ZERO CARBON RUGELEY
WP3-D4: EVALUATION OF MARKET STRUCTURES

Version: 2.0
Date: 29/11/21

Element	Description
Title	Evaluation of Market Structures
Creator	Opus One Solutions
Subject	Local energy market structures
Description	A report to evaluate the different market structures proposed in the earlier reports to draw insight into what structure could be optimal for Rugeley town local market.
Publisher	Opus One Solutions
Contributor	William Mackay, Adriana Díaz Lozano Patiño
Date	The 29th of November 2021
Type	Tex
Format	PDF
Identifier	
Source	
Language	English
Relation	
Coverage	The UK
Rights	Closed
Dissemination / confidentiality	☒ Public/ ZCR webpage/ Social media ☒ ERIS/ IUK Consortiums ☒ Funder ☒ Consortium ☒ Internal

Zero Carbon Rugeley (ZCR) Smart Local Energy System (SLES) design demonstrator is funded by the government's Department for Business, Energy and Industrial Strategy (BEIS) as part of the Industrial Strategy Challenge Fund (ISCF) (link).

Evaluation of Market Structures

Prepared for Engie

Version 2.0
29 November 2021

DOCUMENT VERSION HISTORY

Version	Date DD/MM/YY	Changes	Sensitivity	Targeted recipient (Internal/Outbound)	Author	Reviewer/Approver
1	29/11/121	First Draft	External	Outbound	William Mackay	Raina Kang
2	29/11/121	Format update	External	Outbound	William Mackay	Raina Kang

Table of Contents

1 Introduction ... 3
- 1.1 Background ... 3
- 1.2 Aim ... 3

2 Preliminary work ... 3
- 2.1 Importing Rugeley network model ... 3
- 2.2 Load Profiles ... 4
- 2.3 Distributed Energy Resource placement ... 5
- 2.4 Substituting Locational Marginal Price (LMP) ... 5
- 2.5 Assigning Bids and Offers ... 6

3 Scenarios ... 6
- 3.1 Outline ... 6
- 3.2 Market assumptions ... 7
- 3.3 Market Structures ... 8
- 3.3.1 Cost Savings ... 8
- 3.3.2 Supply Security ... 8
- 3.3.3 Carbon Reduction ... 8
- 3.3.4 Low Barrier to Entry ... 9
- 3.4 Flexibility Services ... 9
- 3.4.1 Peer to Network (P2N) Services ... 9
- 3.4.2 Peer to Peer (P2P) Service ... 12

4 Results ... 15
- 4.1 Peer to Network (P2N) ... 15
- 4.1.1 Constraint Management ... 15
- 4.1.2 Peak Management ... 20
- 4.1.3 ESO-DSO Coordination ... 27
- 4.2 Peer to Peer (P2P) ... 30
- 4.2.1 Maximum Import/Export Capacity Trading (MIC/MEC) ... 31
- 4.2.2 Offsetting ... 32

5 Conclusion ... 36

6 Appendices ... 37
- 6.1 Workshop Bid and Offers (Constraint Management, Peak Management) ... 37
- 6.2 Low Barrier to Entry Bids and Offers ... 39
- 6.3 Low Barrier to Entry Bids and Offers (Peak Management) ... 41
- 6.4 ESO-DSO Coordination Bids and Offers ... 42
- 6.5 Example Bids and Offers P2P Economical Forcing Dispatch (Offsetting) ... 43
- 6.6 Example Bids and Offers P2P Low Barrier to Entry Dispatch (Offsetting) ... 44

1 Introduction

1.1 Background

Zero Carbon Rugeley is designing a sustainable, low carbon, smart local energy system for Rugeley Town and its surrounding area. Work package 3 (WP3) focuses on designing a flexibility market which could allow the connection of additional low carbon assets in this constrained region while avoiding high-cost infrastructure upgrades.

This document builds on to the previous reports submitted by Opus One which define the market structures and flexibility services discussed below (D1 Defining Market Structures), define the different valuation methodologies employed by Opus One for this report (D2 DER Valuation), and assess their viability (D3 Technoeconomic Viability of Valuation Mechanisms).

1.2 Aim

The aim of this report is to evaluate the different market structures proposed in previous milestones and to draw insight into what structure could be optimal for the local region. Secondly, this report demonstrates Opus One's GridOS platform's ability to operate flexibility services within Rugeley. The data presented has been generated through flexibility simulations run through the GridOS Market tool on a representative network model for the 11kV network downstream of the 132kv/11kv Rugeley Town Substation.

2 Preliminary work

2.1 Importing Rugeley network model

In order to run simulations for the Rugeley area, the WPD Rugeley network has been imported into the GridOS platform (Figure 1). Due to WPD restricting data access to full Common Information Model (CIM) network data, Opus One has imported the local network model from GIS files via a proprietary GIS-CIM converter. The GIS data contains a single 132kV/11kV 'Rugeley Town Substation' and 11 feeders. Although each feeder could be modelled individually on the GridOS platform, as WPD procures flexibility for the Rugeley substation as a single 'Constraint Management Zone' (CMZ), all feeders have been amalgamated into a single feeder so to allow the power flow analysis to be run at the substation level.

The GIS conversion involves the conversion of line data to end point data required for Opus One's GIS-CIM conversion. Due to data quality issues, end points of the 'line' data from the GIS data often did not meet. To resolve this, a nearest neighbour algorithm was implemented to aggregate multiple end points within a 50 meter radius into a single averaged end point. Any remaining gaps within the network data were connected via the adding of a short connecting line between disconnected end points.

This GIS conversion has provided a geographical representation of the network but, unfortunately, it is missing impedance data that would make power flow analyses truly representative of the technical dynamics of the local network.

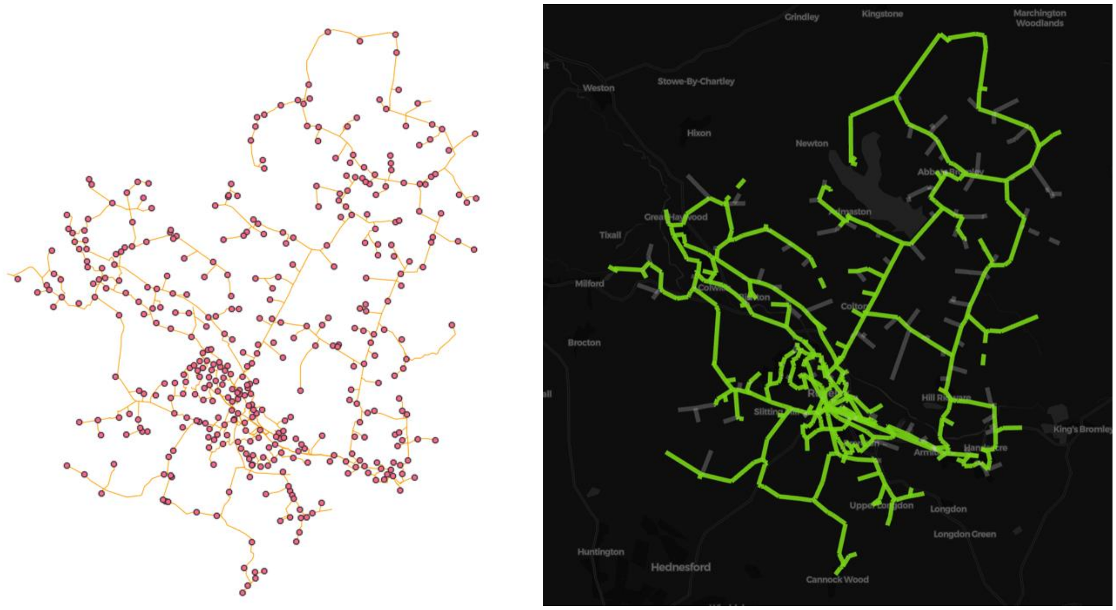

Figure 1 Original Rugeley Network GIS data (left) and Rugeley network in the GridOS Platform (right)

2.2 Load Profiles

The feeder head loading data is a random winter day load profile taken from WP6's baseline modelling work. Figure 2 shows the feeder loading used for the constraint management flexibility service simulation. The feeder loadings for other services are adapted for versions of this core load profile; either slightly increased, in the case of Peak Management, or decreased to an unconstrained level for ESO-DSO coordination and for both Peer-to-Peer services.

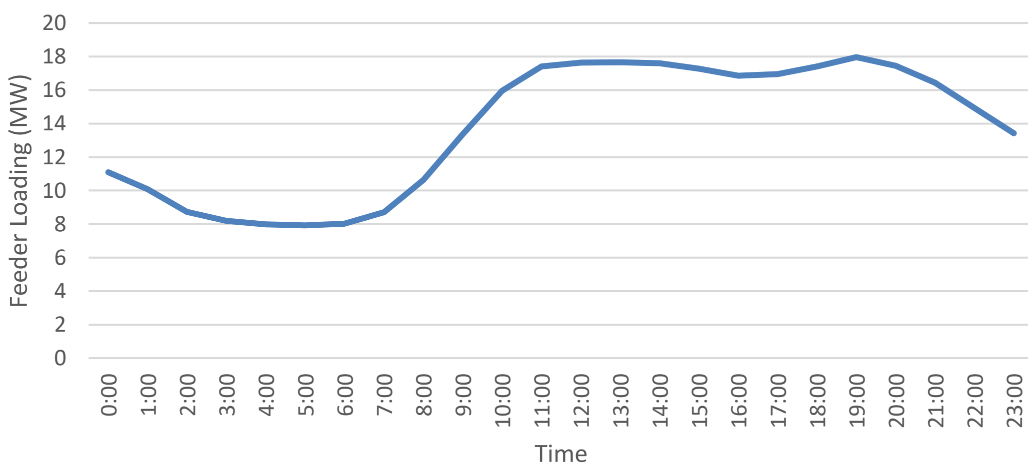

Figure 2 Example Constrained Feeder Loading

The nodal load capacities on this network were also taken from the baseline scenario of WP6's modelling. These loads were recreated on the GridOS platform (Figure 3). The WP6 nodal load modelling focused specifically on the Rugeley Town area, whereas the Rugeley feeders serve also extend out to the wider Rugeley area (local towns, villages, farms etc, Figure 1. To ensure the power flow analysis would also be simulated out into the wider Rugeley area some additional loads were added outside of Rugeley Town loads provided by WP6. All additional nodal loads added were sized within minimum and maximum range of the nodal loads taken from WP6.

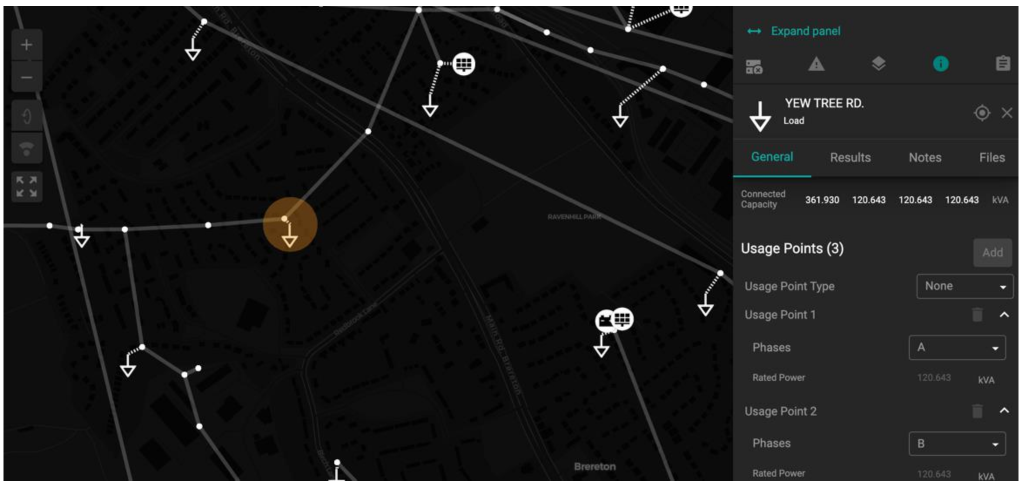

Figure 3 WP3 Nodal Loads imported into GridOS

2.3 Distributed Energy Resource placement

The distributed energy resources (DERs) used in the simulations that inform this report were solar photovoltaic (PV) systems, wind turbines, battery energy storage systems (BESS), synchronous machines, demand response (DR) shifting assets, and DR curtailing assets. These DERs are placed at various nodes on the network. The size of these DERs has been set so to enable multiple DERs to dispatch to resolve the simulated constraints on the network.

A specific BESS was added at the site of Engie Rugeley Power Plant redevelopment to show how low carbon DERs located at this site could engage in the flexibility market.

2.4 Substituting Locational Marginal Price (LMP)

Specific financial models facilitated by the GridOS platform require a Locational Marginal Price (LMP). Since a LMP doesn't exist in Great Britain, LMP is reconceptualised to represent a wholesale energy price. This wholesale energy price represents the opportunity cost from not selling energy outside of the simulated local flexibility market. When inputting bids and offers, the wholesale energy price is used as reference to ensure that offers in this simulation are priced high enough to encourage participation.

2.5 Assigning Bids and Offers

To introduce an element of chance and volatility to the bid and offer prices, to better represent the real world, a workshop was held on 4/11/2021 where different consortium partners and Opus One employees acted as 'market participants' and were assigned 4 DERs (2 BESSs, a DR curtailing asset, and a Synchronous Machine). The market participants assigned bids and offers for their DERs across a 24-hour period.

To ensure pricing data fell within a reasonable range and to increase the probability of a variety of DERs dispatching, participants were instructed to keep their bids and offers between £30/MWh-£70MWh and only input 'cheap' offers (£30-39/MWh) for 2 time periods and 'cheaper' offers '£40-49/MWh' for 4 time periods with all other offers falling between £50-70/MWh.

This workshop served a dual purpose also acting as an educational tool for consortium partners providing further exposure to the operational dynamics of flexibility markets and the GridOS platform.

The workshop and additional Bid and Offer data for all simulations can be found in the appendices.

3 Scenarios

3.1 Outline

This report examines the implementation of 4 different market structures across 5 different flexibility services. There are 3 Peer-to-Network services (P2N) and 2 Peer-to-Peer (P2P) services. The market structures represent priorities of the DSO; therefore, the focus of market structure evaluation will be in relation to the P2N services although some commentary will be made when simulating the P2P services. To run a simulation for each flexibility under each market structure, there are 23 simulations in total with Cost Saving and Supply Security combined into a single simulation for both peer-to-peer services.

Figure 4 shows the Rugeley network and highlights the geographical regions where the different flexibility services are simulated.

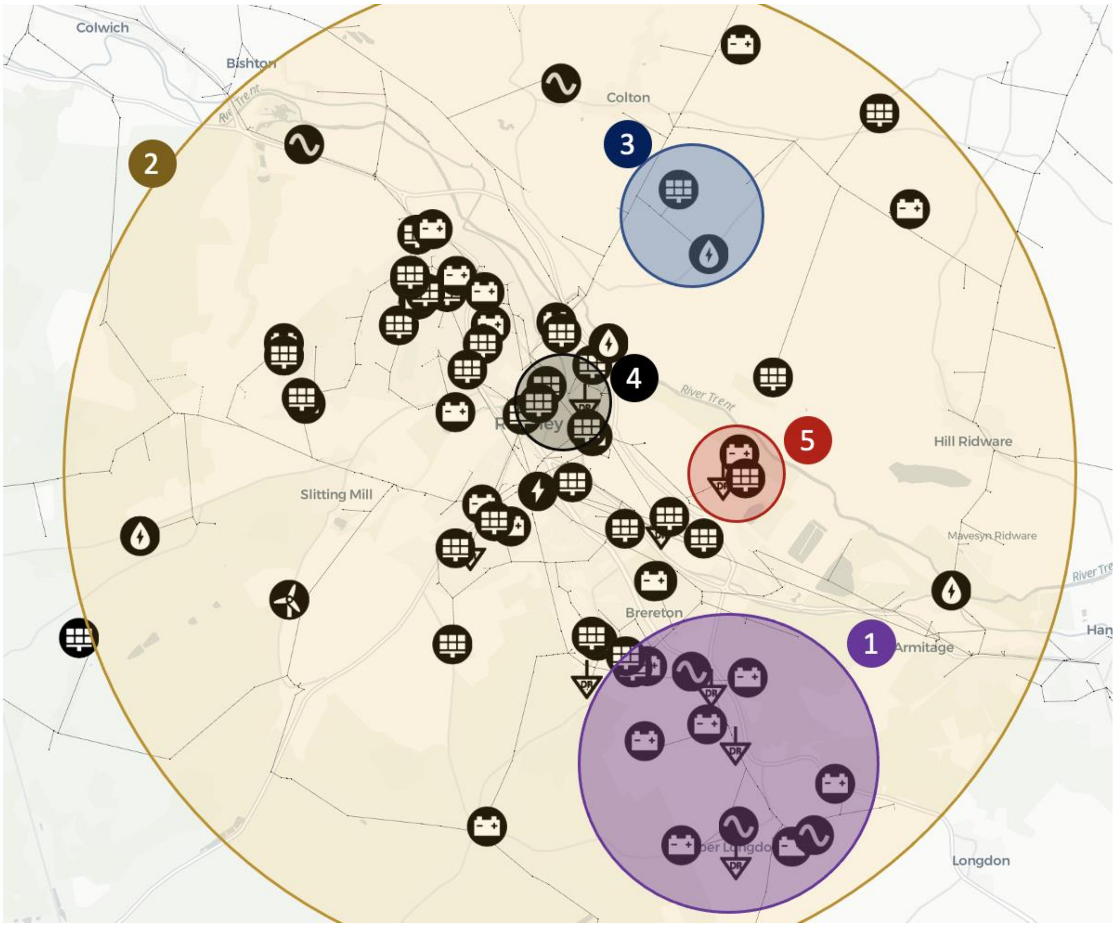

Figure 4 Overview of Rugeley Network with Flexibility Service Locations

	Flexibility Service
1	Constrained Management
2	Peak Management
3	ESO-DSO Coordination
4	MIC/MEC
5	Offsetting

3.2 Market assumptions

To allow comparison, bid and offer prices are held constant across each simulation for the different market structures apart from the Carbon Reduction market structure where offer prices are deliberately reduced for low carbon DERs. Since different DERs are enrolled in different flexibility service bid and offer prices vary between flexibility services.

BESSs are assumed to conduct one cycle a day and to operate only within this flexibility market. This means offers to discharge energy are matched with bids to charge energy to allow net state of charge to be maintained across the 24-hour period. Since BESSs are required to pay to charge while they are paid to discharge, the concept of 'net-revenue' - revenue paid to discharge minus cost of charging - is used when discussing financial outcomes.

3.3 Market Structures

Following on from reports D1-D3, each market structure is paired with the most suitable financial model to represent its objective. For more details on market structures and financial models, please refer to D1 Defining Market Structures and D2 DER Valuation/D3 Technoeconomic Viability of Valuation Mechanisms respectively.

It is worth noting that clearing markets with different financial models (e.g. pay-as-bid vs pay-as-clear) can incentivise different bid and offer behaviour in the real world. Incorporating this different bid and offer behaviour would involve complex game theory and is beyond the scope of this report. However, this is something that should be held in mind when drawing conclusions from this analysis.

3.3.1 Cost Savings

For the Cost Savings market structure, the pay-as-bid financial model is used. Pay-as-bid remunerates all accepted offers at the price at which they have offered. With the assumption of bids and offers being held consistent across market structures, pay-as-bid should provide the lowest cost to the system operator as all other financial models contain some concept of inflating prices, as is explained below.

3.3.2 Supply Security

For the Supply Security market structure, the pay-as-clear financial model is used. Pay-as-clear remunerates all accepted offers at the highest price that was accepted during any particular market time period, aka 'the clearing price'. The Pay-as-clear model represents a Supply Security market structure because GridOS imposes penalties for non-delivery post settlement. By default, this penalty is non-payment for non-deliver; therefore, the additional price elevation provided by pay-as-clear also represent an elevation in the penalty for non-delivery.

3.3.3 Carbon Reduction

For the Carbon Reduction market structure, the LMP+D financial model is used. LMP+D is an Opus One proprietary flexibility valuation methodology. The E1 element of LMP+D, provides a renewable credit which elevates the price at which the low carbon DERs remunerated above their offer price. In this study, the Renewable Energy Credit (REC) is set at £10/MWh. It is assumed that low carbon DER owners are aware of the value of the REC and that they choose to reduce their offer prices by £10/MWh to increase the probability of their offer acceptance while still allowing them to maintain satisfactory revenue.

3.3.4 Low Barrier to Entry

For all other market structures, all DERs placed on the network are above 50kW. The Low Barrier to Entry market structure allows DERs smaller than 50kW to enrol into the flexibility market. These smaller DERs are distributed throughout the Rugeley network and could represent small aggregations of domestic batteries or small behind-the-meter diesel or gas generators.

The DLMP financial model is used. DLMP uses a pay-as bid price but also provides an additional uplift that represent the value of the reduction in network losses. Since the additional enrolment of smaller DERs increases the probability of DERs being located closer to loads, there is a potential additional benefit of lower losses. Using the DLMP methodology will help us quantify this value of reduced loses.

3.4 Flexibility Services

This section briefly describes the different flexibility services and outlines how they are simulated in this study.

3.4.1 Peer to Network (P2N) Services

3.4.1.1 **Constraint Management**

For Constraint Management, flexibility is procured in the form of reduced demand, increased generation, or dispatched storage to mitigate the impact of a specific network constraint. To simulate this service, a line has been derated on the virtual Rugeley network to cause a current constraint under our feeder loading. This creates a risk of infrastructure damage or a localised power outage for loads downstream of the constrained line.

To resolve this network constraint, the downstream DERs (Figure 5) will be dispatched to power local loads. This results in less power being drawn from the feeder and reduces current through the constrained line to a level within its rated capacity.

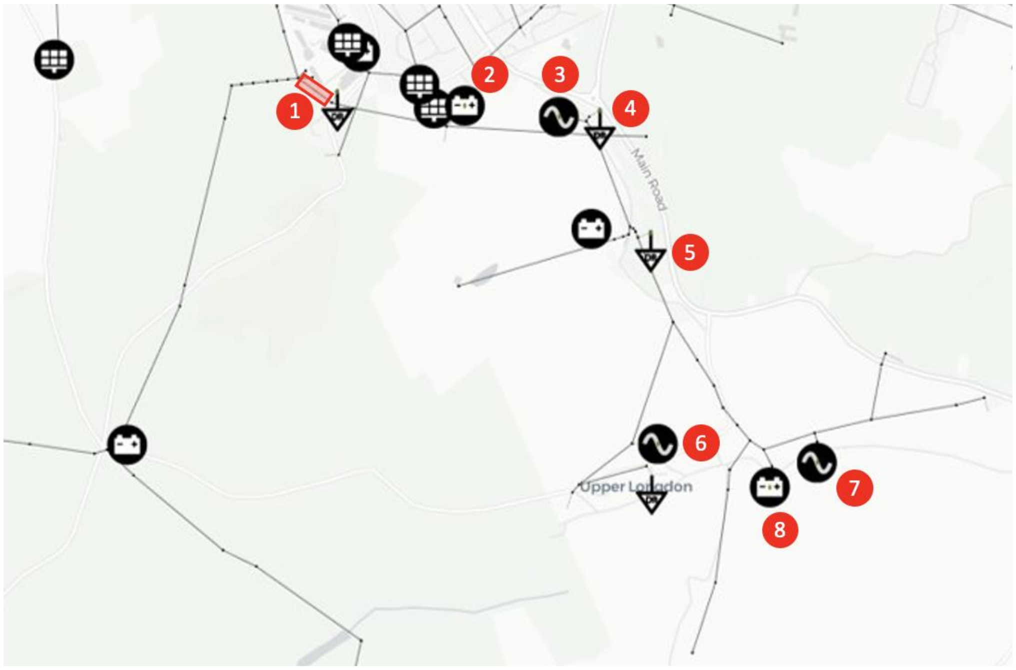

Figure 5 Constraint Management Constraint Location and eligible DERs

	Resource Name
1	Constrained Line
2	Coalpit BESS
3	Batesway SM
4	Batesway
5	Brereton Cross 2
6	Upper Longdon SM
7	Upper Longdon SM2
8	Upper Longdon BESS

3.4.1.2 Peak Management

For Peak Management, flexibility is procured in the form of increased generation, reduced demand, or dispatched storage to mitigate the impact of a period of substation level peak demand on the network. To simulate this service, a feeder loading emulating a peak demand scenario has been uploaded into the GridOS platform, and an upstream line just outside the feeder head has been derated so as to cause a constraint under this load profile. This means all DERs on the entire network are capable of relieving the constraint and are eligible to participate in the market (Figure 6).

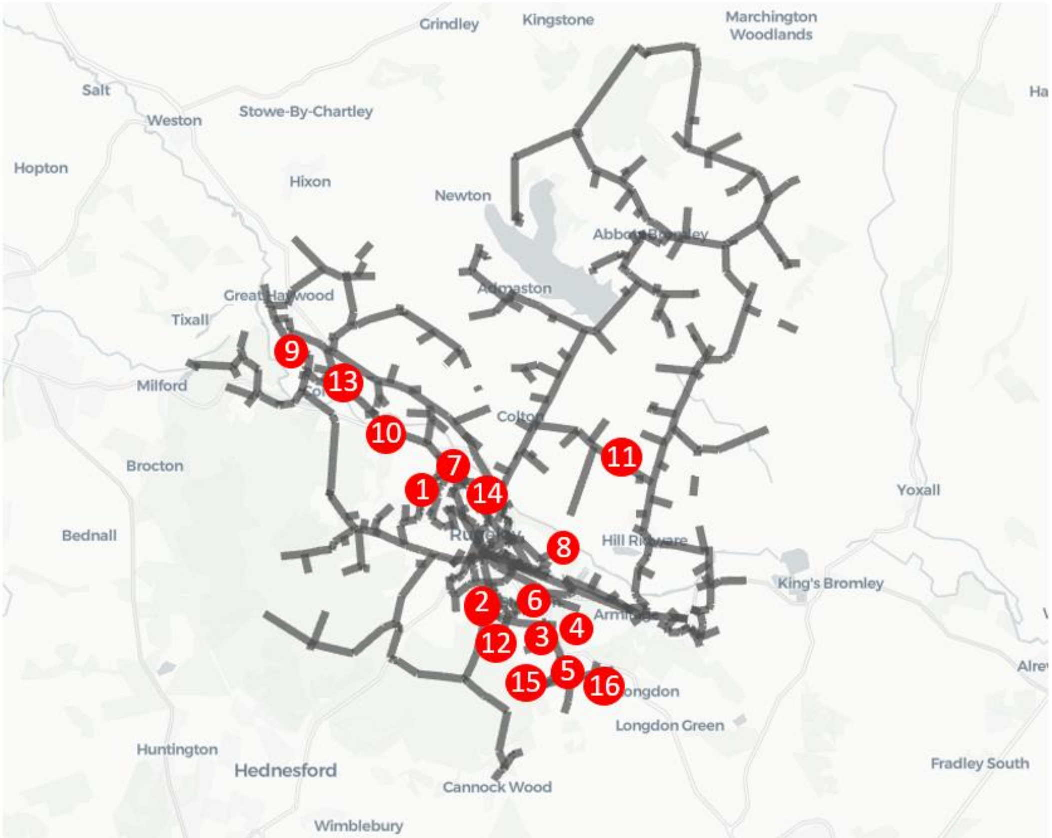

Figure 6: Peak management eligible DERs

	Resource Name
1	Aneurin BESS
2	Arthur Evans BESS
3	Batesway SM
4	Batesway
5	Brereton Cross 2
6	Coalpit Battery
7	Daywell BESS
8	Engie Rugeley BESS
9	Great Haywards BESS
10	Greenside BESS
11	Lichfield Rd. BESS
12	Pinetrees
13	Orchard Lane SM
14	Tesco Superstore
15	Upper Longdon SM
16	Upper Longdon SM 2

3.4.1.3 **ESO-DSO Coordination**

For the ESO-DSO coordination service, flexibility is procured in the form of decreased generation, increased demand, or BESS charging to mitigate the impact of network constraint caused by a DER dispatching to service a National Grid ESO market such as Short Term Operating Reserve (STOR). To simulate this, a run of the river hydro is scheduled to dispatch in line with National Grid's STOR 2021-2022, Season 5 week-day morning service window[1]. Due to additional renewable DERs dispatching at the same time a current violation is caused on a nearby line which needs to be resolved (Figure 7).

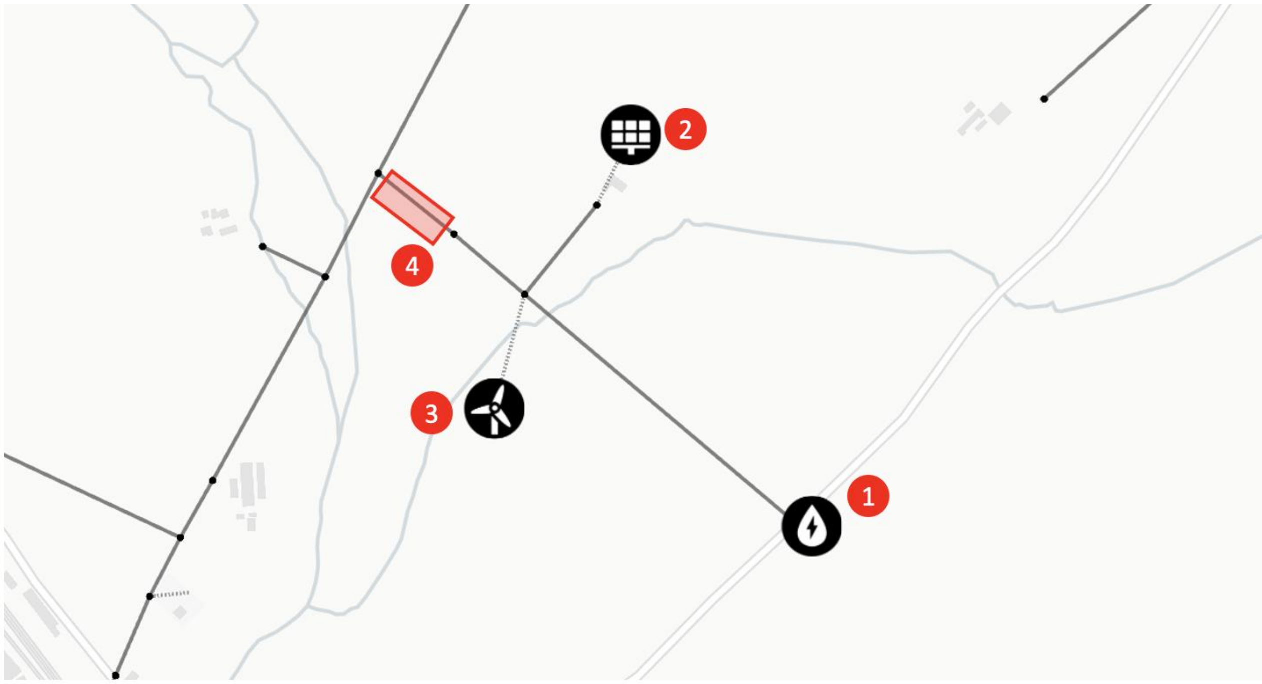

Figure 7 ESO-DSO Coordination DERs

	Resource Name	Rating
1	STOR DER 1	3MW
2	Colton PV	0.1MW
3	Colton Wind	0.1MW
4	Constrained Line	160A

3.4.2 Peer to Peer (P2P) Service

Unlike P2N services, P2P services aren't procured by the DSO to resolve existing network constraints rather they are transactions facilitated to allow DERs/Market Participants to engage in behaviour that is usually restricted while still ensuring the security of the network. Since P2P services aren't used to relieve existing constraints, we use a non-congested feeder load profile for both P2P services.

[1] STOR Service Windows: https://www.nationalgrideso.com/document/186671/download

The GridOS platform has been designed for P2N service primarily. To simulate P2P services and to allow DERs to dispatch without a network constraint, we have inputted negative offer prices to economically force dispatch of these DERs. This forcing action works because the GridOS Optimisation Engines is set with a Cost Saving objective function; therefore, it will always dispatch DERs with negative price which in effect pay the flexibility operator to dispatch. Unfortunately, this restricts our ability to comment on cost/revenue outcomes for peer-to-peer services.

Full P2P functionality actionable without network constraints is under development in the GridOS platform, with a full functionality scheduled for release in Q1 2022.

3.4.2.1 *Maximum import/export capacity trading (MIC/MEC)*

MIC MEC is a peer-to-peer service where one market actor wishes to export or import beyond their agreed contractual maximum limits (agreed at the time of connection). In order to exceed this limit, the buyer offers to pay an alternative market participant to temporarily restrict their own maximum import or export. The increase in limit of the buyer should be matched by the decrease in limit of the seller. This scenario is demonstrated with two BESS resources and synchronous machine (Figure 8). DERs are deliberately placed in close proximity to ensure the inverse actions of the buyer and seller offset each other without causing any unintended knock-on power flow issues.

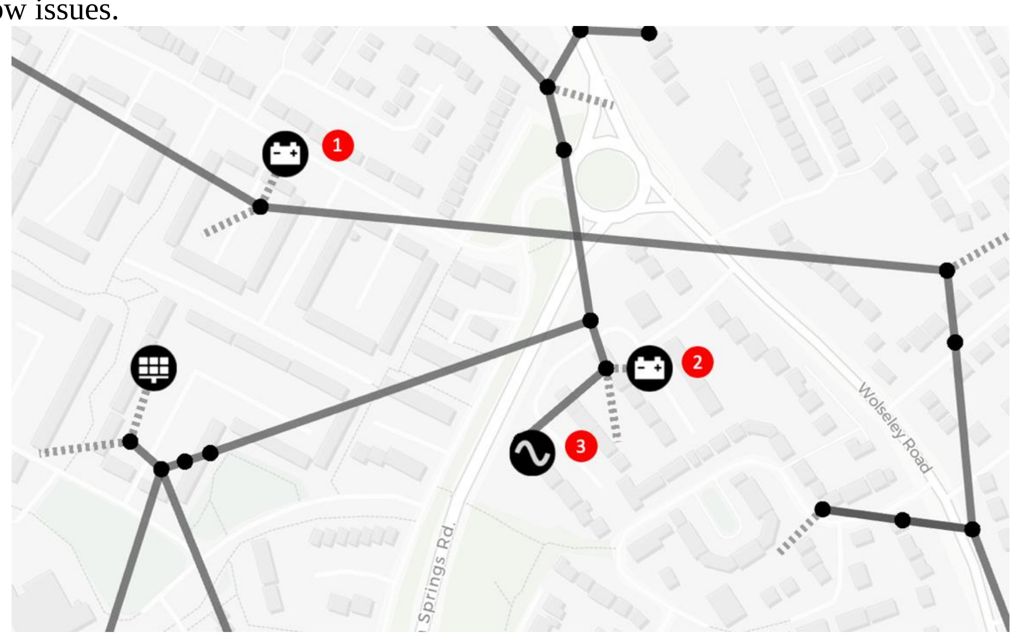

Figure 8 MIC/MEC DERs

	Resource Name	Baseline MEC (kW)	Post P2P MEC (kW)
1	Wat Tyler BESS	400	300
2	Portebello BESS	180	280
3	Portobello SM	100	200

For this report, a MEC trade is simulated. A baseline simulation is first run where Wat Tyler BESS, Portobello BESS and Portobello SM export limits of 400kW, 180kW and 100kW respectively. A second simulation is run where their MEC capacities have been modified up or down. The GridOS platform restricts market participants from inputting offers at volumes (kW) higher than their Maximum Export Capacity. To allow our Market Participants to input a higher offer volume than initially possible, the export limits were changed manually on the platform for the specific day that the analysis was set to run.

3.4.2.2 ***Offsetting***

Offsetting enables a market participant to deviate from a load or generation profile that has been submitted to the system operator when needed. In this report, we simulate a load that wishes to increase its consumption. To offset this higher consumption, a contract is made with a local generator, requesting them to increase their generation to match the increased consumption. This scenario is demonstrated with the use of a Demand Response (DR) shifting asset, to represent the load that increases consumption, and the use of a BESS resource or a synchronous machine, depending on the market structure (Figure 9). Similarly, to MIC/MEC, all DERs have been deliberately positioned near each other to emphasize how this is a transaction that can happen between local market actors and prevent the creation of congestions elsewhere in the network.

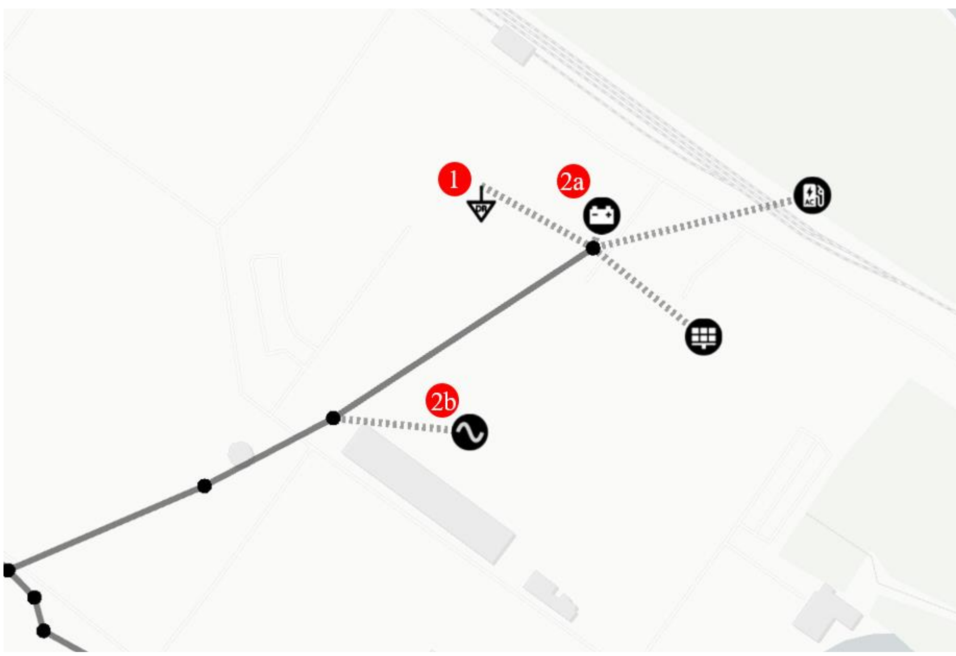

Figure 9: DERs enrolled in Offsetting scenario

	Carbon Minimization Resources	Cost saving Resources
1	Engie Rugeley Development	Engie Rugeley Development
2	Engie Rugeley BESS	Engie Rugley SM

4 Results

4.1 Peer to Network (P2N)

4.1.1 Constraint Management

On November 23rd, GridOS Market program settings were configured to generate pricing events for the constraint management scenario. Programs were rerun under each financial model to represent each market structure.

4.1.1.1 *Cost Saving*

Under the feeder loading, DERs are dispatched to resolve a network constraint between 11am-11pm (Figure 10). To manage state of charge, batteries charge during hours assigned bids, 11pm-2am. Coalpit BESS and Batesway DR provide over 50% of the required 'turn-up' flexibility (Figure 11). In spite of this, Coalpit BESS receives a proportionally small amount (11%) of net-revenue from the auction while Batesway DR and Upper Longdon SM take 28% and 24% respectively (Figure 12). The reason for this discrepancy is the requirement of BESS to charge within the flexibility market to manage state of charge. It is worth noting that within this simulation the equivalent cost isn't captured for other DER types (e.g. the cost of gas for synchronous machines or the business cost of enacting demand response). The total cost for the DSO to resolve this particular constraint across this 12-hour period is £40.46.

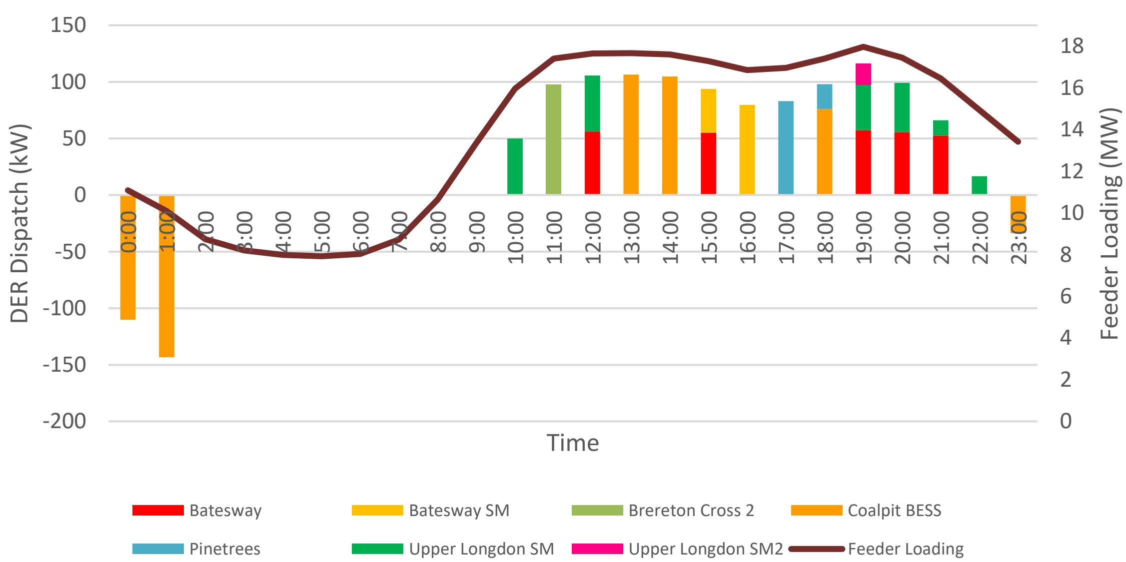

Figure 10 DER Dispatch (Constraint Management, Cost Saving)

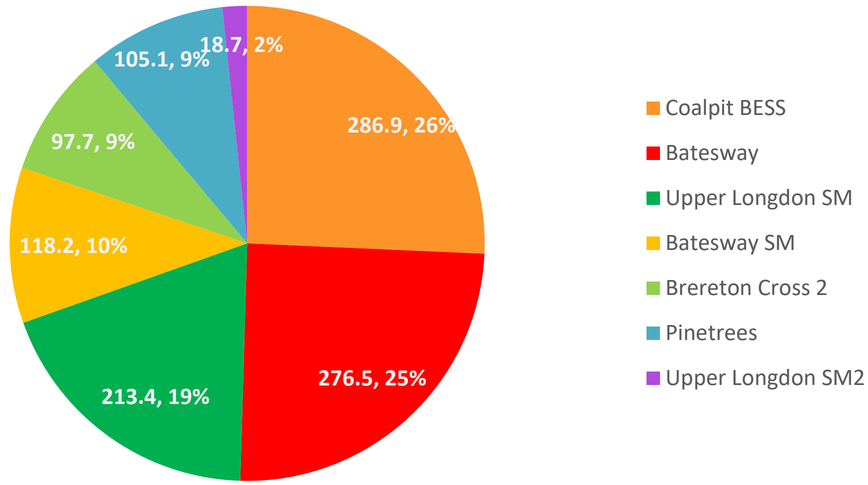

Figure 11 Total DER dispatch across flexibility auction (Constraint Management, Cost Saving)

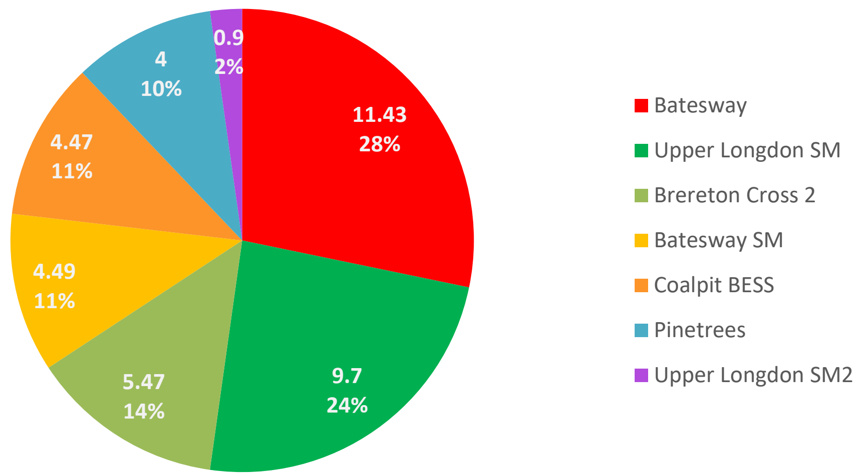

Figure 12 Total DER Net-Revenue (Constraint Management, Cost Saving)

4.1.1.2 ***Supply Security***

Under Supply Security, the exact same DER schedule is dispatched as Cost Saving (Figure 10). The change in Supply Security is in the remuneration calculation post-dispatch (Figure 13).

With the pay-as-clear methodology, the total cost to the DSO to resolve this constraint across the 12-hours is £41.47 a 2.5% increase in comparison to the Cost Saving market structure. The relatively minimal increase is likely due to the size of this constraint only requiring a single DER to be dispatched during the majority of the constrained hours. With this said, the proportion of total revenue is changed with Batesway DR capturing 2% more of total net-revenue available.

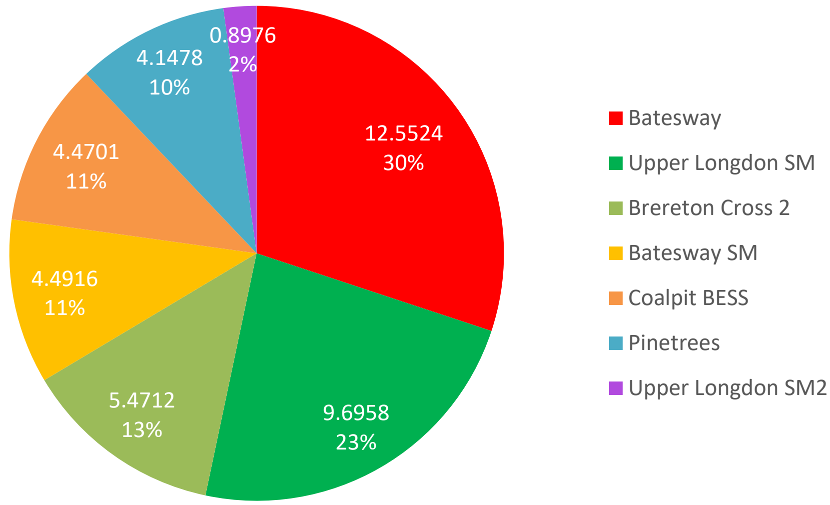

Figure 13 Total Revenue (Constraint Management, Supply Security)

4.1.1.3 ***Carbon Reduction***

The Carbon Reduction Market structure results in a different DER dispatch schedule when compared to Cost Saving and Supply Security. The Low carbon DERs (BESS and DR Curtail) have been dispatched more frequently (Figure 14) resulting in a transition from 69% to 100% of flexibility procured being from green resources (BESS or Demand Response) (Figure 15).

The distribution of revenue changes dramatically under the Carbon Reduction market structure. Brereton Cross DR and Batesway DR increase their total net-revenue from £5.47 (13%) to £18.75 (45%) and £9.70 (23%) to £13.87 (34%) respectively. The total cost for the DSO is £41.08 a 1.5% increase when compared to the Cost Saving Market Structure.

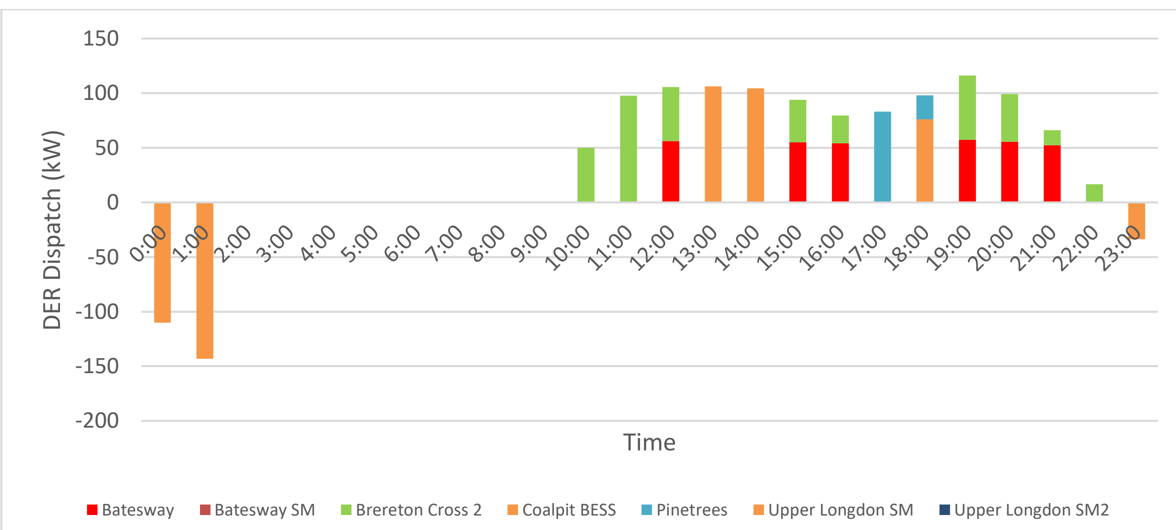

Figure 14 DER Dispatch (Constraint Management, Carbon Reduction)

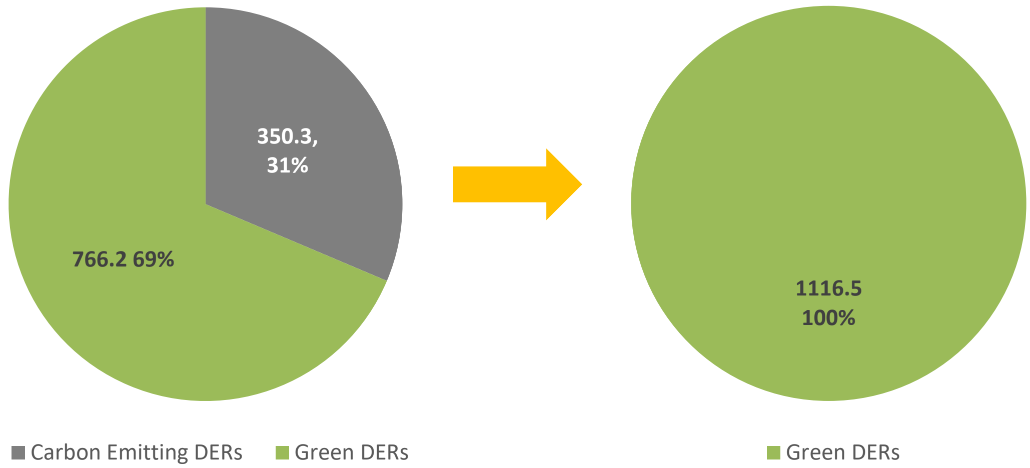

Figure 15 Change in percentage of flexibility procured from green DERs Carbon Reduction (right) vs Supply Security/Constraint Management (left)

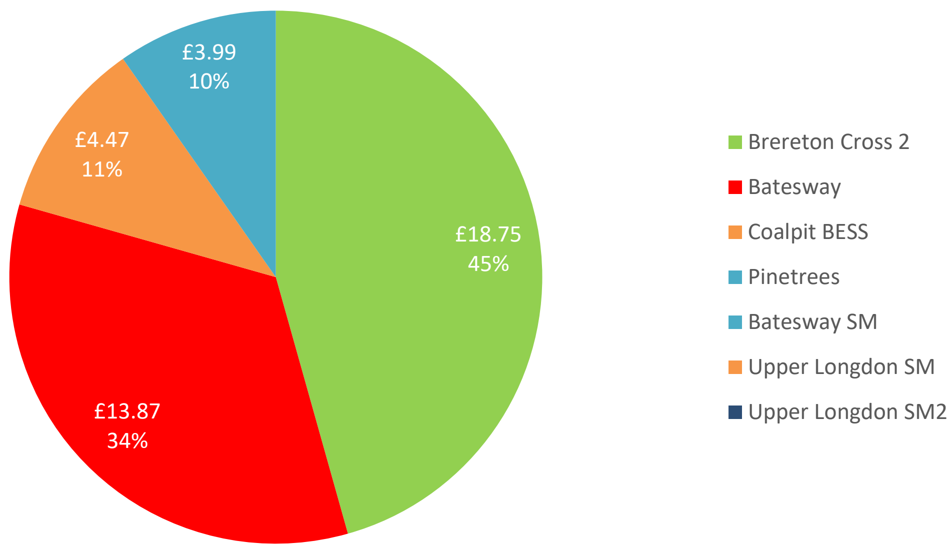

Figure 16 Total Revenue (£) (Constraint Managment, Carbon Reduction)

4.1.1.4 *Low Barrier to Entry*

For the Low Barrier to Entry market structure 4 additional DERs are enrolled into the market (Figure 17).

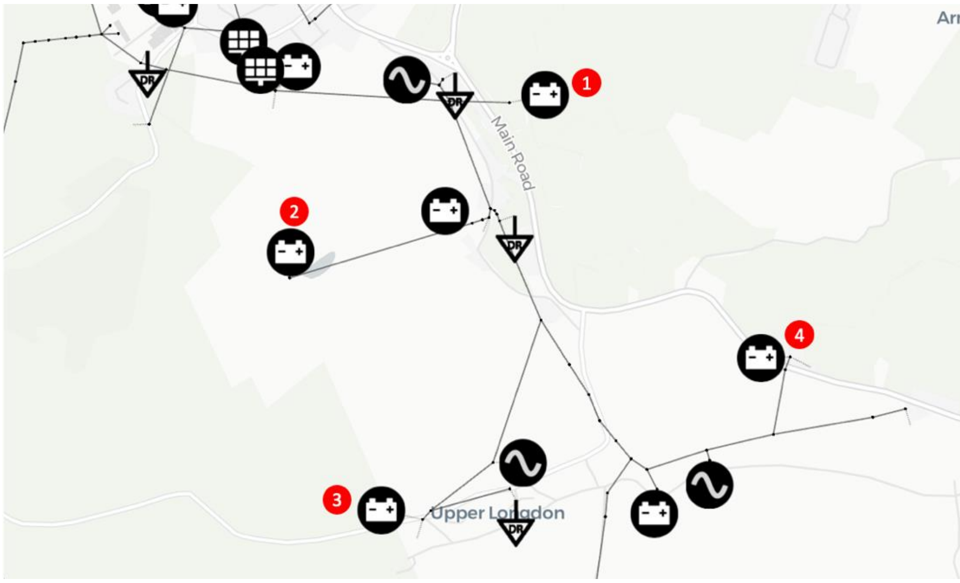

Figure 17 Low Barrier to Entry DERs Constraint Management

	Low-Barrier-to-Entry DER Name	Rating (kW)
1	1LBE BESS	20
2	2LBE BESS	10
3	3LBE BESS	25
4	4LBE BESS	15

With these additional DERs, a change in dispatch is observed with 3 out of 4 low-barrier-to-entry (LBE) DERs dispatching during the simulation (Figure 18). This leads to the original DERs reducing their dispatch and Upper Longdon SM2 no longer dispatching at all.

Low Barrier to Entry reduces the total cost to the DSO below that of even the Cost Saving scenario from £40.46 to £38.97, a 4% decrease. This is despite an additional £1.83 paid across all DERs for reduction of network losses. Interestingly, as seen in Figure 19, the nominal value paid to the highest earners (Batesway DR, Upper Longdon SM and Brereton Cross 2) decreases; however, the proportion of the total revenue paid out to these DERs increases.

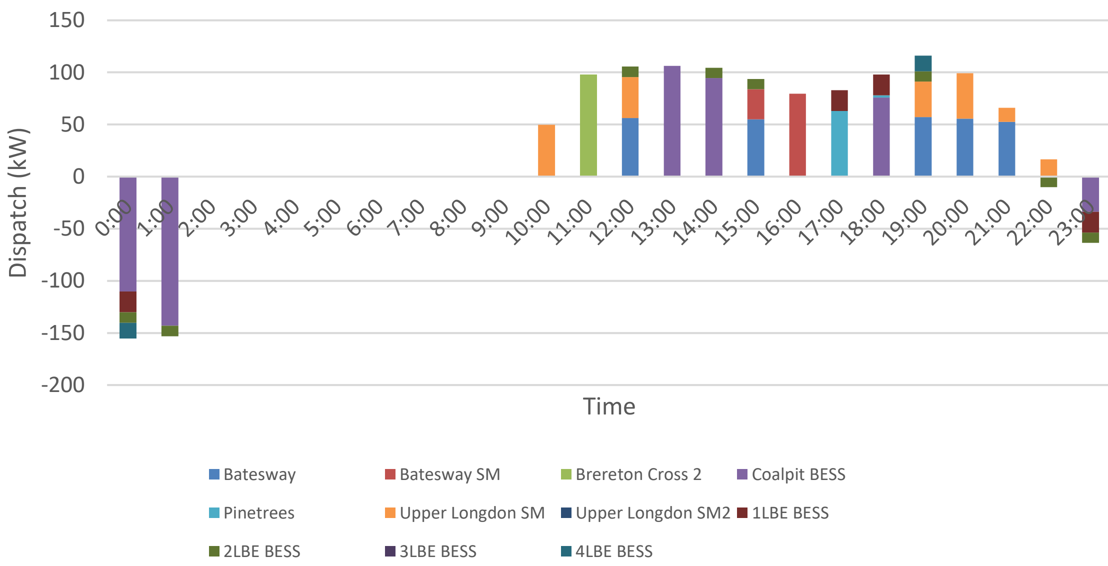

Figure 18 DER Dispatch (Low Barrier to Entry, Constraint Management)

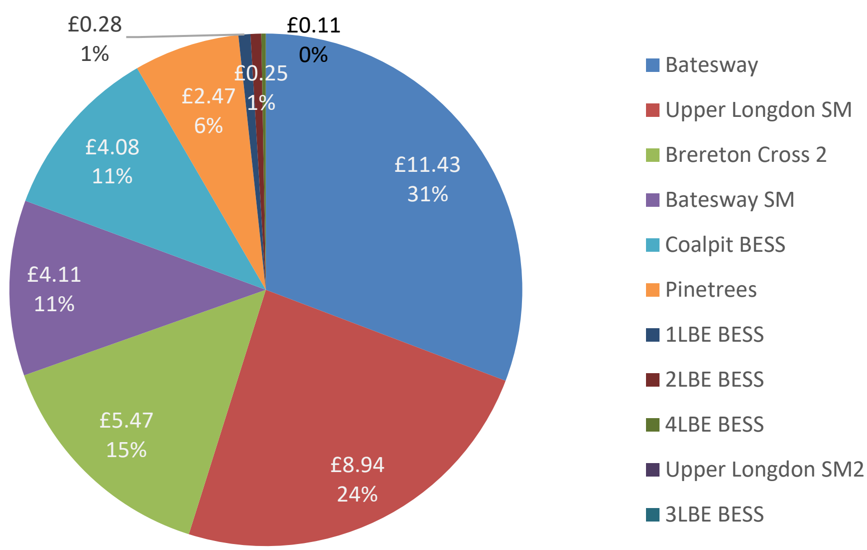

Figure 19 Net Revenue (Constraint Management, Low Barrier To Entry)

4.1.2 Peak Management

On November 25th, GridOS Market program settings were configured to generate pricing events for the peak management scenario. Programs were rerun under each financial model to represent each market structure.

4.1.2.1 *Cost Saving*

Under the peak management feeder loading, peak loading occurs between 10:00-15:00 and again between 18:00-21:00. Like the Constraint Management scenario, the state of charge of BESS assets was managed by assigning them bids between 11pm-2am.

As shown in Figure 20, the procurement of flexibility during peak hours helps decrease the net feeder loading by as much as 5%, which prevents the creation of the associated network constraint.

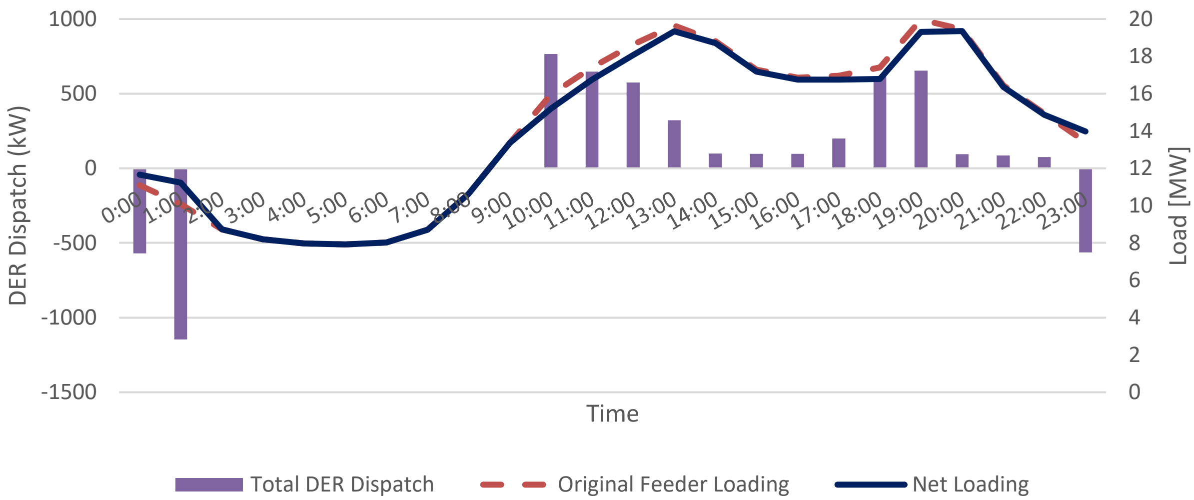

Figure 20: Net feeder loading and total DER dispatch

Figure 21 and Figure 22 take a closer look at the breakdown of flexibility provided by DER type. Under the Cost Saving market structure, 28% of the procured flexibility comes from the Aneurin BESS asset, while 45% comes from three different synchronous machines (Orchard Lane SM, Upper Longdon SM and Upper Longdon SM 2). The total cost to the DSO under this market structure is £122.96.

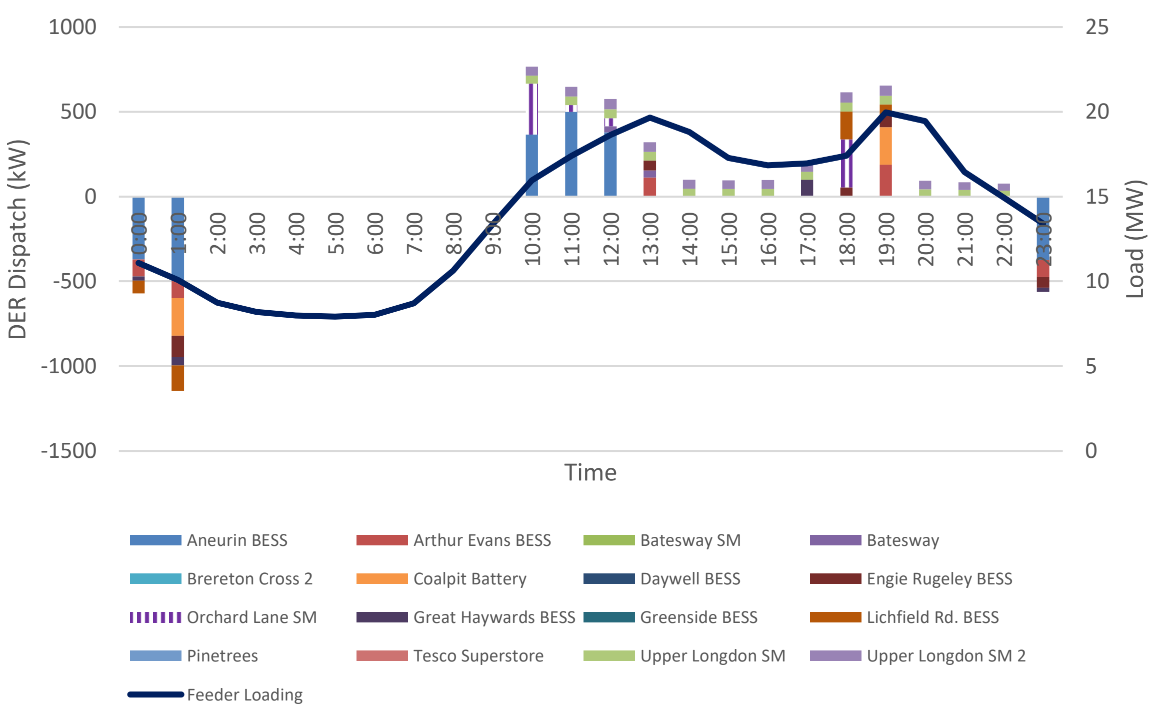

Figure 21: Peak management Cost saving DER dispatch

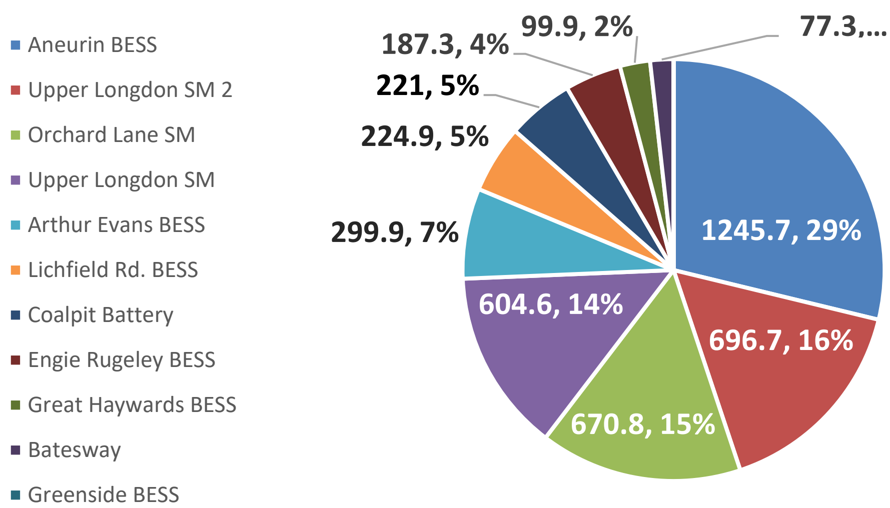

Figure 22: Distribution of DER dispatch for peak management, Cost saving

However, while Aneurin BESS dispatches the highest volume, it does not have the highest total revenue. The highest paid asset under this market structure is the Upper Longdon SM2, despite only providing 16% of the total flexibility.

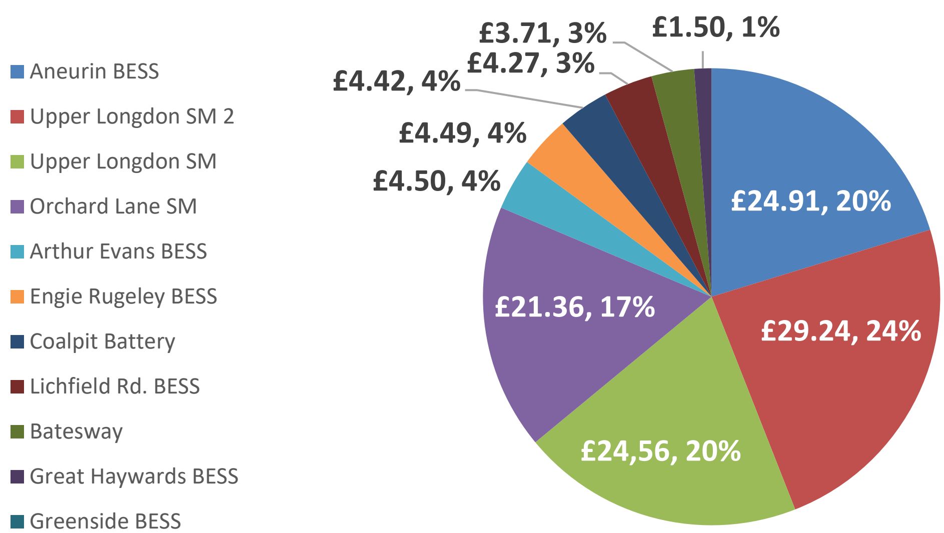

Figure 23: Peak management Cost saving total revenue per DER type

4.1.2.2 ***Supply Security***

Under the Supply Security market structure, the same DER dispatch schedule as with Cost Saving is observed (Figure 21). The change in distribution of revenues is shown in Figure 24. In this case, the market clearing price during peak hours averages at £43.60 per MW. Under this market structure, Aneurin BESS becomes the highest paid DER with a total revenue of £37.37 for the days' dispatch with Upper Longdon SM 2 only receiving a total revenue of £30.50. This could be explained by the greater variety across DERs in offer prices than bid prices which leads to pay-as-clear price inflation only affecting revenue rather than cost. The total cost to the DSO under this market structure is £158.15.

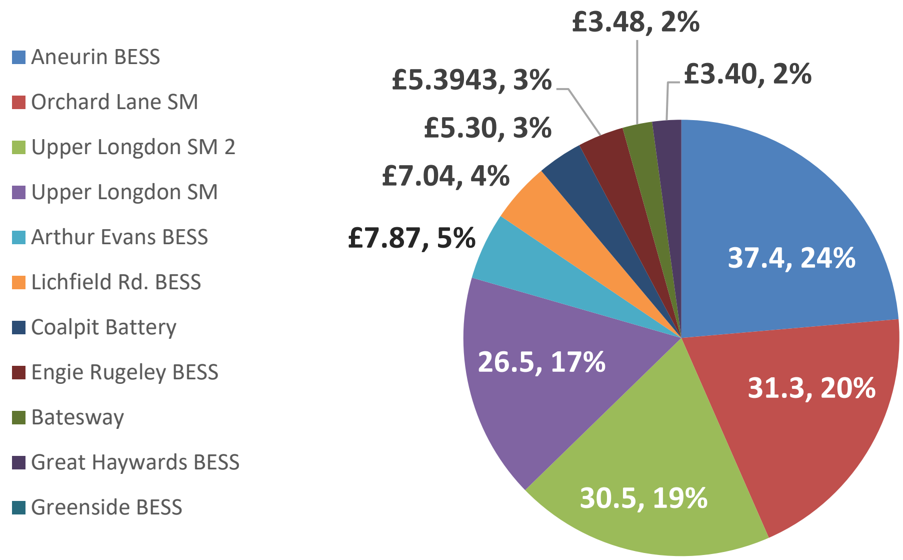

Figure 24: Peak management Supply Security total revenue breakdown per DER type

4.1.2.3 ***Carbon Minimization***

The DER dispatch schedule changes for carbon minimization as observed in Figure 25. Here, low-carbon DERs (DR curtail and BESS resources) get prioritized over carbon intensive ones. Furthermore, when examining the proportion of total flexibility procured by green DER type, there is a significant increase from 53% to 98% when compared to Cost Saving and Supply Security (Figure 27).

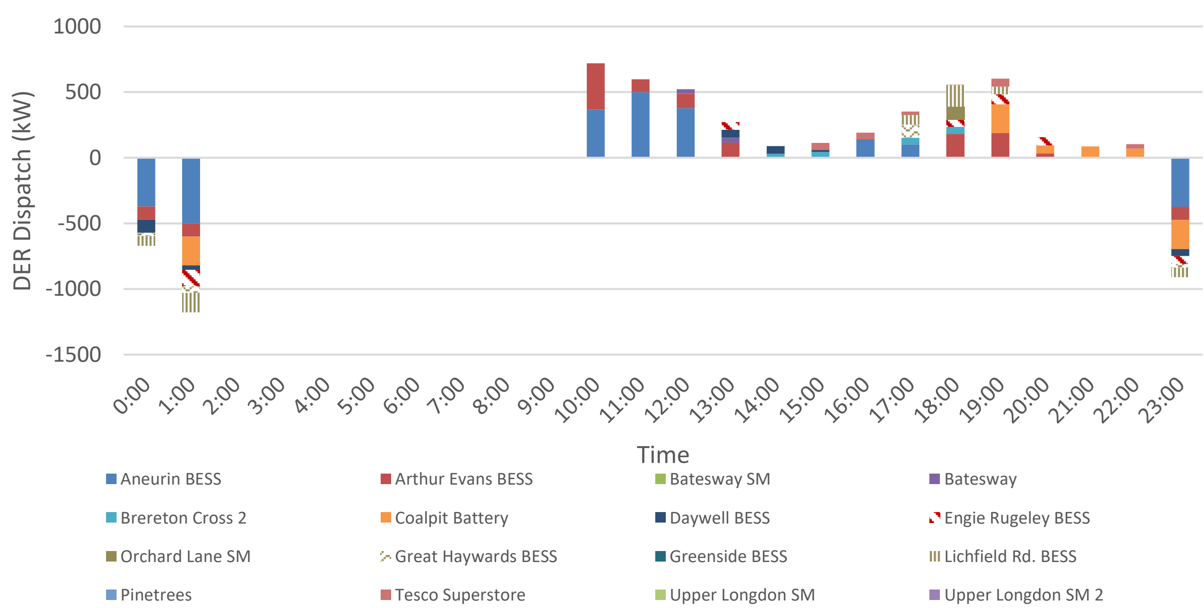

Figure 25: Peak management carbon minimization DER dispatch

Consequently, the pricing distribution across DERs gets impacted, as shown in Figure 26. The highest priced DER becomes the Arthur Evans BESS, with an average price of £4.59 during peak hours, and taking 21% of the total revenue. This is followed by the Aneurin BESS asset, with an average price of £6.69 during peak hours, taking 19% of the total revenue. While Aneurin BESS possess a higher average price than Arthur Evans BESS, its net total price gets decreased due to the higher quantity of power required to recharge Aneurin BESS in comparison to Arthur Evans BESS. Hence, the net total price of Arthur Evans BESS exceeds Aneurin BESS'. The total cost to the DSO under this market structure is £198.59.

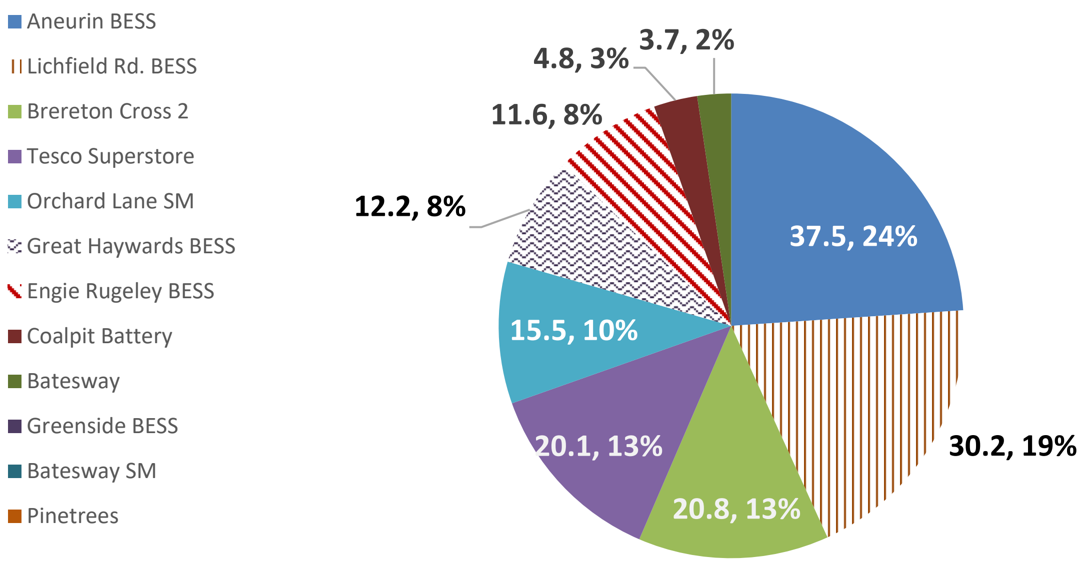

Figure 26: Peak management carbon minimization revenue distribution by DER type

With the more competitive pricing assigned to low-carbon DERs through the LMP+D methodology the percentage of flexibility provided by green DERs increases from 53% to 98% (Figure 27).

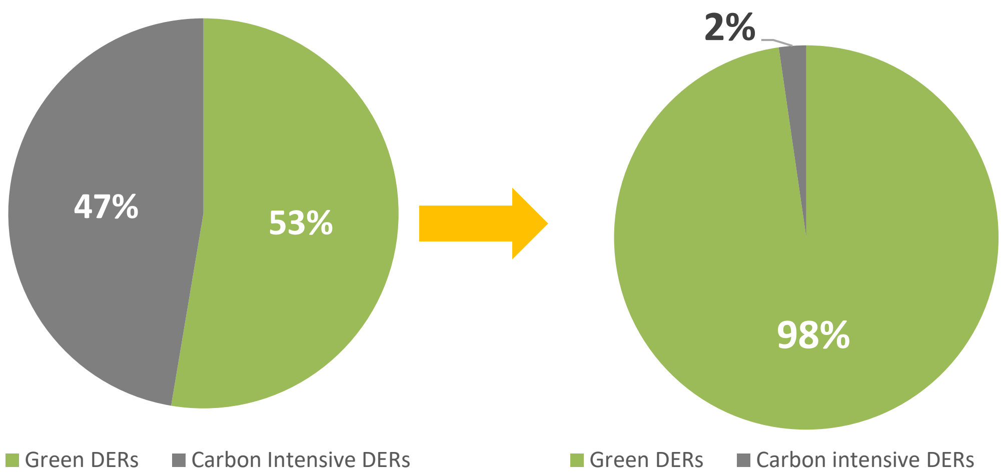

Figure 27: Comparison of Green DERs dispatch versus carbon intensive DERs

4.1.2.4 ***Low Barrier to Entry***

For the low barrier to entry, additional, smaller rated DERs were enrolled in the market. These DERs are shown in Figure 28.

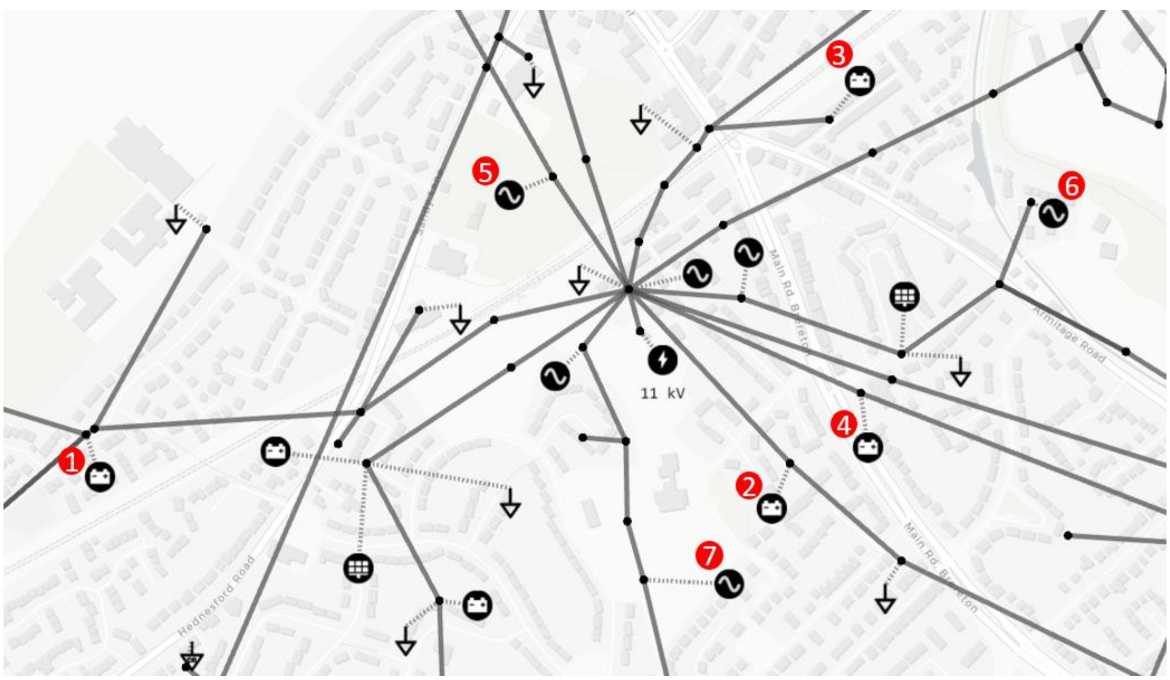

Figure 28: Peak management low barrier to entry added DERs map

	Low-Barrier-to-Entry DER Name	Rating (kW)
1	LBE1 BESS	20
2	LBE2 BESS	15
3	LBE3 BESS	10
4	LBE4 BESS	25
5	LBE1 SM	15
6	LBE2 SM	13
7	LBE3 SM	20

The addition of these DERs changes the overall dispatch schedule, with 5 out of 7 LBE DERs providing flexibility (Figure 29). This leads to the DR curtailing loads being out priced, as well as a reduction in the dispatch of the Upper Longdon SM and Upper Longdon SM2.

The total cost to the DSO is of £128.98, which is a 4.9% increase from the Cost saving market structure, 18.44% decrease than in the Supply Security market structure, and over 35% less than the total cost to the DSO in the Carbon Minimization market structure.

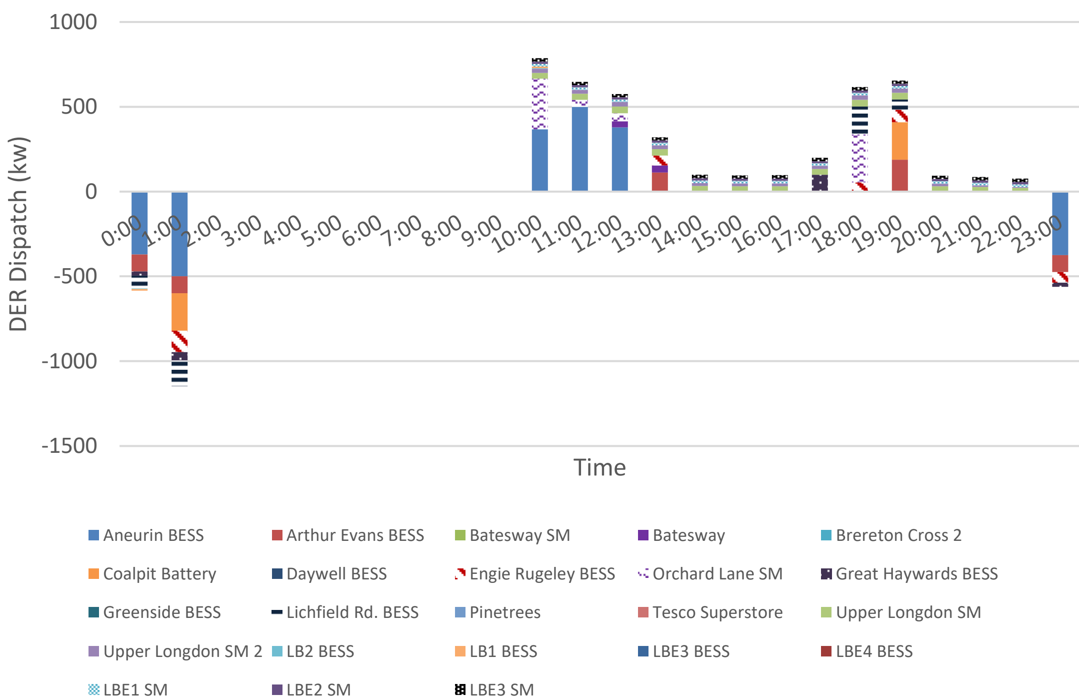

Figure 29: Peak management low barrier to entry DER dispatch

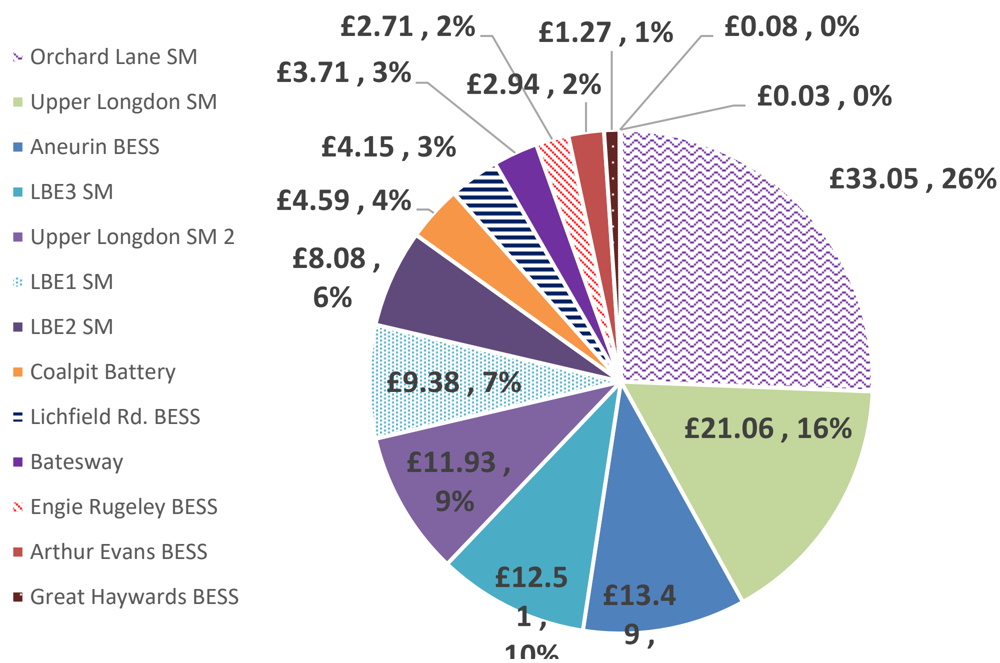

Figure 30: Peak management low barrier to entry total revenue by DER type

4.1.3 ESO-DSO Coordination

On November 26th, GridOS Market program settings were configured to generate pricing events for the ESO-DSO Coordination simulation. As with the other flexibility services, simulations were rerun under each financial model to represent each market structure.

4.1.3.1 *Cost saving*

Figure 31 shows the curtailment request, the baseline and the post flexibility DER dispatch for ESO-DSO Coordination service under Cost Saving. The local network is sized appropriately to allow the STOR DER (3MW) to dispatch without causing a constraint or network issue; however, when local renewables, Colton PV and Colton Wind, also start generating onto the network the current running through a local line, Line 366, exceeds the rated capacity.

Since the DSO has visibility of this network constraint, the ESO-DSO coordination service has accepted the cheapest DER bids to turn down, Colton PV at £52/MWh and Colton Wind at £58/MWh. This pays Colton PV total revenue of £20.87 and Colton Wind £9.92, while allowing STOR DER to dispatch its full 3MW to service the ESO STOR request. The total cost the DSO is £30.79.

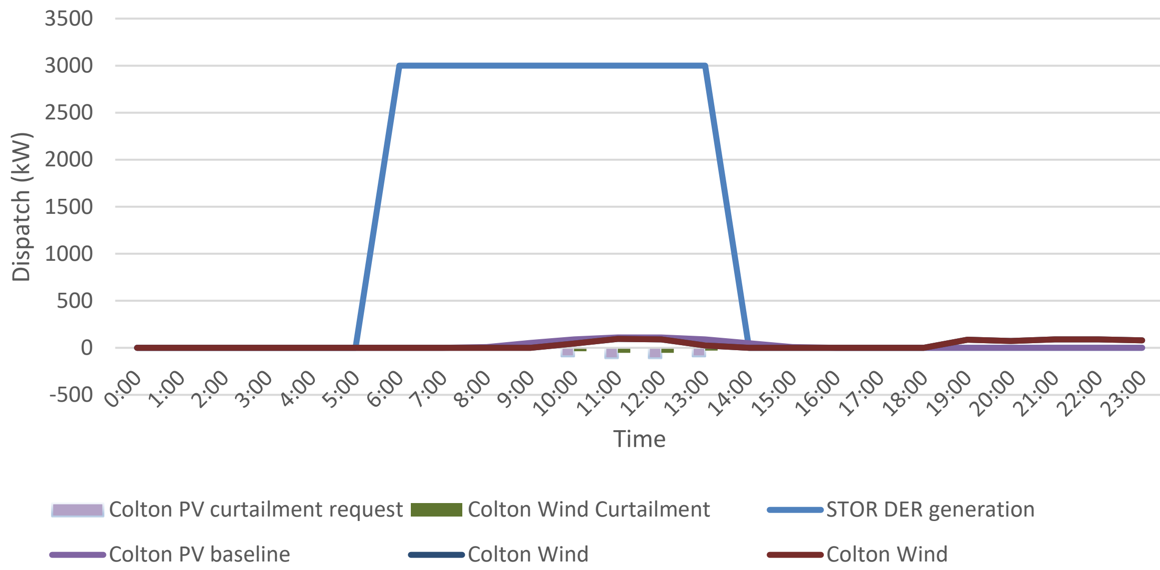

Figure 31 DER Dispatch (ESO-DSO Coordination, Cost Saving)

4.1.3.2 ***Supply Security***

Under the Supply Security market structure, the DER dispatch follows the Cost Saving market structure (Figure 31). Under the Pay-as-Clear financial model, the price that Colton PV is remunerated at is increased from £52/MWh to the Colton Wind's price of £58/MWh for hours 10:00-14:00. This increases Colton PV total revenue by 11.5% from £20.87 to £23.27 Colton Wind remuneration remains the same at £9.92. The total cost the DSO increases by 7.8% to £33.19 when compared to Cost Saving.

4.1.3.3 ***Carbon Reduction***

Interestingly, the Carbon Reduction market structure works in reverse for ESO-DSO coordination when compared to previous structures. In previous market structures, we have wanted to make the flexibility offers of green resources more attractive to the DSO; however, because this simulation involves curtailment, we instead want to make their bids less competitive so that the renewables are not curtailed and the STOR DER Synchronous Machine is curtailed instead. This involves increasing the bid price from £52/MWh and £58/MWh to £62/MWh and £68/MWH for Colton PV and Colton Wind respectively. This leaves the STOR DER synchronous machine as the most cost efficient DER to accept at £60/MWh. Figure 32 shows the DER dispatch under this scenario, with there no longer being any curtailment of renewable generation.

The total cost to revenue earned for curtailment by STOR DER and the total cost to the DSO for this flexibility event £34.34 a 11.5% increase compared to Cost Saving. It is worth mentioning that depending on the contractual agreements between the ESO, DSO and STOR DER, STOR DER could be faced with a penalty for under delivery of the STOR service due to the curtailment. If this is the case, it is possible that curtailment could be more costly as STOR DER could request further compensation to cover the penalty imposed by the ESO.

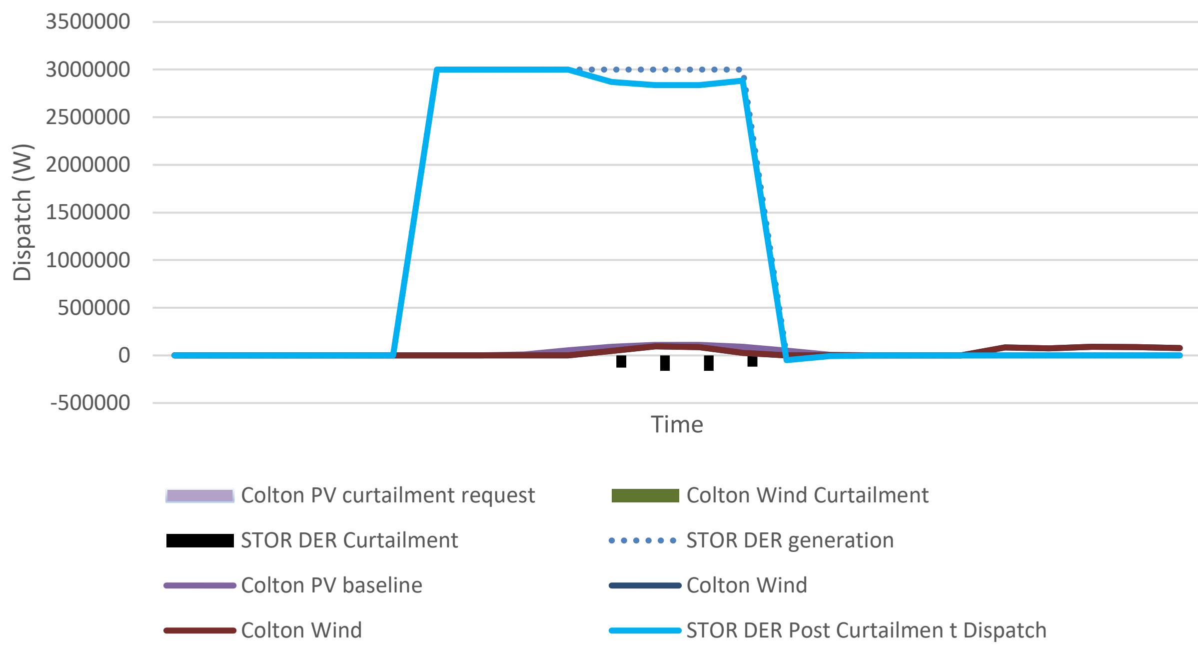

Figure 32 DER Dispatch (Carbon Reduction, ESO-DSO Coordination)

4.1.3.4 ***Low Barrier To Entry***

The low barrier to entry market structure introduces 2 small domestic BESS portfolios (Figure 33). Since these two smaller DERs are batteries, instead of curtailing generation they are able to charge up for later dispatch. This means that they can offer more attractive bid prices. For this simulation, it is assumed that the batteries offer to charge for free (£0/MWh) which makes them more attractive than the renewables that require payment to curtail.

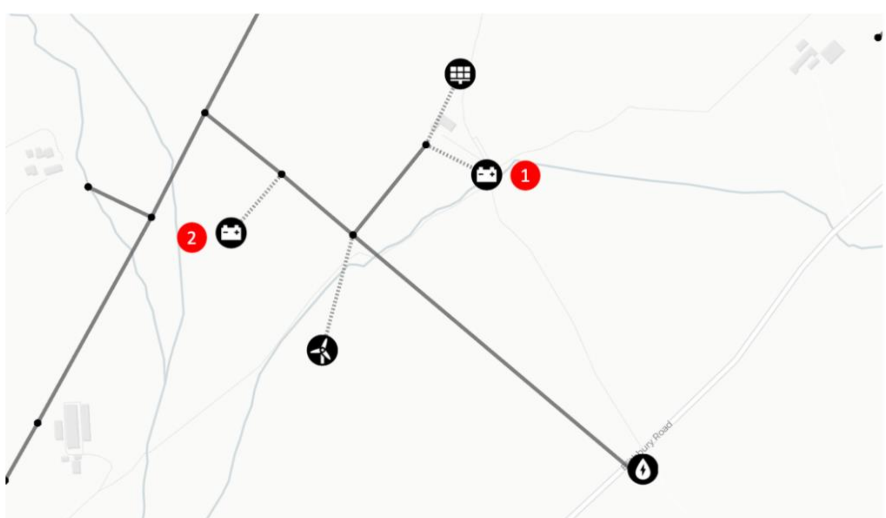

Figure 33 Low Barrier to Entry DERs for ESO-DSO Coordination

	Low-Barrier-to-Entry DER Name	Rating (kW)	Energy (kWh)
1	LBE1 BESS	25	100
2	LBE2 BESS	25	100

Figure 34 shows the DER dispatch by the flexibility market. Both smaller batteries have their full 25kW capacities utilised to charge reducing the requirement to curtail Colton Wind and Colton PV. This provides both BESSs the opportunity to discharge later during the evening to manage state of charge and to make a profit from the price differential between £0/MWh cost of charging and the price at which they sell. The total cost to DSO is now £23.24 a 25% decrease from the Cost Saving market structure.

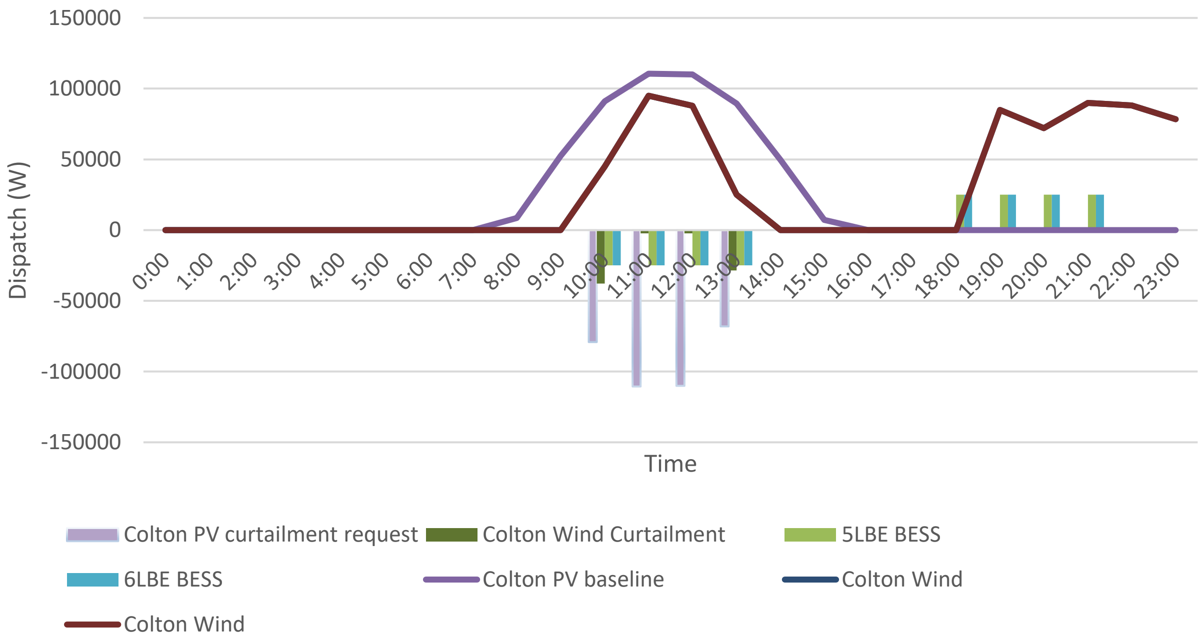

Figure 34 DER dispatch (Low Barrier To Entry, ESO-DSO Coordination

4.2 Peer to Peer (P2P)

P2P functionality is due to be released on the GridOS platform in 2022. Since the functionality is not yet released, we have instead inputted negative offer prices to economically force dispatch of DERs to demonstrate how P2P dispatches operate in P2P flexibility services. Unfortunately, due to the requirement to use negative pricing, the GridOS financial models cannot currently be used to draw insight into revenue impacts of different market structures. Since Cost Saving and Peak Management have the same dispatch behaviour, these two market structures are combined for this section.

A non-constrained feeder loading was used for all P2P transactions.

4.2.1 Maximum Import/Export Capacity Trading (MIC/MEC)

On November 20th, GridOS Market program settings were configured to generate pricing events for the offsetting scenario. The baseline analysis was run for November 21st and the MIC/MEC transaction was run for November 22nd. The simulation was rerun for the different scenarios

4.2.1.1 *Cost Saving and Supply Security*

The baseline dispatch, shown as dotted lines in Figure 35, represents a regular dispatch schedule of the two BESS DERs where both DERs are dispatching at their MEC between 15:00 and 19:00. A P2P MEC trade is executed the next day at hours 15:00 and 16:00 where Portobello SM has purchased additional export capacity from Wat Tyler BESS. Wat Tyler BESS decreases its export during this time period to keep within the contractual requirements specified in the MEC transaction.

The post MIC/MEC trade dispatch schedule, shown as solid lines in Figure 36, shows the ability of Portobello SM to dispatch at levels 100kW higher and Wat Tylers requirements to dispatch 100kW lower than the baseline at time period 15:00 and 16:00.

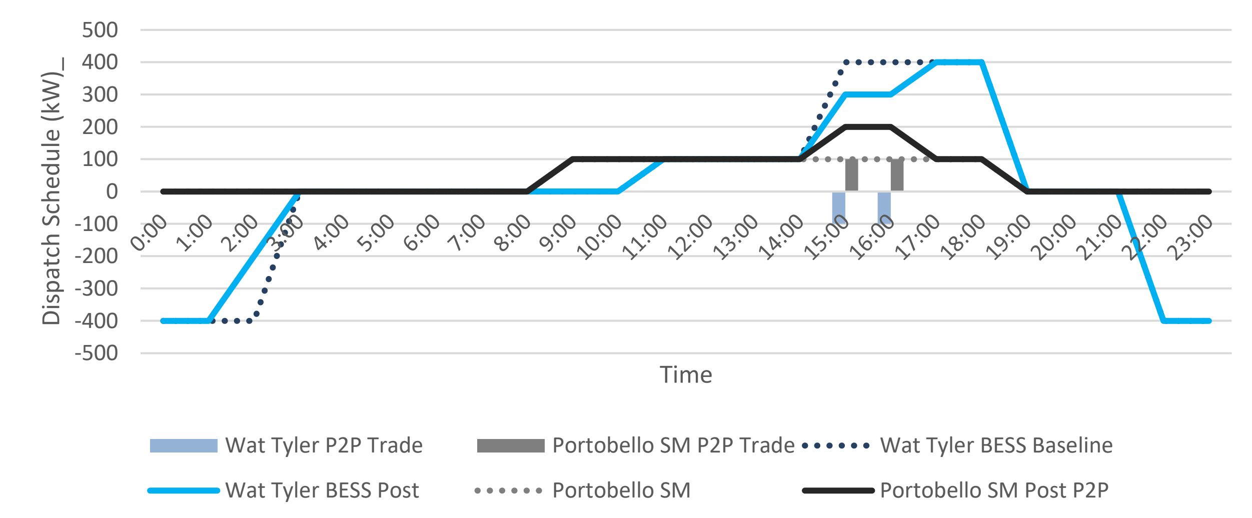

Figure 35 DER Dispatch Schedule (MIC MEC Cost Saving/Supply Security)

4.2.1.2 *Carbon Reduction*

Figure 36 demonstrates that low carbon resources can supply turn up flexibility in the P2P MIC MEC scenario. One key consideration highlighted in these results is that if BESS supply the turn up flexibility, it is likely they will also have to change their dispatch schedule during non-transaction hours to manage their state of charge (as seen with the additional charging period at 06:00 and the change to not discharging at 12:00). This change in dispatch schedule should also be reported to the DSO to ensure no knock-on constraints are created elsewhere in the network.

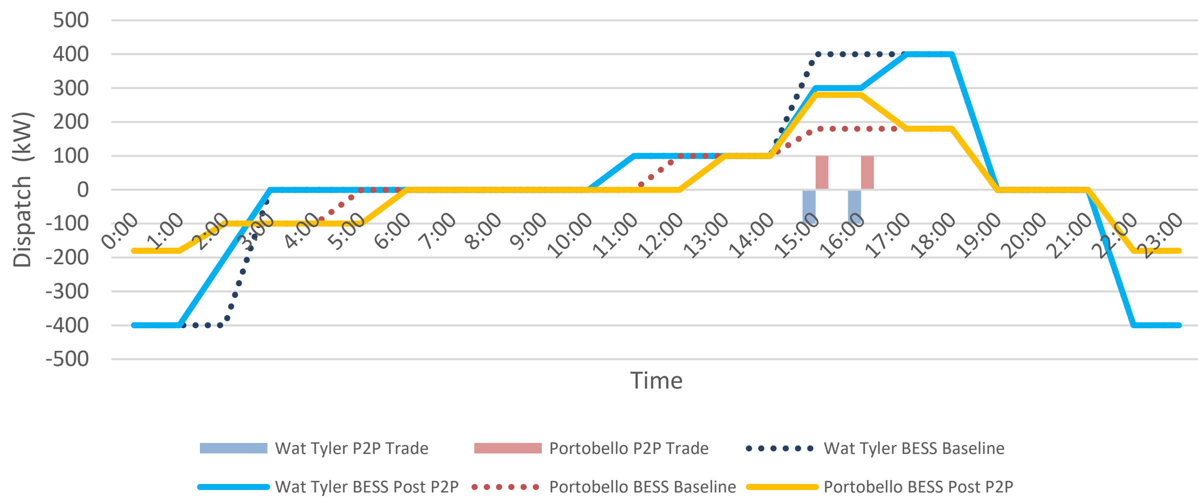

Figure 36 DER Dispatch Schedule (MIC/MEC Carbon Reduction)

4.2.1.3 *Low Barrier to Entry*

Figure 37, demonstrates how the Low Barrier to Entry market structure might be dispatched. It shows that multiple DERs could service the need of an individual participant. If LBE is priced more competitively, the first 25kW of additional export capacity could be purchased from LBE1 BESS with the remaining 75kW purchased from Wat Tyler BESS.

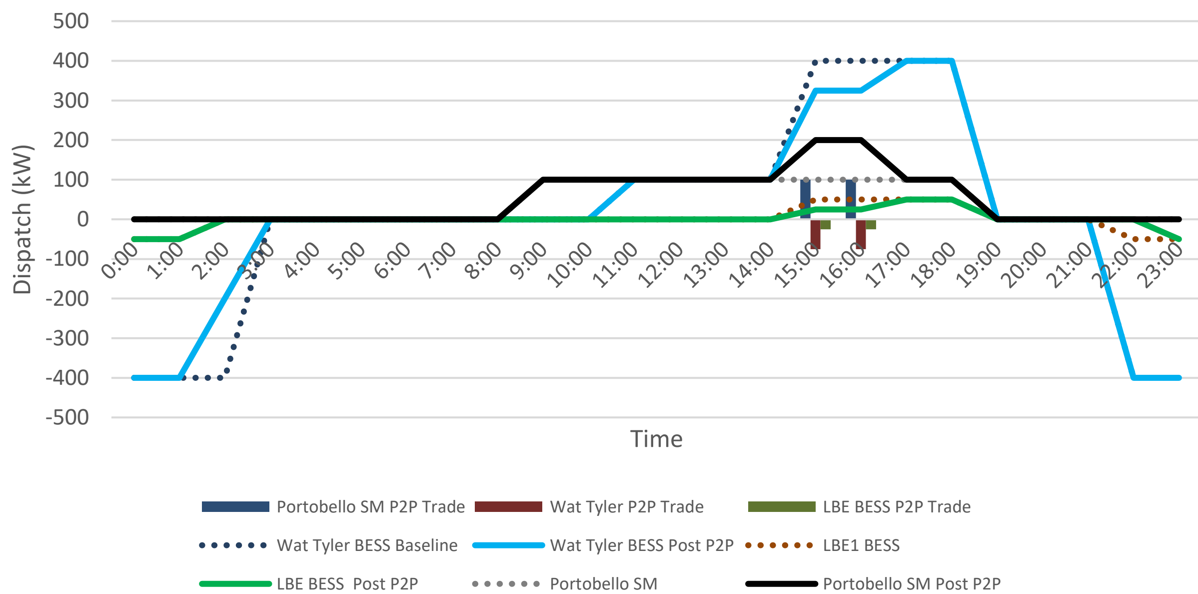

Figure 37 DER Dispatch Schedule (MIC/MEC, Low Barrier to Entry)

4.2.2 Offsetting

On November 20th, GridOS Market program settings were configured to generate pricing events for the offsetting scenario. The baseline analysis was run for November 21st and the P2P transaction was run for November 22nd. Since this is a peer-to-peer transaction, only 2 assets were enrolled in the market. Figure 38 shows a comparison between the baseline consumption of the Engie Rugeley Development load and its increased consumption.

A comparison between the baseline load consumption of load Engie Rugeley Development and its increased consumption is shown in Figure 38. This load profile serves as a basis for the Offsetting scenario to comprehend how the offsetting transaction occurs between the DR shift asset and nearby generators.

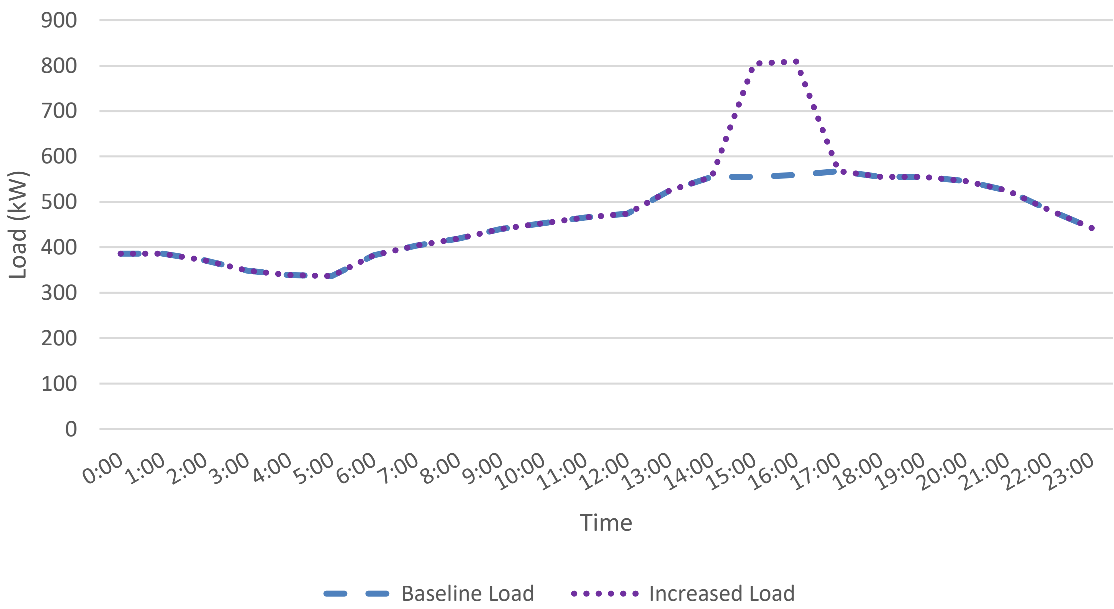

Figure 38: Offsetting load consumption profile comparison

4.2.2.1 ***Cost saving and Supply Security***

A non-constrained feeder loading was utilized for this simulation with the offsetting transaction was set to occur between the hours of 3pm-4pm. Figure 39 shows that when the DR shift asset increases its load consumption by 250 kW, a nearby synchronous machine, Engie Rugeley SM, increases its generation by the same amount. The two DERs offset each other locally preventing any constraints downstream or upstream of the network.

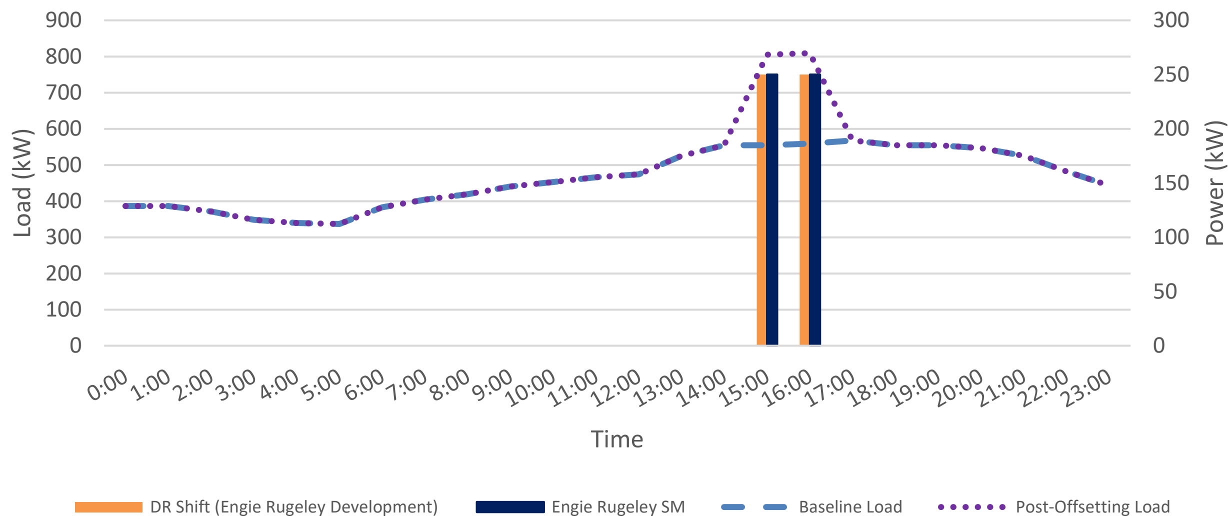

Figure 39: Offsetting Cost saving dispatch and load profile

4.2.2.2 ***Carbon Minimization***

A non-constrained feeder loading was utilized for this simulation. The offsetting transaction was still set to occur between the hours of 3pm-4pm, however, the participating assets involved a BESS unit and the DR shift resource.

From Figure 40 we can observe at 3pm, the DR shift asset increases its consumption by 250 kW, the BESS asset responds by dispatching 250 kW into the network to offset the now-increased load profile. Once again, a noticeable change from the Cost Saving/Supply Security market structure is that under this scenario the BESS asset consumes energy as it charges in the early morning and late night (between 12am-1am and at 11pm). As with MIC/MEC, this behaviour should be reported to the DSO so as to ensure no negative system effects occur during the charging periods.

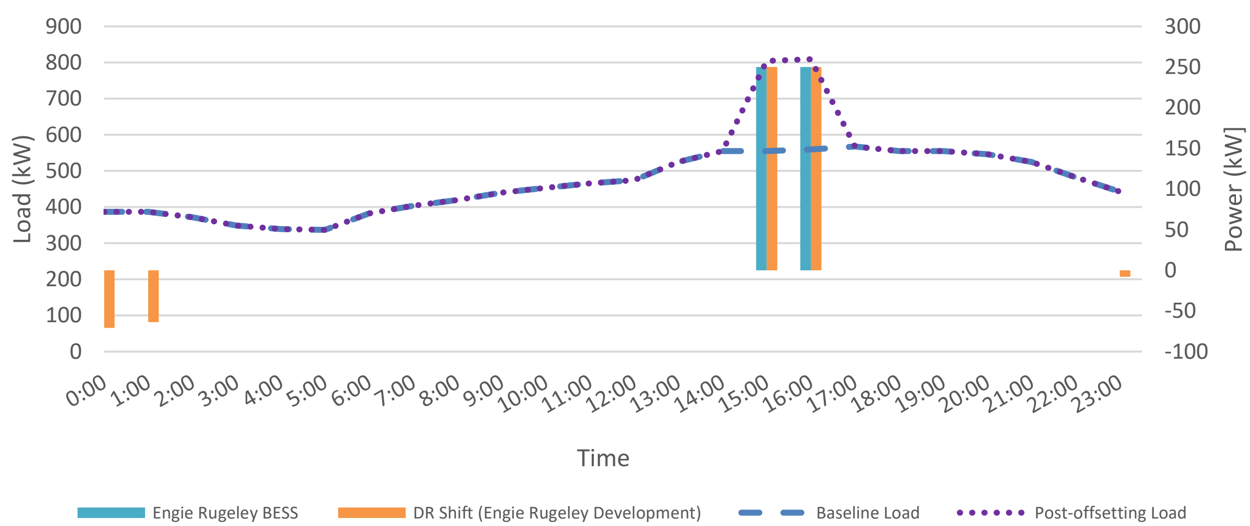

Figure 40: Offsetting carbon minimization dispatch and load profile

4.2.2.3 ***Low Barrier to Entry***

For the low barrier to entry market new, smaller capacity DERs were added to the network (Figure 41).

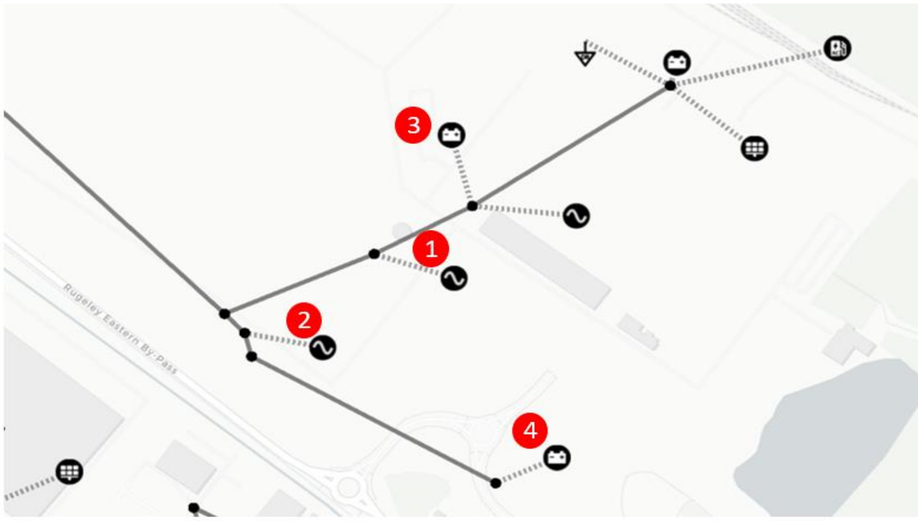

Figure 41: Offsetting low barrier to entry DERs map

	Low-Barrier-to-Entry DER Name	Rating (kW)
1	LBE1 Engie Rugeley SM	90
2	LBE2 Engie Rugeley SM	90
3	LBE3 Engie Rugeley BESS	90
4	LBE4 Engie Rugeley BESS	80

Figure 42 shows that unlike the MIC MEC scenario, the offsetting need could be supplied entirely by smaller DERs; however, it is worth noting that this could increase risk of non/under-delivery due to the greater number of points of failure. The periods of BESS charging are observed between 12am-1am and at 11pm.

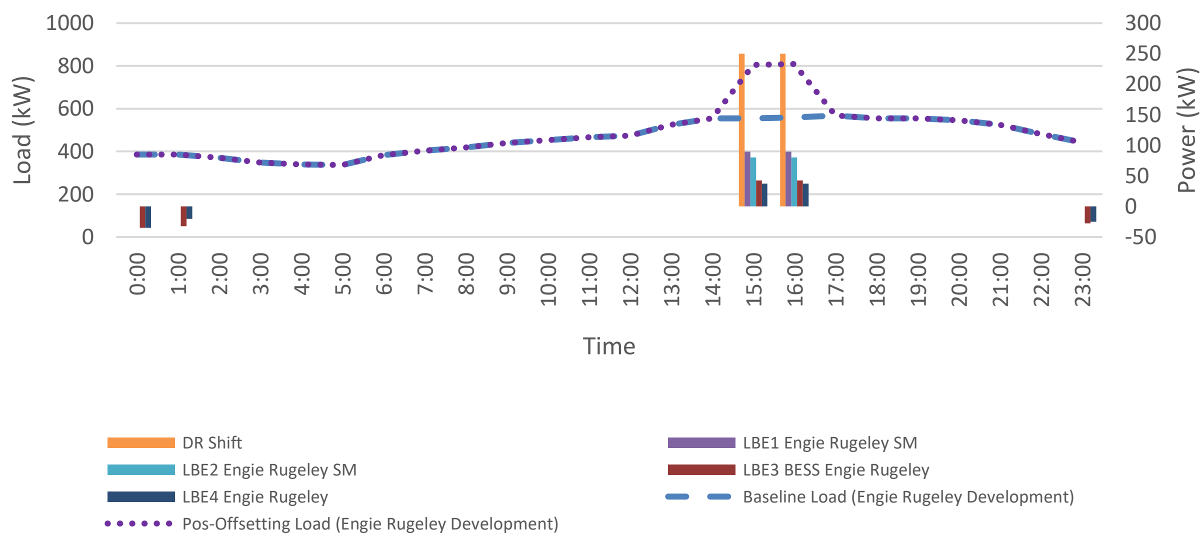

Figure 42: Offsetting low barrier to entry DER dispatch schedule and load profile

5 Conclusion

This report has demonstrated how the GridOS Market platform could implement flexibility markets in the local Rugeley area and has helped reveal numerous insights into the different market structures we have considered.

This report has revealed that with flexibility services that are small or very localised where a single or few DERs can resolve the need (i.e. Constraint Management and ESO-DSO Coordination), the implementation of pay-as-bid (for Cost Saving) vs a pay-as-clear (for Supply Security) financial models does not greatly impact the cost to the DSO or remuneration paid to DER owners. In scenarios where the constraint is larger and less localised, such as in Peak Management, the impact of these two financial models is likely to differ more greatly.

This report has also revealed that a well-priced Renewable Energy Credit or a similar subsidy can greatly improve the proportion of green DERs being dispatched in flexibility markets. However, to affect the proportion of green DERs being dispatched, this REC must be well publicised so operators are aware they can lower their offer prices while still hit their target revenue. Without this awareness, it is possible that certain green DERs will generate greater revenue, but since merit order dispatch decisions are taken on the original offer price, it is unlikely to affect the overall proportion of green DERs dispatching. An alternative method of ensuring a greater proportion of flexibility procured is green would be to automatically deflate green DER offer prices during merit order calculation to prioritise their dispatch but to still reimburse those DERs at their original offer price.

Finally, it has demonstrated the utility of lowering barriers to entry for small DERs to participate in flexibility markets. Additional smaller DERs can provide greater competition lowering the overall cost of procurement of flexibility for the DSO. Moreover, the ESO-DSO market structure has shown that lower barriers to entry could also provide a wider variety of DER types to choose from when servicing turn down needs and could prevent the need to curtail renewables providing an additional benefit in relation to the objective of carbon reduction. It is worth noting that lower barriers to entry could increase risk against Supply Security due to a great number of points of failure, however, well-structured settlement rules and data driven tracking of DER reliability could help mitigate this risk. Although the benefits of low barriers to entry are demonstrated in this report, there is likely a cost in terms greater operational complexity to manage more participants and DERs. Opus One, and other flexibility market software platforms providers, should prioritise an ability to scale and manage a higher number of users to provide greatest value to operators of flexibility markets.

6 Appendices

6.1 Workshop Bid and Offers (Constraint Management, Peak Management)

Time	Aneurin BESS		Batesway		Daywell BESS		Upper Longdon SM		Arthur Evans BESS		Batesway SM		Lichfield Rd. BESS		Pinetrees	
00:00	£25.00	Bid	£45.00	Offer	£25.00	Bid	£63.00	Offer	£25.00	Bid	£58.00	Offer	£25.00	Bid	£38.00	Offer
01:00	£25.00	Bid	£40.00	Offer	£28.00	Bid	£63.00	Offer	£25.00	Bid	£58.00	Offer	£25.00	Bid	£38.00	Offer
02:00	£65.00	Offer	£40.00	Offer	£55.00	Offer	£63.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£48.00	Offer
03:00	£60.00	Offer	£35.00	Offer	£55.00	Offer	£63.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£48.00	Offer
04:00	£60.00	Offer	£35.00	Offer	£55.00	Offer	£63.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
05:00	£60.00	Offer	£35.00	Offer	£55.00	Offer	£63.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
06:00	£60.00	Offer	£35.00	Offer	£55.00	Offer	£63.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
07:00	£60.00	Offer	£55.00	Offer	£65.00	Offer	£63.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
08:00	£60.00	Offer	£55.00	Offer	£65.00	Offer	£40.00	Offer	£60.00	Offer	£58.00	Offer	£44.00	Offer	£62.00	Offer
09:00	£45.00	Offer	£55.00	Offer	£52.00	Offer	£40.00	Offer	£60.00	Offer	£58.00	Offer	£44.00	Offer	£62.00	Offer
10:00	£45.00	Offer	£55.00	Offer	£52.00	Offer	£55.00	Offer	£60.00	Offer	£58.00	Offer	£36.00	Offer	£62.00	Offer
11:00	£45.00	Offer	£55.00	Offer	£52.00	Offer	£55.00	Offer	£60.00	Offer	£58.00	Offer	£36.00	Offer	£62.00	Offer
12:00	£55.00	Offer	£45.00	Offer	£52.00	Offer	£55.00	Offer	£35.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
13:00	£55.00	Offer	£45.00	Offer	£52.00	Offer	£55.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
14:00	£55.00	Offer	£45.00	Offer	£58.00	Offer	£55.00	Offer	£60.00	Offer	£58.00	Offer	£60.00	Offer	£62.00	Offer
15:00	£55.00	Offer	£55.00	Offer	£58.00	Offer	£55.00	Offer	£35.00	Offer	£38.00	Offer	£60.00	Offer	£62.00	Offer
16:00	£55.00	Offer	£55.00	Offer	£58.00	Offer	£48.00	Offer	£60.00	Offer	£38.00	Offer	£60.00	Offer	£62.00	Offer
17:00	£55.00	Offer	£55.00	Offer	£35.00	Offer	£48.00	Offer	£49.00	Offer	£48.00	Offer	£60.00	Offer	£62.00	Offer
18:00	£55.00	Offer	£55.00	Offer	£35.00	Offer	£65.00	Offer	£49.00	Offer	£48.00	Offer	£44.00	Offer	£62.00	Offer
19:00	£55.00	Offer	£55.00	Offer	£58.00	Offer	£65.00	Offer	£60.00	Offer	£46.00	Offer	£44.00	Offer	£62.00	Offer
20:00	£52.00	Offer	£55.00	Offer	£58.00	Offer	£65.00	Offer	£60.00	Offer	£46.00	Offer	£60.00	Offer	£62.00	Offer
21:00	£52.00	Offer	£47.00	Offer	£58.00	Offer	£65.00	Offer	£60.00	Offer	£68.00	Offer	£60.00	Offer	£62.00	Offer
22:00	£52.00	Offer	£48.00	Offer	£58.00	Offer	£65.00	Offer	£60.00	Offer	£68.00	Offer	£60.00	Offer	£48.00	Offer
23:00	£25.00	Bid	£35.00	Offer	£25.00	Bid	£65.00	Offer	£25.00	Bid	£62.00	Offer	£25.00	Bid	£48.00	Offer

6.1 (Cont) – Workshop Bid and Offers (Constraint Management, Peak Management)

Time	Coalpit Battery		Tesco Superstore		Engie Rugeley BESS		Upper Longdon SM2		Great Haywards BESS		Brereton Cross 2		Greenside BESS		Orchard Lane SM	
00:00	£25.00	Bid	£60.00	Offer	£25.00	Bid	£60.00	Offer	£25.00	Bid	£55.00	Offer	£25.00	Bid	£68.00	Offer
01:00	£25.00	Bid	£60.00	Offer	£25.00	Bid	£60.00	Offer	£25.00	Bid	£67.00	Offer	£25.00	Bid	£67.00	Offer
02:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£60.00	Offer	£61.00	Offer	£68.00	Offer	£67.00	Offer	£65.00	Offer
03:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£60.00	Offer	£68.00	Offer	£70.00	Offer	£69.00	Offer	£64.00	Offer
04:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£60.00	Offer	£60.00	Offer	£65.00	Offer	£60.00	Offer	£60.00	Offer
05:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£60.00	Offer	£64.00	Offer	£64.00	Offer	£67.00	Offer	£58.00	Offer
06:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£60.00	Offer	£59.00	Offer	£61.00	Offer	£55.00	Offer	£57.00	Offer
07:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£60.00	Offer	£58.00	Offer	£55.00	Offer	£58.00	Offer	£56.00	Offer
08:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£34.00	Offer	£53.00	Offer	£57.00	Offer	£54.00	Offer	£55.00	Offer
09:00	£55.00	Offer	£60.00	Offer	£55.00	Offer	£34.00	Offer	£53.00	Offer	£56.00	Offer	£44.00	Offer	£55.00	Offer
10:00	£55.00	Offer	£39.00	Offer	£55.00	Offer	£55.00	Offer	£54.00	Offer	£35.00	Offer	£42.00	Offer	£50.00	Offer
11:00	£55.00	Offer	£39.00	Offer	£55.00	Offer	£55.00	Offer	£57.00	Offer	£56.00	Offer	£55.00	Offer	£48.00	Offer
12:00	£55.00	Offer	£46.00	Offer	£48.00	Offer	£55.00	Offer	£54.00	Offer	£32.00	Offer	£53.00	Offer	£44.00	Offer
13:00	£55.00	Offer	£48.00	Offer	£48.00	Offer	£55.00	Offer	£51.00	Offer	£41.00	Offer	£51.00	Offer	£50.00	Offer
14:00	£39.00	Offer	£60.00	Offer	£65.00	Offer	£55.00	Offer	£50.00	Offer	£43.00	Offer	£55.00	Offer	£55.00	Offer
15:00	£39.00	Offer	£60.00	Offer	£65.00	Offer	£55.00	Offer	£46.00	Offer	£44.00	Offer	£40.00	Offer	£56.00	Offer
16:00	£49.00	Offer	£60.00	Offer	£65.00	Offer	£48.00	Offer	£42.00	Offer	£45.00	Offer	£31.00	Offer	£52.00	Offer
17:00	£45.00	Offer	£60.00	Offer	£65.00	Offer	£48.00	Offer	£30.00	Offer	£55.00	Offer	£42.00	Offer	£58.00	Offer
18:00	£49.00	Offer	£60.00	Offer	£39.00	Offer	£48.00	Offer	£31.00	Offer	£52.00	Offer	£54.00	Offer	£43.00	Offer
19:00	£45.00	Offer	£60.00	Offer	£39.00	Offer	£48.00	Offer	£40.00	Offer	£53.00	Offer	£65.00	Offer	£41.00	Offer
20:00	£65.00	Offer	£60.00	Offer	£45.00	Offer	£60.00	Offer	£45.00	Offer	£54.00	Offer	£69.00	Offer	£35.00	Offer
21:00	£65.00	Offer	£60.00	Offer	£45.00	Offer	£60.00	Offer	£50.00	Offer	£51.00	Offer	£58.00	Offer	£32.00	Offer
22:00	£65.00	Offer	£60.00	Offer	£65.00	Offer	£60.00	Offer	£51.00	Offer	£56.00	Offer	£67.00	Offer	£50.00	Offer
23:00	£25.00	Bid	£60.00	Offer	£25.00	Bid	£60.00	Offer	£25.00	Bid	£60.00	Offer	£25.00	Bid	£56.00	Offer

6.2 Low Barrier to Entry Bids and Offers

	1LBE BESS		2LBE BESS		3LBE BESS		4LBE BESS	
00:00	25	Bid	25	Offer	25	Bid	25	Offer
01:00	25	Bid	25	Offer	25	Bid	25	Offer
02:00	60	Offer	44	Offer	60	Offer	60	Offer
03:00	60	Offer	44	Offer	60	Offer	60	Offer
04:00	60	Offer	44	Offer	60	Offer	60	Offer
05:00	60	Offer	44	Offer	60	Offer	60	Offer
06:00	60	Offer	44	Offer	60	Offer	60	Offer
07:00	60	Offer	44	Offer	60	Offer	60	Offer
08:00	60	Offer	44	Offer	60	Offer	60	Offer
09:00	60	Offer	44	Offer	60	Offer	60	Offer
10:00	60	Offer	44	Offer	60	Offer	45	Offer
11:00	60	Offer	44	Offer	60	Offer	45	Offer
12:00	60	Offer	44	Offer	60	Offer	45	Offer
13:00	50	Offer	44	Offer	50	Offer	45	Offer
14:00	50	Offer	34	Offer	50	Offer	50	Offer
15:00	40	Offer	32	Offer	50	Offer	50	Offer
16:00	40	Offer	50	Offer	50	Offer	50	Offer
17:00	32	Offer	50	Offer	40	Offer	50	Offer
18:00	32	Offer	50	Offer	50	Offer	50	Offer
19:00	50	Offer	40	Offer	50	Offer	32	Offer
20:00	50	Offer	50	Offer	50	Offer	32	Offer
21:00	50	Offer	50	Offer	50	Offer	50	Offer
22:00	50	Offer	50	Offer	50	Offer	50	Offer
23:00	25	Bid	25	Offer	25	Bid	25	Offer

	1LBE BESS		2LBE BESS		3LBE BESS		4LBE BESS	
00:00	25	Bid	25	Offer	25	Bid	25	Offer
01:00	25	Bid	25	Offer	25	Bid	25	Offer
02:00	60	Offer	44	Offer	60	Offer	60	Offer
03:00	60	Offer	44	Offer	60	Offer	60	Offer
04:00	60	Offer	44	Offer	60	Offer	60	Offer
05:00	60	Offer	44	Offer	60	Offer	60	Offer
06:00	60	Offer	44	Offer	60	Offer	60	Offer
07:00	60	Offer	44	Offer	60	Offer	60	Offer
08:00	60	Offer	44	Offer	60	Offer	60	Offer
09:00	60	Offer	44	Offer	60	Offer	60	Offer
10:00	60	Offer	44	Offer	60	Offer	45	Offer
11:00	60	Offer	44	Offer	60	Offer	45	Offer
12:00	60	Offer	44	Offer	60	Offer	45	Offer
13:00	50	Offer	44	Offer	50	Offer	45	Offer
14:00	50	Offer	34	Offer	50	Offer	50	Offer
15:00	40	Offer	32	Offer	50	Offer	50	Offer
16:00	40	Offer	50	Offer	50	Offer	50	Offer
17:00	32	Offer	50	Offer	40	Offer	50	Offer
18:00	32	Offer	50	Offer	50	Offer	50	Offer
19:00	50	Offer	40	Offer	50	Offer	32	Offer
20:00	50	Offer	50	Offer	50	Offer	32	Offer
21:00	50	Offer	50	Offer	50	Offer	50	Offer
22:00	50	Offer	50	Offer	50	Offer	50	Offer
23:00	25	Bid	25	Offer	25	Bid	25	Offer

6.3 Low Barrier to Entry Bids and Offers (Peak Management)

	LBE1 BESS		LBE2 BESS		LBE3 BESS		LBE4 BESS		LBE1 SM		LBE2 SM		LBE3 SM	
0:00	£ 25.00	Bid	£ 25.00	Bid	£ 25.00	Bid	£ 25.00	Bid	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
1:00	£ 25.00	Bid	£ 25.00	Bid	£ 25.00	Bid	£ 25.00	Bid	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
2:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
3:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
4:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
5:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
6:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
7:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
8:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
9:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
10:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
11:00	£ 44.00	Offer	£ 45.00	Offer	£ 46.00	Offer	£ 45.00	Offer	£ 40.00	Offer	£ 44.00	Offer	£ 41.00	Offer
12:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
13:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
14:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
15:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
16:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
17:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
18:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
19:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
20:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
21:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
22:00	£ 32.00	Offer	£ 33.00	Offer	£ 45.00	Offer	£ 44.00	Offer	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer
23:00	£ 25.00	Bid	£ 25.00	Bid	£ 25.00	Bid	£ 25.00	Bid	£ 30.00	Offer	£ 34.00	Offer	£ 41.00	Offer

6.4 ESO-DSO Coordination Bids and Offers

Time	STOR DER		Colton PV		Colton Wind		5LBE BESS		6LBE BESS	
0:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
1:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
2:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
3:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
4:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
5:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
6:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
7:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
8:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
9:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
10:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
11:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
12:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
13:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
14:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
15:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
16:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
17:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid
18:00	-60	bid	-52	bid	-58	bid	-30	offer	-30	offer
19:00	-60	bid	-52	bid	-58	bid	-30	offer	-30	offer
20:00	-60	bid	-52	bid	-58	bid	-30	offer	-30	offer
21:00	-60	bid	-52	bid	-58	bid	-30	offer	-30	offer
22:00	-60	bid	-52	bid	-58	bid	0	offer	0	offer
23:00	-60	bid	-52	bid	-58	bid	0	bid	0	bid

6.5 Example Bids and Offers P2P Economical Forcing Dispatch (Offsetting)

	Engie Rugeley Development		Engie Rugeley SM		Engie Rugeley BESS	
0:00	56	Bid	60	Offer	25	Bid
1:00	56	Bid	60	Offer	25	Bid
2:00	56	Bid	60	Offer	55	Offer
3:00	56	Bid	60	Offer	55	Offer
4:00	56	Bid	60	Offer	55	Offer
5:00	56	Bid	60	Offer	55	Offer
6:00	56	Bid	60	Offer	55	Offer
7:00	56	Bid	60	Offer	55	Offer
8:00	47	Bid	60	Offer	55	Offer
9:00	47	Bid	60	Offer	55	Offer
10:00	47	Bid	60	Offer	43	Offer
11:00	47	Bid	57	Offer	43	Offer
12:00	47	Bid	57	Offer	43	Offer
13:00	47	Bid	57	Offer	43	Offer
14:00	48	Bid	57	Offer	43	Offer
15:00	56	Bid	57	Offer	43	Offer
16:00	56	Bid	57	Offer	36	Offer
17:00	56	Bid	57	Offer	36	Offer
18:00	56	Bid	57	Offer	36	Offer
19:00	56	Bid	57	Offer	54	Offer
20:00	56	Bid	57	Offer	54	Offer
21:00	56	Bid	57	Offer	54	Offer
22:00	56	Bid	57	Offer	54	Offer
23:00	56	Bid	57	Offer	25	Bid

6.6 Example Bids and Offers P2P Low Barrier to Entry Dispatch (Offsetting)

	LBE1 Engie Rugley SM		LBE2 Engie Rugeley SM		LBE3 Engie Rugeley BESS		LBE4 Engie Rugeley BESS	
0:00	60	Offer	54	Offer	25	Bid	25	Bid
1:00	60	Offer	54	Offer	25	Bid	25	Bid
2:00	60	Offer	54	Offer	53	Offer	51	Offer
3:00	60	Offer	54	Offer	53	Offer	51	Offer
4:00	60	Offer	54	Offer	53	Offer	51	Offer
5:00	60	Offer	54	Offer	53	Offer	51	Offer
6:00	60	Offer	54	Offer	53	Offer	51	Offer
7:00	60	Offer	54	Offer	53	Offer	51	Offer
8:00	60	Offer	54	Offer	53	Offer	44	Offer
9:00	60	Offer	54	Offer	45	Offer	44	Offer
10:00	60	Offer	54	Offer	45	Offer	44	Offer
11:00	57	Offer	54	Offer	45	Offer	44	Offer
12:00	57	Offer	54	Offer	45	Offer	44	Offer
13:00	57	Offer	42	Offer	45	Offer	44	Offer
14:00	57	Offer	42	Offer	45	Offer	44	Offer
15:00	57	Offer	42	Offer	45	Offer	44	Offer
16:00	57	Offer	42	Offer	45	Offer	44	Offer
17:00	57	Offer	42	Offer	45	Offer	44	Offer
18:00	57	Offer	42	Offer	45	Offer	44	Offer
19:00	57	Offer	42	Offer	45	Offer	52	Offer
20:00	57	Offer	42	Offer	45	Offer	52	Offer
21:00	57	Offer	42	Offer	45	Offer	52	Offer
22:00	57	Offer	42	Offer	45	Offer	52	Offer
23:00	57	Offer	42	Offer	25	Bid	25	Bid