Local Energy Oxfordshire

transition
Moving to a smart future

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Value Chain for Flexibility Providers

Deliverable 2.8

Origami Energy

Version History

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Executive Summary

Local Energy Oxfordshire is a socio-technical innovation project (Project LEO) which aims to demonstrate that a functioning Smart Local Energy Systems (SLES) in Oxfordshire can maximise economic, environmental, and social prosperity in the area. The concept of a SLES is viewed within this project as a local, low-carbon, energy system that engages with all stakeholders in the local area and uses market mechanisms and smart technology to bring value to the DNO network and those connected to it.

To demonstrate the above, Project LEO is ideally placed to work with Ofgem's Network Innovation Competition (NIC) funded project TRANSITION (run by SSE Networks (SSEN)) to deliver new and existing Flexibility Services in the Oxfordshire area and discover the value of Flexibility Services for all involved Market Actors.

This paper focusses on the value of Flexibility Services that exist in flexibility markets today. It considers the interaction of different Flexibility Services and highlights where revenues can be stacked across different time periods. This information can be used as a foundation to determine a value chain for existing services and as a reference point for new projects that wish to consider the value of providing flexibility services.

The Flexibility Services considered in this report are from the existing ESO and DSO markets, as well as the new Peer-to-Peer (P2P) services being developed that will be tested in Project LEO and TRANSITION. The value of P2P services is not determined within the report as the services are at the leading edge of innovation and this will be an output of Project LEO and Project TRANSITION as they explore and develop the facilitation and use of these services. Other Revenue Streams which exist today and can deliver value to the flexibility provider are also explored.

In addition to the value of Flexibility Services, this report also considers the capability of different types of Distributed Energy Resources (DERs) to deliver a flexibility service. Not all technologies have the same capabilities, and some services will be suited for one technology and not for others, e.g. the ESO Dynamic Containment service requires a very fast and controlled response which favours battery technologies and the speed of response cannot be delivered by a thermal asset that cannot respond within one second. The report summarises the capabilities of various technologies to deliver the services considered and these are summarised in Table 1.

Table 1: Ideal and Unsuitable Flexibility Services for Specific DERs

DER	Ideal Flexibility Services	Unsuitable Flexibility Services
Battery Storage	Those requiring fast speed of response, e.g. Dynamic Containment.	Those with a long delivery period, e.g. Optional Downward Flexibility Management or Dynamic DSO Constraint Management.
Combined Heat and Power	Those with a long delivery period, e.g. all DSO Flexibility Services.	Those requiring fast speed of response, e.g. Dynamic Containment.
Commercial Demand	Those where it can be aggregated with many similar DERs to provide a minimum level of capacity, e.g. DSO services.	Those requiring fast speed of response, e.g. Dynamic Containment.
Domestic Demand	Those where it can be aggregated with many similar DERs to provide certainty and a minimum level of capacity, e.g. DSO services.	Those requiring fast speed of response, e.g. Dynamic Containment.
Gensets	Those with a long delivery period, e.g. all DSO Flexibility Services.	Those requiring fast speed of response, e.g. Dynamic Containment.
Hydro (run of river)	Those that can work with seasonally adjusted output, e.g. Wholesale Trading.	Those requiring fast speed of response, e.g. Dynamic Containment.
Industrial Demand	Those with a long delivery period, e.g. all DSO Flexibility Services.	Those requiring fast speed of response, e.g. Dynamic Containment.
Solar PV	Those that need to interrupt generation in the summer period, e.g. Optional Downward Flexibility Management.	Those requiring fast speed of response, e.g. Dynamic Containment.
Wind	Those that need to interrupt generation during high demand, e.g. Optional Downward Flexibility Management.	Those requiring fast speed of response, e.g. Dynamic Containment.

Table 1 considers an average DER in each DER type and as such there may be differences for DERs, i.e. very small or very large DERs; single standalone DERS or DERs aggregated in a portfolio of DERs). Additionally, the combination of different DER types can maximise their service delivery capabilities e.g. energy storage can be used to reshape the generation output of the solar PV so the flexibility provider can deliver Flexibility Services during the evenings when prices are higher.

The report provides two case studies to demonstrate how to determine the value for two typical DERs likely to be available to a SLES. Table 2 shows the revenue available in the existing markets for the case studies within this report (the supporting data is available in the Appendices).

Table 2: Overview of Potential Revenue from Case Studies

Case Study	Services	Potential Annual Revenue
Case Study 1: Community Battery (15kW, 30kWh)	▪ Time of Use Tariff ▪ Sustain Peak Management	£1,506.6
Case Study 2: Demand response (commercial building, 400kW)	Option 1: ▪ Capacity Market	£6,750.00
	Option 2: ▪ Secure DSO Constraint Management ▪ Transmission Charge Management	£30,003.6

The development of this report and its case studies has highlighted four findings:

- **Revenue Stacking** – the ability to stack services must be available to transform the flexibility markets and support the delivery of Net Zero, although this may require some expertise.
- **Fair Value for Flexibility** – a fair value must be renumerated to Flexibility Providers to ensure that the real value of Flexibility Services is recognised.
- **Route to Market** – flexibility services must be standardised, requirements must be simplified and barriers to entry must be reduced across the flexibility marketplace. If a third party is used to access markets, this could significantly reduce the share of the revenue available to the DER owner.
- **Non-Financial Value** – flexibility solutions which provide a sustainability benefit must be rewarded.

Project LEO and its partners own and / or have operational control of various existing DERs in Oxfordshire and have plans to expand their portfolio of DERs during the term of project LEO. This places project LEO in a unique position to test the various flexible services, their value and the barriers to overcome for a Smart Local Energy System to succeed.

This document[1] establishes a value chain for flexibility that enables the LEO partners to prioritise Flexibility Services, determine income from Flexibility Services, prioritise project opportunities and develop value propositions to attract relevant stakeholders. In doing so, Project LEO will support the DNO's 2020 commitment to using Flexibility Services in the future and support more DERs to take part in the existing and future Flexibility Services market.

[1] Please note there is a list of abbreviations located after the Table of Contents as many of the Flexibility Services are abbreviated

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DER	Distributed Energy Resource
DNO	Distribution Network Operator
DSO	Distribution System Operator
ESO	Electricity System Operator
IoT	Internet of Things
MIC/MEC	Maximum Import Capacity / Maximum Export Capacity
NIC	Network Innovation Competition
P2P	Peer to Peer
SLES	Smart Local Energy System

Flexibility Services and other Revenue streams:

BM	Balancing Mechanism
CM	Capacity Market
DC	Dynamic Containment
DCM	Distribution Charge Management
DDCM	Dynamic DSO Constraint Management
EMEC	Exceeding Maximum Export Capacity
EMIC	Exceeding Maximum Import Capacity
FFR	Firm Frequency Response
ODFM	Optional Downward Flexibility Management
OFFST	Offsetting
SDCM	Secure DSO Constraint Management
SEPM	Sustain Export Peak Management
SPM	Sustain Peak Management
STOR	Short Term Operating Reserve
TCM	Transmission Change Management
ToUT	Time of Use Tariff
WT	Wholesale Trading

1 Introduction

1.1 Project LEO

Project LEO (Local Energy Oxfordshire) is a socio-technical innovation project which aims to demonstrate that a functioning Smart Local Energy Systems (SLES) in Oxfordshire can maximise economic, environmental, and social prosperity in the area. The concept of a SLES is viewed within this project as a local, low-carbon, energy system that uses market mechanisms and smart technology to bring value to the distribution network and those connected to it.

One of the objectives of Project LEO is to develop and deliver new and existing services using the flexibility of Distributed Energy Resources (DERs) connected to the electricity system or distribution network (Flexibility Services) in conjunction with the SSEN NIC-funded project TRANSITION[2].

Flexibility Services[1] are typically utilised by:

- the ESO in balancing the electricity system in real-time, e.g. frequency services to manage the imbalance between the level of national demand and the aggregate level of generation;
- the DSO in managing the distribution network, e.g. services to reduce the demand of a DER during peak demand times to avoid additional investment in infrastructure and enabling more demand to connect;
- Market Actors working with each other to address their own issues, e.g. trading import and export capacity between sites to enable increased generation or demand in the local area and avoiding investment in new infrastructure that would delay development; and
- Market Actors managing their own price risk, e.g. reducing demand when electricity prices are high.

1.2 Flexibility in context of SLES

It is worth introducing some fundamental concepts before exploring the value chain for Flexibility providers:

- Flexibility provider can be defined as a Market Actor with demand and/or generation who can use flexibility to deliver Flexibility Services and/or benefits from other Revenue Streams.

[2] Project TRANSITION, https://ssen-transition.com/

- for the purposes of this report, DERs are assets that are connected to the distribution network that may be able to provide Flexibility Services and include demand assets, generation assets and storage assets.[3]
- Flexibility of a DER is defined as "changing the generation and / or consumption pattern of a DER in reaction to an instruction to deliver a Flexibility Service"[2] . Existing and future use cases for Flexibility include:
  - to increase demand, reduce generation or charge a storage unit and enable increased low carbon generation and help achieve a carbon reduction.
  - To achieve Other Revenue Streams by reducing or shift the level of demand, generation or storage in response to price signals, helping to reduce the effective cost of electricity and its transportation.
  - to provide Flexibility Services to the ESO, DSO and other Market Actors to reduce the costs of operating and managing the electricity system (in the case of the ESO) or the distribution network (in the case of the DSO);
  - to accelerate the connection time or reduce the costs for new demand and / or generation projects.
- Market Actors are any organisations that have a part to play (directly or indirectly via a third party) in the use of electricity (including the specification and delivery of new Flexibility Services) and includes, SLES members, suppliers, traders, DSO, and owners of DERs.

Flexibility Services are transacted using a contractual agreement that specifies the Flexibility Service to be provided, the level of delivery, the start and end of the delivery period, and any factors pertinent to the Flexibility Service to be delivered. Flexibility Services are generally traded through markets that use auctions to match buyers and sellers; in the absence of a suitable market, buyers or sellers can interact with other Market Actors directly. For the purposes of LEO and TRANSITION, Flexibility providers should inform the DSO if a Peer-to-Peer (P2P) Flexibility Service has been agreed (but before delivery) if the transaction could affect energy flows on the distribution network. One of the key differences between different markets is the value of Flexibility offered.

[3] FUSION-TRANSITION Joint Work - Common Terminology v6.0

1.3 Value of Flexibility

The DNOs have a Flexibility First commitment[4,5] to consider Flexibility as an alternative to investment for projects valued over £1million[6]. Many Market Actors in GB will benefit from this approach, including:

- ESO from additional Flexibility being available to provide Flexibility Services, increasing competition (although there may be conflicts of need to be addressed);
- DNOs from lower cost flexibility and enabling more distributed generation (mostly renewable generation) to connect to the distribution network, increased competition for the provision of Flexibility Services, and having optionality to contend with an uncertain future;
- new distributed generation projects (particularly renewable generation) from being allowed to connect to the distribution network at a lower cost and quicker than would otherwise be possible;
- electricity customers from lower DNO charges;
- DERs that receive income from providing Flexibility Services to the DNOs, other buyers of Flexibility Services and the delivery of Other Revenue Streams; and
- Government and GB from the benefits of delivering Net Zero.

In general, the value for Flexibility paid to the owner / operator of the DER does not currently reflect the full benefit it delivers to GB[7]. Project TRANSITION published a report[8] that indicated the "value offered in some markets is insufficient to attract investment in new capacity or to

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[4] SSEN Joins Industry in commitment to "flexibility first" approach http://news.ssen.co.uk/news/all-articles/2018/december/flexibility-first-commitment/
[5] ENA Six steps for delivering Flexibility Services, https://www.energynetworks.org/industry-hub/resource-library/open-networks-flexibility-commitment-2019.pdf
[6] Evaluating flexibility an alternative to traditional network reinforcement, Frontier Economics for SSEN, https://www.ssen.co.uk/WorkArea/DownloadAsset.aspx?id=19402
[7] The full path of benefits is complex and in some cases the benefits may not be linked across the markets and system levels. For example, peak-time reduction of demand in a constrained distribution network reduces the need for traditional network reinforcement, which in scale also reduced the costs for DNO and the connected customers. However, at the higher level and scale, reduced peak-time demand may also reduce the need for fossil generation plant running at peak time, potentially impacting the wholesale prices and reducing carbon emissions, providing the benefit for the GB. See also reference below.
[8] "Analysis Of Relevant International Experience of DSO Flexibility Markets", 28 August 2019 https://ssen-transition.com/wp-content/uploads/2019/08/TRANSITION-Analysis-of-relevant-international-experience-of-DSO-flexibility-markets.pdf. The last bullet point can be illustrated by considering what could happen when the DSO instructs the delivery of Sustain Peak Management, paying to reduce the demand on the distribution network. This also reduces the demand on the transmission system and the demand to be delivered by the ESO, at not cost to either party. In addition, the advance notice allows the supplier to balance their portfolio and, possibly, trade any excess again, at no cost.

attract flexibility at the levels required …" which "… will put the security of power systems under greater pressure in the medium term." It found three main reasons for this:

- "flexibility provides a system-wide benefit, which also includes benefits that are not accessible to all market participants;
- each market participant values flexibility based on how it uses the flexibility; and
- some market participants obtain additional benefits as a consequence of purchasing flexibility to provide a single service at either a low cost or no cost."

The above issues are exacerbated as no one party can access all of the value of Flexibility to GB (as a conglomeration of all parties that provide or benefit from Flexibility in any way) and, often, more than one party may be required to deliver a Flexibility Service. The more Market Actors in the chain from the Flexibility provider to the benefit derived from the use of that Flexibility (in its widest sense), the lower the proportion of the overall value that is received by the Flexibility provider. Although this could reduce the contractual burden, this could potentially discourage participation in the markets or new Flexibility to come to market.

Figure 1 illustrates the current Market Actors involved in the GB flexibility markets. The interactions between the various Market Actors are indicated by a shared boundary. For example, a supplier interacts with many of the Market Actors identified:

- access Flexibility directly to manage its portfolio risk;
- use it to access wholesale energy markets via a trader;
- use it to deliver Flexibility Services directly to the ESO or DSO or via an aggregator;
- use it to help the customer (the site on which the Flexibility is located) to manage their energy demand and / or price risk.

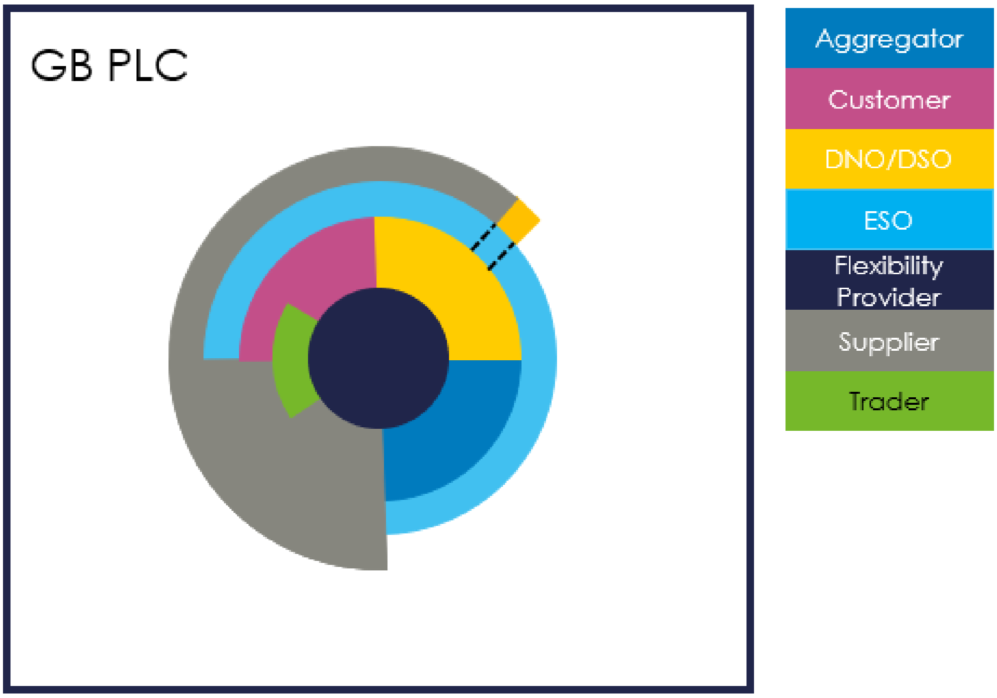

Figure 1: Interactions between Market Actors involved in the delivery of Flexibility Services in GB

Unlocking more of the benefits of revenue streams and rewarding the Flexibility provider for a share of the total value that GB receives from the use of the Flexibility could be transformative in encouraging new Flexibility to come to market.

To ensure a consistent and representative value for Flexibility Services, ESO and DSOs should use a standardised methodology for calculating the value of Flexibility Services which should be published. The transparency would give customers and providers of Flexibility Services confidence in the value of the services and support the growth of the Flexibility Services market.

Flexibility is used explicitly to deliver Flexibility Services (even as part of a portfolio) to realise a revenue stream or to deliver Other Revenue Streams by implicitly affecting the level or pattern of generation or demand to reduce costs. The value of using Flexibility has a financial and non-financial aspect with most Flexibility providers focussing on the financial benefits. However, the non-financial benefits are very important and can be more important to Flexibility providers who have DERs with low levels of Flexibility that receive a relatively low level of financial compensation. Non-financial benefits include supporting community projects for Low Carbon Technologies (LCTs) or non-energy benefits, e.g. providing a fund to provide wider social benefits for the community, providing better local air quality or the opportunity to contribute to the delivery of Net Zero. Regardless of the type of benefit that Flexibility providers receive, it is important that Flexibility Providers are rewarded for their capabilities (technical, economic, personal circumstance, digital or location) fairly and equitably, particularly those in a community context that may not have access to Flexibility individually, are fuel poor or considered vulnerable, but can be rewarded for being part of community that includes DERs with Flexibility. Equally important that the costs for facilitating flexibility are also distributed fairly and not penalising those who unwilling to participate.

1.4 Existing and New Flexibility Services

There are two existing and one nascent flexibility markets:

- **Electricity System Operator** (ESO) market that balances national demand and supply in real-time to ensure the security and quality of electricity supply across Britain's transmission system. This is the most established market that has reduced barriers to entry to increase participation and create a more liquid market. The market continues to evolve new Flexibility Services as it aims to meet our changing system needs, e.g. Dynamic Containment is a new, fast-acting frequency response service that will along with other Containment services under development replace existing frequency response services. However, this market has only one buyer.
- **Distribution System Operator** (DSO) Flexibility Services market is an environment comprising of six independent DSO groups that procure Flexibility Services to address system constraints or potential constraints and maintain the security and quality of electricity supply across GB's distribution networks. Historically, this included projects that increased the level of demand or generation to increase network capacity that was often only required for a few 100's hours during a year. In recent years, Active Network Management schemes have been used to alleviate constraints and, more recently, Flexibility Services are being considered as an alternative method to increase capacity on the network.
- **P2P** Flexibility Services between Market Actors do not involve the ESO or DSO although some Flexibility Services require the prior approval of the DSO before delivery can occur. Power Purchase Agreements are an established P2P energy service but, as a developed P2P service, are out of scope in this report. Other P2P Flexibility Services are developing and projects LEO and TRANSITION will support the development of capacity services, initially trading or sharing capacity.

The services traded on the ESO and DSO markets are summarised in Section 1.4.1 with P2P services that could exist in a future facilitated market described in Table 3.

Table 3: Summary of Flexibility Services that could apply to LEO DERs

Category	Service	Description	Auction Period	Delivery Notice	Delivery Duration	Minimum Capacity
ESO	Balancing Mechanism (BM)	Main mechanism for balancing electricity system in real-time, usually by adjusting generation levels.	Live	3 mins upwards	As required	1MW
	Capacity Market (CM)	Main incentive to ensure there is sufficient capacity to manage peaks using either generation increase or demand reduction.	4-and 1-year ahead	4 hours	Duration of Notice	1MW
	Firm Frequency Response (FFR)	The provision of fast-acting response to changes in system frequency to help maintain it within target levels. Historically, this has been either dynamic (proportional response to small changes in frequency) or non-dynamic (response for a fixed period following larger changes in frequency). The replacement service, Dynamic Containment and similar services, gradually replace all of the existing frequency services. ***Out of scope in this work***[9].	Monthly	1, 10, 30 secs	10 to 1,800 secs	1MW
	Dynamic Containment (DC)	Post-fault service designed to meet the need of fast-acting frequency response when frequency breaches operational limits (+/- 0.2Hz). This is the newest ESO service. Flexibility providers, mainly with battery storage assets, bid to be available to deliver the service for 24hours day-ahead of the delivery. If accepted, flexibility are paid the accepted price £/MW/h for the 24 hours unless unavailability is declared.	Day Ahead	0.5 to 1.0 sec	[continuous]	1MW
	Optional Downward Flexibility Management (ODFM)	Optional Downward Flexibility Management is a service which allows the ESO to request (renewable) generation output is reduced or demand is increased in real-time to manage the electricity system during particularly low demand at times of high generation, typically summer overnights and early morning.	Week Ahead availability submissions	6 hours to 18 hours	3 hours to 6 hours	1MW

[9] These services are not included in the analysis due to their expiry or uncertainty of value.

Category	Service	Description	Auction Period	Delivery Notice	Delivery Duration	Minimum Capacity
	Replacement Reserve	To enable harmonised procurement of balancing services across European transmission operators using interconnectors with Europe. New service, details and participation requirements are uncertain. ***Out of scope for this work.*** [10]	1 hour	15 minutes	1 hour	1MW
	Short-Term Operating Reserve (STOR)	Provides additional active power from generation or demand reduction at short notice. This service is currently suspended and will be reinstated from April 2021.	Seasonally	20 to 240 mins	2 hrs min	3MW
DSO	Sustain - Peak Management (SPM)	A Flexibility Service that delivers Flexibility to address a forecasted need to prevent a critical asset (such as transformer) becoming overloaded due to excess demand	Months to Years	Month Ahead to Day Ahead	[2 hours]	1kW
	Sustain - Export Peak Management (SEPM)	A Flexibility Service that delivers Flexibility to address a forecasted need to prevent a critical asset (such as transformer) becoming overloaded due to excess generation	Months to Years	Month Ahead to Day Ahead	[2 hours]	1kW
	Secure - DSO Constraint Management (pre-fault) (SDCM)	A Flexibility Service that delivers Flexibility to address an emerging issue that could result in an unplanned outage or an event if not addressed.	DNO-dependant	Week Ahead	[2 hours]	1kW
	Dynamic - DSO Constraint Management (post-fault) (DDCM)	A Flexibility Service that delivers Flexibility after an unplanned outage or fault has occurred	DNO-dependant	120 to 15 mins	Up to 8 hours	50kW (total across all DERs

[10] These services are not included in the analysis due to their expiry or uncertainty of value.

Category	Service	Description	Auction Period	Delivery Notice	Delivery Duration	Minimum Capacity
	Restore	A Flexibility Service that uses Flexibility to support restoration of part or all of one or more Distribution Network or Transmission System following a planned or unplanned outage. Have been trialled[11], but not planned in the near future. ***Out of scope for this work***[12].	DNO-dependant	15 mins	[Up to 8 hours]	1kW
P2P	Exceeding Maximum Export Capacity (EMEC)	Two Market Actors on a network with an unconstraint path between each other trade a portion of their export capacity so one can increase its existing export for an agreed period without affecting the network	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
	Exceeding Maximum Import Capacity (EMIC)	Two Market Actors supplied by the same substation trade a portion of their import capacity so one can increase its existing import for an agreed period without affecting the network	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
	Offsetting (OFFST)	Two Market Actors in a constrained area working together so one increases its demand (or generation) before another increases its generation (or demand) by the same amount, with appropriate fail-safe mechanisms	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
Other Revenue Streams	Wholesale Trading (WT)	Use of Flexibility to trade in the wholesale energy markets via third party trader to take advantage of price differentials between different Flexibility Services	Day Ahead On the Day	Subject to agreement	Subject to agreement	Subject to agreement
	Time of Use Tariffs (ToUT)	Use of Flexibility to manage demand to reduce electricity costs in response to the tariff price signals. Applicable to small businesses and residential consumers.	N/A	Time of Use periods defined in the supply contract	Continuous	N/A

[11] National Grid and SP Energy Networks NIC funded Distributed ReStart - https://www.nationalgrideso.com/future-energy/projects/distributed-restart
[12] These services are not included in the analysis due to their expiry or uncertainty of value.

Category	Service	Description	Auction Period	Delivery Notice	Delivery Duration	Minimum Capacity
	Transmission Charge Management (TCM)	Use of Flexibility to manage demand during Triad Periods (the three half-hour settlement periods between November and February with the highest system demand - and separated by at least 10 days) to reduce TNUoS charges (TNUoS charges are based on the average demand during the Triad Periods)	Triad Periods	Forecast only, Triad Periods are not declared in advance by NGESO	30 minutes in each Triad period	Subject to supplier agreement
	Distribution Charge Management (DCM)	Use of Flexibility to manage generation or demand, particularly during Red Band periods (times of peak demand which is both Network and voltage dependent) to receive DUoS benefits (generation) or reduce DUoS charges (demand) (DUoS charges are based on metered generation or demand during - both generator benefits and demand charges are highest during Red Bands)	Continuous (highest impact during Red Band periods)	DUoS charging Bands are published by the DNO	Network and Voltage dependent	Subject to supplier agreement and metering type

1.4.1 Existing Services

The use cases for Flexibility will grow as flexibility markets mature and the need for new Flexibility Services emerge as strain on the network increases from additional demand and distributed generation. The 2020 Future Energy Scenario report[13] identified Flexibility as one of the key themes and predicts electricity Flexibility could exceed 164,000MW by 2050[14]. The Flexibility Services that could apply to LEO DERs are outlined in Table 3 and considered further in Table 4 and Table 5

Four of the DSO Flexibility Services in Table 3 are currently being developed and tested within Project LEO. These are: Sustain - Peak Management, Sustain - Export Peak Management, Secure - DSO Constraint Management (pre-fault) and Dynamic - DSO Constraint Management (post-fault).

Project LEO will look to continue the development of these DSO procured services as they are aligned with the outputs from ON-P[15]. Sustain - Export Peak Management is also a new service included by TRANSITION to be trialled and developed, although there is not yet any market information on this service[16].

1.4.2 New Services within LEO

In addition to the Flexibility requirements of the DSOs, Market Actors (aggregators, DER owners, suppliers, traders, etc) may want to use P2P services to maximise the use of available capacity allocations, maximise the potential of connected LCTs and to trade other services (including the delivery obligations from Flexibility Services agreements). This will be vital to increase the utilisation of the distribution network, enable the significant increase of LCTs required to achieve Net Zero and maximise the available Flexibility. Three P2P Flexibility Services are currently being developed and tested within Project LEO: Exceeding MEC (Maximum Export Capacity), Exceeding MIC (Maximum Import Capacity) and Offsetting. These are explained further below and will be facilitated by the DSO who need to pre-approve the trades to ensure there is no adverse effect on the network or the constraint. LEO refers to these services as DSO-Facilitated Services. Exceeding MIC / MEC – Maximum Import Capacity / Maximum Export Capacity.

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[13] "Future Energy Scenario", published by National Grid ESO, July 2020

[14] The FES value comprises: Electric Vehicles 38,000MW; electricity storage 40,000MW; hydrogen electrolysis 73,000MW; and industrial and commercial demand 13,000MW. Interestingly, there is no value for domestic flexibility which, at 1kW per premise, could exceed 22,000MW (see Number of domestic electricity customer accounts by supplier at https://www.ofgem.gov.uk/data-portal/all-charts)

[15] DNO Flexibility Services Revenue Stacking, published by the Energy Network Association, July 2020

[16] Sustain Peak Management involves reducing demand or increasing generation; the export version involved increasing demand or reducing generation (a bit like the Optional Downward Flexibility Management service the ESO has). It is designed to reduce the impact on the network from peak generation (particularly solar PV in summer).

These are Flexibility Services where two Market Actors within the same substation area can trade some or all of their MEC or MIC one can increase their export or import by an agreed amount whilst the other agrees not to use that portion of their MEC or MIC. The one purchasing the higher MEC or MIC can then increase its MEC or MIC by the agreed amount for the agreed duration. This helps customers to address their own issues, e.g., to resolve generation constraints or to trade MEC when not required. For example, a PV farm with installed generation capacity greater than agreed MEC whilst the other site, within the same network zone, is a run of the river hydro with strong seasonal variability. The unused export capacity from hydro can be traded to the PV farm for the duration of the season when hydro has low output. This service is subject to approval by the DSO because it has the potential to change power flow higher up the network[17].

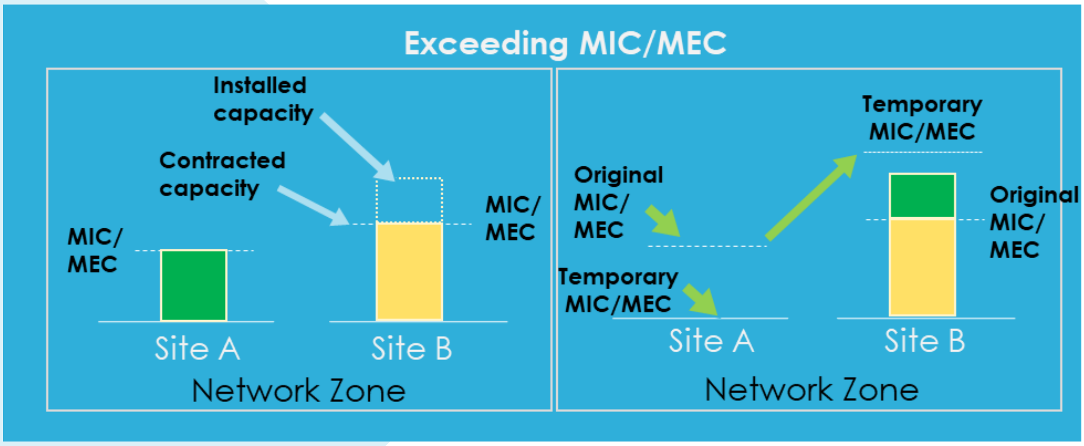


Figure 2: Illustration of the new MIC / MEC Trading Service

1.4.2.1 Offsetting

Similarly, to Exceeding MIC/MEC Flexibility Services, the Offsetting service offers an opportunity to temporally exceed MIC/MEC. For example, a PV farm with installed generation capacity greater than the agreed MEC would like to increase its output and could trade with a demand customer in the same constrained area who can use their Flexibility to enable the increase in generation, creating a no net effect on the constraint but increasing he renewable generation.

In the Offsetting service, two customers in the same constrained area agree as follows:

- the customer wishing to increase their generation above their MEC or their demand above their MIC will obtain prior approval from the DNO;
- the first customer will increase their demand (or generation) within their MIC/MEC;

[17] The vast majority of capacity issues are in relation to generation, so most examples are about generation

- the second customer will increase their generation (or demand) by the same amount once the above step has been confirmed (which may be immediate) and will, effectively, be above their MEC or MIC accordingly;
- the second customer can maintain the increased generation (or demand) until the earlier of:
  - the end of the trade period for that day;
  - the end of the trade; and
  - an interruption to the demand (or generation) of the first customer; here the second customer can resume the increased generation (or demand) once the first customer resumes its increased demand (or generation).

As the increase in demand (or generation) is the same as the increase in generation (or demand), there is no net effect on the power flows at the constraint as a result of this trade. However, this Flexibility Service has the ability to put the network at risk, e.g. if the demand DER fails and the generation continues, the constraint could get overloaded and create a fault. To address this a (near) real-time control system is needed to ensure the integrity of the network is retained during specific issues, including; loss of communications or loss of the demand.

The need for this service could arise if a Market Actor G (e.g. Generator) has more solar PV installed behind the MPAN (e.g. 6MW) than it is allowed to export due to a limited MEC (e.g. 5MW). If Market Actor G wishes to generate the extra 1MW it needs an additional 1MW of MEC. If Market Actor D (e.g. Demand) increases its demand by a similar amount (1MW) in advance of any increase by Market Actor G, then you will always have a safe network and no material effect on the constraint. This is illustrated in Figure 3: Illustration of the new Offsetting Service.

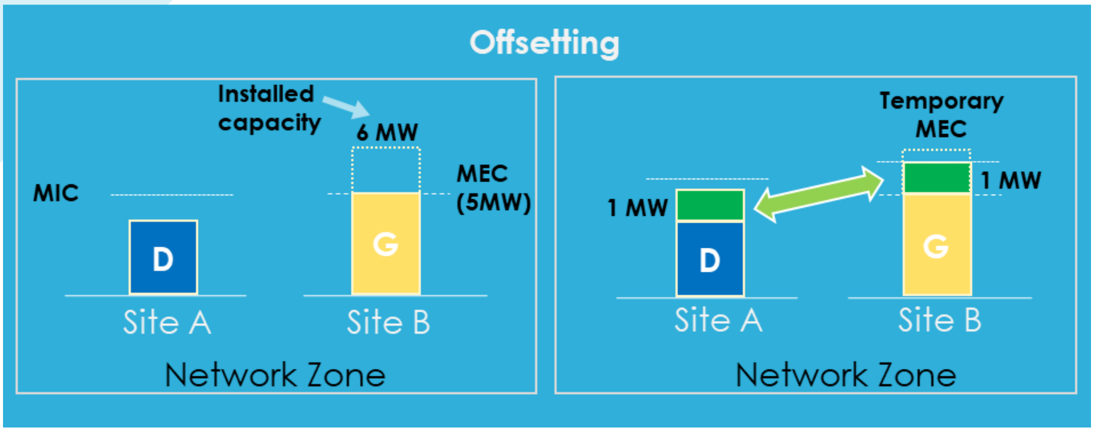


Figure 3: Illustration of the new Offsetting Service

DSO-Facilitated Services allow customers to participate in the P2P flexibility market to maximise the use of their installed capacity and to maximise the use of the available MEC or MIC.

2 Flexible DERs and their capabilities

Flexibility is a deliberate or planned change in the electricity demand or generation of an DER in response to an instruction to deliver a Flexibility Service. Not all DERs are capable of delivering a Flexibility Service on their own as they may not be able to:

- respond quickly enough as per service requirements;
- meet the duration of a Flexibility Service; or
- provide the minimum level required by a Flexibility Service.

2.1 Overview of DER types

The range of DERs that are used to deliver Flexibility Services will grow as the range of Flexibility Services change and as DERs that have a high carbon content become less attractive in the drive to achieve Net Zero. This is illustrated in Table 4 which highlights;

- In a Net Zero world, DERs that currently rely on carbon-intensive fuels (diesel, coal, natural gas) will need to change fuel to a lower carbon one, e.g. hydrogen. DERs that can switch could increase as a source of greener, flexible power whilst those that cannot adapt will reduce. This applies to the "Change Fuel Source" and "CO_2 Emissions too High".
- DERs with low level of Flexibility need a cost-effective control and metering solution to be economically viable. This may be as simple as using the IoT to verify a switch has changed status to prove Flexibility has been delivered. This applies to "Cost Effective Control" and "Metering Solution".

An entry in Table 4 implies that there is a contribution to made by that technology and that it will increase or reduce in penetration or will have no change or is unaffected (grey cells).

Table 4: How DERs Delivering Flexibility Services will Change to Enable the Delivery of Net Zero

DER	Rationale for and Direction of Change				
	Change Fuel Source	CO_2 Emissions Too High	Cost Effective Control	Delivery of Net Zero	Metering Solution
Battery Storage				increase	
Combined Heat & Power	increase	reduce			
Commercial Demand	increase		increase		increase
Domestic Demand	increase		increase		increase
Generation (carbon-based)	increase	reduce			
Hydro (pumped storage)				no change	
Hydro (run of river)				increase	
Industrial Demand	increase	reduce			
Solar PV			increase	increase	
Wind			increase	increase	

2.2 Mapping of DERs to services

The specific DER types that will exist (or are expected to exist) within LEO and TRANSITION and the Flexibility Services they can provide, as indicated in Section 4.1, are summarised in *Table 5*.

Table 5: Table Illustrating the Flexibility Services that could be Delivered from Specific DERs

Technology	ESO					DSO				P2P		Other			
	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC / EMIC	OFFST	WT	ToUT	TCM	DCM
Battery Storage															
Combined Heat and Power															
Commercial Demand															
Domestic Demand															
Gensets															
Hydro (run of river)															
Industrial Demand															
Solar PV															
Wind															

The colour coding used in Table 5 is:

- green boxes ■ – these DERS can deliver the Flexibility Service for the entire duration and have good availability, e.g. industrial demand;
- yellow boxes ■ – these DERs can generally deliver the Flexibility Service for the duration indicated, although may have limited availability and there will be one or two pre-conditions, e.g. seasonal availability, limitation by size or requires pre-conditioning
- orange boxes ■ – these DERs require a number of pre-conditions, e.g. low or seasonal availability and/or capacity needs to be aggregated to meet the minimum requirements for a Flexibility Service or applicable only in context of customer type/size; and
- red boxes ■ – these DERs are unable to deliver a Flexibility Service, e.g. a solar farm cannot generate more electricity on demand.

There are two other aspects of Table 5 that are worth noting:

- the ability of a DER to deliver a number of Flexibility Services provides the opportunity to deliver one service instead of another in order to realise a higher price (price arbitrage), e.g. a battery could be offered in the day ahead Dynamic Containment auctions or in the day ahead wholesale trading market depending on the expected highest price. This strategy should not be used to avoid contractual responsibilities to deliver a Flexibility Service or to game the delivery of Flexibility Services; and

- a group of DERs can be used collectively to deliver a Flexibility Service where some could provide the initial speed of response and initial period of delivery (e.g. a battery which is energy limited and cannot deliver a long duration service) whilst others could either aggregate to extend the capacity and / or duration (e.g. an industrial demand process that may need time to respond so could not provide the speed of response or EVs that could be used to fill in gaps in the delivery profile due to their short duration and low level of capacity compared to many DERs).

2.3 Flexibility Services delivery from a portfolio of DERs

However, an organisation may have or can create a portfolio of DERs to deliver a Flexibility Service by using a mix of DERs that includes:

- DERs that respond quickly enough and deliver the first minutes of a Flexibility Services;
- slower acting DERs that can provide the duration of a Flexibility Service and take over from those that respond quickly; and
- additional DERs that increase the capacity, each of which could deliver some of the capacity and / or duration to deliver the Flexibility Service.

This is illustrated in Figure 4 which shows how similar types of DERs (same colour) can combine to deliver the required Flexibility Service duration and stack to provide the required Flexibility Service capacity.

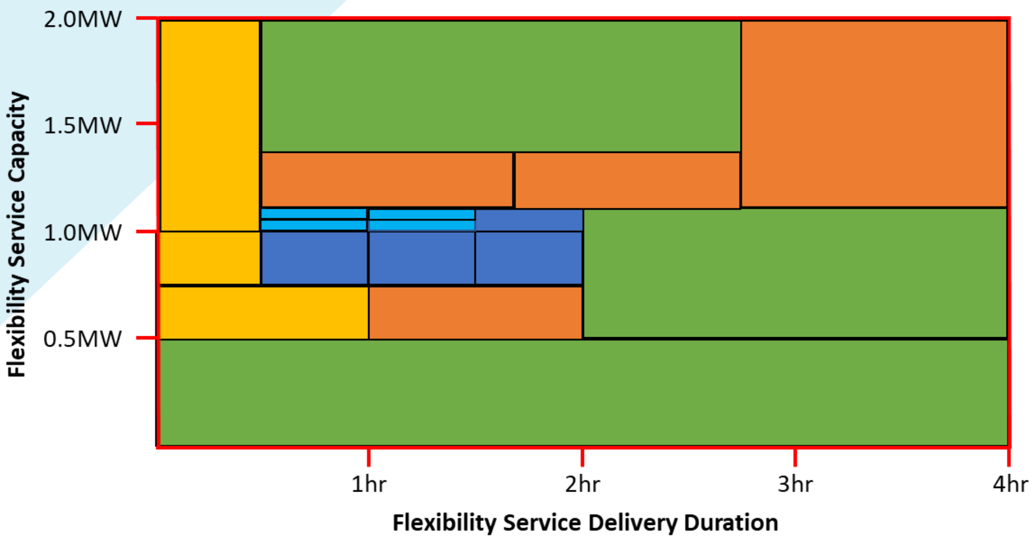


Figure 4: How a Portfolio of Different Assets can Work Together to Deliver a Flexibility Service

3 Accessing Flexibility

Whilst all DERs can provide Flexibility if switched on or off in response to an instruction, this may be an unsuitable, uneconomic or damaging use of the DER and not all DERs are suitable or capable of providing Flexibility in a useful way.

FUSION identified a simple 4-step process[18] to ensure the use of a DER to provide Flexibility has no detrimental effect on the normal operation of the business, is operated within agreed parameters and is a cost-effective proposition. This is summarised in Table 6.

Table 6: FUSION 4-Step Process for using a DER to Deliver Flexibility Services

Step	Summary
1 - Understand	location, type and capacity of DER, likely Flexibility, potential services and usage
2 - Deployment	interacting with the DER to instruct the Flexibility
3 - Testing	commissioning and proving services that can be delivered using the Flexibility
4 - Monetise	making the DER available to deliver services, agreeing the level of delivery and invoicing for services delivered

The process of monetising a DER involves a number of considerations and, whilst this is outside the scope of this report, they are summarised below:

- **Flexibility Markets** – identifying the Flexibility Services that can be delivered from a DER or a portfolio of DERs will influence the markets of interest.
- **Level of Market Knowledge** - understanding the Flexibility Services available in the flexibility markets, analysis of report on Flexibility Services and pricing, and understanding how the auctions work.
- **Direct or Indirect Market Access** – determining whether to access a flexibility market directly (as the contracting party who takes delivery and other contractual risks) or indirectly (contracting with a third party who takes delivery and other contractual risks) and which applies for each flexibility market.
- **Enablement and Control** – to dispatch the DER to deliver Flexibility Services and Other Revenue Streams.
- **Monitoring** – determining the status of the DER and how that affects declarations of availability to deliver Flexibility Services and Other Revenue Streams.
- **Billing and Settlement** – determining and receiving payments for Flexibility Services or savings from Other Revenue Streams.

[18] "Quantifying Flexibility Report, 28 November 2019", Figure 13, Flexibility https://www.spenergynetworks.co.uk/userfiles/file/FUSION_Quantifying_Flexibility_Report.pdf

4 Gross Revenue from Using Flexibility

There are a number of areas to be considered when determining the business case for enabling an existing DER or determining the viability of new DERs to deliver Flexibility Services. The three main areas are considered below:

- the priority ascribed to the delivery of Flexibility Services from the DER (from Table 5; could be services that have a lower delivery cost, a higher profit margin or a fewer delivery periods) versus the primary purpose of the DER and the operational impact of delivering Flexibility Services (if any); it is assumed the primary purpose of the DER is known and it has been agreed to use the DER to deliver appropriate Flexibility Services.
- the costs of using the DER to deliver Flexibility Services and Other Revenue Streams; it is assumed the costs of using the DER and the minimum profit level are known as are the other potential uses for the DER to ensure all opportunities are considered.
- the costs of enabling the DER to deliver Flexibility Services; this is outside of the scope of this report as it is DER- and site-specific, varies from nil to £000's and depends on many variables including:
  - for existing DERs - the age of the DER, the existing capability of the plant and equipment to deliver Flexibility Services (if any) and the economics of making the DER capable of delivering Flexibility Services (if required), including provision of appropriate monitoring.
  - for new DERs - the economics of making the DER capable of delivering Flexibility Services (if not already capable) and proving the delivery with appropriate monitoring.
- the ability of the DER to deliver and stack Flexibility Services with one another and with Other Revenue Stream to increase income; this will be explored in section 4.2.

4.1 Income from Flexibility Services and Other Revenue Streams

The revenue from Flexibility Services depends on the DER capability and the range of Flexibility Services that can be delivered by the DER and provide additional income streams from:

- ESO Flexibility Services
- DSO Flexibility Services
- P2P Flexibility Services
  - from using spare MEC or MIC of one Market Actor to allow the spare installed generation or demand of another Market Actor enable them to export or import more electricity at a site; or

- increasing revenue in a constrained area by increasing the demand or generation of one Market Actor to offset the same level of increase of generation or demand of another Market Actor.

In addition, a DER can be used to deliver Other Revenue Streams:

- reduce the electricity demand or change the pattern of electricity usage at a site using Flexibility to reduce the liability for certain transmission or distribution costs and reduce the variable electricity costs; or
- reduce the electricity demand or change the pattern of electricity usage at a site in response to the electricity cost in a time of use tariff to reduce the effective electricity costs; or
- use Flexibility to arbitrage on price differentials in the wholesale electricity markets via trading agent.

The remainder of this section and relevant Appendices provide an analysis of prices for the range of Flexibility Services identified in 1.4. The analysis uses data provided by independent external sources - LEO partners and third parties may have a more appropriate data set that is commercially sensitive but reflects their market experience. There are a number of issues in providing price information for Flexibility Services from independent external sources:

- the price for a Flexibility Service can be inherently volatile, e.g. Wholesale Trading and Balancing Mechanism as they are related to many other factors including; the level of competition, the effect of weather on demand or generation levels and the level of sentiment in the market. Predicting an absolute price for these services is very difficult as the optimum strategy is often determined at the day ahead stage or on the day.
- the level of data is insufficient to reliably determine a market price for a Flexibility Service if it has been recently launched, e.g. Dynamic Containment.
- there is no data for a Flexibility Service that has yet to be launched or transacted, e.g. Exceeding MEC or Exceeding MIC.

4.1.1 Gross Revenue from ESO Flexibility Services

ESO Flexibility Services are procured in a number of different ways:

- auctions are used for Balancing Mechanism (pay as offered), Firm Frequency Response (pay as offered) and Capacity Market (pay as cleared);
- periodically for Short-Term Operating Reserve (currently suspended but to be reinstated in April 2021); and
- at the day ahead stage for Dynamic Containment

ESO Flexibility Services may also have specific metering and communications requirements or have minimum capacity requirements for participation that may require the aggregation of capacity across a number of DERs. In addition to technical aggregation to meet the minimum capacity requirements, aggregators could also play a role of Virtual Lead Party[19] that help to fulfil the requirement for flexibility provides to comply with Grid Code and Balancing and Settlement Code.

Prices for each Flexibility Service have been analysed and are summarised in Table 7 with the detail in Appendix A-C.

Table 7: Income from ESO Services

Service	Recent values
BM	Balancing Mechanism prices were analysed for 3-4 days selected at random for each month in 2020 and is provided in Appendix A; ▪ the typical daily price range is £3-£70/MWh; ▪ price spikes can exceed £230/MWh for individual or a number of adjacent Settlement Periods, generally when there is a shortage of generation and during cold weather; and ▪ price troughs can be negative for individual or a number of adjacent Settlement Periods (often down to -£70/MWh or less). ▪ Value from managing imbalance is generated by reducing the gap between estimated and actual balance position. Adjusting demand or generating to reduce imbalance during high price periods provides savings and during negative prices provides income.
CM	Capacity Market prices are determined during annual auctions for year ahead (T-1) and four years ahead (T-4) [20]: ▪ T-4 (DY19/20) -£18/kW/year paid during the delivery year. ▪ T-1 (DY20/21) - £1/kW/year paid during the delivery year. ▪ T-4 (DY20/21) - £22.5/kW/year paid during the delivery year. ▪ T-1 (DY21/22) - £45/kW/year paid during the delivery year. ▪ T-4 (DY21/22) £8.4/kW/year paid during the delivery year. ▪ T-3 (DY22/23) - £6.44/kW/year paid during the delivery year[21] ▪ T-4 (DY23/24) - £15.97/kW/year paid during the delivery year

[19] Virtual Lead Party – Entering the Market, Elexon Guidance Note, https://www.elexon.co.uk/documents/training-guidance/bsc-guidance-notes/virtual-lead-party-vlp-entering-the-market/
[20] Capacity market Auction results. https://www.emrdeliverybody.com/CM/Auction-Results-1.aspx
[21] T-3 auction for delivery year 2022/23 was introduced to compensate for the 2018 T-4 auction that was postponed due to the suspension of CM auctions between 2018 and January 2019. https://www.ofgem.gov.uk/system/files/docs/2020/03/2018-19_annual_report_on_the_operation_of_cm.pdf

Service	Recent values
DC	Dynamic Containment was recently launched by the ESO and there is insufficient capacity in the market to meet 100% of the ESO needs. This Flexibility Service competes with Wholesale Trading prices which puts further pressure on prices; ▪ £17/MW/h[22]
ODFM	First introduced in 2020 to help manage the significantly lower than average demand caused by COVID-19. The ESO announced that it saw a need for this service during summer 2021[23] from 23:00 Friday 30 April to 23:00 Sunday 31 October as there is a credible worst-case scenario for 2021. The 2020 service fees[24] below may not be representative for 2021: ▪ £60-200/MW/h but varies by technology and DER capacity (see Appendix B)
STOR	Following suspension in 2020, the ESO is looking to reinstate it from April 2021. Previous prices for seasons 13/14 (see appendix C): ▪ Availability: average £3.91/MW/h, minimum: £0.25 /MW/h, maximum £13.50/MW/h. ▪ Utilisation: average £123.12/MWh, minimum: £15.40/MW/h and maximum £263/MW/h.

4.1.2 Gross Revenue from DSO services

DSO Flexibility Services are procured via two 6-monthly procurement auctions[25] for Autumn and Spring, ahead of need, and generally have minimum capacity requirements of 50kW[26] that may require aggregation of capacity across a number of DERs.

Prices for each Flexibility Service have been analysed from Piclo Flex and are summarised in Table 8 with the detail in Appendix D.

Table 8: Income from DSO services

Service	Recent Prices	
	Availability Payment	Utilisation Payment
SPM	Mean: £148.81/MW/h[27] Median: £15/MW/h[27]	Mean: £378.16/MWh[27] Median: £270/MWh[27]
SEPM	No data as new service	No data as new service
SDCM	£125/MW/h[28] Mean: £392.08/MW/h[29]	£175/MWh[28] Mean: £573.61/MWh[29]

[22] Dynamic Containment tender results – 2021-02-18 https://data.nationalgrideso.com/ancillary-services/dynamic-containment-data
[23] Optional Downward Flexibility Management. https://data.nationalgrideso.com/ancillary-services/optional-downward-flexibility-management-odfm1/r/odfm_letter_to_industry_03.02.2021
[24] Service fees are based on "all or nothing" response for the specified time rather than a specified volume, therefore it is treated as utilisation fee.
[25] https://www.energynetworks.org/assets/images/Resource%20library/ON20-WS1A-P2%20Procurement%20coordination%20implementation-PUBLISHED.23.12.20.pdf
[26] https://www.energynetworks.org/assets/images/Resource%20library/ON20-WS1A-P2%20Existing%20Processes%20(PUBLISHED).pdf
[27] Reinforcement deferral competition as proxy, 58 bids, Historic bids data from competitions across GB, Piclo Flex, https://picloflex.com/
[28] Data from Flexible Power; https://www.flexiblepower.co.uk/flexibility-services
[29] Pre-fault competition as proxy, 385 bids, Historic bids data, Piclo Flex, https://picloflex.com/

Service	Recent Prices	
	Availability Payment	Utilisation Payment
	Median: £101.7/MW/h	Median: £155/MWh
DDCM	£5/MW/h[28] Mean: £15.45/MW/h[30] Median: £5/MW/h	£300/MWh[28] Mean: £271.43/MWh[30] Median: £400/MWh

4.1.3 Gross Revenue from P2P services

The two P2P Flexibility Services (Exceeding MEC / MIC and Offsetting) are new and have not been traded previously in public view or for the shorter periods being considered. As such, there is no data to analyse and no prices to reference. Prices will be collected from the various tests and trials being conducted by LEO and TRANSITION and this will provide data for analysis.

4.1.4 Gross Revenue from Other Revenue Streams

As discussed in the preamble to this section 3, Flexibility can be used to reduce the electricity demand or change the pattern of electricity usage to deliver Other Revenue Streams of which there are four (Transmission Charge Management, Distribution Charge Management, Time of Use Tariff Incentives and Wholesale Trading) that are discussed in this section 4.1.4.

4.1.4.1 Wholesale Trading

The wholesale electricity market is where large volumes of electricity is bought and sold between generators, electricity suppliers and traders before being delivered to end customers. Generators use the wholesale electricity markets to sell electricity to electricity suppliers, other generators and traders and to buy or sell electricity to cover any shortage between their generation, purchases and sales. Electricity suppliers use the wholesale electricity markets to buy and sell electricity to meet the difference between the aggregate demand for all their customers and purchases made directly from generators. Traders use the wholesale electricity market to buy and sell electricity as a commodity, but usually cannot take physical delivery of electricity so trade to balance their purchases and sales. The wholesale electricity markets require participants to provide cash collateral to meet the expected cost if they defaulted on electricity trades and this acts as a barrier to participation in the wholesale electricity markets.

The owner of a DER can use a third party to pay them the wholesale electricity market price for their Flexibility (less any transaction charges). Prices in the wholesale electricity market are volatile and rise and fall regularly, often due to sentiment rather the attitude to external factors, e .g. weather or market changes or government announcements than any underlying reason.

[30] Post Fault competition as proxy, 7 bids, Historic bids data, Piclo Flex, https://picloflex.com/

Table 9: Potential value of Wholesale Trading based on historical prices[31]

Year	Value from differential arbitrage based on perfect foresight
2019	Up to £11.8k/MWh/year
2020	Up to £14.4k/MWh/year

4.1.4.2 Time of Use Tariff Incentives

Customers who have an electricity tariff that has different prices at different times can reduce their electricity costs if they can change the level and pattern of electricity consumption to times when it is cheaper. For example, running a washing machine will be cheaper overnight than during the day. Many suppliers provide a Time of Use Tariff (ToUT), e.g. separate day and night prices with the more innovative suppliers providing more sophisticated tariffs to encourage a change in behaviour, e.g. Octopus Energy[32] and Bulb[33] offer a ToUT to domestic customers and have a ToUT to incentivise electric vehicles to charge overnight: early results from the analysis of Octopus Agile tariff showed that regular consumers shifted 28% of demand at peak time period and those with EVs shifted 47%[34]. Broadly, pilot projects and studies have been assessing the impact on consumers and their uptake of tariffs. One study estimates that a range of ToUTs could deliver System value of up to £272 million per year [35]

ToUTs help electricity suppliers manage their portfolio and reduce their price risk. New technology is aiding this transformation, with smart meters and mobile apps allowing customers to monitor their half-hourly energy costs, making it easier for them to change their level and pattern of electricity usage. Table 10 provides details of a Bulb ToUT illustrating the cost savings if electricity usage is changed from peak times to off peak times.

Table 10: Bulb Energy Dual Smart Tariff Electricity Rates

Region	Off Peak Rate pence per kWh	Peak Rate pence per kWh	Standing Charge pence per day
South West England	13.85	26.35	20.09

[31] Nordpool power market archive for day-ahead prices, https://www.nordpoolgroup.com/historical-market-data/
[32] Bulb Smart Tariff, https://bulb.co.uk/smart/
[33] Octopus Agile Tariff, https://octopus.energy/agile/
[34] Agile Octopus, A consumer-led shift to a low carbon future, 2018, https://octopus.energy/static/consumer/documents/agile-report.pdf
[35] The Value of ToU Tariffs in Great Britain: Insights for Decisionmakers, Brattle Group and UCL, 2017, https://brattlefiles.blob.core.windows.net/files/7347_the_value_of_tou_tariffs_in_great_britain_insights_for_decision-makers.pdf

South East England (includes Oxfordshire)	13.31	25.81	20.01
Yorkshire	12.18	24.68	22.63
Time	4PM-7PM	7PM-12AM, 12AM-4PM	n/a

In the context of project LEO, a domestic customer could benefit from shifting demand away from the peak time to an off-peak time and save 12.5p/kWh. If that domestic customer had a DER with Flexibility, they may be able to reduce their electricity costs further.

A further innovation provided by Octopus Energy is a dynamic ToUT (dToUT) with prices and time periods issued to customers at the day-ahead stage. Whilst these variable rates have less certainty ahead of time, they are more representative of the system needs and constraints. When demand is high (regionally and nationally) and wholesale market prices for electricity are expected to be high, the day-ahead prices in a dToUT will also be high, and vice-versa. With such uncertainty customers are protected from financial risk with price caps.

Analysis of the price differentials of a typical dTOUT indicates that deferring demand from peak-period could have saved an average of 15p/kWh in winter and 12p/kWh in summer during 2019 (see Appendix E). For more flexible DERs, e.g. an energy storage device that stores energy over a day, every kWh moved removed from the six settlement periods in the peak time to the lowest six settlement periods could generate revenue of around £1.14 per day in winter and 90p per day in summer.

Table 11: Gross revenue from ToU tariffs for South East region

Tariff	Estimated Annual Revenue[36]		Suitable DERs
	1 half-hour/day	3 hours/day	
dToUT (Octopus Agile)	£74.06/kWh	£390.24/kWh	Residential energy storage.
	£21.23/kWh	£309.72/kWh	Residential demand response to shift demand immediately after the peak-time.
ToUT (Bulb)	£45.62/kWh	£273.75/kWh	Residential energy storage and Residential demand response to shift demand immediately after or before peak-time.

4.1.4.3 Transmission Charge Management (TRIADs)

Transmission charges cover the provision and maintenance of the transmission system that delivers electricity from one part of the country to another. All customers pay these charges in one way or another, e.g., larger non-domestic customers have these charges separately itemised so they can use Flexibility to reduce their liability to these charges whereas domestic

[36] 3 hours cover entire duration of the peak time; Energy storage is assumed to charge at lowest price and discharge at highest. Demand shift for 1 half-hour is assumed to be the last half-hour of the peak period.

customers have these charges bundled into their electricity cost and cannot benefit from any use of Flexibility to reduce their liability. Prices vary over 27 generation zones and 14 demand zones across GB and reflect the loading on the transmission system and act as an incentive to reduce demand where possible during peak periods.

The amount a customer is liable to pay is determined by their import or export level during "… the three half-hour settlement periods of highest demand on the GB electricity transmission system between November and February (inclusive) each year, separated by at least ten clear days"[37].

The ESO publishes the TRIADs at the end of March for the previous November to February based on electricity system demand data. The TRIADs for the period 2014/15 to 2019/2020 are summarised in *Table 12* and the Demand Tariff information has three categories:

- HH – customers whose electricity usage is measured every Settlement Period;
- nHH – customers whose electricity usage is not measured every Settlement Period; and
- EET – embedded export tariff, a credit for generation connected to the distribution network that has a capacity of less than 100MW.

Table 12: TRIAD Periods and Tariffs for South East Demand Region from 2019/20 to 2021/22

Year	Day of Week	Date	Time (Settlement Period)	Demand Tariff		
				HH (£/kW)	nHH (p/kWh)	EET (£/kW)
2021/22	Forecast			56.77	7.74	-5.82
2020/21	Forecast			56.5	7.5	-8.18
2019/20	Monday	18th November 2019	1700-1730 (35)	56.11	7.496	-22.689
	Monday	2nd December 2019	1700-1730 (35)			
	Tuesday	17th December 2019	1630-1700 (34)			

Analysis of the latest TRIAD events in *Table 12* and historical events in Appendix G indicates a TRIAD is more likely to occur as follows;

- on a Monday (11 out of 18 TRIADs) but never on a Friday (0 out of 18 TRIADs);
- in Settlement Period 35 (17.00-17.30) (12 out of 18 TRIADs), Settlement Period 36 (17.30-18.00) (4 out of 18 TRIADs); and

[37] https://www.nationalgrideso.com/industry-information/charging/charging-guidance#triads

- in any TRIAD month; November (3 out of 18 TRIADs), December (6 out of 18 TRIADs), January (5 out of 18 TRIADs) and February (4 out of 18 TRIADs).

An anomaly occurred in February 2018 due to the "Beast from the East" which resulted in two TRIADs during the month and the latest TRIAD in the data set in *Table 12* due to the effect of increased daylight time.

4.1.4.4 Distribution Charge Management

Distribution charges cover the provision and maintenance of the distribution network that links customers to the transmission network and other customers in the region. All customers pay these charges in one way or another, e.g. larger non-domestic customers have these charges separately itemised so they can use Flexibility to reduce their liability to these charges whereas domestic customers have these charges bundled into their electricity cost and cannot benefit from any use of Flexibility to reduce their liability to these charges directly.

The liability for amount a customer depends on the DNO region, the type of customer and the time of day. Each day has three price bands; red band prices are significantly higher than amber band prices with green band prices being the lowest. These prices reflect the loading on the distribution network and act as an incentive to reduce demand where possible during peak periods. The time bands and charges for Southern Electric Power Distribution (SEPD) half-hourly customers in 2022[38] are summarised in Table 13.

Table 13: Distribution Charges for Half Hourly Metered Customers in SEPD Area from 1st April 2022

Time Period	Red Time Band	Amber Time Band	Green Time Band
Monday to Friday All Year (including Bank Holidays)	16:30 - 19:30		
Monday to Friday All Year (including Bank Holidays)		07:00 - 16:30 19:30 - 22:00	
Monday to Friday All Year (including Bank Holidays)			00:00 - 07:00 22:00 - 24:00
Saturday and Sunday All Year		09:30 - 21:30	00:00 - 09:30 21:30 - 24:00
	Red/black unit charge p/kWh	**Amber unit charge p/kWh**	**Green unit charge p/kWh**
Customers on LV (400V) network with Half-hourly metering	6.206	0.647	0.029
Customers connected directly to LV substation	4.041	0.297	0.010
Customer on HV (11kV) network	3.138	0.208	0.006

[38] DUoS charging schedule from SSEN: https://www.ssen.co.uk/Library/ChargingStatements/SEPD/

Stand alone or aggregated generation on LV network	-5.539	-0.663	-0.032
Standalone or aggregated generation directly connected to LV substation	-4.961	-0.547	-0.025

4.2 Stacking of Flexibility Services and Other Revenue Streams

The income from the delivery of Flexibility Services and Other Revenue Streams can be increased if a DER delivers a variety of services over time. The Energy Networks Association Open Networks Project commissioned a report[39] that identified two means of stacking services which are summarised below and illustrated in Figure 5:

- Coincident Delivery – a DER is used to deliver more than one Flexibility Service or Other Revenue Streams at the same time and get paid twice (or more) during a given time period; or
- Adjacent Delivery – a DER is used to deliver one or more Flexibility Services or Other Revenue Streams during adjacent time periods.

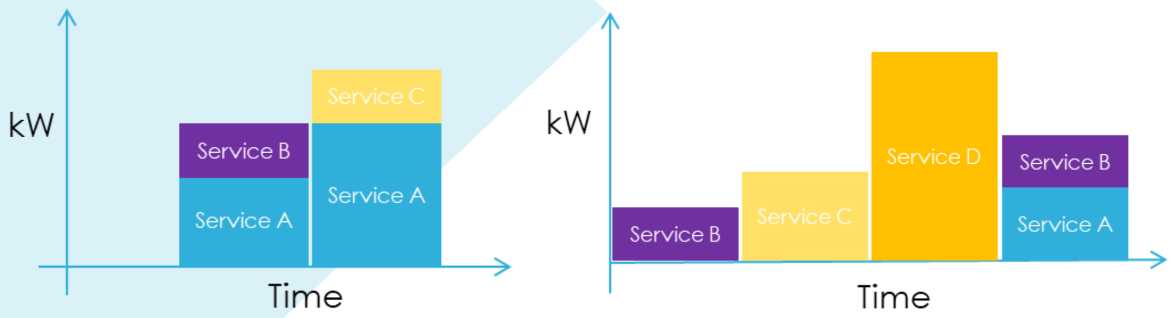


Figure 5: Illustration of stacking services; Coincident Delivery (left) and Adjacent Delivery (right)

The information on the stacking of relevant Flexibility Services and Other Revenue Streams detailed in 1.4 is summarised in Table 14 and Table 15.

Table 14: Compatibility of Flexibility Services and Other Revenue Streams for Coincident Delivery

	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC/EMIC	OFFTS	WT	ToUT	TCM
DCM		41		40	40	40	40	40	40					
TCM				40	40	40	40	40	40					

[39] DNO Flexibility Services Revenue Stacking. Open Networks Projects, published July 2020
[40] DCM and TCM benefits can be achieved only at the time of delivery of Flexibility Services or when managed these chargers does not impact the baseline for validating the delivery of flexibility service.

ToUT		41										
WT							42	42		42		
OFFST												
EMEC/EMIC		43				44	44	44	44			
DDCM		43										
SDCM		43										
SEPM		43										
SPM		43										
STOR												
ODFM												
DC												
CM												

[41] Can be stacked if CM does not rely on baselining to prove delivery.
[42] Requires coordination with corresponding BRP to trade additional volume ahead of EMIC/EMEC.
[43] Flexibility provider may incur penalty if fails to respond to CM Stress event or prove delivered response.
[44] Subject to approval from DNO and the alignment in direction of service delivery: e.g. cannot sell MIC and declare demand response for DNO services, but can buy MEC to export for DSO Services.

Table 15: Compatibility of Flexibility Services and Other Revenue Streams for Adjacent Delivery

	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC/EMIC	OFFST	WT	ToUT	TCM
DCM														
TCM														
ToUT														
WT														
OFFST														
EMEC/EMIC														
DDCM														
SDCM														
SEPM														
SPM														
STOR														
ODFM														
DC														
CM														

In Table 14 and Table 15 the colour of each cell indicates the ability of an DER to provide a specific Flexibility Service or Other Revenue Streams:

- Green ■ – services and benefits can be stacked without reservation or issue;
- Amber ■ – may be stacked under one or two pre-conditions, e.g. baselining is used to prove delivery of service, or if risk of penalty exists se; and
- Red ■ – services and benefits cannot be stacked due to service terms, high likelihood of interference with baselining for proof of delivery or extremely high penalties for non-delivery.
- Grey ■ - not applicable, CM is a continuous service.

4.3 Optimising the Combination of Flexibility Services for a DER

Stacking Flexibility Services can increase the financial benefit through additional opportunities for revenue or savings. However, not all Flexibility Services can be stacked effectively (as illustrated in Table 14 and

Table 15) and the combination of Flexibility Services can create either synergies (could increase the level of revenue or savings over time) or conflicts (could reduce the level of revenue or savings over time). This section 4.3 considers the main factors and illustrates the effect of synergies or conflicts when combining some Flexibility Services.

4.3.1 Technical Capability

The technical parameters of a DER will determine whether a DER is suitable to deliver a particular Flexibility Service, e.g. speed of response or ability to sustain a given level of response. They will also provide an indication of whether a DER can deliver further Flexibility Services, e.g. the recovery time before a DER can be considered able to deliver another Flexibility Service or the number of times a DER can be used in a day. The recovery time may mean that the DER cannot be used to deliver a Flexibility Service in the next settlement period and the limited number of uses may mean a DER is further restricted.

4.3.2 Contractual Requirements

There are two areas in which contracts for the delivery of Flexibility Services affect may affect the stacking of services;

- exclusivity to ensure there is a high certainty of delivery, so Coincident Delivery is not possible, e.g. DC is allowed only be stacked with BM under a limit set of conditions[45]; and
- parameters of the Flexibility Service which may affect the choices in adjacent settlement periods, e.g. a storage or thermal DER may need time to recover before it can be used again.

4.3.3 Flexibility Services Options

Some Flexibility Services have to be instructed in advance of delivery and if no instruction is issued by this deadline, the DER could be used for other purposes (including the delivery of other Flexibility Services).

4.3.4 Wholesale Trading and ESO / DSO Flexibility Services

The combination of Flexibility Services being delivered at one time may affect the level of revenue where the revenue from the delivery of one Flexibility Service is affected by the delivery of another. Such issues arise when considering the delivery of Flexibility Services to the ESO / DSO and the effect on the price for energy through Wholesale Trading.

Wholesale Trading provides an opportunity to maximise additional revenue when contracted to deliver ESO or DSO Flexibility Services. Essentially, the ESO and DSO are paying for the right

[45] Unlocking stacking of BOAs in Dynamic Containment https://www.nationalgrideso.com/document/184466/download

to have the DER provide the capacity when it requires it, but neither are buying the energy. The energy from reducing demand or increasing generation (or storage which can do both) for the Flexibility services can be used by;

- the site to;
  - reduce demand and associated charges; or
  - trade the electricity in the wholesale market to increase revenue.
- the electricity supplier to;
  - reduce their portfolio demand; and / or
  - provide an opportunity to trade to re-balance their portfolio.

EDF Energy has conducted analysis to understand the effect on revenues from Wholesale Trading by the provision of DSO Flexibility Services or the provision of ESO Flexibility Services. The analysis considered the frequency of conflicts or synergies over a year that were categorised as;

- conflicting if an increase in the level of delivery of the Flexibility Service results in lower revenue from Wholesale Trading; or
- synergic if an increase in the level of delivery of the Flexibility Service results in higher or the same revenue from Wholesale Trading.

Figure 6 shows the percentage of conflicts and synergies when a DER combines provision of DSO Flexibility Services with trading the energy in the wholesale market.

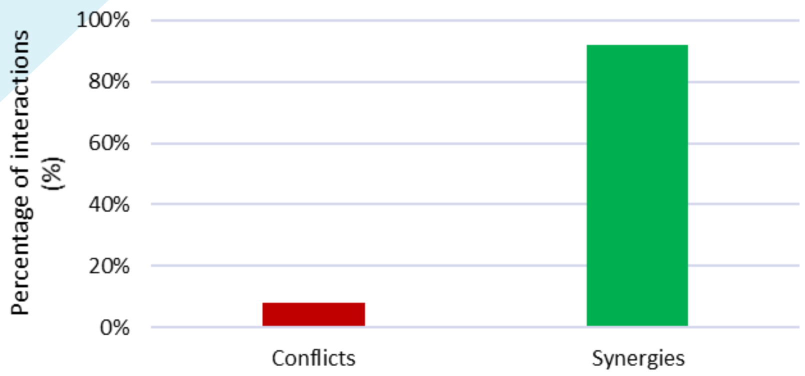
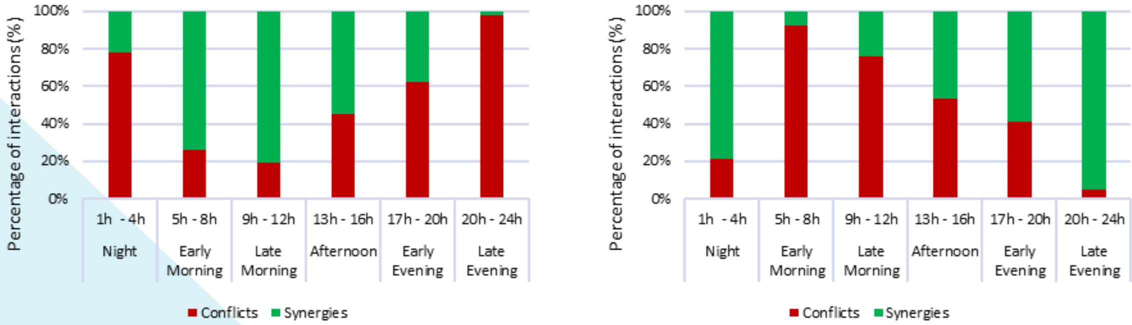


Figure 6: Frequency of interactions over a year between DSO Flexibility Services and wholesale trading

It should be noted that the percentage of conflicts in Figure 6 (approximately 10%) in one year of operation is sensitive to actual market conditions and how often the Flexibility Services are required which would change the percentage of conflicts and synergies in the analysis.

During the analysis of the effect of the delivery of ESO Flexibility Services on wholesale trading revenues it was noted that interactions demonstrated a time of day variation. Figure 7 shows the percentage of conflicts or synergies when a DER combines the provision of ESO / DSO Flexibility Services with maximising its revenue in the energy market.



(a) DSO Services *(b) ESO Services*

Figure 7: Frequency of interactions, in a year, between DSO and ESO Flexibility Services with maximisation of revenue from the energy market.

It is interesting to note that the conflicts between DSO Flexibility Services and wholesale trading are out of synchronisation with those for ESO Flexibility Services and wholesale trading.

The summary of the findings is provided in Table 16.

Table 16: Summary of findings of ESO and DSO Flexibility Services versus wholesale trading

Time Period	Effect of DSO Flexibility Services on revenue from Wholesale Trading (Figure 7(a))	Effect of ESO Flexibility Services on revenue from Wholesale Trading (Figure 7(b))
20:00 to 04:00	▪ very little requirement for DSO Flexibility Services. ▪ Wholesale Trading prices are low to negative with little opportunity to trade and marginally profitable for DERs (at best). ▪ the low level of Wholesale Trading income means any increase in DSO Flexibility Services could have a significant effect on income. ▪ highest conflict period for DSO Flexibility Services.	▪ medium requirement for ESO Flexibility Services that (largely) require demand increase or generation reduction. ▪ Wholesale Trading prices are low to negative with little opportunity to trade and marginally profitable for DERs (at best). ▪ the effect of ESO Flexibility Services is to remove the opportunity for Wholesale Trading. As Wholesale Trading prices are already low to negative price, there is no effect on income. This gives rise to the lowest conflict level of the day.

04:00 to 12:00	▪ low to medium requirement for DSO Flexibility Services. ▪ Wholesale Trading prices are medium with some periods profitable for DERs. ▪ the relatively low use of the DSO Flexibility Services means that scope to reduce Wholesale Trading is low. ▪ lowest conflict period for DSO Flexibility Services.	▪ medium requirement for ESO Flexibility Services that (largely) require demand reduction or generation increase. ▪ Wholesale Trading prices are medium with some periods profitable for DERs. ▪ higher income from Wholesale Trading prices will be adversely affected from an increased use of ESO Flexibility Services. ▪ highest conflict period for ESO Flexibility Services.
12:00 to 20:00	▪ medium requirement for DSO Flexibility Services. ▪ Wholesale Trading prices are high and profitable for DERs. ▪ the relatively low use of the DSO Flexibility Services means there is scope to maximise benefit from Wholesale Trading prices. ▪ medium conflict period for DSO Flexibility Services.	▪ high requirement for ESO Flexibility Services that require demand reduction or generation increase. ▪ Wholesale Trading prices are high and profitable for DERs. ▪ higher income from Wholesale Trading prices could be affected from an increased use of short-notice ESO Flexibility Services but the income would partly offset Wholesale Trading revenue. ▪ medium conflict period for ESO Flexibility Services.

4.4 Practical considerations

This section considers areas to be reviewed regularly by the Flexibility providers to optimise the revenue and profitability of DERs when delivering services in reflection of the market status and availability of services.

4.4.1 Route to Market

Market Actors can choose to access flexibility markets directly where they are the contracting party who take delivery and other contractual risks or indirectly where they contract with a third party who takes delivery and other contractual risks. There are advantages and disadvantages of both routes that can change over time, particularly in relation to changes in the master agreements governing market access and behaviour. The strategy could vary for different flexibility markets and or services.

4.4.2 Market Changes

The needs of the electricity system and distribution networks will change over time, particularly as we move towards Net Zero. This will result in changes to; regulation, how flexibility markets develop, the available Flexibility Services and Other Revenue Streams and as other opportunities will become available. These changes may affect the relative value from using the Flexibility of a DER.

4.4.3 DERs with Low Levels of Flexibility

Although the issue of low level of flexibility applies to all DERs it affects domestic DERs and electric vehicles more where the levels of Flexibility is low. The main issue is finding a cost-effective means of providing Flexibility Services and DER owners often use a third party (see section 4.4.1). Another issue faced by DERs with low levels of Flexibility is proving service delivery where the metering and baselining solutions for DERs with higher levels of Flexibility are uneconomic or inappropriate.

4.4.4 DERs with High Risk of Delivery

The level of certainty and predictability of Flexibility (or even a lack of one or both) can have a significant effect on the value and the risk factor for contracting with that Flexibility. The buyer of such Flexibility will buy more than they need to address such uncertainties to address the risk of non-delivery or unavailability. Two examples help to illustrate these points;

- DNOs typically suffer 40% failure to deliver. If a DNO was prepared to pay £9,000/MWh for availability payment for 5MW of a Flexibility Service they would be prepared to pay £45k. However, they have to contract for 40% more capacity than needed to account for such failures to deliver (7MW), then the price would have to reduce to ~£6,500/MWh. The DNO will still pay out the same across that market (unless availability is higher than expected) but each DER gets paid less than the DNO was prepared to pay.
- Imagine if, in the above example, the DNO is offered Flexibility from batteries that have a 10% failure to deliver. If they were still prepared to pay £45k, then they would contract with
- 5.5MW and the effective price would be ~£8,200. The DNO pays the same overall but each asset gets a higher availability payment.

On the opposite side of the market, aggregators that utilise pools of DERs with low levels of Flexibility or unreliable Flexibility have to factor this risk and contract with more Flexibility than needed to avoid contractual penalties. Ultimately, such compensation on both sides of the market is damaging the value of flexibility and could reduce the appetite for new entrants as demonstrated in the following example;

- assume a DNO needed 5MW Flexibility and there was a 40% failure to deliver, they would need to contract for 7MW in the market to avoid the risk to their assets in the event of failure to deliver; and
- if aggregators also had a failure to deliver risk of 40%, they would contract for 9.8MW to be certain to deliver 7MW and avoid contractual penalties in the event of a failure to deliver.
- The DNO is likely to receive the 5MW they need, but two things have happened;
  - almost half of the DER Flexibility has been sterilised to address failures to deliver on both sides of the market; there needs to be more openness to avoid this situation which is unhealthy as we get closer to Net Zero.
  - the total amount payable by the DNO is uncharged, but would have to support 9.8MW, not the 5MW required and whilst the DNO had a total payment equivalent to £9,000/MW, the maximum the DER would be paid (assuming no margin for the aggregator which is unrealistic) is £4,600/MW, almost half the mount the DNO is willing to pay. Factor in any payment to the aggregator and the DEDR gets [aid a small proportion of the value of Flexibility.

4.4.5 Changes to Regulated Charges

Ofgem is conducting reviews of charges for access and use of the transmission network and distribution networks that will:

- consider existing charging arrangements for generation and demand (affects storage as both a generator and demand) to ensure they meet the interests of current and future consumers;
- promotes efficient access and use of the transmission network and distribution networks; and
- review benefits that accrue to embedded DERs that may distort investment or dispatch decisions related to Other Revenue Streams.

These and future reviews may adversely affect the financial viability of existing and future DERs (particularly generation connected to the distribution network).

5 Case Studies

This section illustrates the process for identifying and delivering revenue from Flexibility Services and Other Revenue Streams using the information provided in this report. Two case studies are provided as a proxy for the DERs available to the LEO partners:

1. Case Study 1: Community Battery (15kW, 30kWh)
2. Case Study 2: Demand Response (commercial building)

The intention is the process in section 5.1 and the case studies will allow the value of Flexibility from different DERs to be determined and prioritised for further site-specific analysis by the DER owner.

5.1 Process for Identifying and Delivering Revenue

The process for identifying and delivering revenue involves **three steps**:

Step 1 - Identify Flexibility Services and Other Revenue Streams that can be delivered from the DER using information from section 2.

Step 2 - Determine individual and aggregate potential revenues from the suitable services using information in section 4.1.

Step 3 - Identify Flexibility Services and Other Revenue Services that can be stacked using information in section 4.2.

5.2 Case Study 1: Community Battery (15kW, 30kWh)

The community energy storage is located at the local community social hub. Its main purpose is to maximise the self-consumption of the roof top solar PV on site, thereby reducing its energy bills. The battery is sized to avoid export to the distribution network during periods of high solar PV output and to provide an opportunity to perform price arbitrage from the two-rate tariff. The local community social hub does not have access to a third-party who can aggregate on its behalf.

5.2.1 Step 1 - Identify Flexibility Services and Other Revenue Streams that can be delivered from the DER

The Flexibility Services and Other Revenue Streams that could be delivered by a generic battery are provided in Table 5 with the relevant excerpt shown in Table 17.

Table 17: General capability to delivery services by battery storage

	ESO		DSO	P2P	Other

	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC / EMIC	OFFST	WT	ToUT	TCM	DCM
Battery Storage															

By assessing the community battery and the specific aspects of the site, the capability to deliver Flexibility Services and achieve other benefits can be updated as follows:

- Suitable Flexibility Services;
  - SPM, SEPM and SDCM are suitable for the battery provided there is no interference with the main function.
  - ToUT is suitable for the battery, particularly in relation to when charging occurs.
- Opportunistic Flexibility Services that have not been included and no value attributed;
  - EMEC / EMIC is suitable for opportunistic trades during periods of unavailability of the battery or to deliver Flexibility Services that require additional import or export capacity.
  - OFFST in suitable provided there are; a suitable counterparty, a commercial agreement and reviewing that it is economic.
  - TCM and DCM are suitable if the hub is half-hourly metered and the supplier charges separately for TCM and DCM. As the arrangements between the community hub and the supplier is not known, it is assumed these charges are embedded in the ToUT and the battery gets no benefit.
  - WT is suitable provided there is third-party access to the market and automated dispatch which is assumed to be uneconomic.
- Unsuitable Flexibility Services;
  - BM, CM, DC[46], ODFM and STOR are not suitable as they do not meet the minimum capacity and duration requirements. Aggregation of the battery with other DERs has not been considered.
  - DDCM is not suitable as it may require a duration of up to 8 hours, significantly more than the capability of the battery.

[46] Battery in the context of this study would be highly capable of delivering DC if it is aggregated with other suitable DERs to achieve 1MW combined capacity via a third party. Such arrangements introduce complexity and require sharing of revenue with a third party involving multiple options that are out of scope for this report.

Including the above aspects that address potential reconditions for service delivery, the revised list of Flexibility Services and Other Revenue Streams that could be delivered using the battery are summarised in Table 18.

Table 18: Specific capability to delivery services by community battery

	DSO			P2P		Other
	SPM	SEPM	SDCM	EMEC / EMIC	OFFST	ToUT
Battery Storage						

5.2.2 Step 2 - Determine individual and aggregate potential revenues

The battery is considered to be suitable for participating in the following Revenue streams: SPM, SEPM, SDCM, EMEC/EMIC, OFFST and ToUT. The potential value available for each of these distinct services is summarised in Table 19.

Table 19: Revenue from Flexibility Services and Other Revenue Streams

Services	Nominal Value	Suitability (hours)	Potential Value
SPM	Availability £15/MW/h[47] Utilisation: £270/MWh	Availability: 120[48] Utilization: 20	£108.00
SEPM	Future, but relevant service – value unknown		unknown
SDCM	Availability £101.70/MW/h Utilisation: £155.00/MWh	Availability: 120 Utilisation: 20	£229.56
EMEC/EMIC	Future, but relevant service – value unknown		unknown
OFFST	Future, but relevant service – value unknown		unknown
ToUT (Bulb)[49]	£45.62/kWh/year	All year	£1,398.60[50]

5.2.3 Step 3 - Identify Flexibility Services and Other Revenue Services that can be stacked

[47] Median prices for SPM from analysis of historic bids and competitions on Piclo.Flex platform.
[48] 120 hours are based on expected availability for four hours at peak time on the weekdays for 6 winter weeks (4 hours / day * 5 days / week * 6 weeks).
[49] Bulb Smart Tariff is only offered to domestic customers and is a fixed price tariff using different charging times. For simplicity it is used here as a proxy for ToU tariff offered to businesses as it is usually bespoke and not publicly available.
[50] This is £45.62/kWh * 30kWh for the battery = £1,398.60

Section 4.2 details the ability to stack services using Coincident Delivery or Adjacent Delivery. The ability of the community battery to stack relevant Flexibility Services and Other Revenue Streams is summarised in Table 20 and Table 21.

Table 20: Stacking through Coincident Delivery for the community battery

	SPM	SEPM	SDCM	EMEC/EMIC	OFFTS
ToUT					
OFFST					
EMEC/EMIC					
SDCM					
SEPM					

Table 21: Stacking through Adjacent Delivery for the community battery.

	SPM	SEPM	DDCM	EMEC/EMIC	OFFST
ToUT					
OFFST					
EMEC/EMIC					
DDCM					
SEPM					

As shown in Table 19, the most valuable revenue is from responding to ToUT which determines the priority for a review of Table 20 and Table 21. This review shows that for:

- Coincident Delivery – ToUT may be stacked with SPM but not SEPM. As a result, only revenues from ToUT and SPM are considered; and
- Adjacent Delivery – ToUT may be stacked with SPM and SEPM.

As ToUT may be stacked with SPM in both Coincident Delivery and Adjacent Delivery, any overlap between the peak time period of the ToUT and the delivery window for SPM is not relevant, provided the battery has a dedicated, approved meter that can be used to validate delivery. Consideration of the battery to stack ToUT and SEPM could have consequences for the battery and its state of charge and is discounted.

Therefore, the total potential revenue from the Coincident Delivery of services for the community energy storage rated at 15kW and 30kWh is;

- ToUT £1,398.60
- SPM £ 108.00
- Total value £1,506.60

5.3 Case Study 2: Demand response (commercial building, 400kW)

This case study involves a commercial building with mixed use; shared office space and social venues with the building in use during the day and evenings. The building provides Flexibility by adjusting the operation of the heating, ventilation, and air conditioning (HVAC) system and cold storage system which can be interrupted for one hour each due to the thermal nature of the DERs. The Flexibility of the HVAC system is 250kW and can be delivered for one hour. The flexible load of the cold storage is 150kW and can be delivered for one hour. The Flexibility can be used in two combinations; 400kW for one hour (both assets operating coincidentally) or 150kW in one hour followed by 250kW in another hours (both assets operating in adjacent hours).

The agreement with the supplier includes explicit Triad charges and energy units are charged on two rates: day and night.

5.3.1 Step 1 - Identify Flexibility Services and Other Revenue Streams that can be delivered from the DER

The Flexibility Services and Other Revenue Streams that could be delivered by generic commercial demand are provided in *Table 5* with the relevant excerpt shown in Table 22.

Table 22: General capability to delivery services by commercial demand

	ESO					DSO				P2P		Other			
	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC / EMIC	OFFST	WT	ToUT	TCM	DCM
Commercial Demand															

By assessing the HVAC and cold storage and the specific aspects of the site, the capability to deliver Flexibility Services and achieve other benefits can be updated as follows:

- Suitable Flexibility Services:
  - SPM, SEPM and SDCM are included as the combined duration of both DERs meet the requirements of the services and have 150kW continuous response for 2 hours.

- TCM and DCM are being explicitly passed through to the site by the supplier.
- the DERs could deliver BM but there would be a third party charge for providing market access.
- the DERs could deliver CM but there would be a third party charge for providing market access.

- Opportunistic Flexibility Services that have not been included and no value attributed:
  - as EMIC and OFFST are only applicable for opportunistic trades during a short period of closure, e.g. maintenance when the DERs could be unavailable and import capacity can be released, it has not been included.
- Unsuitable Flexibility Services:
  - DC is unsuitable due to the requirement of the service to adjust power proportionally to the frequency deviation within 1s.
  - ODFM and STOR service will be classified as unsuitable due to the minimum entry and requirement by duration. Also, aggregation is out of scope.
  - DDCM could last up to 8 hours which is beyond the capability of the DERs.
  - ToUT only include the energy costs and it is a day / night rice so there is no advantage to shifting demand over these times.
  - there is no opportunity for WT as the savings from the ToUT could be higher than the benefits from WT and there may be minimum capacity limits which the site is unlikely tot meet.

Taking into the account aspects discussed above, the revised list of Flexibility Services and Other Revenue Streams that could be delivered using the DERs from the commercial building are summarised in Table 23.

Table 23: Specific capability to delivery services by commercial demand

	ESO		DSO			Other	
	BM	CM	SPM	SEPM	SDCM	TCM	DCM
Commercial Demand							

5.3.2 Step 2 - Determine individual and aggregate potential revenues

For the identified compatible Flexibility Services and Other Revenue Streams. Table 23 shows the estimated value per service that could be achieved with demand response.

Table 24: Revenue from Flexibility Services and Other Revenue Streams

Services[51]	Nominal Value	Suitability (hours)	Potential Annual Value
BM	Variable and high value prices are unpredictably rare.		Unpredictable
CM	T-1 (DY21/22) - £45/kW/year[52]	All year, only 2 hours in duration.	T-1: £6,750.00
SPM	Availability £15/MW/h Utilisation: £270/MWh	Availability: 120[53] Utilization: 20	£1,080.00
SEPM	Future, but relevant service – value unknown.		-
SDCM	Availability £101.7/MW/h Utilisation: £155/MWh	Availability: 120 Utilisation: 20	£2,295.60
TCM	£56.77/kW/year	Assuming successful capture of all Triads	£22,708.00[54]
DCM	3.138p/kWh during demand response 0.208p/kWh during recovery		£25.50[55]

5.3.3 Step 3 - Identify Flexibility Services and Other Revenue Services that can be stacked

To identify the maximum potential revenue from the demand response, the identified compatible services are assessed for stacking opportunity for Coincident Delivery (Table 25) and Adjacent delivery (

Table 26).

Table 25: Stacking of the services for Coincident Delivery, compatible with commercial demand response.

	BM	CM	SPM	SEPM	SDCM	TCM

[51] Excludes cost of third party providing market access which could range from 5% to 40%.
[52] Assuming the intermediate party (e.g. an aggregator) was successful in securing sufficient capacity under T-1 auction.
[53] 120 hours are based on expected availability for four hours at peak time on the weekdays for 6 winter weeks.
[54] Customers who choose to be exposed to the Triad charges tend to manage them and hence already achieve some of these savings.
[55] Difference between Red and Amber DUoS charges for HV connected site. Assuming at the end of 2-hour duration of demand response, assets bounce back in energy use by ~10% over an hour to return to normal operating temperatures.

DCM						
TCM						
SDCM						
SEPM						
SPM						
CM						

Table 26: Stacking of the services for Adjacent Delivery, compatible with commercial demand response.

	BM	CM	SPM	SEPM	SDCM	TCM
DCM						
TCM						
SDCM						
SEPM						
SPM						
CM						

As shown in Table 24, the highest revenue Flexibility Service is TCM (assuming the site does not already deliver TCM, which is possible) and this determines the priority for a review of Table 25 and

Table 26. However, if the site already manages TCM, the next highest revenue Flexibility Service is CM which would determine the priority for a review of Table 25 and

Table 26. Both options are considered and summarised in Table 27.

Table 27: Evaluation of Coincident Delivery and Adjacent Delivery for TCM and CM

	Lead Flexibility Service	
	TCM	**CM**
Coincident Delivery	▪ Can be stacked with; – CM, DCM, SPM, SEPM, SDCM ▪ Cannot be stacked with; – BM	▪ Can be stacked with; – TCM, DCM, SPM, SEPM, SDCM, BM ▪ Cannot be stacked with; – None
Adjacent Delivery	▪ Can be stacked with; – BM, SPM, SEPM, SDCM ▪ Cannot be stacked with; – None	▪ Can be stacked with; – N/A (continuous service) ▪ Cannot be stacked with; – N/A (continuous service)
Conclusion	If TCM is the lead Flexibility Service then it can be stacked with a range of Flexibility Services but none can be delivered coincidentally. The obvious choice is SDCM as it has the highest revenue of the other Flexibility Services. As such, revenue will come from the delivery of TCM and SDCM.	If CM is the lead Flexibility Service it is incompatible for stacking with other Flexibility Services that are being delivered regularly through demand reduction or generation increase. These Flexibility Services would erode the baseline against which any CM delivery is determined. As such, the only revenue for this option is from CM.
Revenue	▪ TCM £27,708.00 ▪ SDCM £ 2,295.60 ▪ Total value £30,003.60[56]	▪ CM £6,750.00 ▪ Total value £6,750.00

[56] This value ignores any third party fees for market access which could amount to 5% to 40% of the total income for a Flexibility Service.

6 Conclusions and Recommendations

The report has provided an overview of the value chain for Flexibility Services and Other Income Streams that apply to Market Actors engaging in the flexibility marketplace. The report highlights that the value of new services can be difficult to realise due to the uncertain value of these to all Market Actors (including the Flexibility Service buyer). While this particularly applies to new markets, such as the nascent P2P market, it also applies to existing markets where new services are introduced e.g. Dynamic Containment and Replacement Reserve. This uncertainty around defining a value for Market Actors engaged in the marketplace can restrict the development of Flexibility as a solution, and only with the realisation of the whole value can Flexibility be an integral part of the future for our whole system.

In analysing and presenting the value of Flexibility today, this report has highlighted four areas which must be addressed to develop the flexibility markets and thereby enable the delivery of Net Zero:

- **Revenue Stacking** – the value of Flexibility varies by the network conditions locally (power flows, capacity, voltage and connected DERs) and a range of other compounding variables (market liquidity, service type, service maturity and technical capability of the Flexibility provider). As such, the value will change over time, even in as little as one year. The business case for new Flexibility therefore relies on the availability of multiple revenue streams. Stacking of Flexibility Services reduces the overall revenue risk, by reducing the reliance on one revenue stream but may involve third parties to provide market access. The ability to stack more services must therefore be enabled to transform the flexibility markets and support the delivery of Net Zero.
- **Fair Value for Flexibility** – the use of Flexibility provides benefits to Market Actors and GB for which no remuneration is made. A fair value for the benefits of Flexibility could transform the flexibility markets and support the delivery of Net Zero. As Flexibility is more and more considered an integral part of the solution, this could see the real value being recognised. However, the value of flexibility can only equal the benefit delivered and should provide fair value against the alternatives.
- **Route to Market** – the route to market for the participation in Flexibility Services varies according to a number of factors (service, marketplace, DER type and capacity and the relative size of the DER portfolio (if any)). Flexibility markets are largely designed for large portfolios of DERs, or large DERs. Standardising services across the flexibility marketplace, simplifying requirements and reducing the barriers to entry even further (even through intermediate markets) will enable a significant increase in participation of DERs with low

levels of flexibility (which could represent over 22,000MW of Flexibility). Addressing these issues will also increase the relative value for these Flexibility providers and could transform the flexibility markets and support the delivery of Net Zero. However, the move towards "flexibility as infrastructure" needs to be carefully managed if existing standards are to be maintained (although some users may not value them and could be prepared to pay less for a lower standard of service).

- **Non-Financial Value** – the value of Flexibility is often considered in financial terms and sustainability aspects can be overlooked. Flexibility is a tool which can be used to facilitate a greater penetration of LCTs and also influence behaviours to provide a whole system benefit for all Market Actors, not just the ESO and DSO. Whilst these sustainable values can be hard to realise, this can partly address by the recognition of these contributions in the procurement and incentivisation of Flexibility solutions. Rewarding Flexibility solutions which provide a sustainability benefit or favouring these in market auctions can further promote the investment in sustainable solutions paving the way to Net Zero.

7 Recommendations

The following recommendations are proposed;

- Projects LEO and TRANSITION provide insight into how the flexibility markets and flexibility marketplace could develop and feedback to the Energy Networks Association Open Networks Project, Ofgem and BEIS.
- LEO partners trial the process used in section 5 and provide feedback so it can be iterated.
- LEO uses DERs with low levels of Flexibility to deliver Flexibility Services with a variety routes to market to determine the viability of such DERs and the effect of market mechanics on value.
- LEO approaches TRANSITION to explore the procurement issues discussed in section 4.4.4.
- LEO considers alternative solutions to monitor and meter DERs with low levels of Flexibility that comply with Code Change P375 that can support the use of local metering to verify Flexibility Services.
- LEO considers the development of standard format for P2P Flexibility services.

8 Appendix A – Analysis of ESO Balancing Mechanism Prices

The ESO despatches generation and other Flexibility in the Balancing Mechanism to balance the electricity system in real-time. These prices are not reported but they are used to derive the System Price which is reported in www.bmreports.com. Data from or up to 4 random days were analysed for each month of 2020.

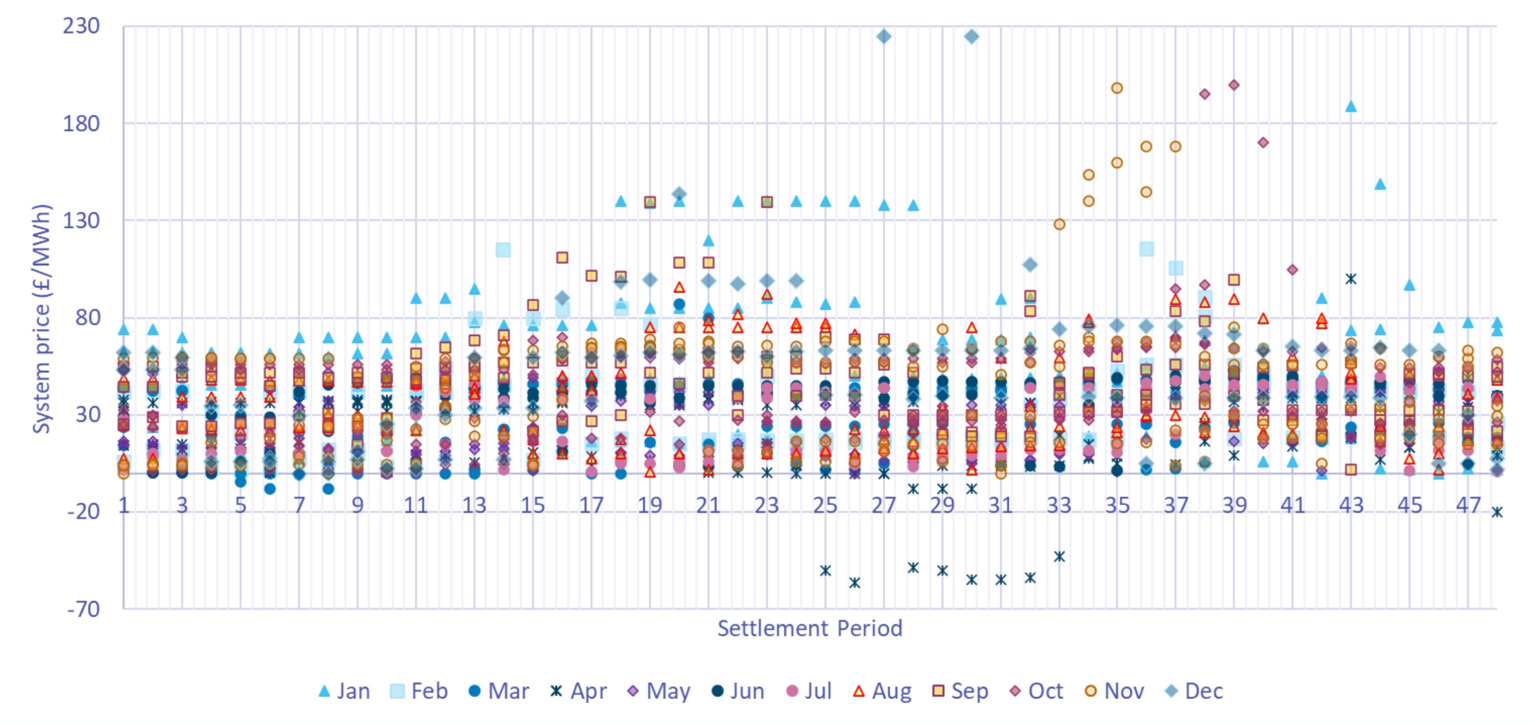


Figure 8: System Price for Random Days In 2020 (capped at £230/MWh due to very high prices)

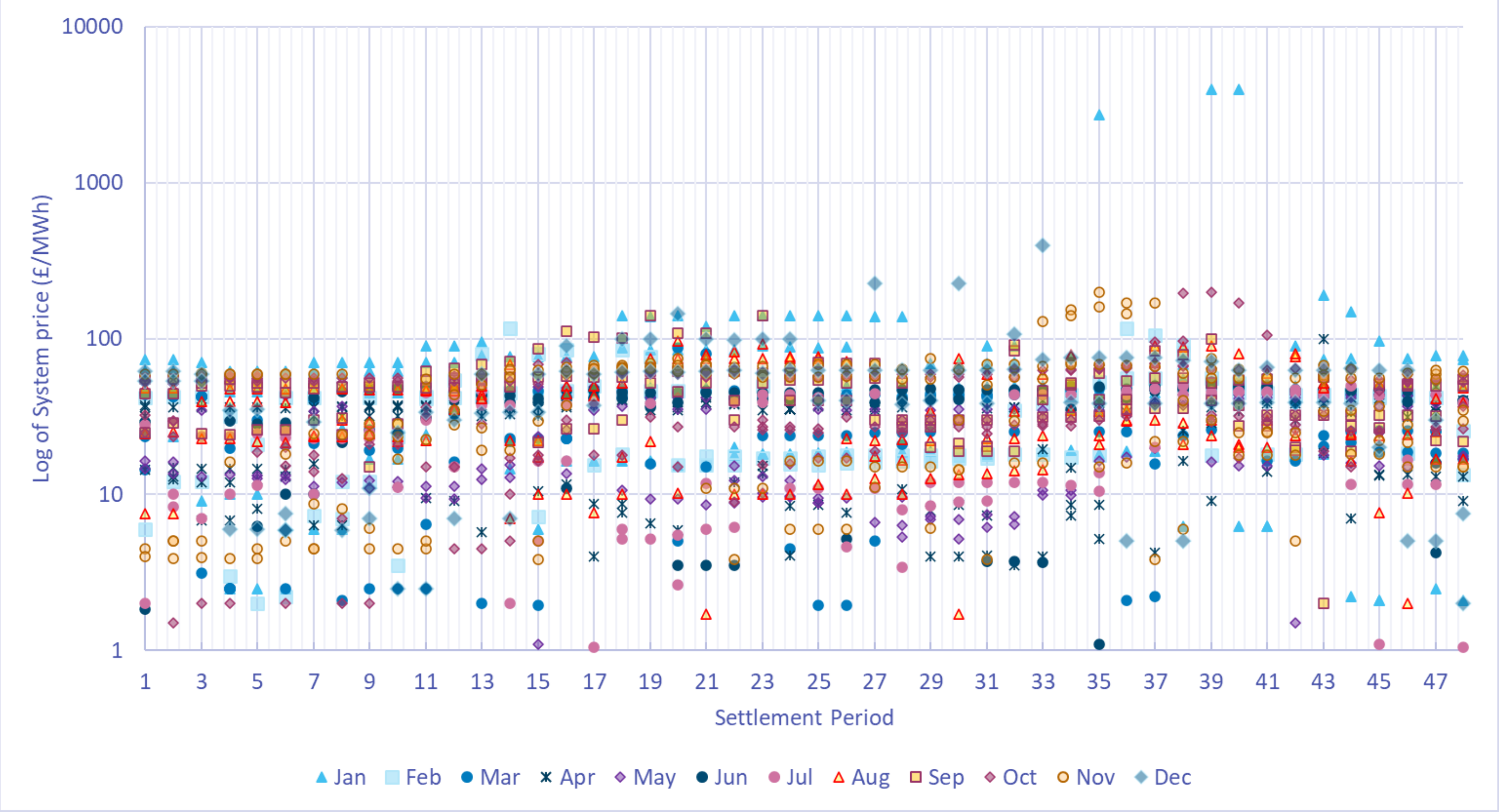


Figure 9: Log of System Price for Random Days In 2020 (does not show negative prices)

9 Appendix B – Analysis of ESO ODFM Prices

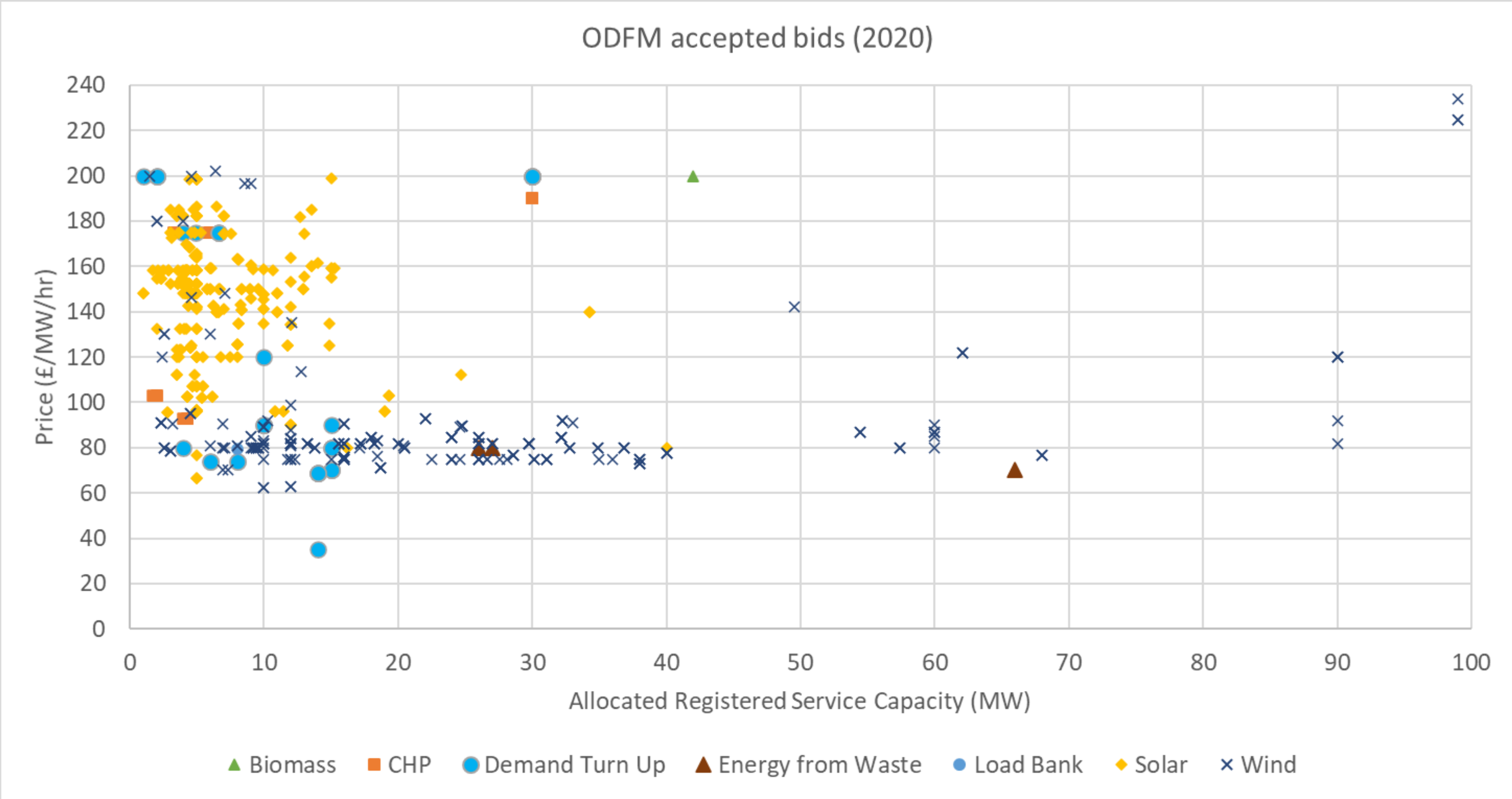


Figure 10: Accepted ODFM bids per technology and capacity (2020 data)

10 Appendix C – Analysis of ESO STOR prices

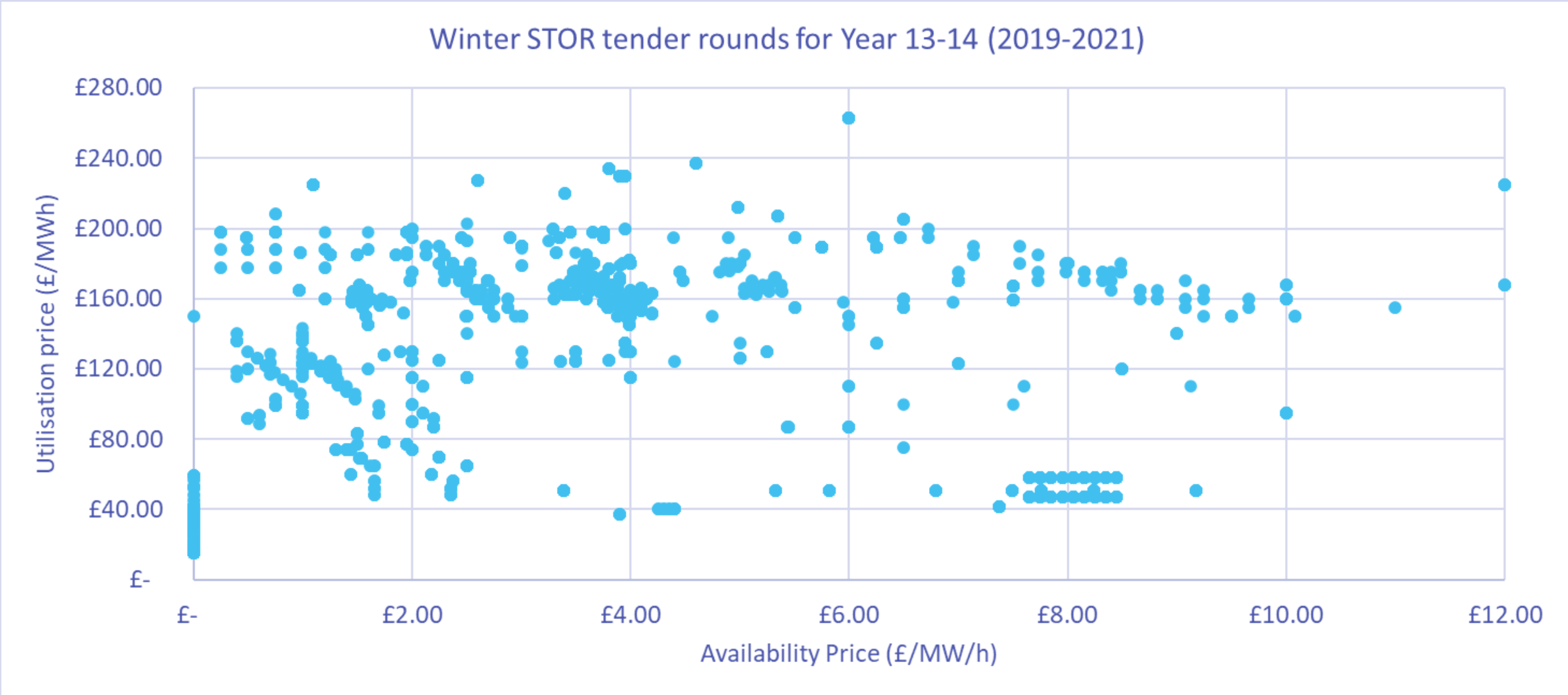


Figure 11: Accepted bids in Winter STOR tender rounds for Years 13 and 14.

11 Appendix D – Analysis of DSO Flexibility Services Prices

Five of the six DNOs advertise their Flexibility requirements using the Piclo Flex platform which allows data for historic auctions to be downloaded from https://picloflex.com/ . This data is available in the figures in this Appendix D for the Sustain, Secure and Dynamic Flexibility Services. There is no data for the Restore Flexibility Service.

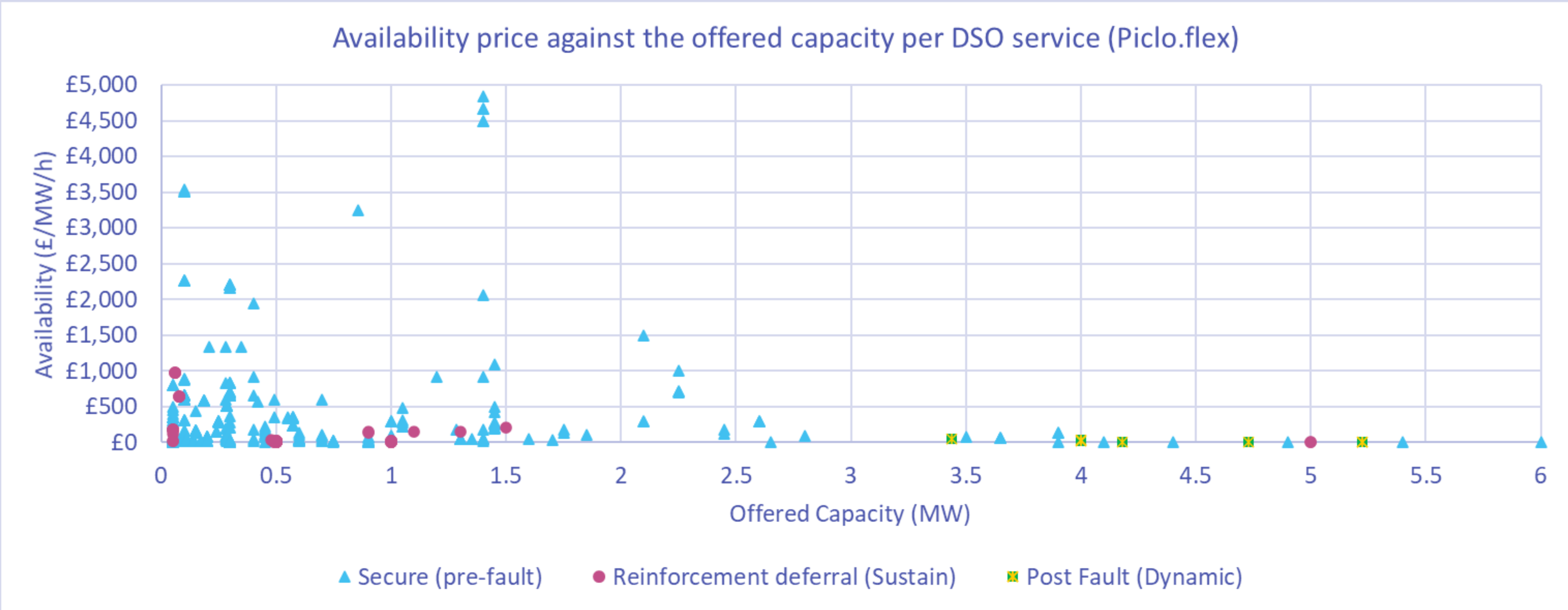


Figure 12: Spread of Availability price for accepted bids for competition for the three DSO services across multiple DNOs.

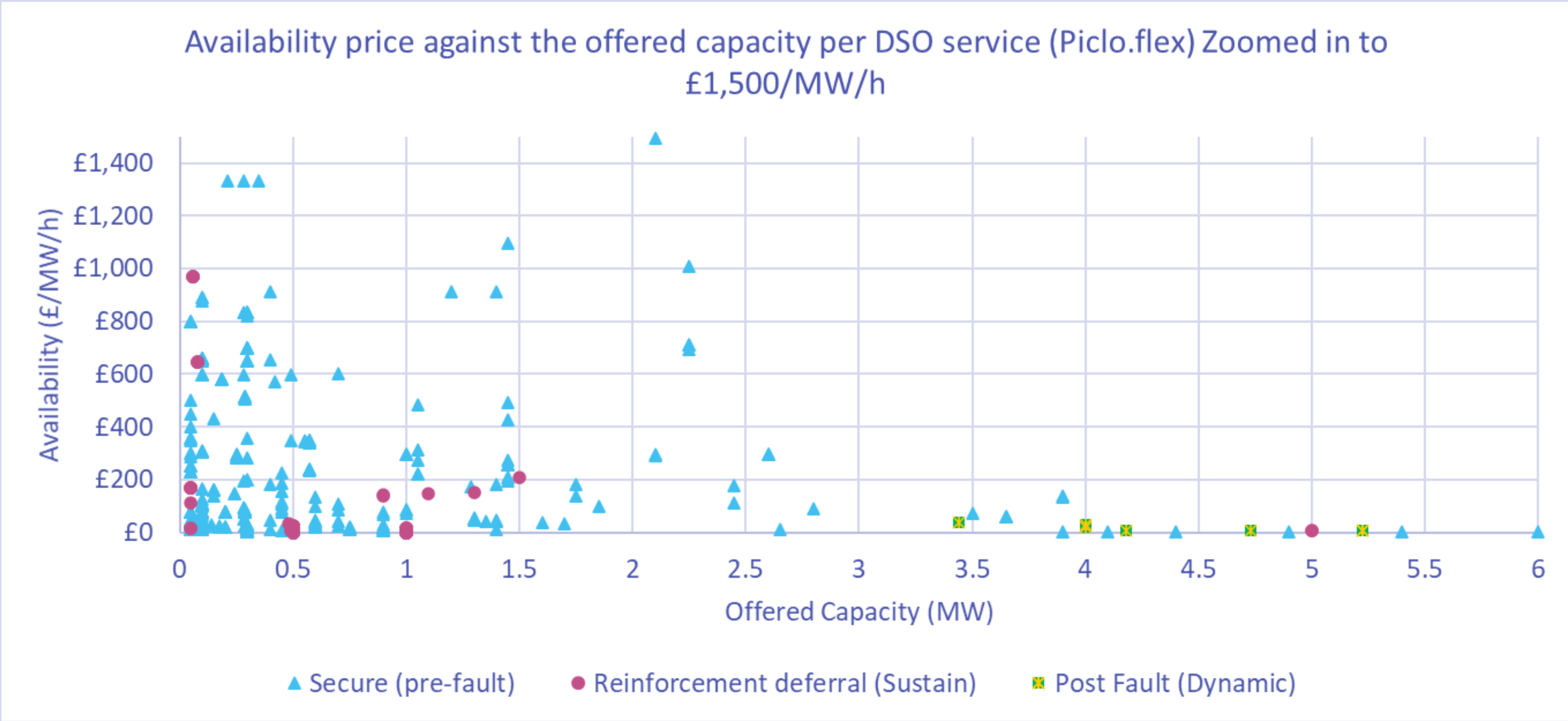


Figure 13: Figure 14: Spread of Availability price for accepted bids for competition for the three DSO services across multiple DNOs – zoomed in to bids under £1500/MW/h

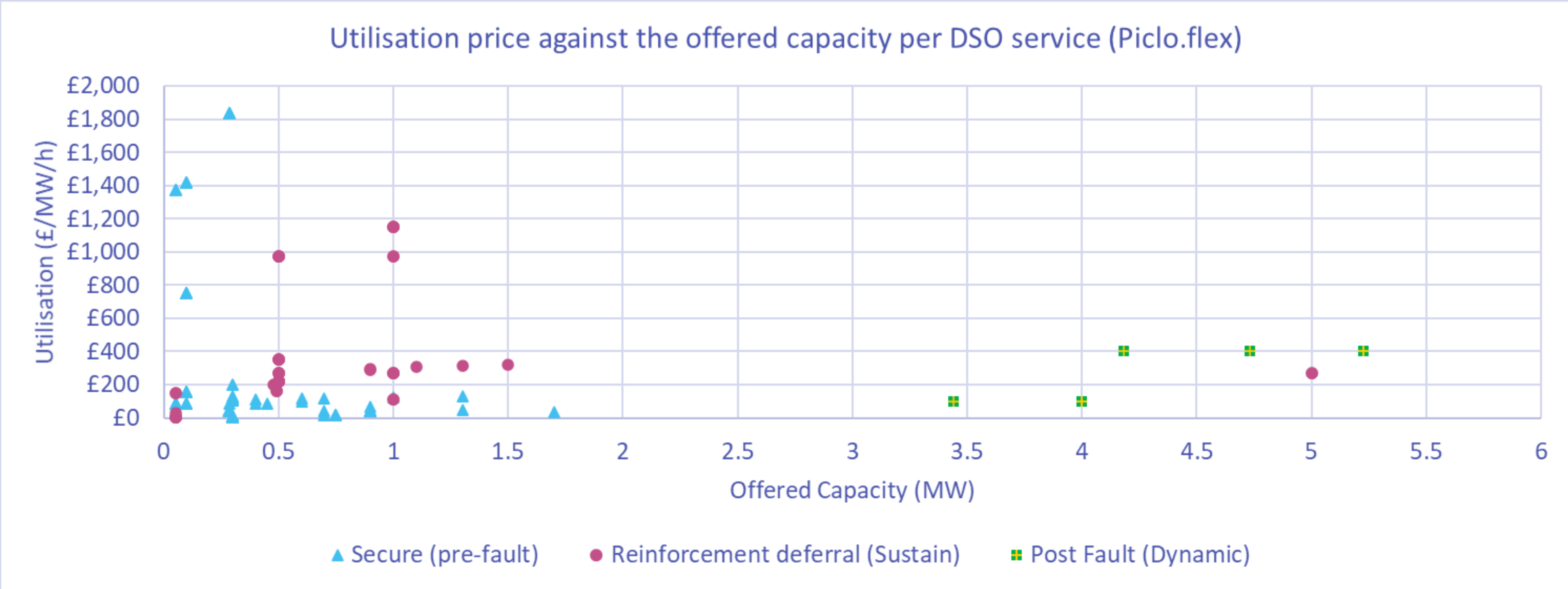


Figure 15: Utilisation prices for accepted bids for the three DSO services.

12 Appendix E – Analysis of the Price Differentials of dToUT and Wholesale day-ahead.

The range of prices for a typical dToUT are graphically displayed in Figure 16; the average price is graphed with the range of prices for different days represented by the coloured zone around the average.

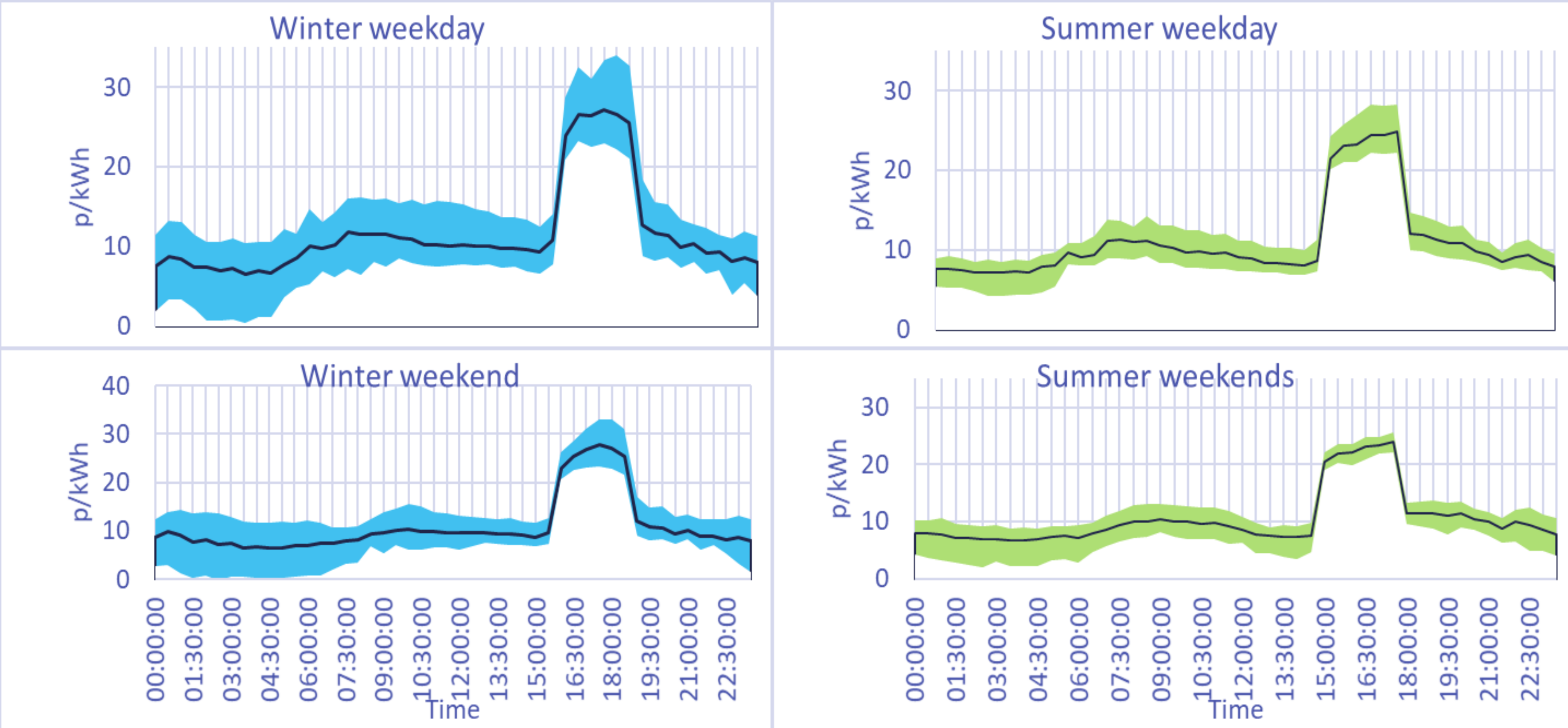


Figure 16: Middle 90% range of prices for the Octopus Agile tariff over winter and summer weekdays and weekends (2019).

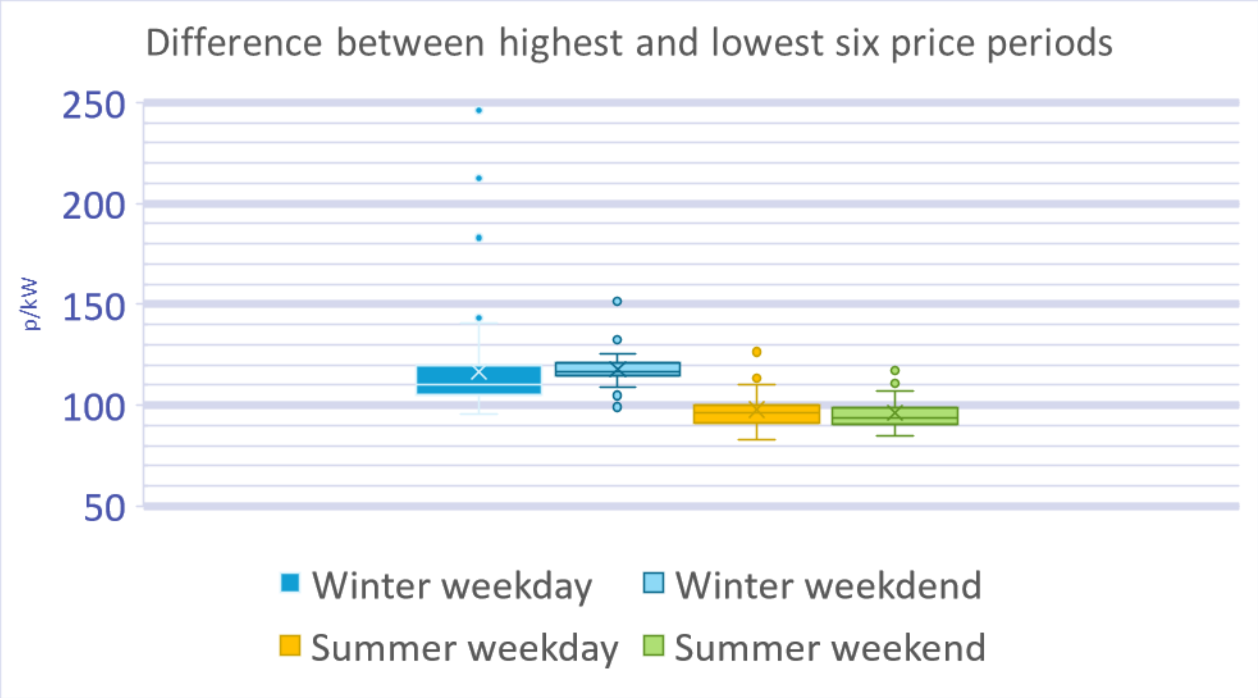


Figure 17: Seasonal differences between daily peak and off-peak prices for Typical dToUT (2019) used to determine battery price differentials.

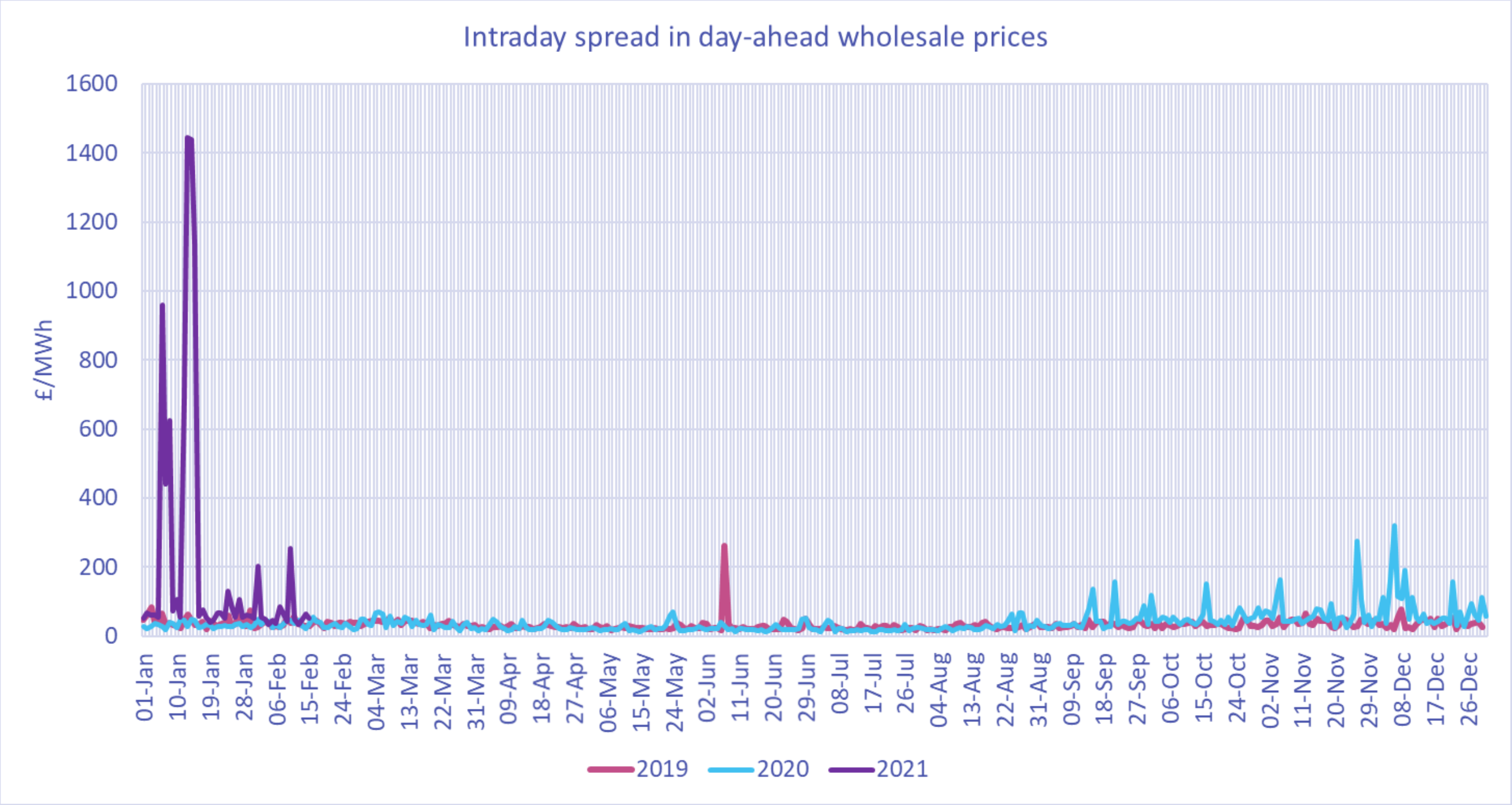


Figure 18: Intra-day difference for day ahead wholesale prices from Nordpool exchange, https://www.nordpoolgroup.com/historical-market-data/.

13 Appendix F – Historical Triad periods

Year	Day of Week	Date	Time (Settlement Period)	Demand Tariff		
				HH (£/kW)	nHH (p/kWh)	EET (£/kW)
2021/22	Forecast			56.77	7.74	-5.82
2020/21	Forecast			56.5	7.5	-8.18
2019/20	Monday	18th November 2019	1700-1730 (35)	56.11	7.496	-22.689
	Monday	2nd December 2019	1700-1730 (35)			
	Tuesday	17th December 2019	1630-1700 (34)			
2018/19	Thursday	22nd November 2018	1700- 1730 (35)	52.11	7.71	-37.164
	Monday	10th December 2018	1700- 1730 (35)			
	Wednesday	23rd January 2019	1730-1800 (36)			
2017/18	Monday	11th December 2017	1700- 1730 (35)	52.54	7.48	-
	Monday	5th February 2018	1730-1800 (36)			
	Monday	26th February 2018	1800-1830 (37)			
2016/17	Monday	5th December 2016	1700- 1730 (35)	49.204	6.65	-
	Thursday	5th January 2017	1700- 1730 (35)			
	Monday	23rd January 2017	1700- 1730 (35)			
2015/16	Wednesday	25th November 2015	1700- 1730 (35)	43.74	5.81	-
	Tuesday	19th January 2016	1700- 1730 (35)			
	Monday	15th February 2016	1730-1800 (36)			
2014/15	Thursday	4th December 2014	1700- 1730 (35)	37.66	5.17	-
	Monday	19th January 2015	1700- 1730 (35)			

Year	Day of Week	Date	Time (Settlement Period)	Demand Tariff		
				HH (£/kW)	nHH (p/kWh)	EET (£/kW)
	Monday	2nd February 2015	1730-1800 (36)			

14 Appendix G – Per DER lookup table for revenues from DSO Flexibility Services

	SPM		SEPM		SDCM		DDCM	
	Utilisation	Availability	Utilisation	Availability	Utilisation	Availability	Utilisation	Availability
Nominal Value (taken from table 6)	£270/MWh	£15/MW/h	N/A	N/A	£155/MWh	£101.7/MW/h	£271.43/MWh	£15.45/MW/h
Technology [57]	Potential Value (£/MW) [58]	Potential Value (£/MW)[59]	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)
Battery Storage	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Combined Heat and Power	1080	300	n/a	n/a	620	2034	1085.72	309
Commercial Demand	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Domestic Demand	1080	300	n/a	n/a	620	2034	1085.72	309
Gensets	5400	1800	n/a	n/a	3100	12204	5428.6	1854
Hydro (run of river)	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Industrial Demand	5400	1800	n/a	n/a	3100	12204	5428.6	1854
Solar PV	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Wind	2700	750	n/a	n/a	3100	12204	2714.3	772.5

[57]Colour coding system taken from Table 3
[58]Utilisation Potential Value: Green value based on 20 hours per year, Yellow value based on 10 hours, and Amber value based on 4 hours.
[59]Availability Potential Value: Green value based on 120 hours per year, Yellow value based on 50 hours, and Amber value based on 20 hours.

15 Appendix H – Look-up table for benefits from avoided charges

Technology	Other				
	WT[60]	TouT[61]	Demand Tariff[61]		
Nominal Value [62]	Up to £14.4k/MWh/year	p12.5/kWh	HH (£56.77/kW)	nHH (p7.74/kWh	EET (£5.82/kW)
Battery Storage	7200	250	2838.5	387	-291
Combined Heat and Power	7200		1135.4	154.8	-116.4
Commercial Demand	4320	1500	2838.5	387	-291
Domestic Demand		625	1135.4	154.8	-116.4
Gensets	7200		6812.4	928.8	-698.4
Hydro (run of river)	7200		2838.5	387	-291
Industrial Demand	7200	250	6812.4	928.8	-698.4
Solar PV	11520		1135.4	154.8	-116.4
Wind	11520		1135.4	154.8	-116.4

[60]Potential Value based on Availability: Green value based on 80% of total value, Yellow value based on 50% of total value, and Amber value 30% of total value
[61] Potential Value based on Availability: Green value based on 120 hours per year, Yellow value based on 50 hours, and Amber value based on 20 hours.
[62]Colour coding system taken from Table 3