexibility in the study area during the phase 2 trial period, the Fusion Service Request (FSR) was not designed to meet any specific network needs, but rather was designed to maximise the value and learnings from the trial through realising high numbers of dispatches in response to a variety of simulated use-cases.

The key factors when determining the quantity of the flexibility availability to be procured through the FSR tender were the following:

- Minimizing the possibility of erroneously creating undesired risk to the network from flexibility dispatches from the trial (keep then below 500kW)
- Maximizing the amount of data that can be generated to ensure that it is of sufficient volume to allow for statistically robust analysis.
    - Maximize number of dispatches
    - Maximize variety of CP voltages
    - Maximize diversity of flexibility services tested
- Provide maximum impact and bandwidth for trial delivery
    - Ensure availability is within office hours
    - Secure availability throughout trail period

The flexibility requirements for each location have been published in the Fusion Service Request (FSR) documents and are summarised in the tables below for the two primaries and three feeders.

Table 2 FUSION Flexibility requirements in St. Andrews

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-250	250	Apr22-Sept22	Mon – Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-250	250	Oct22-Mar23	Mon – Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-250	250	Apr22-Sept22	Mon – Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-250	250	Oct22-Mar23	Mon – Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-250	250	Apr22-Mar23	Mon – Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 3 FUSION Flexibility requirements in Leuchars

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)

1	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-250	250	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-250	250	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-250	250	Apr22 – Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 4 Flexibility requirements in St. Andrews 11kV Feeder 18612

		Response Type*						
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-150	150	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak	60

							Management	
3	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-150	150	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-150	150	Apr22-Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 5 Flexibility requirements in St. Andrews 11kV Feeder 18614

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-500	500	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management	60

							(Pre-fault)	
4	2022/23	-500	500	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-250	250	Apr22 – Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 6 Flexibility requirements in St. Andrews 11kV Feeder 18616

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-150	150	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-150	150	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management	60

							(Pre-fault)	
5	2022/23	-100	100	Apr22-Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Project FUSION has developed additional service requirements which have been specified within the Flexibility Service Agreements (FSAs) between the aggregators and SP Energy Networks.[10] These additional service requirements are described below:

1. Maximum Response Time: This parameter depends on the service. Sustain Peak Management, Secure DSO Constraint Management (pre-fault) and Dynamic DSO Constraint Management (post-fault) have a maximum response time of 17 hours, 30 minutes and 15 minutes respectively.
2. Minimum Sustain Time: 60 minutes
3. Metering requirements: Minute-by-minute metering is required to monitor the provision of the flexibility services aggregated in 30-minute intervals for data sharing purposes.
4. Metering point: The metering point can be at asset level (i.e. sub-metering) or at boundary level (i.e. the main meter between the Site on which the Distributed Energy Resource (DER) is located and the SP Energy Networks network).
5. Baseline for measuring delivery: A nomination baseline is used for the settlement of the delivered flexibility. As per USEF terminology, the D-programme which is issued before the Flexibility Offer is used as baseline.

2.2.4 Flexible asset breakdown and flexibility providers

The trial attracted and enabled aggregators to offer flexibility from end consumers within a variety of sectors and asset types. Figure 2 Figure 2 below shows that most of the flexibility (34%) was provided by EV chargers. In total, the contracted flexibility was about 1.5 MW.

10 Flexibility Service Agreement (FSA) template: Flexibility_Services_Agreement_Template.pdf (SP Energy Networksergynetworks.co.uk)

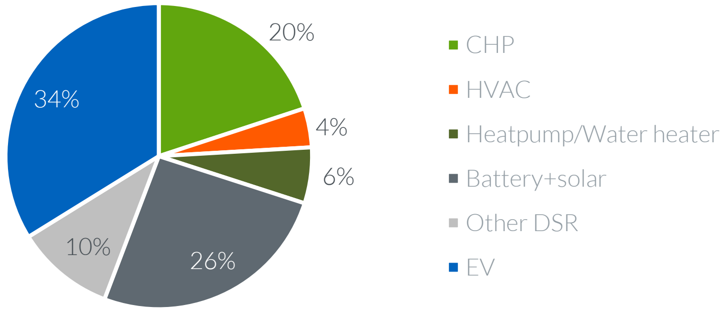


Figure 2 Flexible asset breakdown in the FUSION trial.

The following tables, Table 7 and Table 8Table 7Table 8, provide an overview of Gridimp and Orange Power aggregators' assets respectively at the five congestion points, the two primaries and the three feeders, and their flexible capacity. Orange Power used all residential assets and Gridimp commercial and industrial; resulting in 80% of the flexible capacity for the trial being represented by residential assets.

Table 7 Gridimp overview of assets at each congestion point

Aggregator name	Congestion point	Type	Flexible Capacity [kW]
Gridimp	Leuchars Primary	CHP	60
Gridimp	Leuchars Primary	HVAC	34
Gridimp	St Andrews Primary	HVAC	40
Gridimp	St Andrews Primary	CHP	220
Gridimp	St Andrews Primary	HVAC	8
Gridimp	St Andrews Primary	HVAC	10
Gridimp	St Andrews Primary	HVAC	35
Gridimp	St Andrews Primary	HVAC	30

Table 8 Orange Power overview of assets at each congestion point

Aggregator name	Congestion point	Type	Flexible Capacity [kW]
Orange Power	Leuchars Primary	EV	210
Orange Power	Leuchars Primary	Heat pump/ water heater	25
Orange Power	Leuchars Primary	Battery + solar	115

Orange Power	Leuchars Primary	Other DSR	58
Orange Power	St Andrews Primary	EV	340
Orange Power	St Andrews Primary	Heat pump/ water heater	40
Orange Power	St Andrews Primary	Battery + solar	211
Orange Power	St Andrews Primary	Other DSR	69
Orange Power	St Andrews 11kV-18612	EV	41
Orange Power	St Andrews 11kV-18612	Heat pump/ water heater	6
Orange Power	St Andrews 11kV-18612	Battery + solar	12
Orange Power	St Andrews 11kV-18612	Other DSR	7
Orange Power	St Andrews 11kV-18614	EV	45
Orange Power	St Andrews 11kV-18614	Heat pump/ water heater	6
Orange Power	St Andrews 11kV-18614	Battery + solar	12
Orange Power	St Andrews 11kV-18614	Other DSR	6
Orange Power	St Andrews 11kV-18616	EV	49
Orange Power	St Andrews 11kV-18616	Heat pump/ water heater	6
Orange Power	St Andrews 11kV-18616	Battery + solar	12
Orange Power	St Andrews 11kV-18616	Other DSR	6

The tables above shows the actual flexibility that was enabled and activated throughout the trial. This differs to what was registered in the Flexibility Service Agreements (FSA), one aggregator having been able to attract significantly more flexible capacity than was anticipated in the agreement, and the other less. For the latter, there were some CHP and HVAC assets that were unexpectedly unable to provide flexibility due to an incident with the university's district heating system, which, in turn, affected their usage regimes.

2.3. OPERATION – MAIN DIFFERECES BETWEEN PHASES 1 AND 2

This section presents the overview of the use cases simulated during the trial phase 2. The main difference between phases 1 and 2 is that for phase 2, real time forecasts from the DSO were used instead of the simulated forecasts used for phase 1.

Although there was no real congestion affecting the substations and feeders, the cases were designed so that flexibility would be dispatched by simulating a number of plausible events. Within each use case there are several test cases depending on the day-ahead and intraday forecast of the substation or feeder load. The test cases that were simulated during trial phase 2 have been described in detail in the **ITLR#3 report** which was published in December 2022.[4]

The first subsection below describes the use cases that were adapted to include the real-time element of phase 2 of the trial. These use cases explain the logic that the DSO follows to trade flexibility, i.e., to request flexibility from the aggregators and then order it when required (i.e., issue a FlexOrder). Then, the second subsection shows statistics on the number of events simulated per test case and per range of requested power.

It is worth noting that the simulations were executed according to a schedule that was designed to ensure that all test cases were trialled and that a high turn-over of events were achieved to maximise the volume of relevant empirical data generated for subsequent analysis within the boundaries of the contracts.

2.3.1 Overview of use cases and test cases deployed in Phase 2

2.3.1.1 Use case – Secure DSO Constraint Management (pre-fault)

Use case description: There is a need to reduce the demand on a distribution network asset [immediately or at least within the hour] under certain system conditions and at certain times of day for a maximum duration of time to keep that asset within its operational capability. This could support the network to avoid fault conditions, during both planned and un-planned maintenance work, or where a constraint is forecast, using a DSO-triggered service.

The flexibility required can come from one of three actions that help to reduce demand at the Meter Point Administration Number (MPAN): (1) a reduction in demand, (2) an increase in generation, or (3) discharging a battery.

3 test cases were simulated under the Use case – Secure DSO Constraint Management (pre-fault):

- Test case 1.1 - Secure DSO Constraint Management (pre-fault) - Reserve + Order/ No Order
- Test case 1.2 - Secure DSO Constraint Management (pre-fault) – Free Bid + Order / No Order
- Test case 1.3 - Secure DSO Constraint Management (pre-fault) - FlexReservationUpdate

2.3.1.2 Use case – Dynamic DSO Constraint Management (post-fault)

Use case description: There is a need to reduce the demand on a distribution network asset immediately following a network fault, for a maximum duration to keep that asset within its operational capability. This service is unplanned but could be scheduled at times of high network risk.

The flexibility required can come from one of three actions that help to reduce demand at the substation: (1) a reduction in demand, (2) an increase in generation, or (3) discharging a battery.

5 test cases were simulated under the Use case – Dynamic DSO Constraint Management (post-fault):

- Test case 2.1 – Dynamic DSO Constraint Management (post-fault) - Reserve + Order / No Order
- Test case 2.2 - Dynamic DSO Constraint Management (post-fault) - Reserve + no Order
- Test case 2.3 - Dynamic DSO Constraint Management (post-fault) - Free bid + Order / No Order
- Test case 2.4 – No fault outside availability window - Free bid + no Order
- Test case 2.5 - Dynamic DSO Constraint Management (post-fault) - FlexReservationUpdate

2.3.1.3 Use case – Sustain Peak Management

Use case description: There is a need to reduce the demand on a distribution network asset to keep that asset within its normal operational capability. This could be as a result of a forecast capacity constraint on the asset at a particular time, e.g. to reduce the demand on a critical asset during winter tea-time peak, using a DSO planned service. This service supports the deferral or avoidance of conventional approaches to network reinforcement.

The flexibility required can come from one of three actions that help to reduce demand at the MPAN: (1) a reduction in demand, (2) an increase in generation, or (3) discharging a battery.

3 test cases were simulated under the Use case – Sustain Peak Management:

Test case 3.1 – Sustain Peak Management - Reserve + Order

Test case 3.2 - Sustain Peak Management - Free bid + Order (when possible)

Test case 3.3 - Sustain Peak Management - FlexReservationUpdate

2.3.2 Summary of test cases deployed in Phase 2

Phase 2 of the FUSION project trialled the different test cases for the two primary substations at St. Andrews and Leuchars, as well as the St. Andrews 11 KV Feeders 18612, 18614 and 18616, all in the East Fife area.

Each simulation tested how FUSION trial participants (FTPs) responded to the different test cases outlined above. The number of simulations of each test case at each congestion point is shown below in Figure 3. The simulation schedule focused on test cases where flexibility is ordered (i.e. test cases 1.1, 2.1 and 3.1) to maximise the volume of empirical data generated where flexibility is delivered. The schedule also ensured that there was data on all the other test cases.

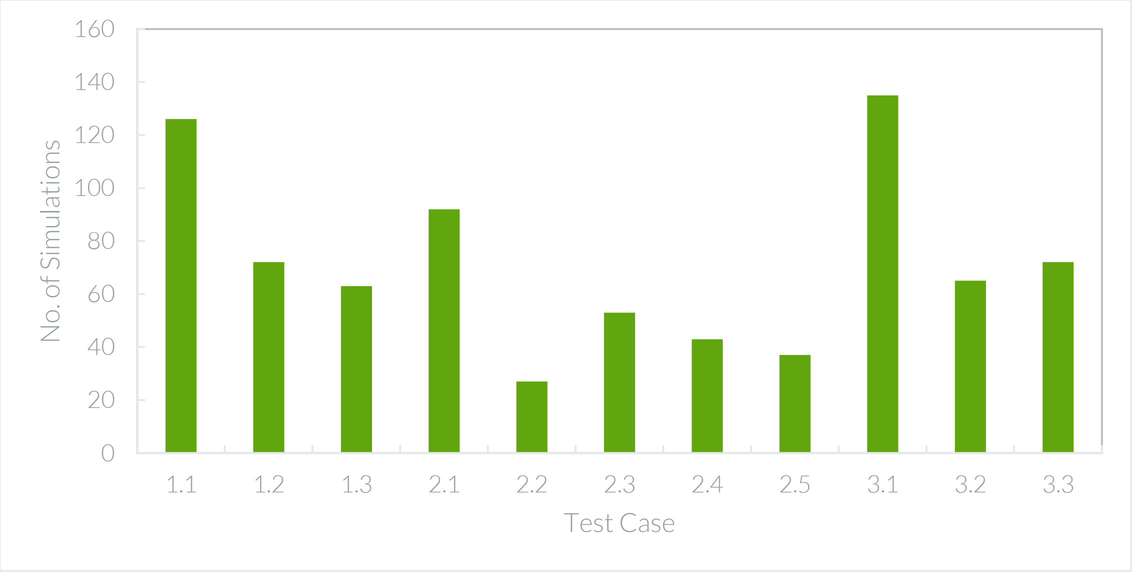


Figure 3 Number of simulations for each test case at all congestion points

The distribution of power requested is shown in Figure 4Figure 4. Phase 2, compared to phase 1, has tested the 0-100 kW range more due to the lower quantity of capacity available at feeder level. At substation level in St Andrews and Leuchars, where there is more flexibility connected available, FUSION was able to test requesting greater amounts of flexibility.

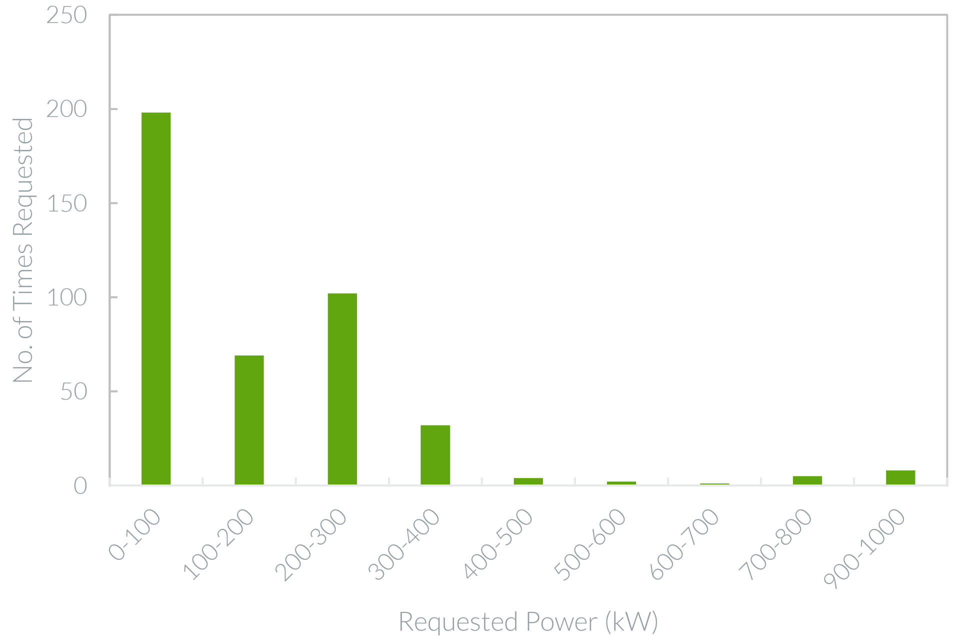


Figure 4 Histogram showing the range of power requested across all congestion points

3. Trial simulation overview

This section provides an overview of the results primarily from Phase 2 of the trial with reference to the Phase 1 results in certain places (please refer to ITLR#2 and ITLR#3[4] for more detailed results from this Phase).[4] The section offers insights into the delivered flexibility and the observed trends in requests, offers and orders and outlines the method used to analyse the available data before looking at three key topic areas: trial summary statistics, reliability of delivery and offer prices. For each topic, we provide the scope of the analysis, the results and the learnings and conclusions.

3.1. GENERAL REMARKS

The primary analysis for Phase 2 has been conducted on data collected between 19/04/2022 and 01/03/2023, which corresponds to the start of Phase 2 trial period and a deadline that the project had to impose to be able to complete the analysis in time for the report to be published in April 2023. The data included the following:

1. Meter data - from each aggregator at portfolio level at each congestion point and from the DSO at the substation.
2. Validation Phase Information – including D-programmes, FlexRequests, FlexOffers and FlexOrders.
3. Trial Simulation Schedule – a pre-determined list of the FlexRequests and FlexOrders to be placed. The trial simulation schedule includes the plan for activating the test cases examined in this trial. This schedule acted as a guideline for the DSO however individual decisions of whether to order flexibility were made on a day-to-day basis.
4. Settlement Information – showing payments due for delivered flexibility for each event and each aggregator.

The data was downloaded from the FUSION Flexibility Platform's (FFP) central database using a combination of Structured Query Language (SQL) scripts and power query. It was then cleansed to avoid duplicate database entries and post-processed to enable the analysis to be done.

Meter data from aggregators was typically only available for those days that FlexRequests were issued. The meter data includes the half-hourly imported and exported energy, which was then converted into net average power for each time interval (i.e. import energy – export energy multiplied by two). Gridimp and Orange Power provided meter data for the ISP's where FlexOrders were issued in 100% and 90% of cases respectively. This data allowed us to calculate the volume of flexibility that was delivered by comparing it against their D-programme baseline, which they provided day-ahead.

3.2. TRIAL SUMMARY STATISTICS

3.2.1 Scope

The purpose of this section is to provide an overview of the scale of the trial, including the number of messages that have been exchanged and the volume of flexibility that has been delivered. We also draw comparisons between the results from Phase 1 and 2 of the trial.

3.2.2 Results and Analysis

We have summarised the results of the trial based on the messages exchanged between the DSO and aggregators in the USEF Validation Phase (Table 9)Table 9. These are principally FlexRequests, FlexOffers and FlexOrders. The DSO requested flexibility, via a FlexRequest, 632 times throughout the trial across all congestion points (211 in Phase 1 and 421 in Phase 2). During Phase 2, the DSO requested a larger range of flexible power compared with Phase 1, including FlexRequests of 1000 kW and requested more flexibility overall compared because of the addition of the 11kV feeders to the list of congestion points.

As in Phase 1, the trial continued to see more FlexOffers being made by aggregators than FlexRequests, as would be expected with FlexOffers being made per aggregator . More significantly, 94% of FlexRequests received at least one FlexOffer which demonstrates the reliability of aggregators to offer flexibility when the DSO requests it.

The number of FlexRequests that are followed up by a FlexOrder is governed by the simulation schedule and the DSO's operational decisions. 388 FlexOrders were issued in Phase 2, which provides a large sample to explore characteristics such as the reliability of aggregators being able to deliver the flexibility ordered.

Aggregators continued to overdeliver on the ordered flexibility, as was the case in Phase 1 (shown in the "Total Flexibility Realised" row). To avoid this overdelivery from masking what is happening at other times in the trial, the "Total Flexibility Delivered" has been calculated by capping the response at 100% of the FlexOrder power. Accounting for this, the "delivered" flexible energy makes up 77% of the ordered energy in Phase 2 of the trial. This percentage is less than was achieved in Phase 1 of the trial (89%) because of the challenges encountered by one aggregator in defining an accurate baseline from which to calculate the delivered flexibility (see Section 3.3.2). Gridimp changed their baseline methodology moving from Phase 1 into Phase 2 to a method that was less accurate and had to revert to their original method halfway through Phase 2. This has impacted the overall reliability figures for Phase 2.

Finally, the total utilisation payments in Phase 2 exceeded Phase 1 due to the additional congestion points added and the trial experimented with different volumes of flexibility.

Table 9 FUSION Phase 2 Trial Summary Statistics

Message	Statistic	Phase 1	Phase 2	Phase 1 & 2	Comments
FlexRequests	Total number of FlexRequests	211	421	632	
	Range of FlexRequest Power Requirements	5-500 kW	0.4-1000 kW	0.4-1000 kW	
	Total Flexibility Requested	28.5 MWh	97,0 MWh	125.5 MWh	Averaged per ISP
FlexOffers	Total number of FlexOffers	268	557	825	
	Number of FlexRequests with at least one offer	202	394	596	
	Total Flexibility Offered	29.6 MWh	100.5 MWh	130.1 MWh	
FlexOrders	Total number of FlexOrders	153	387	440	
	Total Flexibility Ordered	17.9 MWh	38.3 MWh	55.2 MWh	
	Total Flexibility Delivered	15.9 MWh	29.6 MWh	45.5 MWh	Capped at 100% of FlexOrder

	Total Flexibility Realised	23.8 MWh	64.5 MWh	88.3 MWh	Not capped at 100% of FlexOrder
	Total utilization Payments for Flexibility Delivered	£7109	£21,616	£28,625	

A new aspect in Phase 2 of the trial is the addition of the 11kV feeders as congestion points. We have therefore isolated the summary statistics for these sites and compared them with congestion points at the two primary substations (Table 10). The results show that while the primary substations still involved the majority of flexibility that was ordered, there was sufficient data for the 11kV feeders to gain insights into how the trial has performed at this network level.

The number of FlexRequests was approximately equal at primary substations and 11kV feeders, however the average flexibility requested was much larger at the primary substations than at the substations as would be expected (as demonstrated by the difference in the total flexibility requested).

The other notable feature is that aggregators overdelivered more energy as a percentage of the FlexOrder energy at the 11kV feeders than at the primary substations (226% and 161% respectively). This feature shows that aggregators were more likely to overdeliver when smaller quantities of flexibility is requested.

Table 10 FUSION Phase 2 Trial Comparison Between Primary Substation and 11kV Feeders

Message	Statistic	Primary Substations	11kV Feeders
FlexRequests	Total number of FlexRequests	216	205
	Range of FlexRequest Power Requirements	9-1000 kW	9-861 kW
	Total Flexibility Requested	77.9 MWh	19 MWh
FlexOffers	Total number of FlexOffers	363	194
	Number of FlexRequests with at least one offer	210	185
	Total Flexibility Offered	68.8 MWh	31.7 MWh
FlexOrders	Total number of FlexOrders	255	132
	Total Flexibility Ordered	34.4 MWh	3.9 MWh
	Total Flexibility Delivered	26.4 MWh	3.2 MWh
	Total Flexibility Realised	55.7 MWh	8.8 MWh
	Total utilization Payments for Flexibility Delivered	£19,348	£2267

3.2.3 Learnings and Conclusions

The scale of the trial has increased in Phase 2 as more flexible assets and congestion points have been added. The DSO has experimented with requesting smaller and larger volumes of flexibility compared with Phase 1 including up to 1000 kW. In response to DSO requests, the aggregators continued to offer flexibility to FlexRequests in the vast majority of cases (94%). The trial, therefore, was generating sufficient data to explore the trial's learning objectives in more detail.

The aggregators continued, in general, to overdeliver on the volume of flexibility that is ordered despite changes to the FSA to reduce the penalties for underdelivery. The explanations for this are explored further in the next section, however it is important to note that from a network management perspective overdelivery is not always desirable. One of the risks of over delivery of flexibility is that it becomes more difficult to counteract the action to neutralize the effect on the system balance (the so-called redispatch); redispatch is a necessary part of any activation of flexibility as part of a constraint management service that is not being examined in this trial. In the trial, aggregators were not penalised for overdelivery in the FUSION trials, but neither are they remunerated for it.

3.3. RELIABILITY OF DELIVERY

3.3.1 Scope

The purpose of this section is to outline whether the aggregators have been able to deliver flexibility when it is ordered and to identify patterns and trends in how and when flexibility is delivered.

It is worth noting that the calculation of the amount of flexibility delivered is based on the difference between the nominated d-programme power and the meter reading of the actual demand/generation for each ISP. Therefore, it is important that figures for reliability are considered alongside the baseline accuracy (refer to Section 4.1.2 for further discussion on baselining and Section 4.1.4 for impact of reliability and baselining on DSO procurement cost).

3.3.2 Results and Analysis

Orange Power continued in Phase 2, as in Phase 1, to overdeliver on the ordered flexibility volume (Figure 5Figure 5): in the case of the 11kV feeder "18612", the average overdelivery is 14 times the ordered flexibility. In the aggregator interviews, Orange Power confirmed that this is by design as they compensated for the known inaccuracy of their baseline, to ensure that they deliver at least 100% of a FlexOrder. They are also had an issue with the time it takes for data to become visible showing how they assets are being used. For some assets the latency was within 5 seconds whereas for others it can take up to 1 day. This delay has also meant they continued to be conservative by overdelivering on flexibility.

Gridimp experienced different challenges in Phase 2 of the trial. At St. Andrew's primary substation, they consistently delivered negative flexibility (i.e. their generation has decreased or demand has turned up) (Figure 6Figure 5). Gridimp's feedback was that they have been focusing on getting more flexible assets enabled because they have not had enough assets available to meet their contracted availability volume. This focus has meant that they dedicated less time to ensuring their baseline is accurate, which made it challenging to determine how much flexibility Gridimp are delivering. Therefore, the unreliability of their baseline explains the reason for the negative average delivered flexibility. At Leuchars, Gridimp delivered on average close to the FlexOrder power (94%), however, it is noteworthy that Gridimp were using the same baseline methodology for the first half of Phase 2 of the trial as at St Andrews.

Figure 5 Average Percentage of FlexOrder Power Delivered Per ISP for Phase 1 and 2

More can be understood about the performance of each aggregator by plotting the response to each FlexOrder over the trial period (Figure 6 & Figure 7). The results show that in June and July, Gridimp underdelivered significantly at St Andrews. The reason for this is that the baseline that was provided day-ahead, consistently suggested that their CHP plants would be generating electricity. Whereas the outturn showed that their assets were a net demand on the substation. The settlement, which is calculated by subtracting the baseline from the outturn, therefore showed a large increase in demand when the flexibility was ordered. Gridimp have learnt from this and updated their baseline methodology to automate the creation of the baseline and make it more reflective of the operation of their assets. Some improvement to their delivery were observed from November 2022 onwards (at St Andrews the RRMSE improved from -275% to 33%).

The results also suggest, if interpreted directly, that Gridimp were far more consistent at delivering flexibility at Leuchars at approximately 100% of the FlexOrder power throughout Phase 2 of the trial. It is worth reiterating though that the impact of an inaccurate baseline is that it reduces the confidence that one should have in this reliability metrics.

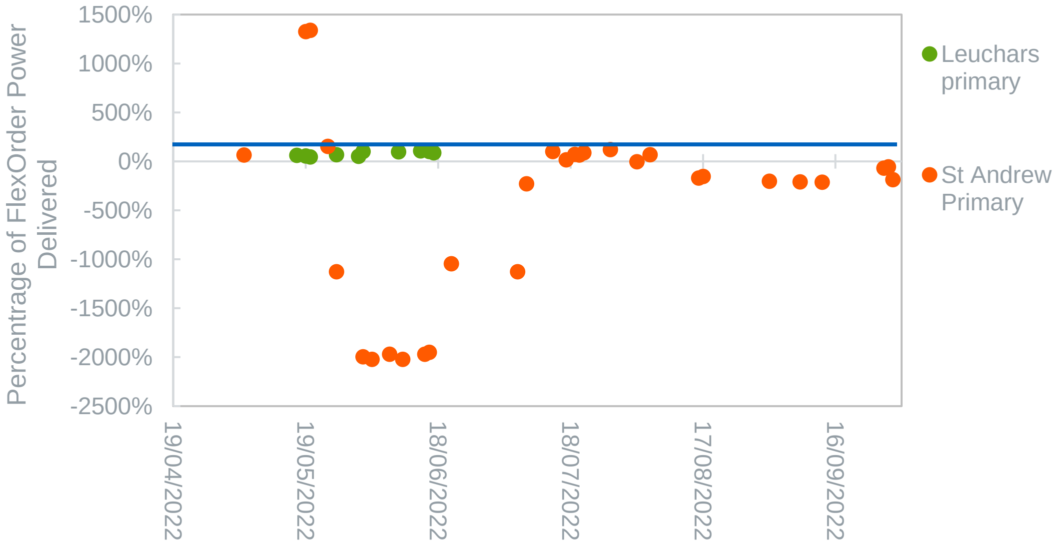


Figure 6 Average Percentage of FlexOrder Power Delivered Per ISP by Gridimp in Phase 2 - April to September 2022

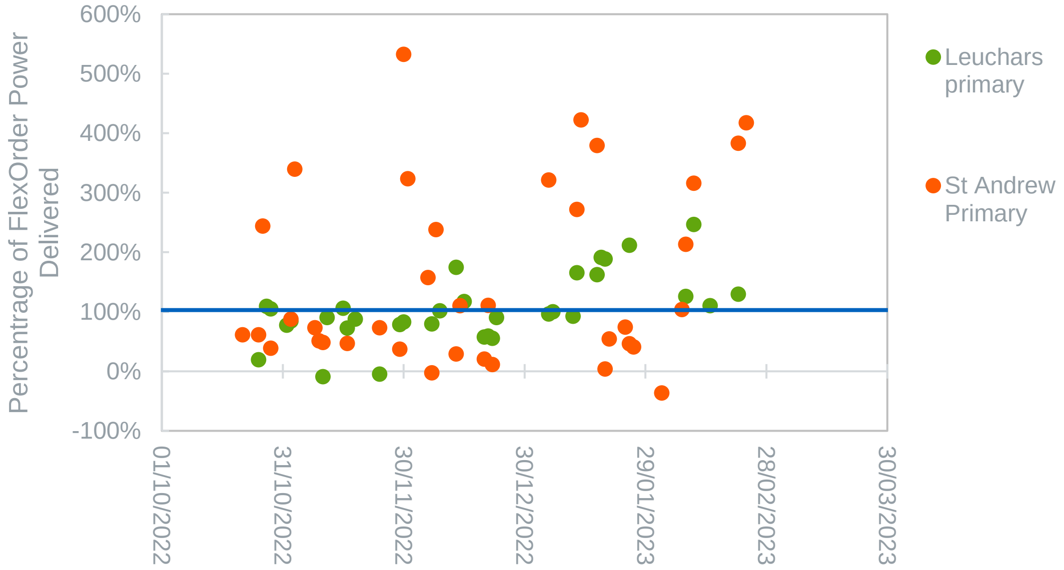


Figure 7 Average Percentage of FlexOrder Power Delivered Per ISP by Gridimp in Phase 2 - October 2022 to March 2023

The plot of Orange Power's delivery over time shows the variation between the primary substations and the 11kV feeders (Figure 8). The results show that Orange Power tended to over-deliver more frequently at the 11kV feeders than at the primary substations. The delivery for Leuchars and St Andrews primary was consistently closer to the 100% than at the "18612" feeder in particular. The reason for this is a combination of the increased bias of the aggregator baseline at the 11kV feeders (discussed in Section 4.1.2) and that Orange Power had fewer of its assets connected to each feeder making it difficult to predict what the behaviour of them is going to be. This means that they were very conservative when dispatching the flexibility to make sure they meet at least the FlexOrder power, which led to them to overdeliver.

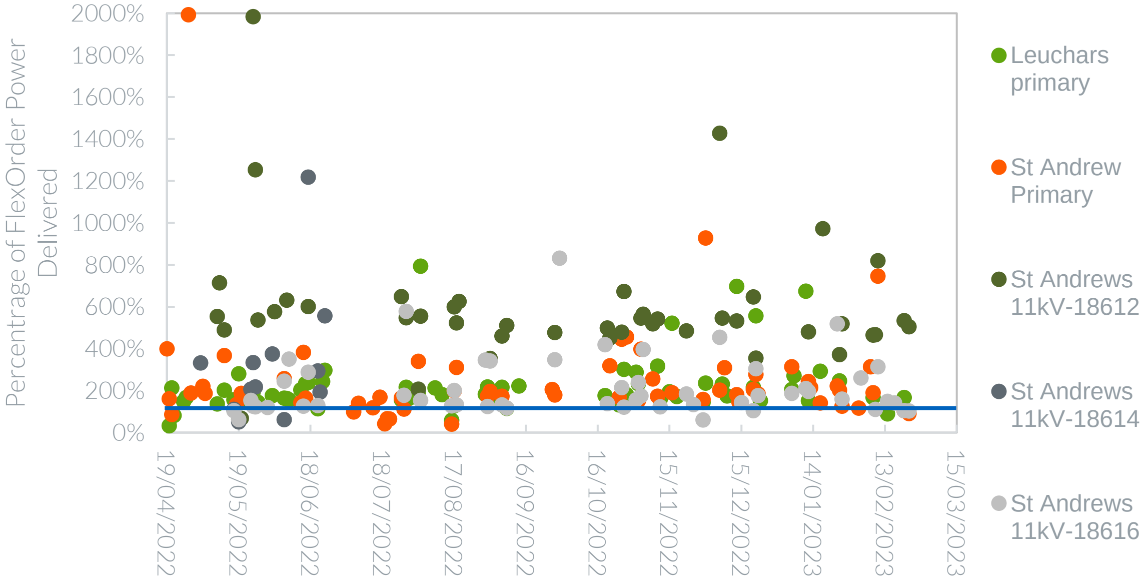


Figure 8 Average Percentage of FlexOrder Power Delivered Per ISP by Orange Power in Phase 2

Our analysis also investigated the correlation between the time of the activation window and the percentage of the FlexOrder that was realised (Figure 9): The aim was to understand whether aggregators were more reliable at delivering the agreed amount of flexibility at different times of day. The results show that aggregators were marginally more likely to deliver closer to the FlexOrder power outside of the availability windows (before 11am and after 3pm). One possible explanation of this is that certain assets have greater potential to change their demand outside of availability window such as EV chargers whose flexibility is based on the travelling patterns of the owners, however this needs to be further discussed with aggregators. It is worth noting that the sample size for these cases was smaller as the majority of FlexOrders (69%) were issued within the main availability window. For larger portfolios of flexibility, the reliability of delivery is an important factor in determining the volume of flexibility that is required. Awareness that this may change throughout the day is therefore a useful insight from the trial.

It is notable that the spread of data for the percentages of the FlexOrder delivered was greater in Phase 2 that in Phase 1 (Figure 9). However, it is worthwhile noting that Phase 2 was running for nearly twice as long and includes the 11kV feeders as congestion points in addition to the primary substations.

Figure 9 Percentage of FlexOrder delivered by aggregators by Time of Day for Each ISP in Phase 1 and 2

We also analysed the impact of the notice time, which links to the different services, between the issue of the FlexOrder and the activation of flexibility (Figure 10). The sustain service had the longest notice time, since the flexibility is requested day-ahead, whereas the secure and dynamic service had a notice period of 30 minutes and 15 minutes respectively. Figure 10Figure 10 shows more clustering around the 100% delivery value for FlexOrders that were issued day-ahead compared with intra-day. Overall, the results demonstrate that the notice time had an impact on the percentage of FlexOrder delivered (sustain service had an average delivery of 217% while secure and dynamic averaged 145% combined).

The large outliers that can be seen grouped horizontally around the -1000% and -2000% values provide evidence for the issues that were seen with the aggregators' baselines. . These instances are all for Gridimp at St Andrews with a similar FlexOrder power. The fact that the percentage of FlexOrder power delivered was consistently wrong by a similar amount, shows that the underlying assumption about whether the CHP was on or off was not correct.

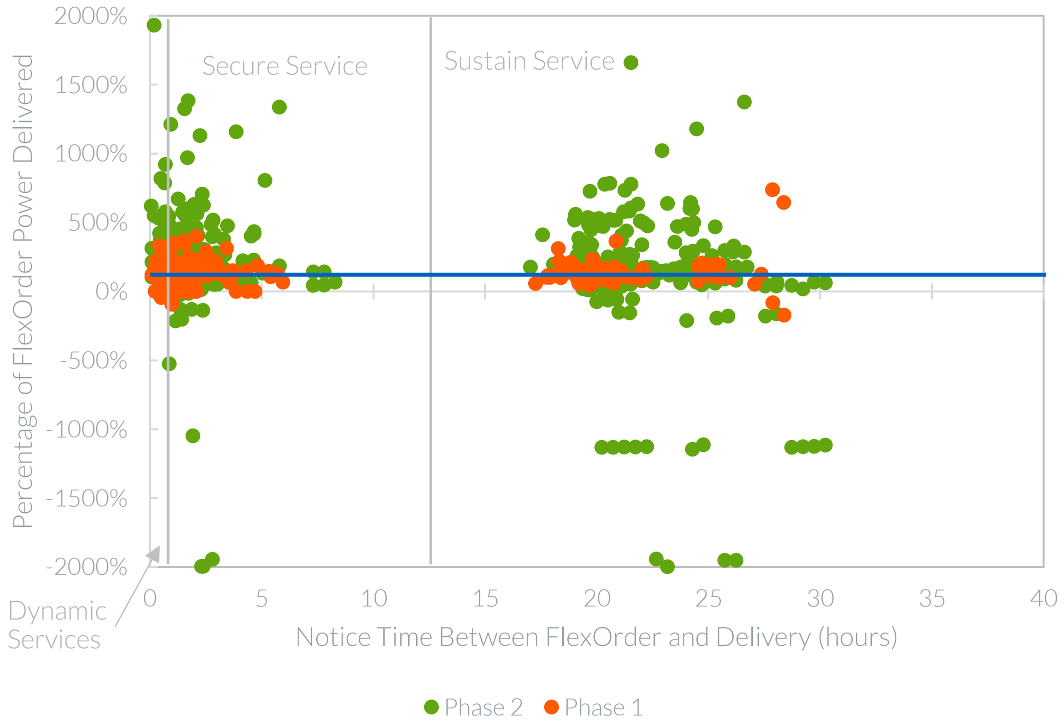


Figure 10 Percentage of FlexOrders Realised by aggregators by Notice Time Between FlexOrder and Utilisation for Each ISP in Phase 1 and 2

We calculated the reliability of day-ahead and intraday FlexOrders to determine whether one was more reliable (Figure 11Figure 11). Our results show that flexibility that was ordered day-ahead was more reliably delivered than intraday across all congestion points (except for Gridimp at St Andrews – although it is worth noting that issues with their baselining were present at Leuchars as well). which, as described previously, had issues with the accuracy of the baseline). Orange Power expressed a preference for day-ahead FlexOrders as this gives their customers more time to respond, which may explain the difference between day-ahead and intraday results. Gridimp stated that their CHPs have a ramp time of 15 minutes, therefore in instances where the FlexOrder was sent less than 15 minutes in advance there may be some impact from ordering flexibility intraday In general, Gridimp, stated that their system is fully automated, so there should not have been a significant difference between intraday or day-ahead.

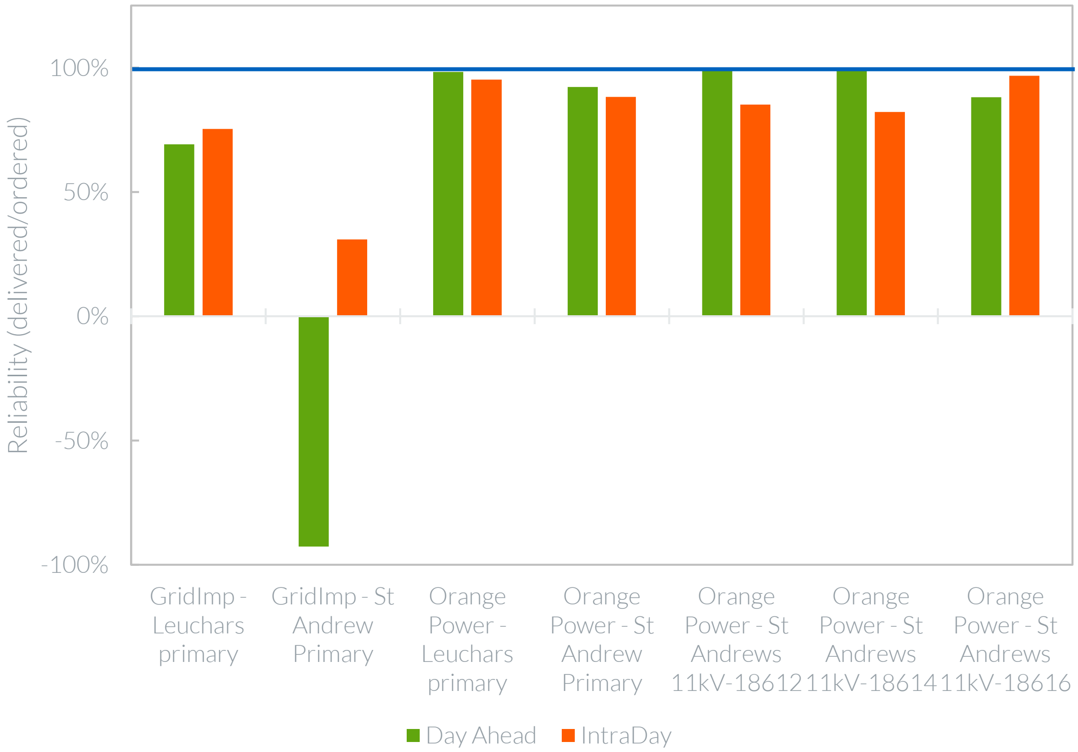


Figure 11 Comparison of Day Ahead and Intraday Reliability in Phase 2

We also calculated the overall reliability in Phase 2 at the different congestion point (Figure 12Figure 12Figure 11). The results show that, with the exception of Gridimp at St Andrews, all congestion points achieved a reliability of 73% or higher . Overall, aggregators were able to reduce their demand or increase generation in response to a FlexOrder in 92% of ISPs, which is down from 97% of ISPs in Phase 1. The reason for this is largely due to the performance of Gridimp at St Andrews due to the inaccuracy of their baseline.

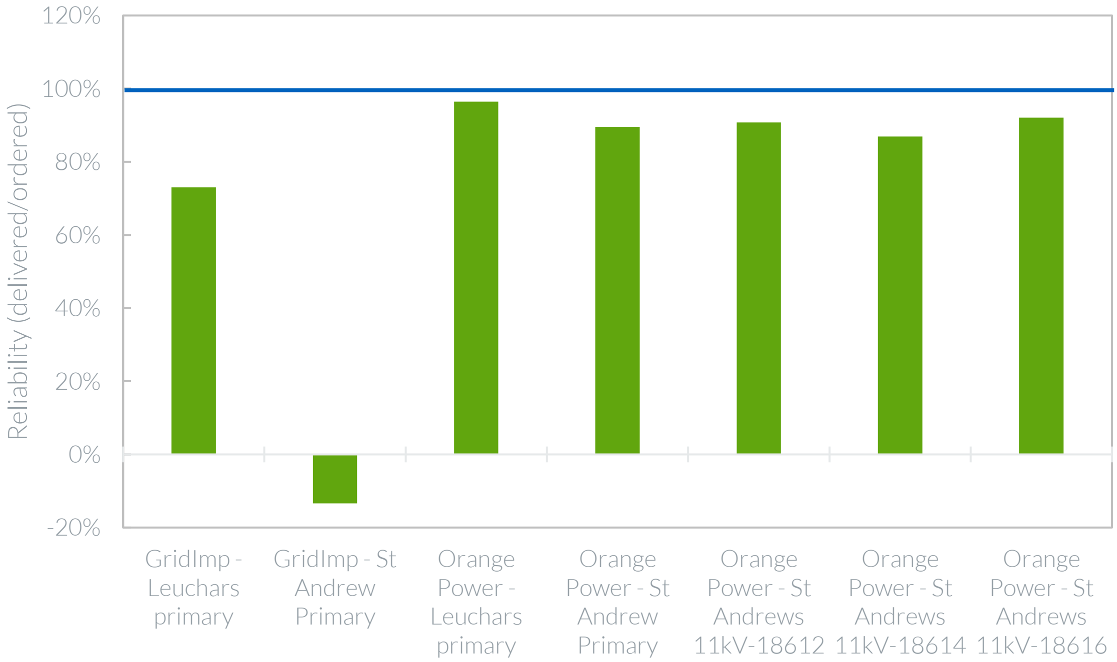


Figure 12 Phase 2 Reliability Calculated by Dividing Delivered Power (capped at 100% of FlexOrder) by ordered power

Finally, to understand how the reliability has changed throughout Phase 2, we also analysed the reliability for each month of the trial (Table 11Table 11). The results clearly suggest that Gridimp's reliability has improved throughout the trial, with a marked improvement observed at St Andrews primary substation. There is a clear step change after September when Gridimp changed their baselining methodology although it worth noting that it is still the lowest performing aggregator at a congestion point. At this congestion point, Gridimp had a 220kW CHP that typically made up a large percentage of flexibility offered. This means that the baseline accuracy and reliability were dependent on being able to reliably predict the behaviour of that one asset which they were not able to do. This is discussed in more detail in Section 4.1.2. Orange Power broadly achieved the same reliability throughout the trial.

Table 11 Reliability of Delivery of Aggregators During Phase 2 of Trial

	GridImp		Orange Power				
Month	Leuchars primary	St Andrews Primary	Leuchars primary	St Andrews Primary	St Andrews 11kV-18612	St Andrews 11kV-18614	St Andrews 11kV-18616
Apr 22	-	-	44%	97%	-	-	-
May 22	56%	-5%	100%	100%	75%	84%	92%
Jun 22	96%	-1824%	100%	100%	-37%	92%	97%
Jul 22	-	-18%	100%	76%	100%	-	100%
Aug 22	-	-96%	93%	86%	100%	-	96%

Sep 22	-	-138%	75%	100%	100%	-	79%
Oct 22	60%	69%	100%	100%	100%	-	89%
Nov 22	61%	70%	100%	90%	72%	-	59%
Dec 22	77%	63%	100%	86%	84%	-	78%
Jan 23	94%	76%	100%	100%	100%	-	100%
Feb 23	100%	65%	98%	86%	100%	-	78%

3.3.3 Learning and Conclusions

The trial results show that aggregators achieved an average reliability in Phase 2 of 77%, although it is noteworthy that this will be negatively impact by Gridimp's reliability at St Andrews. When considering only Orange Power's performance across the five congestion points they were active, they achieved a reliability of 87%.

We have discussed the method used to calculate reliability with the TRANSITION project, another flexibility market trial based on Oxford. Their calculation method followed the following equation:

$$Reliability_{TRANSITION} = \frac{Hours\ available}{Hours\ contracted}\ x\ \frac{Flex\ delivered}{Flex\ ordered}$$

There is no mechanism within USEF for aggregators to indicate the number of hours their assets are available therefore it is not possible to make direct comparisons between the two trials. Instead USEF focuses on aggregators response to requests for flexibility as the primary measure of flexibility.

Results displayed in this section have shown that aggregators were more conservative by activating more flexibility when dispatching a smaller number of assets. This conservatism was to ensure that they achieve at least the ordered flexibility and is demonstrated most clearly at the 11kV "18612", which had the highest over-delivery of all congestion points.

The outlier in terms of reliability was Gridimp at the St Andrews primary substation. The reason for this was the inaccuracy of the baseline, which is affected heavily by whether the CHPs were in an off or on state. Due to the inaccurate baseline, the results gave the impression that the aggregator had either increased demand or decreased generation in response to a FlexOrder. However, if the baseline had correctly accounted for whether the CHPs were on or off, then the delivered flexibility would have shown a significantly improved performance. Since the ITLR#3,[4] Gridimp changed their baselining methodology - as is possible with a nomination baseline - which led to a significant improvement in their reliability (Table 11Table 11). This finding emphasises the importance of having a reliable baseline from which to measure the response. The baseline accuracy is discussed in more detail in Section 4.1.2.

3.4. OFFER PRICES

3.4.1 Scope

The purpose of this section is to provide an overview of the prices of FlexOffers that aggregators have sent in response to FlexRequests. Our analysis includes the distribution of offer prices for each aggregator and the relationship between offered power and offer price. The section provides insights into the pricing strategies adopted by the aggregators.

3.4.2 Results and Analysis

Table 12Table 12 below summarises the minimum, maximum and average offer price for Phase 2 of the trial at each substation by aggregator. Overall, Figure 13Table 12 shows that Gridimp's offer prices remained at or close to the contract price caps for utilisation during the service window. Gridimp confirmed this in their interviews as much of their activities are automated. The only exception was during the St Andrew's golf tournament where they offered a maximum offer price of £0.8/kWh as a free bid.

Table 12 Flexibility Offer Prices from the Phase 2

Aggregator	Congestion Point/Aggregator	Minimum Offer Price in Trial (£/kWh)	Maximum Offer Price in Trial (£/kWh)	Average Offer Price in Trial (£/kWh)
Gridimp	Leuchars primary	0.4	0.4	0.40
	St Andrews Primary	0.4	0.8	0.43
Orange Power	Leuchars primary	0.49	0.99	0.74
	St Andrew Primary	0.49	0.99	0.76
	St Andrews 11kV-18612	0.49	0.99	0.77
	St Andrews 11kV-18614	0.49	0.9	0.53
	St Andrews 11kV-18616	0.49	0.99	0.79
	Combined Results	0.4	0.99	0.66

[1] The values differ by aggregator but are the same for all service windows, notification periods and contract types

Results from the trial showed the majority of Gridimp's FlexOffers were priced between £0.4 and 0.5/kWh (Figure 13Figure 13). Orange Power offered flexibility at a wider range of prices in Phase 2, particularly during the St Andrews Golf tournament in July. At St Andrews, 71% of their FlexOffers were £0.7/kWh or above. These prices show Orange Power utilised the increase in the price cap for free bids that was introduced after Phase 1 of the trial (from £0.5 to £1/kWh). Further analysis on how the offer prices changed due to free bids is described in Section 4.1.1.

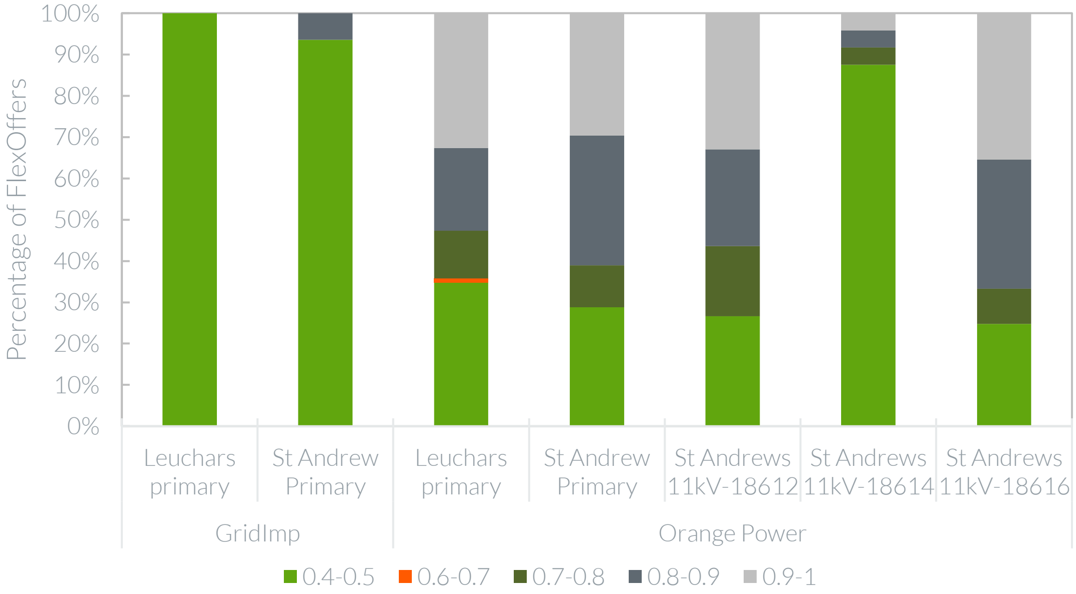


Figure 13 Distribution of Offer Prices for Each Congestion Point and aggregator

We also investigated the relationship between the volume of offered power and the offer price. The analysis showed that volumes of offered power had a small effect on the offer price (Figure 14

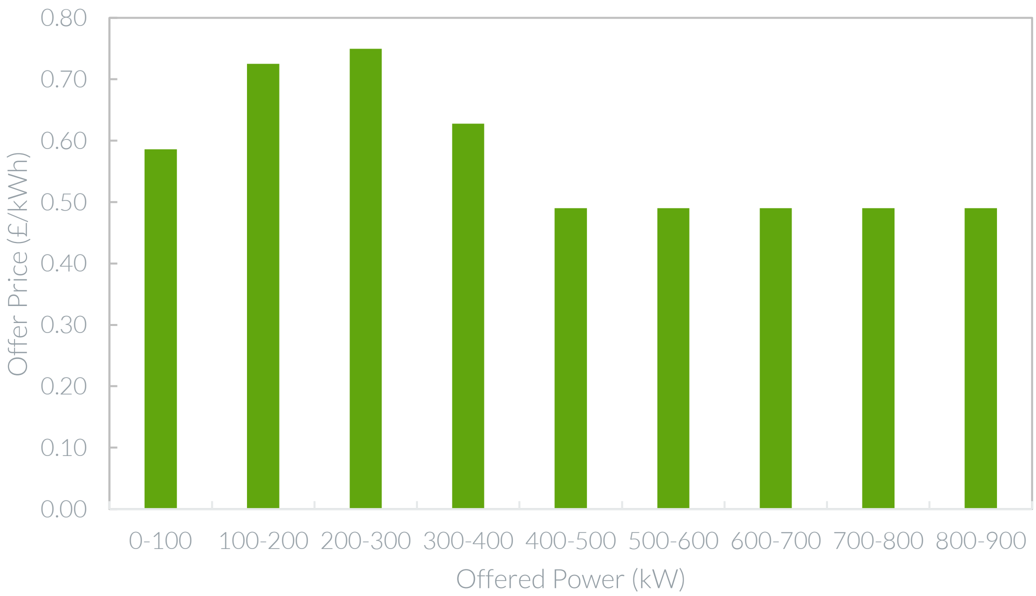


Figure 14 Comparison of Offered Power and Average Offered Price

Figure 14). However, there is insufficient data from offers below 100kW to draw firm conclusions.

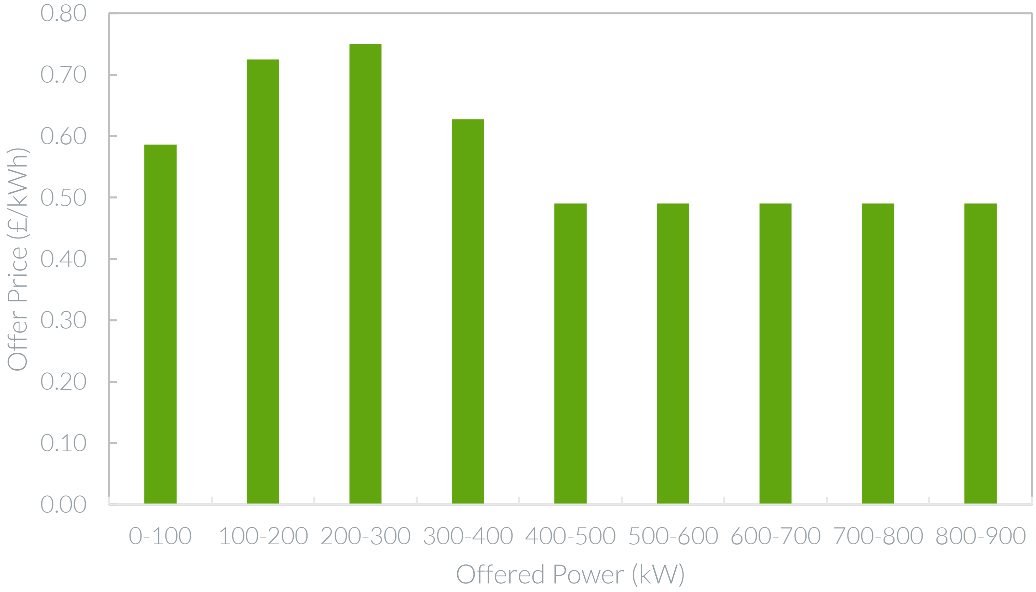


Figure 14 Comparison of Offered Power and Average Offered Price

3.4.3 Learnings and Conclusions

This section has demonstrated that offer prices remained relatively constant throughout Phase 2 of the trial and no real patterns or strategies have emerged regarding the pricing of utilisation. Gridimp's offer prices remained either very close to or at the contract price caps for utilisation whereas Orange Power offered flexibility at a wider variety of prices.

The price that aggregators were paid for availability continued to be higher than that for being activated. One of the reasons for this was to encourage participation in light of the high wholesale electricity prices at the time of the trial. The other reasons were to cover the capital costs associated with applying USEF and for the control systems necessary to provide flexibility, and to attract new aggregators to the area to ensure that at least two were able to participate in the trial. Feedback from Gridimp was that due to the increased incentive of the availability payments against utilisation, their focus was on securing the availability payment rather than on varying the offer prices and providing free bids.

4. Trial learnings

This section summarises the trial learnings at the end of phase 2. This section comprises of subsections which describe the learnings of each trial objective. The trial objectives were agreed by project FUSION partners through a number of workshops prior to the commencement of the live trial.
A few trial learnings, which are based on qualitative analysis and not on updated quantitative information, have not changed since the publication of ITLR#2 and ITLR#3.[4] For transparency and completion purposes of the current report, these trial learnings are summarised in the section 4.2. Trial learnings which are based on updated information are analysed in detail in section 4.1.

4.1. UPDATED TRIAL LEARNINGS

4.1.1 Free bids

4.1.1.1 Scope

Free bids are flex offers which aggregators send in response to a FlexRequest from the DSO, that is either outside of their availability window or above their contracted power. Free bids only receive a utilisation payment.

4.1.1.2 Methodology

This subchapter aims to present the quantitative analysis of free bids in the FUSION project and qualitative assessment based on interviews with aggregators and the DSO.

4.1.1.3 Results & Analysis

Qualitative analysis

During Phase 1, aggregators found identifying free bids complicated and perceived the free bid price cap to be too low to encourage participation, resulting all bids submitted at (close to) the price cap. In phase 2, the FSA increased the price cap of free bids to 1) explore the real cost of free bids and 2) to reflect the increasing energy prices at the beginning of 2022. On several occasions, the DSO communicated in advance to aggregators that they could submit free bids to a particular request (e.g., planned maintenance, St. Andrews tournament). In addition, the trial increased the number of free bid requests to create a more solid data base.

The conversations with aggregators revealed that aggregators do not prioritise this mechanism. Gridimp has signalled that since their flexibility trading is fully automated, with the system responding to requests in the same manner regardless the time of the day or the requested power. The only occasions in which Gridimp has purposely provided free bids was when SPEN asked for them explicitly. Although this could be arguably fixed in the system, Gridimp has been focusing their resources on enabling assets to be able to deliver flexibility under the availability contract. The non-delivery/non-availability of flexibility under availability contract penalises Gridimp payments, and logically they are incentivised to solve this problem.

OP also does not have an automated mechanism to identify requests outside the availability window. However, OP has manually sent free bids in multiple occasions outside the contracted availability window, and these are normally characterised by a higher price than normal bids. The reason for this is that this aggregator has a greater pool of enabled assets and is more actively looking for ways to get remunerated for their flexibility.

Assets –Both aggregators have non-firm capacity assets only. This means that there is a need for back-up enabled flexible capacity to ensure the full contracted availability. Gridimp's portfolio did not have extra capacity next to the contracted amount. The portfolio capacity was not firm, causing reliability problems in their service delivery (see Section 3.3). On the other hand, OP had a larger portfolio than what is contracted under the availability contract to ensure long-term availability with non-firm capacity.

What did aggregators do with this extra non-firm capacity? Although the aggregators perceive that the free bid mechanism is useful and helps to optimise non-firm flexible capacity, they did not fully make use of it during Phase 2. Gridimp did not use free bids due to issues with normal service delivery and no extra unused capacity. OP did send free bids; however, they also did not fully explore the mechanism possibilities due to having no clear view on the extra available capacity due to lack of short-term portfolio monitoring.

Aggregators mentioned that the FSA does not provide enough clarity or detail on when an offer is considered a free bid and when it is considered a normal bid. However, neither aggregator explored this with SPEN during the contracting phase indicating it was not found sufficiently commercially interesting. OP mentioned the possibility to explore segregating its portfolio in two parts, one for the unpredictable DSR (non-firm) and another for the automated customers that can be controlled, where having also availability contracts would be preferred.

Effect on business case – Even if OP did not make full use of the mechanism, they still highlight that it could be very beneficial for its business case. Rising the price cap for free bids in the FSA has encouraged OP to send more free bids. However, even if increased, OP indicated that it was still low given the current energy crisis context. This highlights once again the importance of opportunity costs when it comes to flexibility. OP indicated that a higher free bid price cap is not only interesting for them but also for the public. With the current energy context, the public has also become more energy aware, and OP expects more interest with higher price caps. This also helps aggregators attracting more general customers than only early adopters. OP also highlighted the importance of free bids for value stacking.

Finally, on the DSO side, relying on non-firm mechanisms, such as free bids, and moving away from availability contracts, is still considered a risk. SP Energy Networks believes that they would consider exploring moving into a system that was more reliant on free bids as long as there was sufficient market liquidity to make that approach statistically reliable. Further analysis would also have to be conducted regarding how aggregators perform with less availability contracts.

Quantitative insights

Aggregators priced free bids at a higher price than normal bids at all congestion points where both were used (Figure 15Figure 15). All free bids were priced at the cap price or very close to it. The average free bid price is greater than the normal bid price at all the congestion points, however, it is worth noting the DSO does not pay any availability cost for the former.

Reliability is a key aspect for the DSO, they indicated that to incorporate the use of free bids the trial must prove it to be sufficiently reliable. Figure 16Figure 16 shows that for most of the congestion points, the reliability of free bids is very similar to normal bids. According to Orange Power, the slightly lower reliability in Orange Power's portfolio may be related to the time windows in which the free bids were requested.

The average offered power for free bids was greater that the power for normal bids at all congestion point (Figure 17Figure 17). Within contracted availability windows, Orange Power has offered additional flexible power in multiple occasions, in some instances the results show that they offered nearly 300kW more. Figure 18Figure 18 presents the average power that was offered above contracted power for congestion point. This means that on average, the DSO is saving 611 kW of contracted capacity. This represents 64% of the overall contracted capacity for all congestion points. Orange Power each clarified that the slight difference in volumes offered in and outside the availability window is probably due to the number of assets in each location.

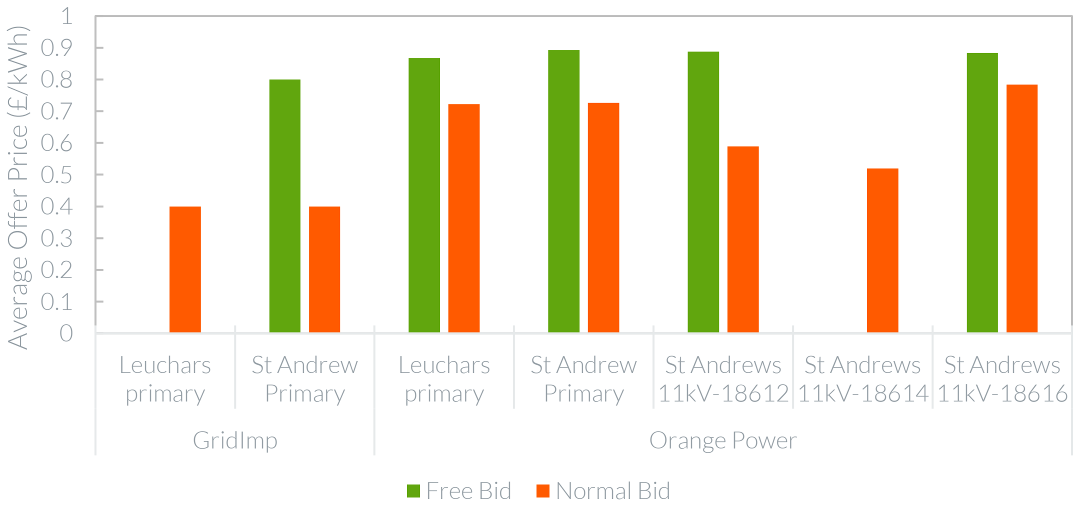


Figure 15 Comparison between offer prices of free bids and normal bids

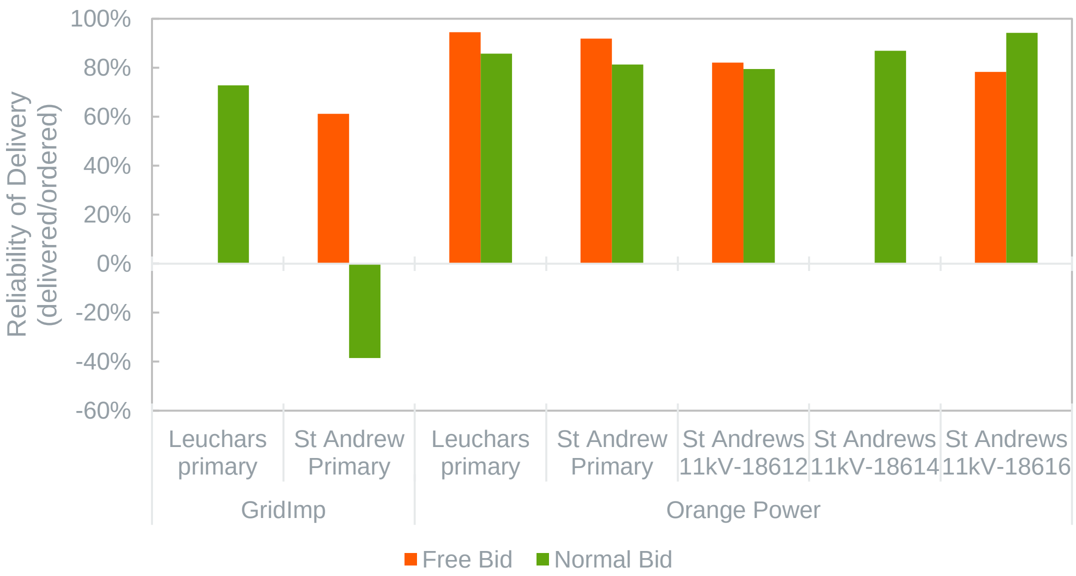


Figure 16 Comparison of reliability of delivery for free bids and normal bids

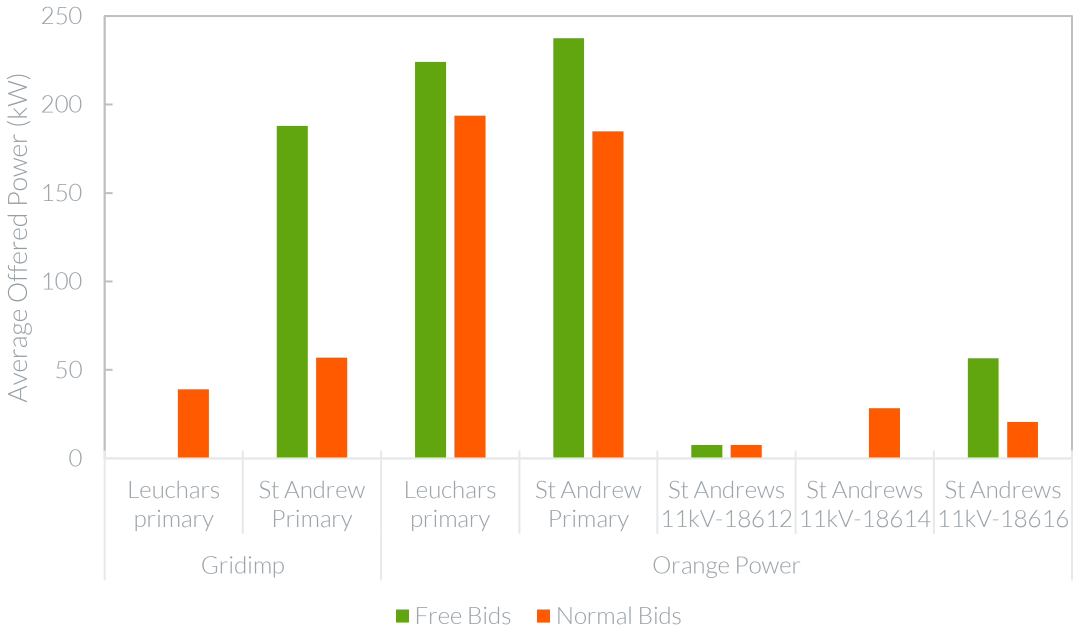


Figure 17 Comparison of average offered power for free bids and normal bids

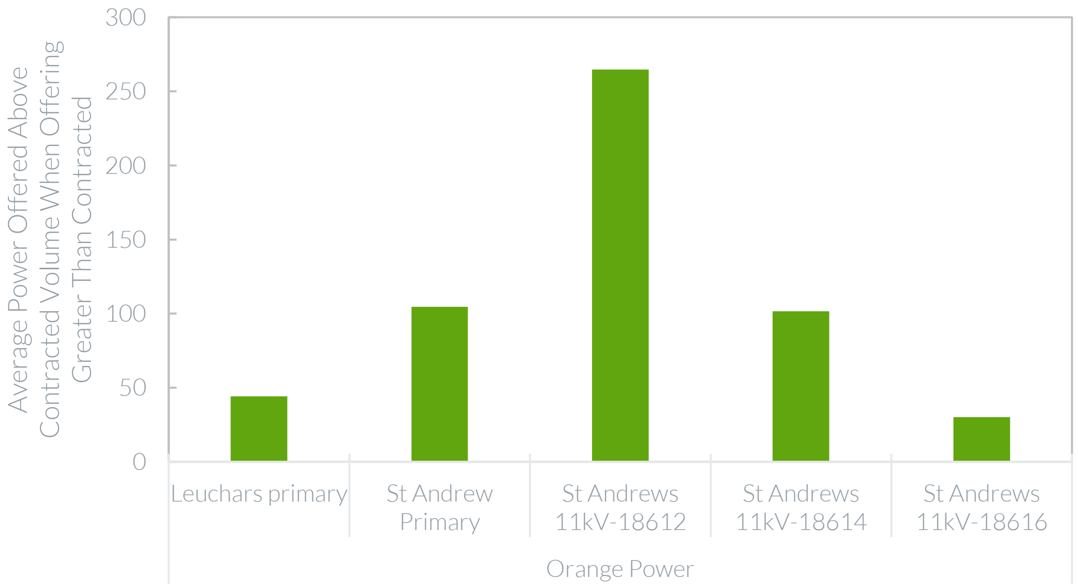


Figure 18 Average power offered above contracted volume when offer exceeds contracted volume

4.1.1.4 Conclusions and Learnings

- Free bidding is, according to the aggregators, a mechanism that will contribute to making more flexibility available and positively impact their business case by enabling additional revenue on non-firm capacity and value stacking in the future.
- Raising the free bids price cap in phase 2 had a positive effect in raising public interest (from aggregators' customers) on flexibility and is a good incentive to encourage participation.
- The current contractual arrangements and payment structure do not make free bids sufficiently interesting for aggregators. While aggregators appreciate the mechanism as extra revenue source, their focus is to fulfil their obligations on availability and get the payment through the availability contract.

- To participate in free bids, the aggregator needs to have short-term flexibility monitoring capabilities.
- The DSO saved 64% of the contracted capacity thanks to the extra capacity made available by the aggregator outside the availability contract (i.e. free bids).
- Even considering the potential savings, the DSO would only consider relying on free bids if there is sufficient market liquidity to make that approach statistically reliable.
- Ultimately, the trial has shown that the free bidding concept works but the current market and system is not mature enough yet to fully leverage this mechanism.

4.1.2 Baseline Design

4.1.2.1 Scope

DSO products for congestion management typically use historical baselines as a basis for the validation and settlement of the delivery. A recent ENA Open Networks study (Workstream 1A, Product 7 2021) suggests widening up the possibilities for FSPs, by allowing nomination baselines when the default baseline in not sufficiently accurate. The scope of the FUSION trial is to assess the performance of nomination baselines against quantitative and qualitative criteria and provide learnings and insights to wider GB industry.

The FUSION trial is using nomination baselines (i.e., D-programmes) as prescribed by the USEF framework. The nomination baseline is defined as the forecast of the generation or demand profile of the asset or portfolio if no flexibility activation would take place. In USEF, the forecast is determined by the Flexibility Service Provider (FSP) and sent to the DSO before a predefined deadline (e.g. gate closure). The DSO can then use this profile to calculate the deviation of the metered data from the planned profile. In general, the choice of method(s) to perform the forecast is left at the discretion of the FSP.

4.1.2.2 Methodology

This objective builds on the analysis carried out in previous the ITLR#2 and ITLR#3[4] reports, evaluating the baseline against the following criteria: Accuracy (including variation and bias), simplicity and inclusivity. The aspects on integrity (potential for gaming behaviour) and stickability are left out of the analysis.

To assess quantitative aspects, the baseline variability against the measured meter data will be calculated using the normalized mean absolute error (Equation 2), which is derived from subtracting the measured meter power (m_t) from the baseline value (b_t) to get the error (d_t) at each time step (t) (Equation 1). This approach has been selected as outliers have less of an effect compared with using the variance, therefore, the normalized mean absolute error is more representative of the general spread of errors, allowing outliers to be addressed separately. The bias will be calculated using the normalized mean bias (Equation 3). Finally, the accuracy will be calculated with the relative root mean square error (RRMSE) (Equation 4), which assesses the error after n values.

$$d_t = b_t - m_t \qquad \text{(Equation 1)}$$

$$nmae_p = \frac{\sum_{t \epsilon T} |d_t|}{\sum_{t \epsilon T} m_t} \qquad \text{(Equation 2)}$$

$$bias_p = \frac{\sum_{t \epsilon T} d_t}{\sum_{t \epsilon T} m_t} \qquad \text{(Equation 3)}$$

$$RRMSE = \frac{\sqrt{\frac{1}{n}\sum_{t\epsilon T} {d_t}^2}}{\frac{1}{n}\sum_{t\epsilon T} m_t} \qquad \text{(Equation 4)}$$

The different parameters are calculated on non-event days and excludes weekends and public holidays.

Finally, the effect that the baseline accuracy has had on the reliability has been assessed by estimating the probability of delivering at least 100% of the FlexOrder once the accuracy is taken into account. The methodology that followed was to:

- Calculate bias for each aggregator at every congestion point
- Calculate standard deviation of error for each aggregator at every congestion point
- Correct D-programme for bias to calculate the best estimate (i.e. the p50) as per Equation 5
- Calculate the number of standard deviations that the FlexOrder is away from the best estimate (i.e. the z-scores) for each ISP (Equation 6)[11]
- Calculate probability of the delivered power being greater than the FlexOrder power by assuming a normal distribution using the z-score lookup tables

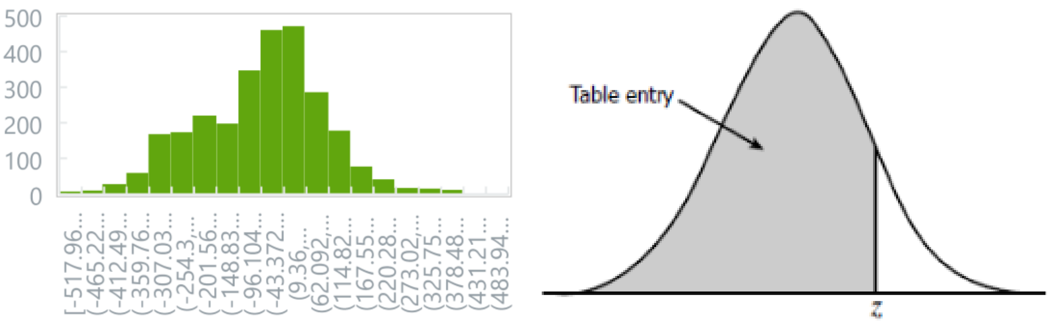


Figure 19 Example distribution of error between D-programme and meter data (for Orange Power at St Andrews) to justify the approximation as a normal distribution to calculate the probability

Average probability of achieving equal to or greater than the FlexOrder power across Phase 2 of the trial

$$p50 = dprogramme \times (1 - bias_p) \qquad \text{Equation 5}$$

$$z = \frac{x - \mu}{\sigma} \qquad \text{Equation 6}$$

Where,

x = observed value = FlexOrder power

μ = corrected D-programme accounting for bias = p50

σ = standard deviation of inaccuracy in baseline

[11] Z-Score: Definition, formula and uses

4.1.2.3 Results & analysis

This analysis has focused on the non-event days of Phase 2 of the trial. Gridimp provide daily meter data therefore this analysis looks at the full trial duration. Orange Power provided meter data for the days that FlexRequests are issued and only a sample of their non-event day data from May and June 2022 that has been used for this analysis. We are therefore not able to comment nor on the performance of the baseline in other months of the year or any recent improvements to Orange Power's baseline accuracy that may have happened since this date.

4.1.2.3.1 Accuracy

The accuracy of Gridimp's baseline has varied significantly throughout Phase 2 of the trial (Figure Figure 20Figure 20). Following feedback after the production of ITLR#3,[4] Gridimp implemented changes to their baseline methodology (as aggregators are able to do with a nomination baseline) that improved the accuracy of their baseline. Prior to these changes Grdimp's RRMSE ranged from -275% to -57%, at the two congestion points where they have implemented flexibility. However, following the changes their accuracy improved to between 33% and 71%. As described in the previous section, an RRMSE value for a good or acceptable baseline should be below 10% or 20% respectively. Therefore, these values still indicate a poor baseline accuracy. To explore this further, the individual portfolio characteristics are assessed below:

- Gridimp – St. Andrews: The baseline accuracy at St. Andrews was initially poor in Phase 2 (RRMSE of -275%). The portfolio consists of a combination of HVAC and a CHP that is on when the district heating provider is not providing heat to its customer. Gridimp changed their baselining method in Phase 2 of the trial from New England model that is also used in the LEM, to manually inputting what the demand or generation is going to be for large periods of time. A typical example of this is in Figure 21. This method led to significant error as the expected demand was set at a constant value for whole days at a time and only reviewed infrequently. The presence of the 220kW CHP also made it more difficult to forecast as whether the CHP was in an on or off state had a large impact on the total demand. Therefore, the D-programmes was reliant on information about the district heating plans on maintenance or expected behaviour and any unexpected events would affect the baseline accuracy. The baseline showed a strong positive bias meaning that the baseline consistently overestimated what the demand turned out to be. Following feedback on the baseline quality, Gridimp reverted back to using the New England Model which saw the baseline accuracy improve to 33% RRMSE (Figure 20Figure 20). The bias also improved significantly from 178% to 0%.
- Gridimp – Leuchars: the accuracy of the baseline for Leuchars was broadly the same pre and post the changes to the baselining methodology (-57% and -71% respectively) (Figure 20Figure 20). The reason for the baseline accuracy being initially better at St Andrews was that the D-programme was consistently set to 0kW and their portfolio consisted of two smaller CHPs that have been operational a low number of hours, therefore, the baseline was straightforward to predict. In the last few months of the trial, the CHPs turned on more regularly that before and also new residential assets were connected, which explains why the improvement in the baseline accuracy may not have been as much as one would expect. The bias has improved from -88% to -23% from before Gridimp implemented changes to their methodology, which means that the impact of tending to underestimate what the demand turns out to be is now less.

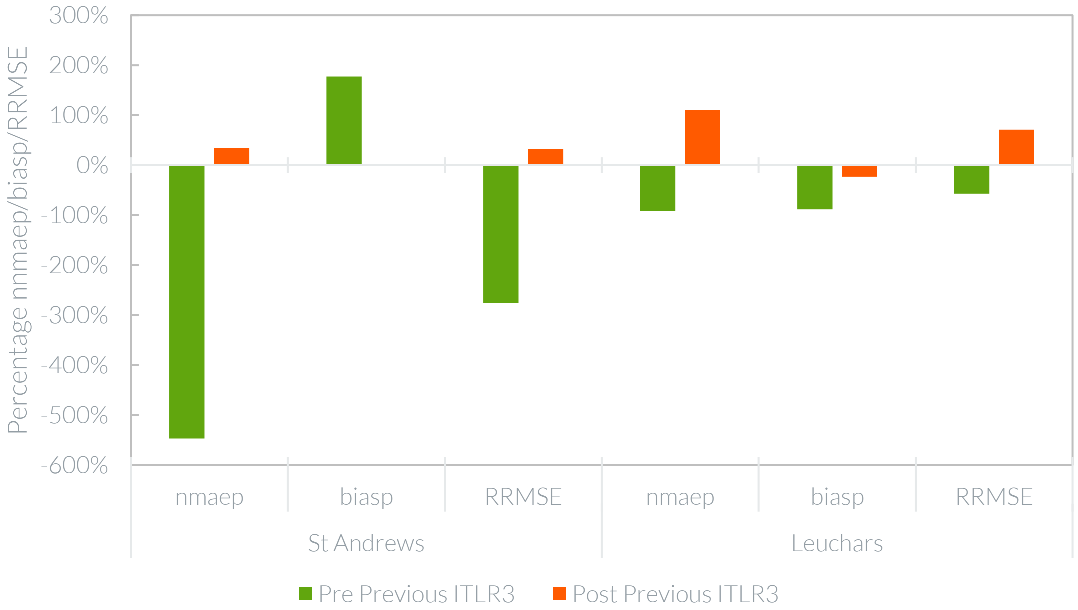


Figure 20 Phase 2 baseline accuracy Comparison for Gridimp Before and After they Implemented Changes to their Baseline Methodology Following ITLR#3[4]

Figure 21Figure 21 shows Gridimp's baseline at St Andrews for various days in June to represent an example of how Gridimp's constant D-programme affected the accuracy of the baseline.

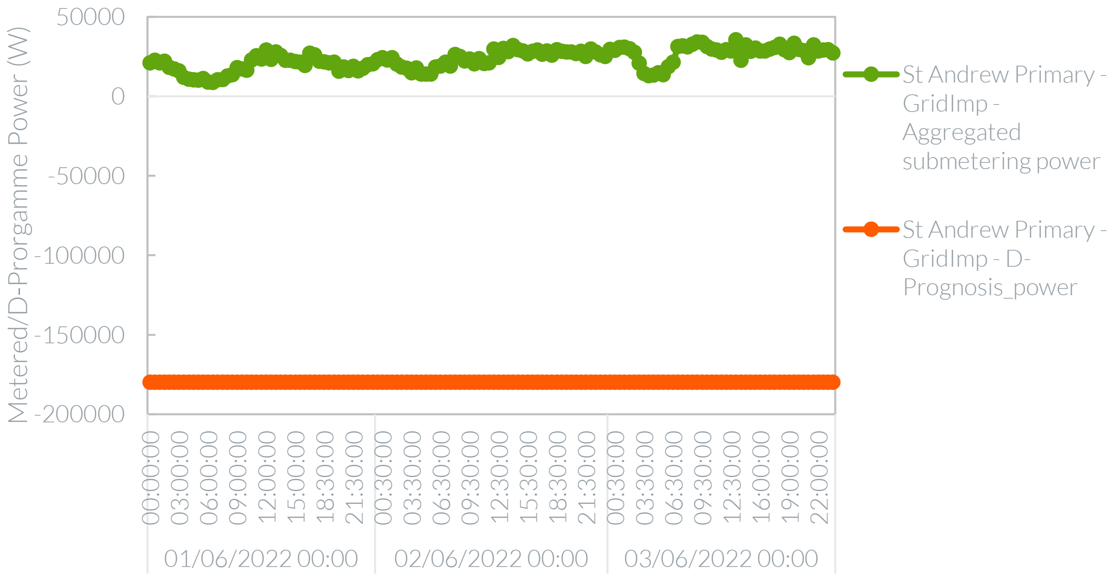


Figure 21 Gridimp – St Andrews D-programme vs sub-meter measurements. Note that generation is denoted as negative power

The accuracy of Orange Power's baseline, for the period studied, ranges from an RRMSE of 63 to 183% across the different congestion point. To explore this further, the individual portfolio characteristics are assessed below:

- Orange Power – St. Andrews: This portfolio is composed of EV chargers, water heaters, and solar PV. Orange Power's forecasting method consists of forecasts per technology supported by machine learning. The RRMSE was 69% which is an improvement on the results from Gridimp but still outside the range of what would be considered acceptable for a baseline. OP struggled initially with data feeding issue and with allocating resources to focus and improve baselines. Rather, they decided to under-promise and overdeliver to avoid the penalty. To assess the accuracy of the forecast, an accuracy factor would have to be applied to correct the bias. Furthermore, OP added new customers which then did not align with the forecasts in the baseline.

- Orange Power – Leuchars: This portfolio includes EV chargers and other residential assets. Orange Power uses the same forecasting method as for the St. Andrews' portfolio. This portfolio forecast is the most accurate out of all of them, at a 63% RRMSE. Orange Power's portfolio at Leuchars consists of a higher proportion of solar PV than at St Andrews which have a more predictable usage pattern for the machine learning algorithm to predict.
- Orange Power – 11kV Feeders: For the feeders, Orange Power decided to use a combination of the machine learning algorithm and manual corrections where appropriate. This additional step was added because of the low number of assets connected to each point, which meant that the behaviour of one or two customers can have a large impact on the demand. Orange Power manually check each forecast created by the machine learning algorithm and if any of the parameters is outside the expected intervals, the D-programme is resubmitted to manually correct them. Despite this additional check the RRMSE for the 11kV feeders was still outside of the range that is considered acceptable (ranging from 103% to 183%). Another contributory factor to the error was that Orange Power had a fault where the same D-programme was received for all three feeders, which has also impacted their results.

Orange Power had a positive bias as each of the congestion point, indicating that they are overestimating what their demand is going to be day-ahead. This means that when the settlement is calculated, the estimated delivered flexibility is likely to be less than the actual flexibility that is delivered.

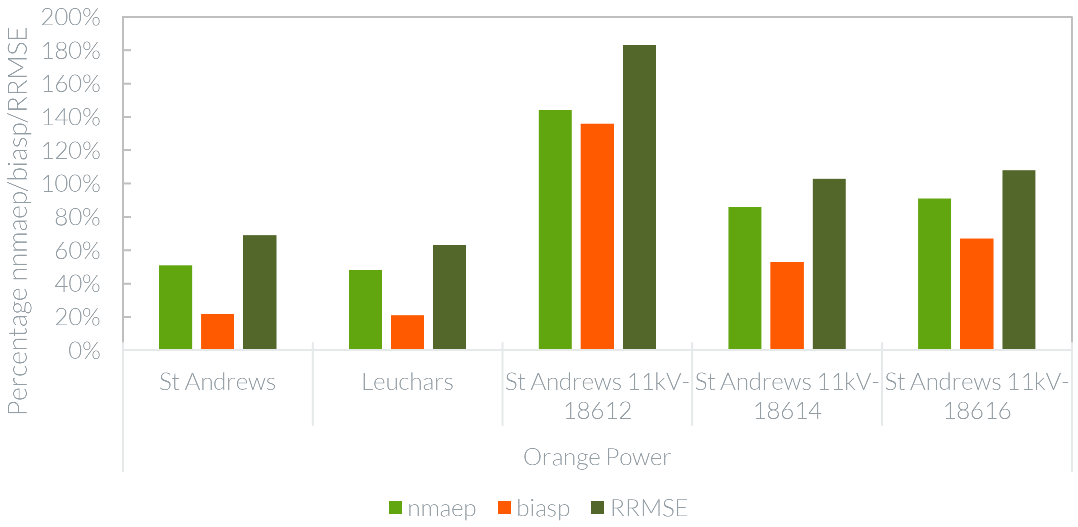


Figure 22 Phase 2 baseline accuracy in May and June 2022 for Orange Power

The importance of the baseline accuracy is emphasised when examining the ISP with the largest measured delivery of flexibility in the trial so far (Figure 23Figure 23). According to the settlement calculations 266kWh of flexibility was delivered based on subtracting the meter power from D-programme. In reality, as shown below, the delivery was a lot less because the baseline was significantly overestimating what the demand would be. By taking the metered demand before the flexible delivery, the reduction in the demand is closer to 110kWh of 40% of what was calculated for settlement. This emphasised the importance of an accurate baseline.

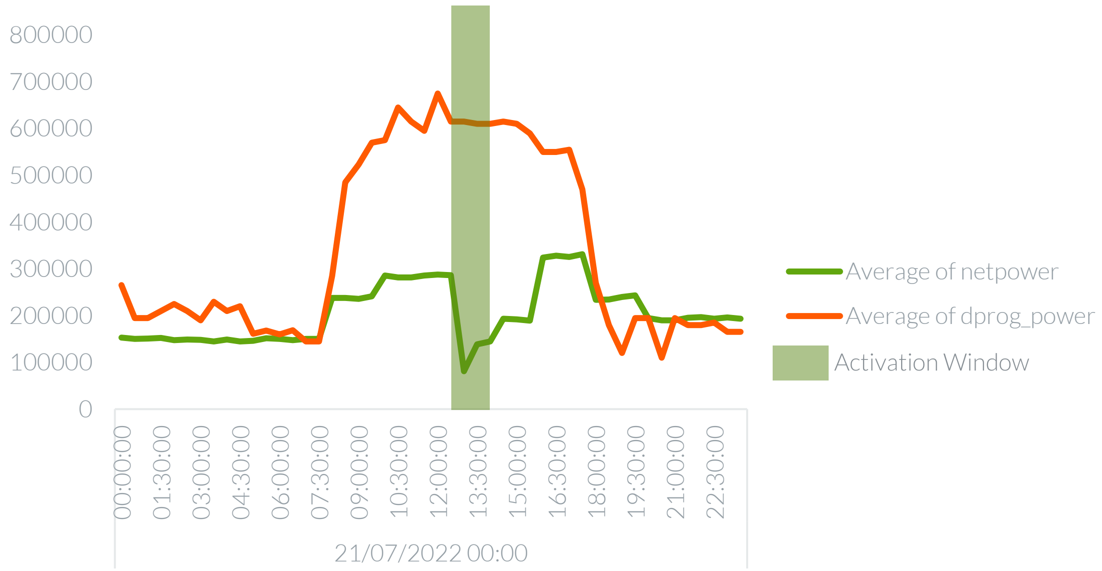


Figure 23 Comparison between D-programme power and meter power for day with highest delivered flexibility. Flexible response is much lower than what will be calculated for settlement due to overestimate of D-programme

The accuracy of the baseline between Phase 1 and 2 of the trial has been compared. Orange Power's baseline accuracy reduced by approximately 5% from Phase 1 to Phase 2 and the other notable change is in the bias at Leuchars which changed from a negative bias (i.e. overestimating the outturn) to a positive bias.

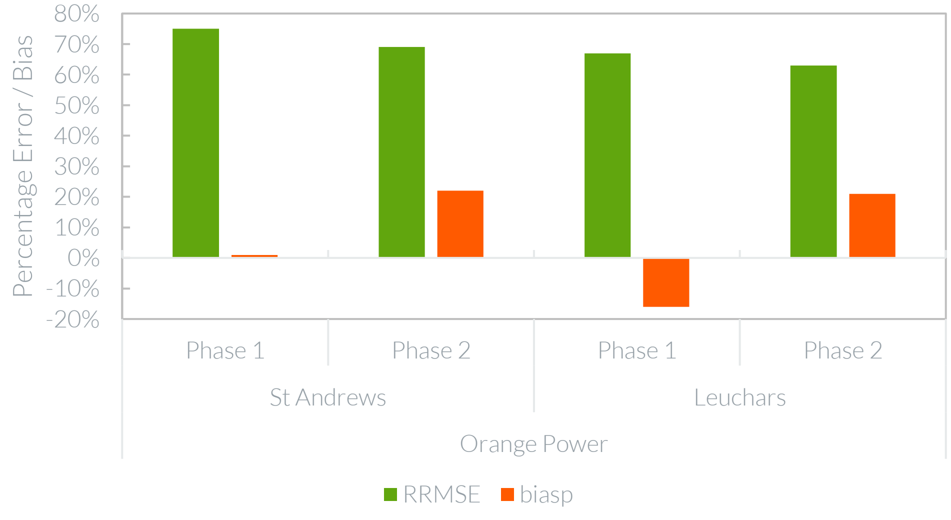


Figure 24 Comparison between Phase 1 and Phase 2 baseline accuracy

Since the previous interim learning report (ITLR#3),[4] we have also extended our comparison of different baselining methodologies to include meter before and meter after (MBMA). An MBMA baseline is a flat baseline at the same level as the pre-activation meter reading. Metering readings of the activation window can then be compared with the baseline to calculate the delivered flexibility.

The accuracy of an MBMA can be determined by calculating the error between the meter reading before with the meter reading during activation. We have calculated the RRMSE in this way and presented it alongside our analysis on the use of a historical baseline (calculated using the ENA's online baselining tool[12]) that was carried out as part of the previous interim learning report and results from a nomination baseline observed in the trial (Figure Figure 25).

The results shows that MBMA and historical baselines performed better in terms of RRMSE compared with the aggregators' nomination baseline. A historical baseline was still not able to achieve an accuracy considered acceptable for baselining and MBMA scored on the borderline of what is considered acceptable. While an MBMA baseline did perform the best of the three baseline methods, it is worth noting that there is a greater risk of gaming associated with this method and that this must be factored in when considering its use.

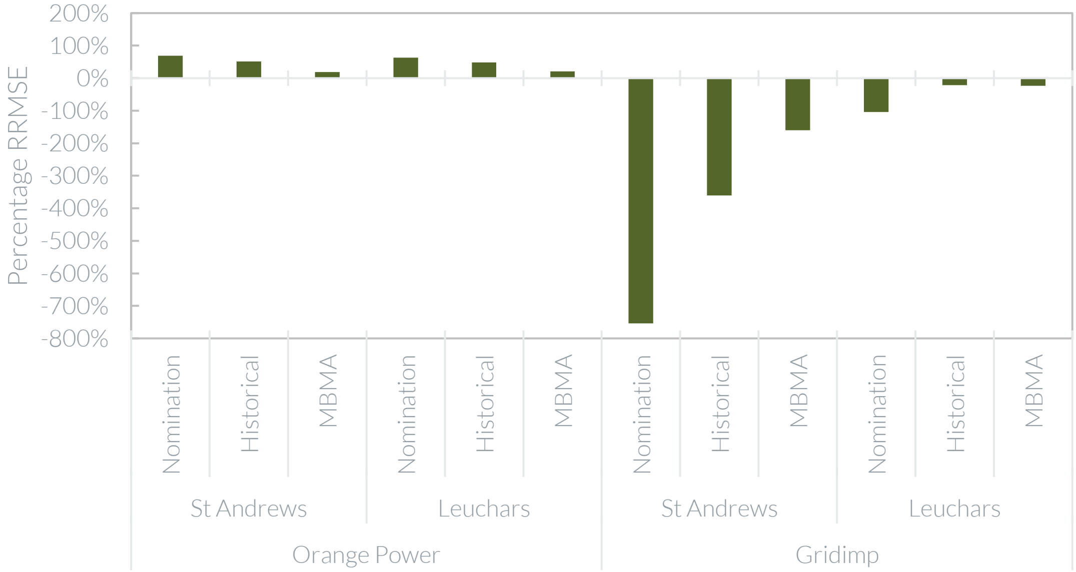


Figure 25 Comparison of RRMSE for Nomination, Historical and MBMA Baselines in May and June 2022

We subsequently explored whether the DSO could apply a same day adjustment to the aggregator's nomination baseline in order to improve the accuracy and bias. We adjusted the baseline based on the meter reading at 11am on the day of delivery to account for any significant bias in either direction of the baseline (Figure 26). We chose the same months for Orange Power as the analysis above (May and June 2022) due to data availability but for Gridimp analysed the months of November and December 2022 after the aggregator had implemented the changes to their baselining methodology.

The example below of how a same day adjustment is applied (Figure 26) shows one of the main challenges around applying a same day adjustment. Namely the impact of what time of day is chosen. For larger load will less variability this has less of an impact however where the flexible loads are small, as shown in the example, applying an adjustment may in some instances not help improve an aggregator's baseline.

[12] Refer to ITLR3 Section 4.4 for more detail on the methodology and results.

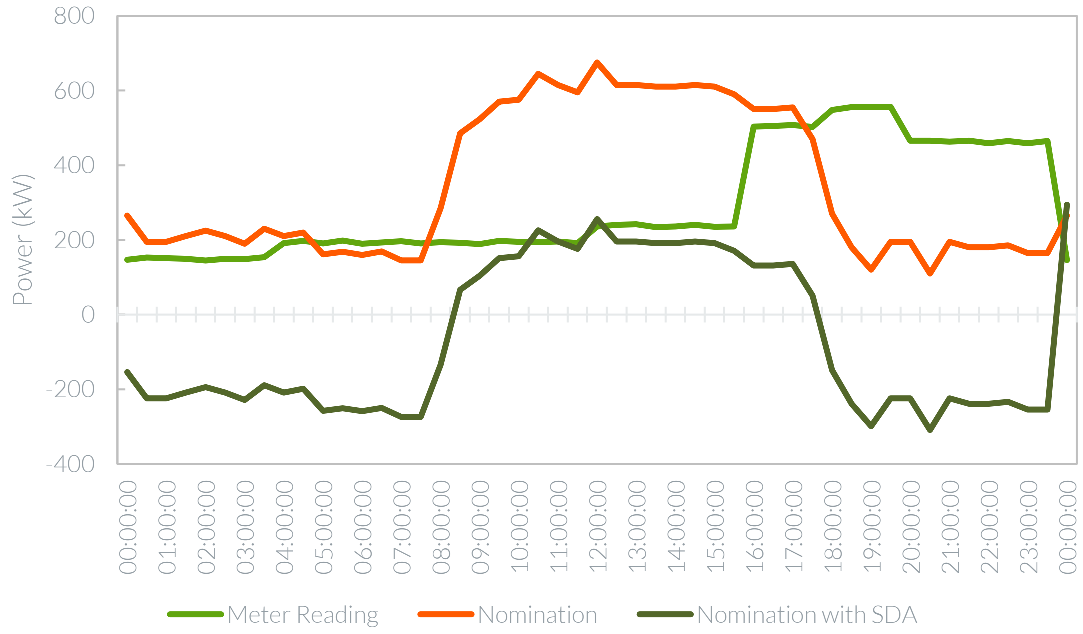


Figure 26 Application of Same Day Adjustment to Nomination Baseline for Example Day. Error between the meter reading and nomination baseline with SDA at 11am is equal to zero.

Overall, the results of this assessment (Figure 27) shows that applying a same day adjustment to the nomination baseline does not provide a noticeable benefit to the baseline accuracy for either aggregator at the congestion points studied. When focusing on Orange Power specifically, while the two accuracy metrics remain approximately the same, a same day adjustment causes the bias to switch from being a positive bias to a negative bias with an even large magnitude at both congestion points. The practical implications of this are that applying this adjustment will mean that the DSO would be systematically underestimating Orange Power's power demand and therefore underestimate how much flexibility is delivered and the resultant payment for the delivered flexibility.

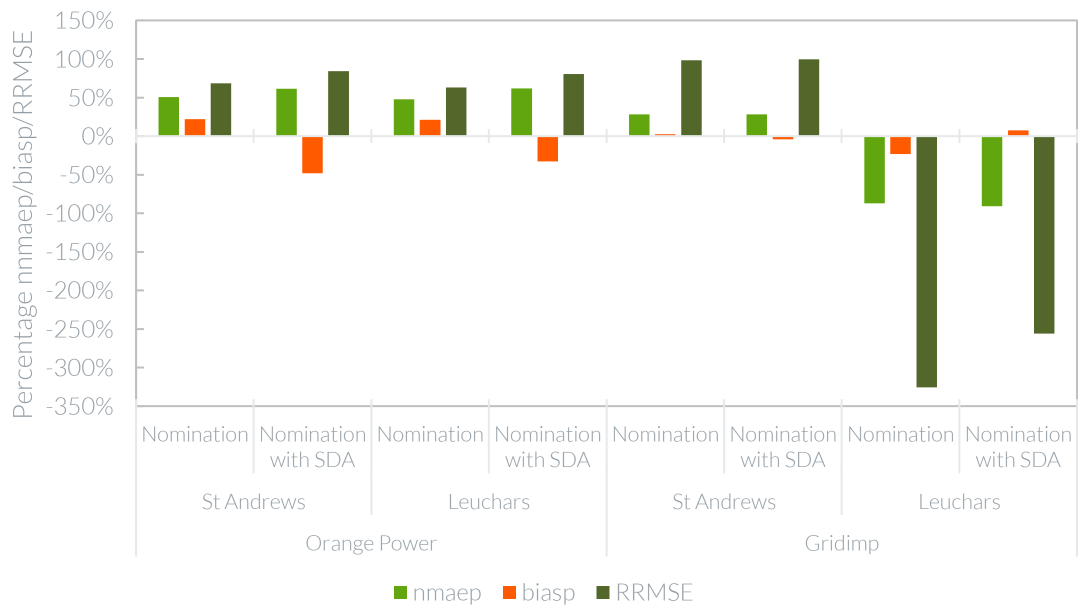


Figure 27 Comparison of Nomination Baseline with and without a Same Day Adjustment

Finally, we calculated the reliability after taking into account the accuracy of the aggregators D-programme baselines (

Table 13

Table 13). The results are presented in terms of the probability that aggregators achieved at least 100% of the FlexOrder and show a range of probability between 50-77%. These probabilities signify that it is difficult to be sure that the required flexibility has been delivered. The primary reason for this is the large standard deviation in the baseline error, which makes it more difficult to be confident of how much flexibility the aggregator has delivered. These results emphasize the need for an accurate aggregator baseline to guarantee that the procured flexibility is delivering benefit to the network.

Table 13 Reliability of aggregators delivering greater than FlexOrder power after accounting for baseline accuracy

		Reliability of Aggregators Delivering Greater than FlexOrder Power After Accounting for Baseline Accuracy*
Gridimp	Leuchars primary	77%
	St Andrews Primary	59%
Orange Power	Leuchars primary	53%
	St Andrews Primary	51%
	St Andrews 11kV-18612	60%
	St Andrews 11kV-18614	53%
	St Andrews 11kV-18616	50%

*The baseline accuracy used for Gridimp in this assessment reflects their results after the changes they implemented to their baselining methodology

Overall, in the Phase 2 interviews, the aggregators and the DSO supported the idea of ongoing monitoring and more regular feedback on the accuracy of the baselines. One option to address this is to add clause in the FSA to include monitoring responsibilities.

Other mechanisms to encourage reliability could also be implemented such as accounting for the accuracy of the baseline in the calculation of reliability or the settlement. In the longer-term, there could be a retrospective reliability metric to select bids based also on their historical performance, carefully considering the weight this could have in the decision process. SP Energy Networks stated that before considering whether to implement these or other mechanisms as a requirement, an enhanced understanding of the baseline would first be necessary.

4.1.2.3.2 Simplicity

The level of effort has increased in Phase 2 as the aggregators have trialled alternative approaches to improve the accuracy of their D-Programme including, in the case of OP for the 11kV feeders, adding a manual check to verify and amend the output of the machine learning algorithm. While this has reduced the simplicity, this shows aggregators capitalising on one of the main strengths of nomination baselines: the ability to adapt and change the methodology based on knowledge of the assets rather than having to follow a prescriptive historical baseline methodology OP expressed a preference for D-programmes in their Phase 2 interview.

4.1.2.3.3 Inclusivity

The aggregators participating in the trial have indicated that they are positive about the use of D-programmes since it allows to baseline the diversity of assets in their portfolios. The aggregators have indicated, however, that intraday submission of D-programmes (after FlexRequest has been sent by the DSO) would be beneficial to improve accuracy.

4.1.2.4 Conclusions and Learnings

The FUSION trial has successfully used D-programmes (i.e. nomination baselines) for flexibility delivery quantification and settlement.

The accuracy shown by the D-programmes varies per portfolio type. The accuracy of one of the aggregators has improved from Phase 1 into Phase 2 and the other has seen challenges moving into Phase 2. The overall accuracy of the D-programmes is still poor when compared to what literature define as "good" or "acceptable" baseline methodologies. It is worth noting that the portfolios are relatively small, which generally are more difficult to forecast than bigger portfolios.

In Phase 2, aggregators have been capitalising on the opportunity that nomination baselines offer to trial different baseline methodologies to improve the accuracy of their forecasting. Gridimp has trialled inputting a constant baseline to represent the on or off state of their CHPs. This trial has shown that the previous baseline methodology they used, the LEM average, was more accurate, therefore, Gridimp have switched back to using the LEM average. Gridimp also stated that they would introduce an adjustment to the baseline with latest data before submission day-ahead to better correct to the large changes in the state of CHPs. This has contributed to the improvement seen in Gridimp's baseline accuracy and bias.

Orange Power has tested a baseline methodology based on a machine learning algorithm with manual oversight at the 11kV feeders to account for the smaller flexible capacity that is connected.

Analysis on the accuracy of different baselining methodologies showed that nomination and historical baselines were not able to achieve an accuracy that is considered "acceptable" for baselining, however an MBMA baseline achieved on the borderline of "acceptable". It is worth noting that there are gaming risks associated with MBMA baselines that have not been assessed as part of this analysis. Additionally, applying a same day adjustment to the aggregator's nomination baseline did not improve the measured accuracy and bias and therefore the DSO would not have benefited from retrospectively applying this adjustment.

A review of the trial reliability after considering the accuracy of the aggregators D-programme baselines has shown that challenges remain around verifying that the aggregator has delivered the required flexibility. The primary reason for this is the large standard deviation in the baseline error, which makes it more difficult to be confident of how much flexibility the aggregator has delivered. This emphasises the important of baseline accuracy in a well-functioning flexibility market.

4.1.3 Market Coordination Mechanism (MCM)

4.1.3.1 Scope

During FUSION trial phases 1 & 2, flexibility trading was performed according to the USEF market coordination mechanism (MCM), which facilitates trading and consists of five phases – contract, plan, validate, operate and settle. During the trial, the contract phase was done at the procurement stage whereas the phases from plan to operate were conducted day-ahead and intraday. The settle phase occurred once per month.

The scope of this objective is to evaluate the experience of the difference parties using this mechanism as well as the fit to the different services.

4.1.3.2 Methodology

This objective is evaluated in a qualitative and quantitative manner. The qualitative element was covered through interviews and questionnaires that DNV conducted with aggregators and SP Energy Networks during the previous report and we only provide a summary of our learnings. The qualitative analysis covers:

- Experience of aggregators and DSO using the MCM
- What is the FlexReservationUpdate value to the AGR (by bringing flexibility to other markets)?
- Partial FlexOrders

The quantitative analysis covers:

- MCM impact on reliability
- MCM impact on efficiency linked to DSO forecast accuracy
- Rebound considerations

4.1.3.3 Results and Analysis

The qualitative analysis of the MCM has not changed since the publication of ITLR#3[4] in December 2022 and therefore a summary of these learnings is provided below.

Experience using MCM: The experience with MCM has been positive, driven by the fact that the whole process is defined in a single system and there is no need to use different platforms for the different trading phases. Aggregators and SP Energy Networks made suggestions for improvement on contract timing aspects (week-ahead availability contracts) and bid selection (inclusion of carbon emissions information).

Partial FlexOrder: Phase 2 had the ambition to trial partial FlexOrders, however, this was not possible due to FFP limitations in the UFTP implementation. Aggregators proved to be capable to submit partial FlexOffers. The DSO would find this feature particularly useful in their operation of the FFP, in situations in which the need for flexibility intraday is lower than the requested amount day ahead.

FlexReservationUpdates: FlexReservationUpdates is a USEF concept that allows the DSO to release the aggregator from their availability contractual obligations when flexibility is not needed. Aggregators believe that FlexReservationUpdates bring significant value to them.

The quantitative analysis is provided in the following sections.

MCM impact on reliability

In theory, the MCM could have a positive impact on reliability because:

- It allows portfolio bids which would enable more flexibility to aggregators to choose assets that are available in the moment of delivery as well as the diversification of assets to provide a service.
- It allows shorter timeframes for flexibility trading which allows representation of the close to real time status of the flexible assets.

The full analysis on reliability during the FUSION trial can be found in Section 3.3. The trial results show that aggregators have achieved reliability of 73% or above at all congestion points except for Gridimp at St Andrews. From October 2022, Gridimp resolved the issues with their baseline and then even Gridimp at St Andrews achieved a reliability of 69%. When focusing solely on Orange Power, the average reliability is 88%

Since there is not enough data on BaU DSO flexibility services, the reliability assessment needed to be performed against other trial results.

Reliability results in other flexibility trials

- BaU – Energy Networks, ENWL, UKPN, SSE and Western Power were consulted. Small volumes have been traded, with currently no data available.
- Other available trial data (Table Table 14Table 14) – the reliability values found are 58-72%, averaging **65%.** These values are not fully comparable. For further assessment, the key partners of these main projects could be further consulted.

Table 14 Flexibility reliability in DSO services obtained in GB innovation projects

Project	Key partners	Calculation method	Final value	Main References
TRANSITION & LEO project (2022)	Origami (now Baringa), SSEN, Electricity North West	Reliability index = supply delivered/ supply purchased	Weighted average is 72%.	Transition & project LEO – Market Trials Report (Period 1)
Cornwall LEM (2019) Phase 1 = The Visibility Plugs and Socket (VPaS) project (May-Aug 2019) Phase 1 and 2 (May-Dec 2019)	Imperial College London, WPD, Centrica	Delivery proportion = service delivered (MWh)/service procured (MWh)	Phase 1 – on average, 60% of the expected MWh were delivered. Phases 1 and 2 average = 58.3%	Cornwall LEM Flexibility Market Platform LEM Flexibility Market Platform Design and Trials Report Cornwall LEM report repository
ENTIRE (2019)	WPD	Service reliability is acceptable if dips in requested output are not below 95%.	22% of events were continuously above 95%, 41% were above 63%.	Visibility Plugs and Socket – Phase 1 interim learning report ENTIRE – operational trials report ENTIRE Project Website

Comparison

The flexibility delivery under FUSION trial is between 3% and 30% more reliable than the one calculated under other DSO flexibility trials.

Project partners acknowledge that the reliabilities in the different trials are not fully comparable, however this is the only data available to perform such calculation.

Hence, we recommend to DSOs to register and publish this data for the wider benefit to industry.

MCM impact on efficiency linked to DSO forecast accuracy

Background and hypothesis

The MCM could have a positive impact on efficiency because:

- It enables shorter timeframes for the DSO to have a more accurate view on the grid needs and presumably a lower forecasting error.
- The DSO would need to procure less flexibility to account for potential forecasting errors

This analysis looks into the load forecast accuracy for longer timeframes (up to 4 days ahead) which aligns with the common DSO BaU operations, and shorter-term forecasts (day-ahead, and intraday) that characterises the USEF MCM. The difference in accuracy would determine the potential impact that USEF could have on flexibility procurement efficiency.

Quantification

The load forecast is used by the DSO to determine the required volume of flexibility. In practice, the load forecast includes a certain inaccuracy. This inaccuracy leads to a bandwidth in the forecast. To mitigate the impact of an inaccurate forecast, flex procurement needs to be based on the upper bound of the load forecast to account for this inaccuracy. This could lead to a higher flexibility procurement than necessary. This analysis covers the load forecast inaccuracy for 5 congestion points: Leuchars, St Andrews, feeder 18612, feeder 18614 and feeder 18616.

The questions answered in this analysis are:

- How does the accuracy of the forecast vary in the days before the event and what does that tell us about when flexibility should be procured?
- How does the inaccuracy of the forecast influence the DSO procurement strategy?

This exercise is performed for the service window 10:00 – 18:00 because the peak of the day generally falls within this period, see Figure 28graphs below. The analysed period is October 2021-June 2022. Two datasets are analysed: the actual metering data of the congestion points and the forecasted load.

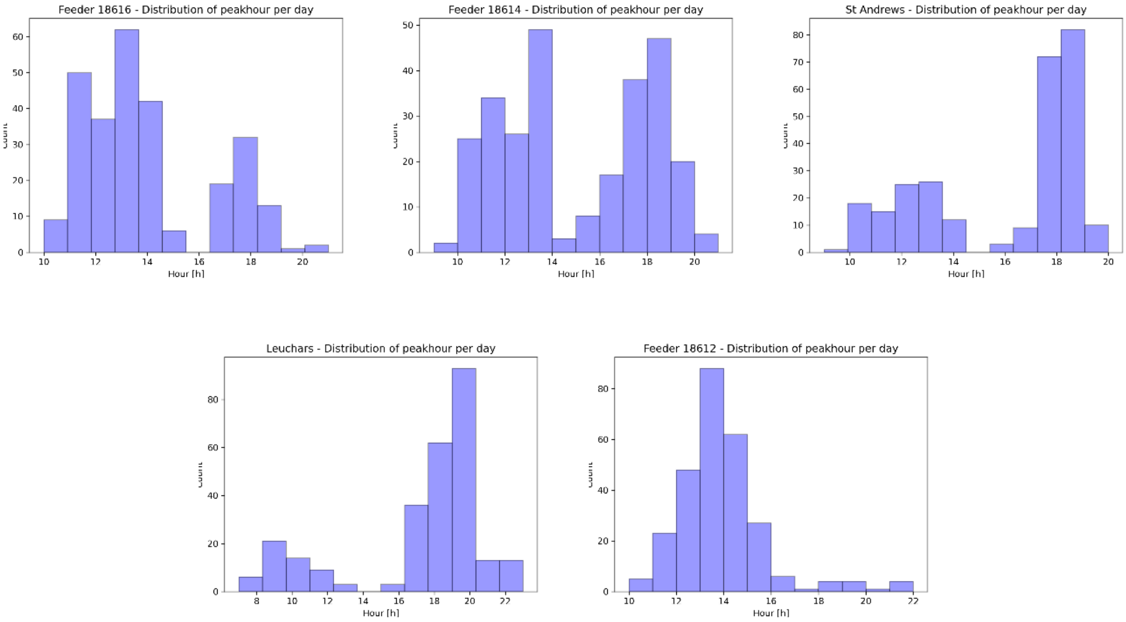


Figure 28 Distribution of peak hour per congestion point

The forecast of mid-day (12:00) is taken, in order to have one forecast datapoint per day. Then the difference between the forecast and the actual metering data is calculated per *forecast day* [Δ = Actual - Forecast]. Forecast day is here defined as 4, 3, 2, 1 days before and intra-day. This results in a load difference between the forecasted load and the metering data per day. Then, the difference is divided by the Forecast [λ = Δ / Forecast], to get the inaccuracy in a percentage (represented by symbol λ).

This exercise is repeated for all metering datapoints, which is about 5000 per congestion point. The inaccuracy is then plotted in a distribution graph to show the median and the spread of the inaccuracy.

When the inaccuracy percentage is positive, the forecast is lower than the actual, thus more flexibility should be procured than forecasted.

Flex procurement can include the load forecast inaccuracy to mitigate the impact of an inaccurate forecast. Flex procurement on day *i* would be as follows:

$$\text{Flex procurement}_{\text{day } i} = \text{Forecast}(1+\lambda_{\text{day } i}) - \text{Rating}$$

All results are included in the tableTable 15 below. For one congestion point (Leuchars) the distribution plots of the load forecast inaccuracy are included in Figure 29Figure 29. In the graphs, the median and the standard deviation is given. In this case, the median is negative for each day, indicating a slight overall overestimation of the forecast. That would mean that currently, flex procurement is also slightly overestimated. As the distribution curve is normally distributed, we can assume a 68% confidence as one standard deviation and 95% confidence as two standard deviations. 68% confidence interval means that 68 samples of the datapoints lie inside the upper and lower bounds of the standard deviation.

For example, for the intraday forecast the median inaccuracy is -0.56% and one standard deviation is 11.02% (inaccuracy of 10.46%). A less risk-based approach would be taking two standard deviations (95% confidence) and leads to an inaccuracy of 21.48%.

Table 15 Load forecast inaccuracy results per congestion point, columns are median (M), 68% confidence and 95% confidence

Congestion point	Load Forecast Inaccuracy														
Days before	Intra-day			1			2			3			4		
	M	68%	95%	M	68%	95%	M	68%	95%	M	68%	95%	M	68%	95%
Leuchars	-0.6	10.46	21.48	-0.8	10.51	21.81	-0.9	10.65	22.23	-0.7	11.25	23.9	-1.2	11.29	23.82
St Andrews	-0.3	6.79	13.83	-0.4	6.87	14.11	-0.2	7.39	14.94	0	7.89	15.74	0.03	8.36	16.69
St Andrews 11kV-18612	-0.9	13.88	28.68	-1	14.16	29.31	-0.6	14.75	30.13	-0.5	15.3	31.1	-0.6	14.45	29.49
St Andrews 11kV-18614	-3.6	121.7	246.9	-3.8	122	247.7	-4.3	122.4	249	-4.3	122.8	249.9	-4.5	123.1	250.6
St Andrews 11kV-18616	-1.6	10.04	21.71	-1.9	10.11	22.12	-1.6	10.35	22.33	-1.5	10.57	22.64	-1.2	10.74	22.7

The results indicate that the accuracy and the confidence of the forecast is generally better for shorter timeframes than longer timeframes. However, this difference is not relatively small ranging from 1 to 3% improvement in intraday timeframes.

How would this affect the DSO procurement?

The DSO would account for the risk of any potential forecast errors when procuring flexibility. The results tell us that procuring flexibility within a shorter timeframe following the USEF MCM, the DSO would need to procure 1-3% less flexibility compared to longer procurement timelines (3-4 days ahead).

The effect of the forecast accuracy in the overall DSO procurement strategy is further developed in Section 4.1.4.

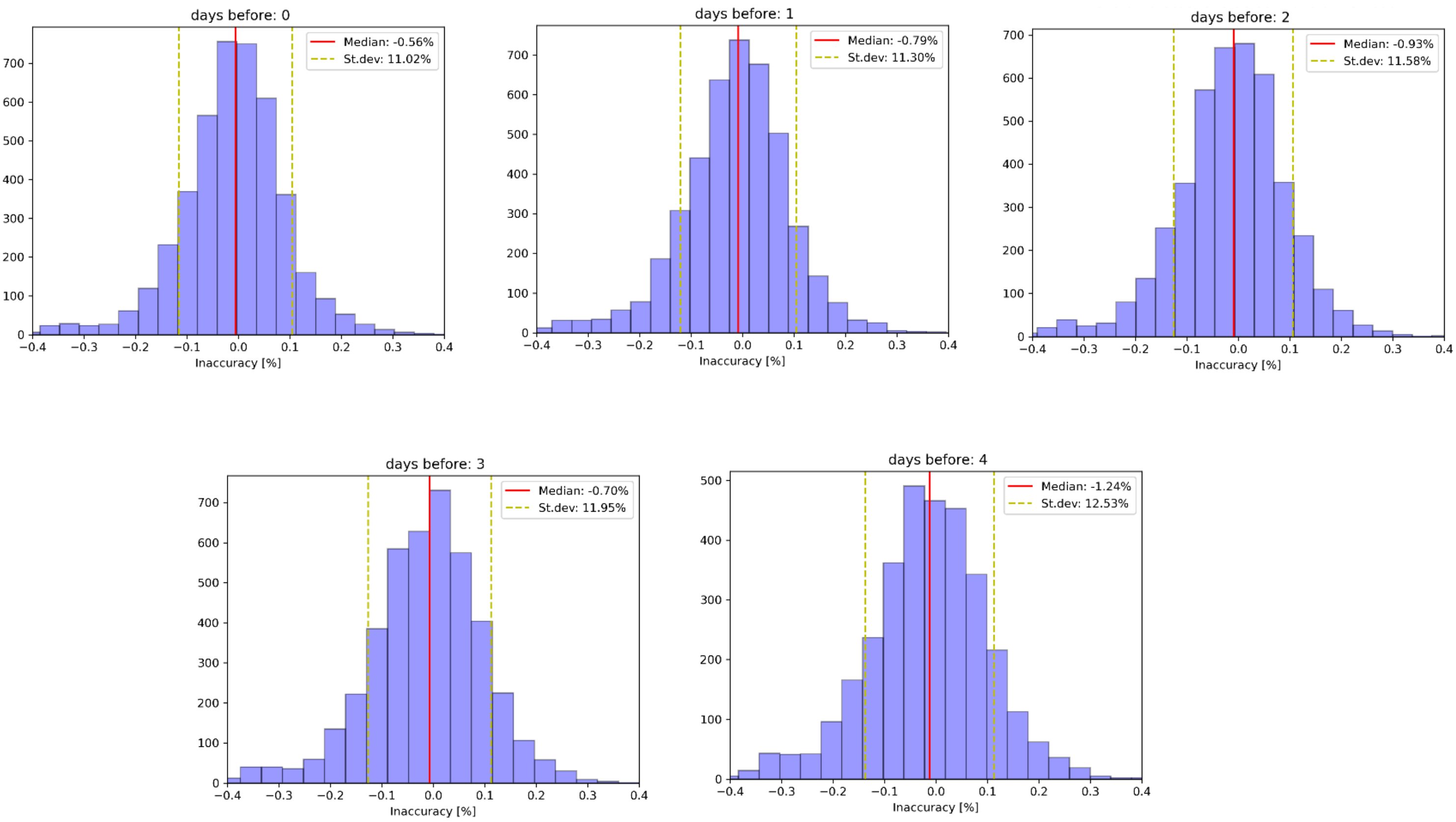


Figure 29 Distribution figures of load forecast inaccuracy of congestion point Leuchars

Rebound considerations

Phase 2 had the ambition to incorporate the rebound effect into the flexibility procurement. The MCM allows for the aggregators to provide rebound forecast attached to their FlexOffers. However, this was not possible because aggregators did not have the capability to forecast the rebound effect of their offers. Next to this, it was considered to measure the rebound effect based the difference between delivery and the baseline outside the delivery period. This approach was also not possible due to poor baseline quality.

Instead, project partners decided to quantify the potential rebound effect on the FUSION trial following a theoretical approach. The outcome of this exercise was used by project partner Imperial College London in their report Role and value of FUSION concept in supporting cost effective electricity system decarbonisation.

DNV quantified a representative FUSION rebound following this methodology:

1) Research the theoretical rebound (%) based on literature;

2) Calculate the weighted theoretical rebound per aggregator portfolio per congestion point;

3) Calculate the additional energy that would need to be procured to counteract any rebound that would have a negative impact in each congestion point;

The following table gives an overview of DNV's literature and desktop research into the rebound effect per technology identified at the aggregators Orange Power and Gridimp. The second column gives an indication of the rebound effect. The rebound effect is defined as a percentage of the flex volume [MWh] that would return after a general flex event. The description column gives a description of the source or DNV commentary.

Table 16 Rebound band per technology

Asset type	Rebound [%]	Description
EV	40% (lower band), 70% (higher band)[13]	For EVs there is a difficulty to assess the rebound as it is very situation dependant (e.g., charging behaviour, capacity of connected EVs during and after the flex action). The 40-70% bandwidth is assumed because EVs are likely to be charging already the next period (after the flex event) and it would only prolong the period of charging. When a flex event occurs in the afternoon, it could mean that EVs would not charge 100% due to the EVs leaving the charging station.
Heatpump/Water heater	71.4%[14]	Retrieved from a science journal; based on air-to-water heat pumps for space heating; the study was conducted for a residential building in Spain; duration of flex event was two hours.
Battery+solar	54% (lower band), 84% (higher band)[15]	Difficult to assess the rebound, as it is very situation dependant (e.g., charging & discharging behaviour, capacity of connected battery during and after the flex action, timing of recharging after flex event); rebound efficiency of 14% is added to the lower and higher band.
Other DSR	50%[16]	Due to lack of insights on the particular technologies participating in this group, an assumption was made.
CHP	0%[17]	There is no rebound affect visible, when using CHP for a flex action; CHP are only used as backup system (when district heating is malfunctioning); however, the operating system predominately will activate boilers for the backup heating.
HVAC	75%[18]	Retrieved from a science journal; assessed the rebound effect on the Thermostatically Controlled Loads (TCLs) when using HVAC and Electric Water Heaters for demand response actions; analysis was conducted by designing a 500-house residential neighbourhood.

[13] DNV internal, comments from aggregator

[14] Kathirgamanathan, A., Péan, T., Zhang, K., De Rosa, M., Salom, J., Kummert, M., & Finn, D. (2020). Towards standardising market-independent indicators for quantifying energy flexibility in buildings. Energy And Buildings, 220, 110027. doi: 10.1016/j.enbuild.2020.110027

[15] DNV internal

[16] DNV internal

[17] Comments from aggregator

[18] S. Halbe, B. Chowdhury and A. Abbas, "Mitigating Rebound Effect of Demand Response using Battery Energy Storage and Electric Water Heaters," 2019 IEEE 16th International Conference on Smart Cities: Improving Quality of Life Using ICT & IoT and AI (HONET-ICT), 2019, pp. 095-099, doi: 10.1109/HONET.2019.8908081.

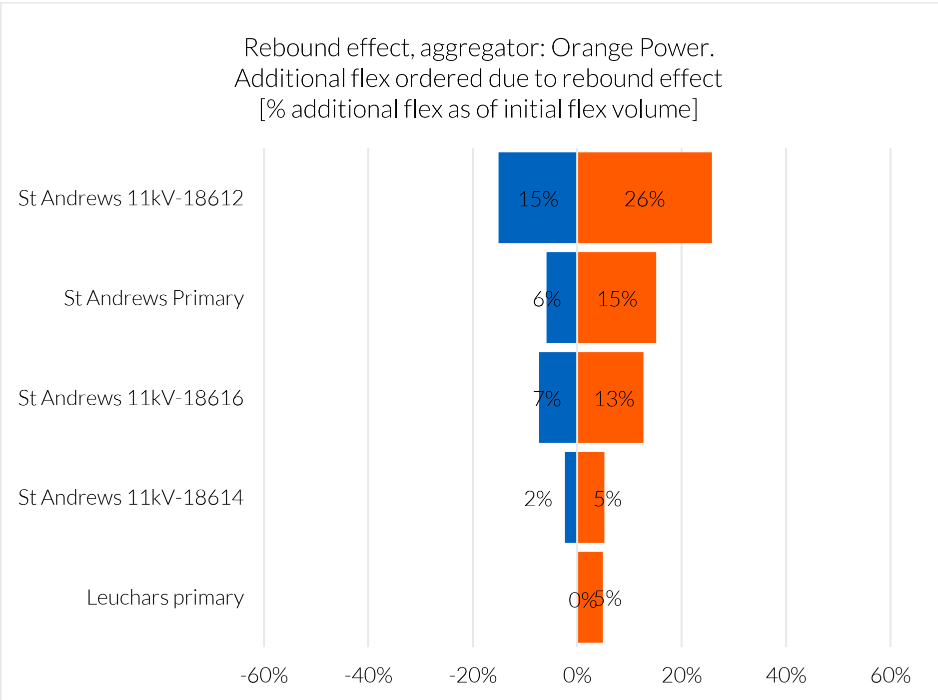
When aggregating the different rebound effects per technology in the aggregators' portfolios:

- OP portfolios across the different congestion point ranges between 46% and 71%
- Gridimp portfolios across the different congestion points ranges between 0% and 16%

Finally, the rebound % is applied to theoretical flexibility activations for each congestion point. This exercise is performed per aggregator and per congestion point. For this exercise, DNV assumed that the rebound would take place after the flex event and has a duration as long as the flex event.[19] For example, when a flex event takes 4 hours, the rebound would take place the 4 hours after the flex event. The rebound is calculated as the weighted percentage of the aggregators' portfolio times the total flex volume of the previous flex event. The rebound volume is assumed to be spread evenly over the duration of the rebound.

The results suggest that the rebound effect associated with OP is higher due to the portfolio composition. The figure below presents the theoretical rebound effect of Orange Power in a tornado plot. The tornado plot shows the additional flex required due to the rebound effect of a previous flex event. The lower scenario is shown by the green bars and the higher values in the blue bars. It shows that, for example at St Andrews 11 kV-18612 the rebound's impact on the congestion point would require an additional 15-26% of flexibility procurement.

Under the assumption that the portfolio currently operated at St Andrews 11kV-18612, is the most reflective of future portfolios, our short analysis indicates 20% as a reasonable estimate for the additional costs due to the rebound effect in a USEF market.



[19] Note that, it could be that the rebound starts directly after the flex event, with the power not spread out over the rebound period but directly starting at full power in the beginning of the rebound period. However, as the pattern of the rebound is very asset and location dependent, it was now assumed that the rebound takes place over a fixed duration. This could lead to an actual underestimation of the rebound effect.

4.1.3.4 Conclusions and Learnings

- Aggregators consider the MCM useful, clear and well structured, as they benefit from the whole process being defined in a single system, avoiding the need to use several systems across different phases.
- Aggregators and DSO made suggestions for improvement on contract timing aspects (week-ahead availability contracts) and bid selection (inclusion of carbon emissions information).
- MCM has a positive impact on reliability - between 1-28% increase - compared to other DSO flexibility trials.
- MCM has a positive impact on efficiency linked to DSO forecast accuracy. Because of its shorter procurement and dispatch timeframes, USEF allows a 1-3% reduction of DSO flexibility needs to account for forecast inaccuracy for the locations studied.
- Project FUSION has calculated a theoretical rebound impact that a future representative portfolio would have in East Fife congestion points, the results indicate that ~20% more flexibility needs to be activated to counteract negative impact of rebound. For future research, project FUSION recommends making an empirical analysis on rebound effect.

4.1.4 DSO flexibility procurement cost drivers

4.1.4.1 Scope & Methodology`

FUSION seeks to demonstrate whether the use of USEF innovative elements will lower the over-all costs of flex procurement. This can be accomplished in two ways (apart from CAPEX and OPEX costs for the DNO):

- Lowering the price of flexibility (attracting more flexibility, remove barriers, lower investment costs)
- Lowering the required volume (either availability, utilisation or both)

This section provides insights on the second element, by discussing several of the main cost drivers for flexibility procurement, focusing on the utilisation costs (utilisation volumes). The aspects that have been considered are:

- Load forecast accuracy
- Baseline accuracy
- Service delivery reliability

The load forecast is used by the DSO to determine the required volume of flexibility. Load forecasts include a certain inaccuracy. This inaccuracy leads to an upper and lower bound of the load forecast resulting in more flex procurement than is required.

A baseline approximates the energy consumption or generation by an aggregator if no flexibility is activated. It is used to determine the required volume of flexibility (both availability and utilisation). In practice, baseline methodologies include a certain inaccuracy. This inaccuracy leads to a bandwidth for service delivery and can lead to two scenarios

- The DSO carries the risk by factoring in the inaccuracy when it procures flexibility by procuring more than required
- Aggregators carry the risk and factor it in by overdelivering of what was ordered

In both scenarios, the cost of flexibility is likely to increase. Either because the DSO regularly procures more flexibility than required or because the aggregator increases the price per kW that they contract as available to ensure they have enough assets. In reality, the risk from the inaccuracy of the baseline is likely to affect both parties.

The final driver is that the service delivery by aggregators is not fully reliable. The DSO mitigates against this by either contracting with multiple aggregators or by over-procuring flexibility at additional cost. A service contract can include a minimum service level on performance and reliability; however it is worth noting that the higher the reliability requested by the DSO, the higher the unit price of the service.

In this section, we firstly describe the additional flexibility required after accounting for FUSION's Phase 2 trial results for the forecast accuracy, baseline accuracy and reliability These results are then compared with an approximation of the additional flexibility that would have been required in a hypothetical business-as-usual case that assumes typical values for the three different cost drivers.

4.1.4.2 Methodology

Using the results from Phase 2 of the FUSION trial, we have examined all cost drivers together to understand their combined impact on the additional flexibility required ().

The additional flexibility required due to the baseline accuracy is based on the normalised mean average error and assumes that an even share of the risk is divided between the aggregator and the DSO. It is worth noting that this extra flexibility only accounts for the average error in the baseline therefore the value would be higher if the DSO wanted to ensure to a greater confidence that the flexibility procured was sufficient to meet the system need.

The column related to the additional flexibility required due to DSO load forecast accuracy shows the inaccuracy per congestion point for the one day before forecast with a 95% confidence level.

Finally, the additional flexibility required due to reliability delivery is based on the Phase 2 reliability figures (Section 3.3Figure 12).

To calculate the combined additional flexibility required due to all factors, the impact from each driver was compounded to give an overall additional percentage.

Next, we calculated the same table but using equivalent values for the forecast accuracy, baseline accuracy and reliability in a hypothetical business-as-usual case (Section 4.1.3Error! Reference source not found.Table 18). The purpose of this was to estimate whether more flexibility would have been required for a trial setup that was more akin to current BaU flexibility procurement processes. In those, the flexibility is procured further in advance of delivery, using a historical baseline methodology and as observed in Section 4.1.3.3, achieves a lower reliability.

For BaU, we used the DSO load forecast inaccuracy per congestion point four day ahead forecast with a 95% confidence level. To reflect the accuracy of a historical baseline, the results from the normalized mean average error for the ENA's mid-8 in 10 baseline method were used[20]. Finally, as discussed in Section 4.1.3.3, flexibility delivery under FUSION trial is between 1% and 28% more reliable than the one calculated under other DSO flexibility trials. We have therefore used the midpoint of this range to estimate how this affects the additional flexibility required.

The final step was to calculate the difference between the trial results and the hypothetical BaU case by subtracting the trial results for all factors combined from the business-as-usual comparison (i.e. a positive value (coloured in green) reflects that more additional flexibility is required in BaU than in FUSION).

4.1.4.3 Results and Analysis

Additional Flexibility Required Based on FUSION Trial Results

The results show that significant additional flexibility would be required across all congestion points to account for the different drivers: ranging from 61% to 463% (Table 17Table 17).

20 Based on the assessment carried out in ITLR3 or the months of May and June 2022 and using the ENA's Flexibility Baselining tool

Table 17 Additional flexibility required due to different cost drivers based on FUSION Phase 2 trial results

Aggregator	Congestion Point	Additional Flex Required due to DSO Load Forecast Accuracy	Additional Flex Required due to Baseline Accuracy	Additional Flex Required due to Reliability of Delivery	Combined Additional Flex Required due to all Factors
Gridimp*	Leuchars	22%	55%	27%	140%
	St Andrews	14%	17%	116%	188%
Orange Power	Leuchars	22%	24%	9%	66%
	St Andrews	14%	26%	12%	61%
	St Andrews 11kV-18612	29%	72%	19%	164%
	St Andrews 11kV-18614	248%	43%	13%	463%
	St Andrews 11kV-18616	22%	46%	18%	110%

*The baseline accuracy used for Gridimp in this assessment reflects their results after the changes they implemented to their baselining methodology

The impact of the load forecast accuracy varies significantly across the different congestion points. DSO can procure closer to real-time or improve the forecasting methodologies. FUSION assessed the forecast accuracy in different time frames (Section 4.1.3) and found that there was only several percentage points difference between the 95% confidence interval for intraday and four days ahead therefore there is not a significant benefit when ordering closer to real time. We have also tested both day ahead and intraday trading of flexibility (Figure 11). The results showed that intraday FlexOrders were less reliable than day-ahead, therefore ordering more flexibility day-ahead would have reduced the additional flexibility required.

The baseline accuracy had the largest impact on the additional flexibility required. The options that are typically available to a DSO to improve the accuracy are to allow different baselining methodologies or to allow sub-metering of assets. FUSION tested a nomination baseline and sub-metering which allows aggregators to choose the precise methodology and adapt it as they see fit. Gridimp have implemented changes to their baseline methodology that has improve the accuracy and therefore reduced the cost impact on themselves and the DSO.

Finally, the service reliability had the least impact on the additional flexibility required. Increase service level (i.e. raise penalties for under-delivery). FUSION monitors service reliability to provide greater insights to DSOs as to the reliability of aggregators in delivering flexibility.

Business-as-Usual Case Comparison

The results show that the business-as-usual case requires more flexibility in five out of the seven congestion points. For the two instances where the trial requires more flexibility, the reason for this is the much-improved accuracy of the ENA's 8 in 10 method compared with the accuracy observed in the D-programme. This emphasizes the need to focus on aggregator baselines as the trial progresses.

Table 18 Additional flexibility required assuming business-as-usual values for load forecast. baseline accuracy and reliability

Aggregator	Congestion Point	Additional Flex due to DSO Load	Additional Flex due to Baseline Accuracy	Additional Flex due to Reliability of Delivery	Combined Additional Flex due to all Factors	Delta Between Additional Flex in

		Forecast Accuracy				FUSION and BaU[1]
Gridimp	Leuchars	24%	7%	42%	88%	-52%
	St Andrews	17%	133%	131%	527%	339%
Orange Power	Leuchars	24%	17%	24%	80%	14%
	St Andrews	17%	19%	27%	76%	15%
	St Andrews 11kV-18612	29%	33%	34%	129%	-35%
	St Andrews 11kV-18614	251%	33%	28%	496%	33%
	St Andrews 11kV-18616	23%	30%	32%	111%	2%

[1] A positive value (coloured in bright green) shows that more additional flexibility is required in BaU than in FUSION

4.1.4.4 Conclusions and Learnings

The trial shows show that the different cost drivers would have a significant impact on the volume of flexibility required by the DSO to ensure that the required flexibility is delivered. In particular the baseline accuracy has a large impact, for the FUSION trial as well as BaU, and therefore is an area that requires attention as the trial moves into the final stages.

An even split in the risk of reliability of delivery (and baselining implications) between the DSO and aggregators was assumed, however it is important to have a better understanding on how to split the risks between DSO and aggregator. Besides, it is key to understand how different measures would impact both the DSO and aggregators, for example if a certain level of baseline accuracy was required, some flexible technologies might be excluded, leaving more expensive technologies which would come at a higher cost for the DSO. The following questions will be explored in the close down report since they need further stakeholder engagement:

- How do the risk distribution affect the flexibility cost?
- How can it be achieved without hampering the entry of flexibility into the market?
- How does it affect the decision process of the DSO?
- Should reliability and baseline quality be included in the tendering process? How would that affect the aggregator and the DSO?
- How would the inclusion of other baseline methodologies, e.g. historical with same-day-adjustment, would affect the DSO?

The comparison between the trial results and a hypothetical business-as-usual case has shown that the FUSION trial requires less additional flexibility at five of the seven congestion points. This shows that the USEF framework can reduce uncertainty in the drivers that affect flexibility procurement costs and therefore reduce DSO costs compared with BaU flexibility markets.

It is also worth noting that conclusions about reliability cannot be drawn without accounting for the baseline quality. These two drivers are therefore interlinked, and both have to be addressed to give confidence that flexibility delivery will be solve grid congestion when it is ordered.

4.1.5 USEF Flexibility Trading Protocol (UFTP)

4.1.5.1 Scope

In the FUSION trial, the interaction between SP Energy Networks (DSO) and the aggregators has been formalised the USEF Flexibility Trading Protocol (UFTP), now known as SHAPESHIFTER.[21] The USEF Flexibility Trading Protocol (UFTP), describes the interactions and communication exchange between aggregators and DSOs to resolve grid constraints at distribution level. The UFTP covers all phases in the USEF MCM (contract, plan, validate, operate and settle) and is designed to be used as a stand-alone protocol for flexibility forecasting, offering, ordering and settlement processes.

4.1.5.2 Methodology

To carry out a qualitative assessment, DNV engaged with SPEN, OpusOne and aggregators. The FUSION project has also submitted a change request to the UFTP protocol to SHAPESHIFTER in response to the analysis that has been approved.

4.1.5.3 Results and analysis

Experience using UFTP: Both aggregators consider the UFTP has worked smoothly throughout the phases of the trial, with communication being timely and straight forward. Aggregators shared that implementing the protocol encouraged them to also assess and improve their own processes.

There is also awareness of the fact that the UFTP is perceived as complex. However, aggregators suggest that UFTP has a similar level of complexity as other standards that automate the process end-to-end. This implies that UFTP should not be compared with other protocols that only cover simpler processes, such as dispatch and metering, and do not include market interaction.

SPEN also indicated that they have not experienced any issues using the protocol throughout Phase 2. They highlighted that in the future it would be beneficial to automate the process to send FlexRequests. This is something that UFTP enables and could be implemented in the FFP.

Settlement process: A more automated settlement process would be beneficial, nonetheless, challenging due to the high number to features that are to be considered. At present, UFTP only covers the utilisation payment linked to FlexOrders but it does not cover availability payments or accounts for the aggregator performance. Hence, they suggest adding availability payments to the protocol.

Contributions of Project FUSION to the protocol

1. Allow multiple congestion points per connection – approval of change by SHAPESHIFTER

Project FUSION has continuous engagement with the Technical Steering Committee (TSC) of SHAPESHIFTER (under LF Energy) to provide feedback on issues that the project encounters. SHAPESHIFTER has approved a change submitted by the FUSION project to solve an issue raised by OpusOne (FFP provider).[22]

OpusOne argued that the UFTP, by design, does not store any other information regarding the grid topology, such as a hierarchical representation of the network, impacting the level of power flow interaction possible between voltage levels, which is a regular occurrence on distribution networks. For example, the implementation of 11kV feeders under 33kV substations proved challenging to implement given that UFTP does not have a native mapping of congestion points. Hence, the FFP could not map a connection to both voltage levels. And hence as a protocol, UFTP also does not support more granular network-model based analysis such as CIM network models.

This criticism although, valid, does not apply to UFTP because any network representation or mapping is outside UFTP's scope. UFTP covers the flexibility trading of portfolios located in different

21 https://www.lfenergy.org/projects/shapeshifter/
22 https://github.com/shapeshifter/shapeshifter-specification/issues/66

places of the network, how the network is connected and power system analysis is for the DSO to manage on their own systems. The reason it is designed as such is that UFTP could be then implemented regardless the network configuration or DSO systems. This criticism brought to attention, however, an issue that would not allow allocating certain connection to two or more congestion points in the Common Reference simultaneously. This limitation did not allow to reflect the potential impact of a connection in different congestion points (or for different grid configurations), limiting the potential use of a connection to solve different congestion problems.

The FUSION project proposed the improvement consisting of allowing one connection identifier to be linked to multiple congestion points. The DSO now has the freedom to link the connection to different congestion points in the Common Reference . This change has been approved by the Technical Steering Committee and is now part of the UFTP specification 3.0.1.

2. The ITLR#2[4] report described the changes requests that were submitted in the project FUSION context (by Gridimp) to the SHAPESHIFTER TSC on 1) metering and 2) service type. These changes were also approved by the TSC and version 3 of UFTP/SHAPESHIFTER[23] has now also added:

   - Metering message: This message is exchanged during the Settle phase for the aggregator to send meter data to the DSO. This was added to enable metering exchange in the absence of meter data from the meter data company (MDC) which would normally be at MPAN/main meter level. This message enables the exchange of submeter data directly between aggregator and DSO.
   - Service type attribute in FlexRequest message: This attribute enables the DSO to add the service type that they need (e.g. dynamic, sustain, secure) in their FlexRequest. This change will make the protocol align better with the current DSO product design in GB.

4.1.5.4 Conclusions and learnings

The conclusions of the assessment of the UFTP objectives are:

- Aggregators and SP Energy Networks found the experience with UFTP smooth and positive. Aggregators perceive that the complexity of the protocol is on par with other protocols that cover similar processes.
- FUSION Project is continuously interacting with SHAPESHIFTER TSC to discuss potential improvements to the UFTP protocol.
  - Previous change requests described in ITLR#2 and ITLR#3[4] and feedback given by Project FUSION has already been implemented in version 3 of the protocol.
  - The change request regarding the congestion point hierarchy has been submitted and approved, implemented in the UFTP specification 3.0.1.[24]

4.1.6 Business case of USEF-based flexibility market

4.1.6.1 Scope

The scope of this objective is to demonstrate the proof of concept and evidence the business case of commoditised flexibility (locally and for GB) through a USEF-based flexibility market. As USEF covers multiple aspects, this objective is broken down into three sub-objectives:

- Are there changes to USEF required for adoption by the GB energy market?

[24] https://github.com/shapeshifter/shapeshifter-specification
[24] https://github.com/shapeshifter/shapeshifter-specification

- Can the commoditization of all technologies be demonstrated? Does USEF create a level playing field?
- Are the network needs / service needs covered by the level of procured flexibility?

4.1.6.2 Methodology

This objective is evaluated on a qualitative manner based on the trial experience and statistics, GB BaU flexibility context, as well as previous project FUSION reports.

4.1.6.3 Results and Analysis

Changes to USEF required for adoption by the GB energy market

The FUSION due diligence and the trial have demonstrated that overall, the USEF framework, can be applied to the DSO flexibility services in the GB market. There were/are, however, certain elements that could be improved.

It is worth noting that the Project FUSION has been contributing throughout the duration of the project with the USEF foundation to make improvements to the USEF framework that were already implemented (until 2021 due to the cease of activities of the USEF foundation). In 2020, Project FUSION conducted the study GB Reference Implementation of USEF[25] where DNV identified a number of modifications to the USEF framework that are needed for adoption by the GB energy market. The main outcomes of this report concluded that to fit the GB market, USEF would potentially need to go through the following modifications:

1. The USEF flexibility value chain will be extended to include GB's dynamic (i.e., post fault) products;
2. The USEF flexibility value chain will be extended to include GB's secure and sustain (i.e. pre-fault) products;
3. The USEF roles will accommodate additional roles or responsibilities which are found in GB's arrangements; and
4. The development of the Common Reference and the CRO role will use insights from the FUSION trial and other GB initiatives to ensure compliance with GDPR requirements.

For the last version of USEF: The Framework Explained (2021),[26] Project FUSION worked together with the USEF foundation to incorporate the above elements (1-3) into the latest version of the framework.

Next to that, during the trial additional elements were identified:

- Dynamic service: Although FUSION trialled and proved that USEF could support the dynamic service, the process could be further optimised. The main issue is that the DSO needs to send FlexRequests in advance, for a certain capacity and duration, which means that there is little room for flexibility of response once a fault occurs. For example, if a fault occurs, the DSO will not know what the duration of the fault will be, but it would need to send a FlexOrder to an aggregator with a determined activation length. Consequently, this could incur in the activation being overly long (which implies more costs). To tackle this, USEF could consider adding a mechanism to stop a FlexOrder.
- Demand turn-up: The USEF congestion management process is not designed to cover the demand turn-up service. By doing certain adjustments in the way the FFP was used, the DSO could dispatch the service, however, it was evident that process does not fully accommodate this (and it could not be automated). This gap would be considered outside the USEF scope.

[25] https://www.spenergynetworks.co.uk/userfiles/file/GB_Ref_Implementation_of_USEF.pdf
[26] https://www.usef.energy/app/uploads/2021/05/USEF-The-Framework-Explained-update-2021.pdf

Demonstrate the commoditization of all technologies and that USEF creates a level playing field

This demonstration can be provided by:

1. The variety of assets that have participated in the FUSION trial (see Section 2.2.4).
2. The USEF framework is technology neutral by design. The aggregators do not need to inform the DSO on the technology (or technologies) behind their portfolio bid throughout the flexibility trading mechanism. The DSO would select offers based on price and technical characteristics (power, start time, end time).

Moreover, aggregators have indicated that the USEF framework allows them to bring more residential flexibility due to other aspects such as free bids that are explored throughout this document.

The final sub-objective "Are the network needs / service needs covered by the level of procured flexibility?" will be covered in the next FUSION report.

4.1.6.4 Conclusions and learnings

The conclusions for this objective are:

- The FUSION trial has proven that USEF framework is largely applicable to the GB DSO flexibility services. Project FUSION has collaborated in making modifications to increase the compatibility and has identified two different areas that could be considered in the future to improve the suitability of USEF with the DSO standardised products.
- The FUSION trial has proven that USEF created a level playing field for the participating aggregators and technologies, which included a high participation of residential assets.

Next steps for this objective is to answer the final sub-objective: Are the network needs / service needs by the level of procured flexibility? The answer to this will be the result of integrating the learnings of ICL Role and value of FUSION concept in supporting cost effective electricity system decarbonisation with further analysis on the final trial data.

4.1.7 DSO potential and Efficient DNO Network Management

4.1.7.1 Scope

The scope of this learning is to explore 1. the potential for localised demand-side flexibility utilisation to accelerate new demand connections to the network that otherwise would require traditional reinforcement and 2. the potential use and value of flexibility within geographically local regions to further enhance efficient DNO network management.

4.1.7.2 Methodology

This objective is evaluated by compiling and analysing information presented in the ITLR reports and in the discussion at a workshop held on the 23 January 2023 among project partners.

4.1.7.3 Conclusions and learnings

The detailed analysis can be found in the report 'FUSION ITLR4 – Report on Origami Actions'. This assessment confirmed that flexibility services can be used to sufficiently control demand and mitigate constraints with a suitable level of confidence. By delivering flexibility to alleviate simulated constraints in the DSO network, FUSION has showed how a using a nomination baseline methodology close to delivery increases the certainty of delivery. Over-delivery was common, nonetheless, this was to avoid a reduction of the payments for under-delivery or due to errors in the baseline. This over-delivery should be avoided to prevent stability issues.

FUSION also confirmed that flexibility service contracts hold suitable assurance on the provision of flexibility over the long-term where network reinforcement would otherwise be required. In addition, it was concluded that there is sufficient flexibility available to enable new connections without reinforcement. The RIIO-ED2 Business Plan identified 1,557 sites that would be constrained that could be resolved by flexibility and market testing identified more flexibility than required.

Furthermore, it was established that local flexibility can deliver the range of flexibility services which are available to regional (and national) markets and can provide suitable flexibility to all parts of the network. Flexibility can be delivered at one voltage level to meet an instruction for a flexibility service (DSO and/or ESO) at a higher voltage level. One aggregator registered their assets to deliver BaU services and the new ESO Dynamic Flexibility Service which confirms that assets that deliver BaU services (local and regional) could be used for some ESO services (regional and national).

FUSION also explored how the delivery of flexibility services at two local boundaries can provide an additive or complimentary flexibility support to the common network. It was proven that increasing the flexibility on one of the St Andrews 11kV feeders would not benefit any other St Andrews 11kV feeder but would reduce the loading of St Andrews primary substation by the same amount.

4.2. SUMMARY OF PREVIOUSLY REPORTED LEARNINGS

This section summarises trial learnings that have not changed since the last publication. We include in this report for completeness. For more details please refer to ITLR#2 and ITLR#3.[4]

4.2.1 Common Reference Operator (CRO)

4.2.1.1 Scope & Methodology

The Common Reference Operator (CRO) is responsible for operating the common reference (CR), the repository that contains detailed information on network congestion points, associated connections, and active aggregators in those connection points. The CR enhances transparency by allowing aggregators to get the information on the congestion points where they are active (and only those for confidentiality and privacy reasons). It also allows DSOs to get visibility on the aggregators operational at their congestion points.

Through interviews with aggregators and the DSO, this chapter aims to assess their experience when fulfilling the CRO role and interacting with the CR, to analyses who should perform the CRO role, its benefits, and challenges.

4.2.1.2 Findings & Conclusions

- Throughout the FUSION trial, SP Energy Networks has successfully fulfilled the Common Reference Operator role by populating the CR section of the platform according to the contracts.
- Aggregators' experience: Aggregators interacted with the Common Reference platform at the beginning of trial phases 1 and 2. The CRO enabled aggregators to provide their information and get input back on the congestion points where they operate. During the interviews, aggregators indicated the following.
    - Providing the necessary information is expected to be more time-consuming when there is a wider program with more assets.
    - OP proposes to explore the addition of two extra fields to the CR; 1. The type of services that might be needed by the DSO and offered by the aggregator and 2. Extra information during the ordering process such as congestion point location and entity address. OP suggests clarifying how the entity address, the GSP and the MPAN are linked and have them be aligned to have a clear common language.
    - SPEN indicates this would be worth further exploring how to make data recognisable and standardised, highlighting the need to be compliant with data protection policies.

    - Gridimp indicates that currently, identifying the connection point IDs used in USEF to form the trades is done manually through Scottish Power by the aggregator providing them with the MPAN and suggests exploring how this step could be done within the CRO.

- CR at DSO level: Maintaining the CR at DSO level is considered beneficial. Further coordinating with ESO requests could unlock value staking opportunities.
- Cybersecurity: OP highlights that, compared to other platforms, the CR has a security advantage with encryption, that it covers both DA and intraday.

4.2.2 DSO Data Transparency

4.2.2.1 Scope & Methodology

Aggregators have to access and handle significant data on congestion points, market rates, trades, events, assets, and sites, among other. This subsection aims to explore through interviews with the aggregators and the DSO how data transparency can be enhanced, understanding data as network, market and dispatch data.

4.2.2.2 Findings & Conclusions

- Level of transparency offered OP is satisfied and suggests implementing in the future a weekly transparency forum or sharing more information on the website to further enhance transparency. Gridimp considers the tender process transparent and suggest clarifications regarding the bid selection for utilisation contracts.
- Aggregator data sharing: Aggregators have not faced issues when sharing data.
- Aggregators data access: OP encountered an internal issue aligning APIs with the code as there was a need for updates every time a manufacturer changes an API. Gridimp indicated that getting the MPAN data from residential assets is currently challenging as consumer consent is hard to obtain.
- Interaction with other market players and privacy concerns: OP does not face privacy concerns, as what is established in the ICC and GDPR is strictly followed, and information is shared at portfolio level. Gridimp highlighted that the information that USEF requires is in line with what is needed in BaU; therefore, does not cause any challenge. SPEN considers there might be privacy concerns if a separate entity was to act as a CRO. Despite USEF being encrypted, there might be sensitive data, therefore, there would have to be a thorough due diligence process to ensure how the data is stored, handled and processed.
- Data reliability and accuracy: OP carries out pre-processing of the data to remove noise and flag potential issues with the data coming from the submeter or the API despite not having experienced meaningful issues with data accuracy. Further addressed in Section 3.3 and Section 4.1.4.
- Trackability and traceability: Aggregators were satisfied, with OP signalling that from the asset side, not all APIs were available from the manufacturers and Gridimp indicating that mapping the MPAN to the connection was time consuming and not so easily traceable.
- Responsibility for deviations for residential assets: Residential assets have availability payments and currently aggregators, regardless of the size of their portfolio, would have to take on the responsibility of deviations. OP suggests exploring how, in the future, this responsibility can be covered by the DSO.
- Transparent communication exchange: DNV identified that aggregators find identifying the service requested challenging and hard to automate, as this process is hindered by the different services having different service windows. This results in aggregators sometimes not identifying which bids are free bids and which are not. Gridimp indicates that adding

information of the service type to the FlexRequest could be useful to implement in the long-term.

4.2.3 Commercial Mechanisms

4.2.3.1 Scope & Methodology

One of the aims of Project FUSION is to explore the commercial mechanisms available to encourage consumer participation in providing flexibility, with a particular focus on how well USEF facilitates these mechanisms. Project FUSION assesses how effectively commercial mechanisms support providers with lower levels of flexibility and explore how the project could be used to inform the development of such mechanisms.

To inform the above objective, feedback has been collected using a variety of means, including a series of questionnaires and interview sessions with each of the aggregators participating in the FUSION trials and summarised in this report. The assessment has focused on three areas:

- Identifying barriers and opportunities in recruiting new flexible assets
- Impact of market procurement timelines on recruiting additional customers
- Effectiveness of Free Bids Mechanism at Encouraging Participation

4.2.3.2 Findings & Conclusions

4.2.3.2.1 Barriers and Opportunities

Aggregators discussed barriers and opportunities with regard to encouraging consumer participation.

These challenges are summarised below:

- Challenges in recruiting additional flexible assets from business customers;
- Technical challenges in connecting and enabling assets due to logistics and communication barriers with business customers;
- Lack of financial incentives that reward utilisation compared to availability, which discourages domestic customers with lower flexible capacity;
- Customer operational considerations (e.g. participation in flexibility services could affect customers' operations);
- Lack of standardisation of meter data across different assets; and
- Privacy and GDPR considerations when asset level information needs to preferred. Sharing information at portfolio level is preferred.

Opportunities and incentives for participation according to the aggregators are summarised below:

- Longer notification times between FlexOrders and delivery are preferred. For example day ahead notification provides customers with more visibility of when their assets will be utilised and can therefore adapt accordingly.
- Increase incentive for delivery when notification times are shorter to overcome increased inconvenience to the customer would help attracting more customers.
- Aggregators continue to recommend that the balance between utilisation and availability incentives could be improved by rewarding delivery over availability.
- The inclusivity of the baseline methodology (i.e. nomination baseline) is seen as another factor that impacts the ability to connect new assets.
- Allow stacking of revenue from the trial with other service.

- Raising the free bids price cap in Phase 2 of the trial had a positive effect in raising public interest on flexibility and increased the incentive to encourage participation.

4.2.3.2.2 Market Procurement Timelines

According to aggregators, procurement timelines affect their ability to recruit additional customers. FUSION's trial requirement to declare available capability 6 months in advance was considered a discouraging factor in recruiting, as it does not allow flexible assets to stack with other markets and it creates uncertainty with regard to the availability of flexibility.

Aggregators suggested instead a framework contract with availability declarations within the contract window from one month to one week ahead, which is their preferred option. This proposed arrangement overcomes the difficulties in predicting faults that impact their ability to deliver and provides smaller assets with greater flexibility about when they participate in the flexibility market.

Notification time between FlexOrder and delivery is also important to customers. Ordering day ahead provides customer with more visibility of when their assets will be utilised and is therefore more appealing to them.

4.2.3.2.3 Effectiveness of Free Bids Mechanism at Encouraging Participation

While it is recognised that USEF's free bids mechanism provides more opportunity for revenue through enabling additional income outside of long-term contracts, Aggregators advised that the current contractual arrangements and payment structure do not sufficiently incentivise the submission of free bids and their focus in Phase 2 of the trial was on fulfilling their obligations on availability. Ultimately, the trial has shown that the free bidding concept works but the current market and system is not mature enough to fully leverage this mechanism.

4.2.4 D – programmes

More details on this objective can be found in FUSION' Interim Trial Learnings Report #2 (ITLR#2).[4] [4]

4.2.4.1 Scope & Methodology

D-programme (or D-prognosis) is a forecast that the aggregator provides day-ahead to the DSO and contains the net load or generation of each aggregator portfolio per congestion point. This forecast is submitted before flexibility trading, which means that it does not include DSO service deliver.

The learnings for D-programmes focused on the functionality of D-programmes to provide visibility to the DSO for their own forecast as well as having the visibility on the flexibility amount that could require from aggregators. During our assessment of this objective, we engaged with SPEN's flexibility team as well as SPEN's forecasting provider (SIA partners).

The main question that we investigated was the process of potentially integrating of the D-programmes in the existing forecasting process. We also looked into potential accuracy improvements if D-programmes were integrated into the existing processes. The results are summarised below.

4.2.4.2 Findings and Conclusions

D-programmes could be incorporated into substation load forecasting by following this process:

1. Subtracting aggregator sub-meter data (from the flexible assets participating in the trial) to the substation measurements that feed into the substation forecast algorithm.
2. Running the forecast algorithm to forecast the non-aggregator load
3. Summing up the D-programmes of aggregators active at the substation

The key barriers, however, to integrate D-programmes following this process is that:

- The aggregator would need to communicate real time sub-meter data, which could be costly.; and

- DSO forecast would need to include different forecasting methodologies for day-ahead or for longer periods of time, because D-programmes are only submitted day-ahead.

With regards to D-programmes' contribution to improving DSO load forecasting accuracy, our engagement with SIA partners shows that the current DSO substation forecast is highly accurate (estimated 2-3% of error) and therefore further reducing the error would have small impact on the flexibility activations day-ahead. However, the D-programmes and other type of information (such as asset type, capacity, etc) could greatly contribute for lower voltage forecast, especially below 11 kV, which are not part of the FUSION trial.

Given the low accuracy that were observed in D-programmes, the project decided to investigate further the impact of flex trading timing in the accuracy of the DSO forecast. This is further explained and analysed under the Market Coordination Mechanism objective.

4.2.5 Sub-metering arrangements

In phase 1 project FUSION promised to investigate the potential to access MPAN data in order to assess enhanced learnings from the implementation (or not) of sub-metering arrangements. Due to regulatory arrangements which do not facilitate the access of MPAN data by DNOs, there are no further learnings derived from this objective.

Therefore a summary of phase 1 learnings is provided below. More details can be found in the **ITLR#2**[4] that was published in May 2022.

4.2.5.1 Scope & Methodology

During FUSION trial, the flexibility validation was performed using exclusively sub-meter data for all congestion points and participating aggregators. Some of the assets, such as CHPs and EVs, had an installed sub-meter prior aggregation services. Whereas for other residential assets the sub-meter was installed by the aggregators. The scope of this objective was adjusted to assessing the experience of the DSO and aggregators with sub-metering.

This objective assessment is based on qualitative information from the SP Energy Networks BAU department and aggregators, which was attained through workshops, bilateral discussions, and the provision of questionnaires.

4.2.5.2 Findings and Conclusions

SPEN BAU team only receive MPAN data for the validation and settlement of flexibility services, except for residential assets where only sub-metered data is available. They did not express a preference on the use of MPAN compared to the use sub-metering data and vice versa.

Both aggregators prefer the use of sub-metering in flexibility services:

- Sub-metering offers better resolution and visibility of the asset behaviour;
- Sub-metering allows for better control of assets;
- Forecasting at asset sub-meter level is more straightforward;
- Access to MPAN data of residential assets is not possible to non-supplier aggregators.

4.2.6 Additional learning – Demand turn up

During phase 2 trial, SP Energy Networks explored the possibility of engaging with another aggregator to trial a demand turn-up service. Although USEF supports this concept, the FFP was not designed to place orders for demand turn-up, nonetheless, the test was conducted and demonstrated that it could be used to do so. This trial demonstrated that, whilst the FFP and the AGR-stub were not designed for this purpose and do not offer the same quality of user experience in this configuration, they can be configured to trade demand turn-up services.

This is positive news because it means that:

1. Not only can the AGR-stub provide a means for aggregators to participate in a USEF flex market (like FUSION) without having to implement any IT development of their own, but also;
2. They can use this configuration to trade both demand turn-down and demand turn-up.

5. Stakeholder engagement and wider impact

This section contains a summary of the interactions of the project FUSION with other initiatives, projects or organisations including its participation in the Energy Innovation Summit and its interaction with the key stakeholders ENA OP, Ofgem and Shapeshifter.

5.1. FUSION'S PARTICIPATION IN THE ENERGY INNOVATION SUMMIT

SP Energy Networks was a headline sponsor for the Energy Innovation Summit that was held in the Glasgow SEC Centre celebrated at the end of September 2022. This summit provided a valuable opportunity for stakeholder engagement, project exposure and promotion. A breakout session on the topic of flexibility was held in which the FUSION project was presented, explaining its learnings to date.

5.2. INTERACTIONS WITH THE ENA ONP

Project FUSION supported ENA ONP Product 5 (P5) under Workstream 1A to develop and assess the potential implementation of the 'primacy rules,' that will be used to manage potential conflicts between ESO and DSO services.

This study focused on the interaction between Short Term Operating Reserve (STOR) providers and Active Network Management (ANM) generators in the same area where opposite instructions could be issued by the ESO and DNOs. It explored the use case in which the ESO instructs a STOR generating asset to increase MWs, and subsequently the DNO curtails a different generator through ANM, which counteracts the ESO instructed STOR service.

The objective of this project was to quantify the economic impact on all parties involved of the primacy rules that would mitigate this conflict, to help ENA members understand which rules deliver the most efficient outcome for the end consumer.

This exercise concluded in a separate report that will be made publicly available on the FUSION website,[27] therefore this report does not address the results of the study.

5.3. INTERACTIONS WITH OFGEM

Project FUSION meets with Ofgem to discuss the project progress and share insights on interim learnings and next steps. In December 2022, Project FUSION presented a 'show & tell' to an audience of Ofgem representatives, which comprised a presentation of interim learnings and a Q&A session. In November 2021, a similar session was held for the previous trial phase.

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[27] https://www.energynetworks.org/industry-hub/resource-library/on22-ws1a-p5-primacy-rules-cost-benefit-analysis-final-report-(13-dec-2022).pdf

5.4. INTERACTIONS WITH SHAPESHIFTER

Project FUSION representatives attends the monthly TSC SHAPESHIFTER meetings. In these meetings, the SHAPESHIFTER (formerly known as UFTP) user community discusses improvements to the protocol, change requests, processing of the changes in the protocol and specifications, etc. Project FUSION has discussed multiple changes requests based on the trial experience. Since the publication of ITLR#3[4] in December 2022, SHAPESHIFTER has approved a change submitted by the FUSION project to solve an issue raised by OpusOne (FFP provider). For details regarding this change refer to Section 4.1.5.

5.5. INTERACTIONS WITH TRANSITION PROJECT

Project FUSION representatives held a workshop with representatives from the TRANSITON project, which is also running a flexibility market trial for businesses in Oxfordshire. The workshop was held on the 31st of January 2023 to share experiences of baselining. The workshop included an overview of each trial and a summary of the main learnings related to how baseline are produced and used in local flexibility markets. An outcome of the workshop was a set of recommendations and a plan to discuss and test these recommendations in a webinar that will be held towards the end of April 2023 with relevant stakeholders.

6. Next steps

The next steps for project FUSION include the following:

- Following the workshop with project TRANSITION in January 2023, a webinar will be held towards on 25th April 2023 with relevant stakeholders in order to discuss workshop's findings and recommendations on baselining.
- A combined FUSION – TRANSITION short report will be published to reflect and address feedback which will be acquired during April's webinar.
- Project FUSION will publish a close down report before November 2023 as per the requirements of the NIC Governance document.

Glossary

Term	Definition
Aggregator (AGR)	A service provider that contracts, monitors, aggregates, dispatches and remunerates flexible assets at the customer side. (USEF terminology)
Availability Payments	Payments made for being available to deliver the contracted Flexibility Service during a specified time period (described as the 'Service Window').
Combined Heat and Power (CHP)	The use of a heat engine or power station to generate electricity and useful heat at the same time.
Common Reference (or congestion point repository)	USEF defines the Common Reference as a repository which contains information about connections and congestions points in the network.
Common Reference Operator (CRO)	In USEF, the CRO is responsible for operating the Common Reference. The CRO's role is to ensure the publication of both the DSO flexibility requirements and the associated flexibility assets in each congested point as well as the standardisation of this publication for all distribution areas.
Congestion Management	The avoidance of the thermal overload of system components by reducing peak loads. The conventional solution to thermal overload is grid reinforcement (e.g. cables, transformers). Congestion management may defer or even avoid the necessity of grid investments.
Constraint Management Service Provider (CMSP)	A provider of constraint management services to a DSO or the TSO. This is a USEF role and is not currently used in GB. This role takes on specific responsibilities in communicating and coordinating flexibility transactions with the ESO and DSOs, to ensure effective deployment of flexibility as well as effective management of network constraints. Responsibilities also involve ensuring efficient dispatch of flexibility to maintain the safety and reliability of the networks.
D-programmes	Aggregator forecast of the amount of energy to be consumed or produced at a given congestion point.to be shared with DSOs in congested distribution network areas.
Delivered Flexibility	The term delivered flexibility is used solely for flexibility that meets the FlexOrders. It is the amount of the ordered power that was delivered during the activation window measured by looking at the change

	in power from the baseline to the meter readings and capping it at the power output agreed in the FlexOrder
Distribution System Operator (DSO)	As defined in DIRECTIVE 2009/72/EC: A natural or legal entity responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.
Flexibility	Ability of an asset or a site to purposely deviate from a planned or normal generation or consumption pattern.
Heating, Ventilation and Air Conditioning (HVAC)	The use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space.
Market Coordination Mechanism (MCM)	The Market Coordination Mechanism in USEF includes all the steps of the flexibility trading process, from contractual arrangements to the settlement of flexibility. USEF splits the flexibility trading process in five phases and describes the interactions between market participants and information exchange requirements in each phase of the MCM.
Prosumer	This role refers to end-users who only consume energy, end-users who both consume and produce energy, as well as end-users that only generate (including on-site storage). (USEF terminology)
Realised Flexibility	The total change in power from the baseline to the meter readings during the activation window.
Settlement Period	The time unit for which imbalance of the balance responsible parties is calculated. In GB is 30 minutes.
USEF Flexibility Trading Protocol (UFTP)	A protocol that describes the interactions for the exchange of flexibility between aggregators (or other flexibility service providers) and DSOs.
Utilisation Payments	Payments made to flexibility service provider for energy delivered as part of a Flexibility Service