Enduring Auction Capability

Market Design Explainer

October 2024

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Enduring Auction Capability Project

The RIIO-2 Business Plan committed NESO to delivering **co-optimised procurement of day-ahead Frequency Response and Reserve services**, which would be **scalable** and **extendable** to new services and products

N-SIDE has been selected as a strategic partner to develop the auction clearing algorithm.

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OPTIMIZING YOUR DECISIONS

The Enduring Auction Capability (EAC) Project is implementing a new market for Frequency Response and Reserve Services

The overall EAC solution comprises:

- A new market design and updated procurement rules

- A new auction clearing algorithm

- An in-house portal (part of the Single Markets Platform) to access the market

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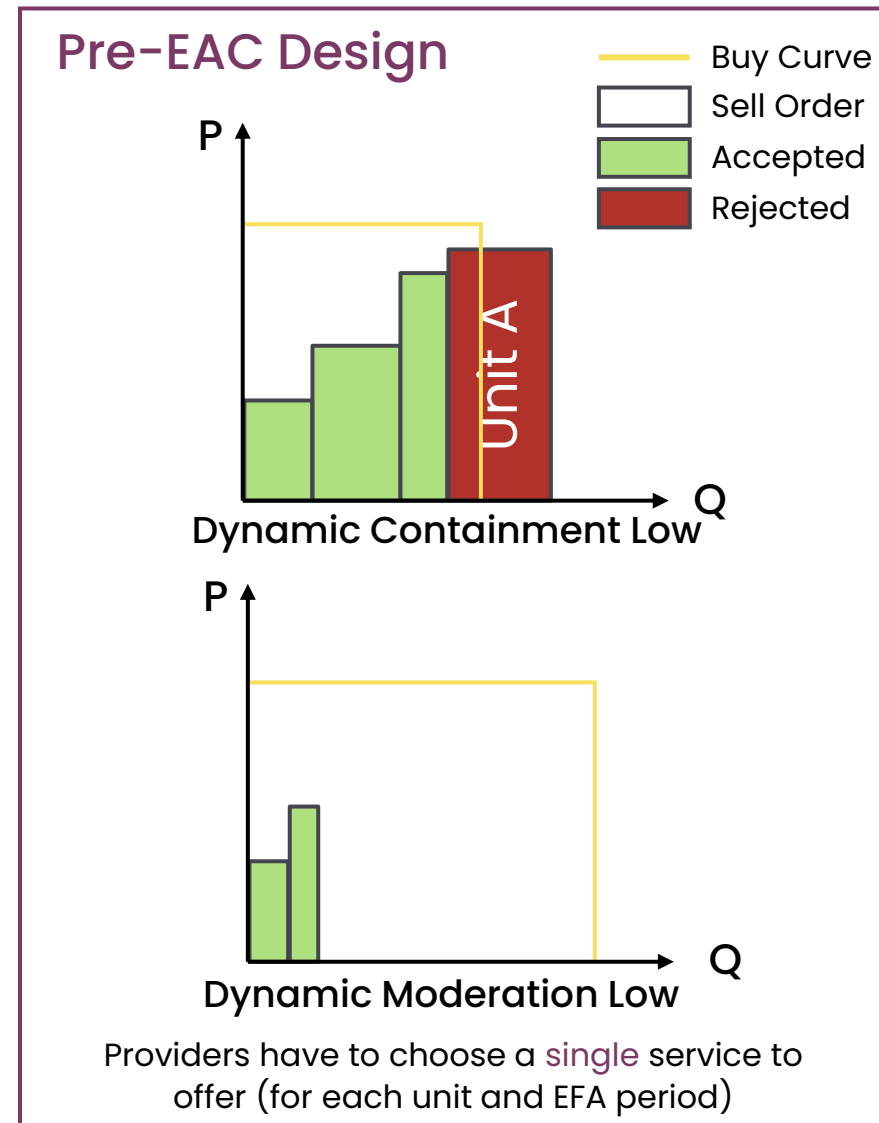
Challenges with the Pre-EAC Market Design

The previous design of the Frequency Response market has several **challenges**...

- Providers blind guess where other parties will tender - risk of oversupplying a single market with others left undersupplied

- Limited ability to split capacity and stack revenues across different services

- Limited options available to market participants (e.g., maximum of three orders per unit per delivery period, with only one 'child' allowed for each 'parent' order)

"The proposed arrangement which requires participants to choose which product they would like to participate in, is likely to lead to inefficient procurement. We believe that services will be under or oversubscribed and not all requirements met."
- Market participant

Pre-EAC Design

Legend:
— Buy Curve
☐ Sell Order
🟩 Accepted
🟥 Rejected

Dynamic Containment Low

Dynamic Moderation Low

Providers have to choose a single service to offer (for each unit and EFA period)

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Key changes and benefits

- Frequency Response Services (Dynamic Containment, Dynamic Moderation, and Dynamic Regulation), Quick Reserve, and Slow Reserve are procured together in **a single auction** (following launch of reformed Reserve services).

- All workflow processes (unit management, order submission, etc.) are available with a **single login** on the NESO's Single Market Platform.

- A **new API** is available for submitting sell orders and retrieving auction results (alongside a user interface on the platform).

New features of the market design include:

- **Co-optimisation** – Participants can submit alternative offers to the auction. The auction will clear the alternative that optimises the market most efficiently.
- **Splitting** – Units can simultaneously deliver products from different services within frequency response. New performance monitoring rules will apply.
- **Negative Pricing (for dynamic response products only)** – Sell orders can be priced below £0/MW/h. Clearing prices may also be negative. The settlement methodology and performance penalties have been updated.
- **Overholding** – Cleared quantities of sell orders can exceed the NESO requirements if this results in a more efficient (higher welfare) solution overall.

New Market Design and Clearing Algorithm

	Single market for response and reserve	Frequency Response services (Dynamic Containment, Dynamic Moderation, Dynamic Regulation) and the new Reserve services (Quick Reserve, Slow Reserve) are procured simultaneously in a single, pay-as-clear auction
	Co-optimisation	The auction clearing algorithm is able to select between alternative provider offers and alternate NESO requirements to better optimise the overall market clearing
	Splitting	Participants may offer to deliver more than one Frequency Response service (DC, DM, DR) simultaneously from the same market unit
	New sell order design	Compared to the previous market for frequency response, new sell order features are enabled to facilitate co-optimisation and other market features
	New clearing algorithm	Our strategic partner, N-SIDE, is developing a new, bespoke market clearing algorithm to enable the new market features
	Negative prices	Provider offer prices, NESO bid prices, and market clearing prices may be less than zero, to enable providers to offer to pay the NESO for offering an ancillary service
	Overholding	The auction clearing algorithm may clear a quantity of service in excess of NESO requirements if this better optimises the market

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The NESO is planning an ongoing education campaign to educate both existing and new participants about the new market and platform

- This document is targeted mainly at new or current participants in the current auction for the reformed Frequency Response services (Dynamic Containment, Dynamic Moderation, Dynamic Regulation) and Reserve services (Balancing Reserve, Quick Reserve, Slow Reserve)…

- … but it will also be useful for new participants or current participants in STOR. We explain terminology as we go along.

- The document gives an overview of some of the elements of the market design and contains simple and advanced examples of the construction of sell orders.

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Market Fundamentals

➢ Market Welfare, Consumer Surplus and Producer Surplus

➢ Market Welfare Example

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Market Welfare, Consumer Surplus and Producer Surplus

In its simplest case, the market clears at the intersection point of the demand and the supply curves.

- **Social / market welfare**
  - is defined as the sum of consumer surplus (CS) and producer surplus (PS)
  - is a function of order acceptance therefore does not depend on the market clearing price
- **Consumer surplus and producer surplus** depend on the market clearing price.
- The **objective function** finds the order selection that maximises the market welfare and the clearing prices that minimise total procurement costs.
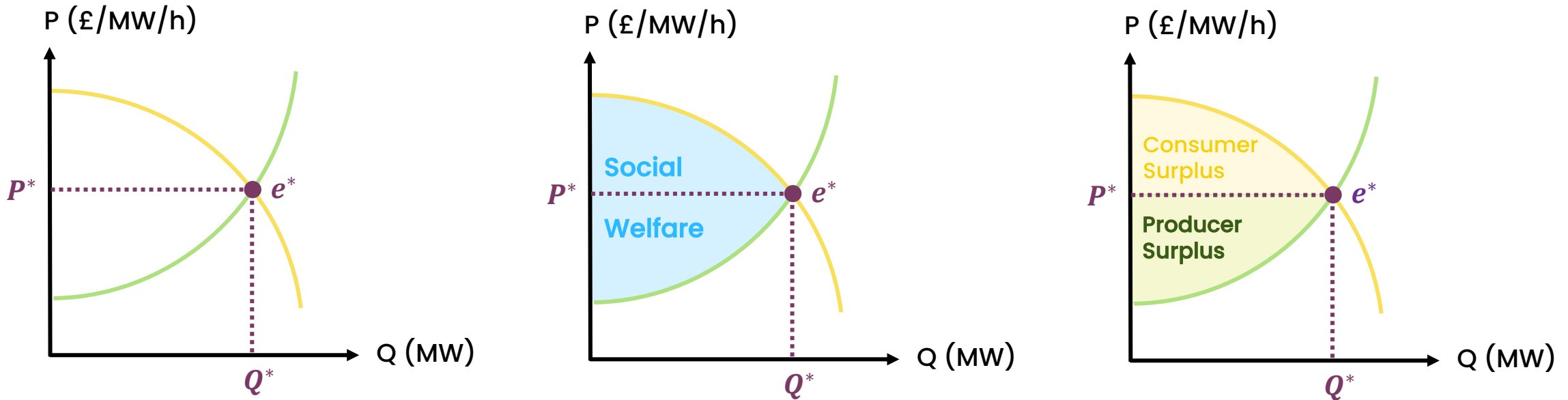
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Market Welfare Example

Consider the following example:

- NESO would like to procure $50MW$ of Product X. The maximum price NESO is willing to pay is £$100/MW/h$.

- Provider A offers $20MW$ at £$40/MW/h$.

- Provider B offers $30MW$ at £$80/MW/h$.

→ The market clears $50MW$ at £$80/MW/h$.

Type	Order ID	Participant	Product	Volume	Price
Buy	a	NESO	X	50	100
Sell	1	A	X	20	40
Sell	2	B	X	30	80

The market welfare and surpluses are calculated as follows:

Consumer Surplus (CS)

- $Consumer\ Surplus = (£100 - £80) \times 50MW = £1000/h.$

Producer Surplus (PS)

- $Producer\ Surplus_A = (£80 - £40) \times 20MW = £800/h,$

- $Producer\ Surplus_B = (£80 - £80) \times 30MW = £0/h,$

- $Total\ Producer\ Surplus = £800/h + £0/h = £800/h.$

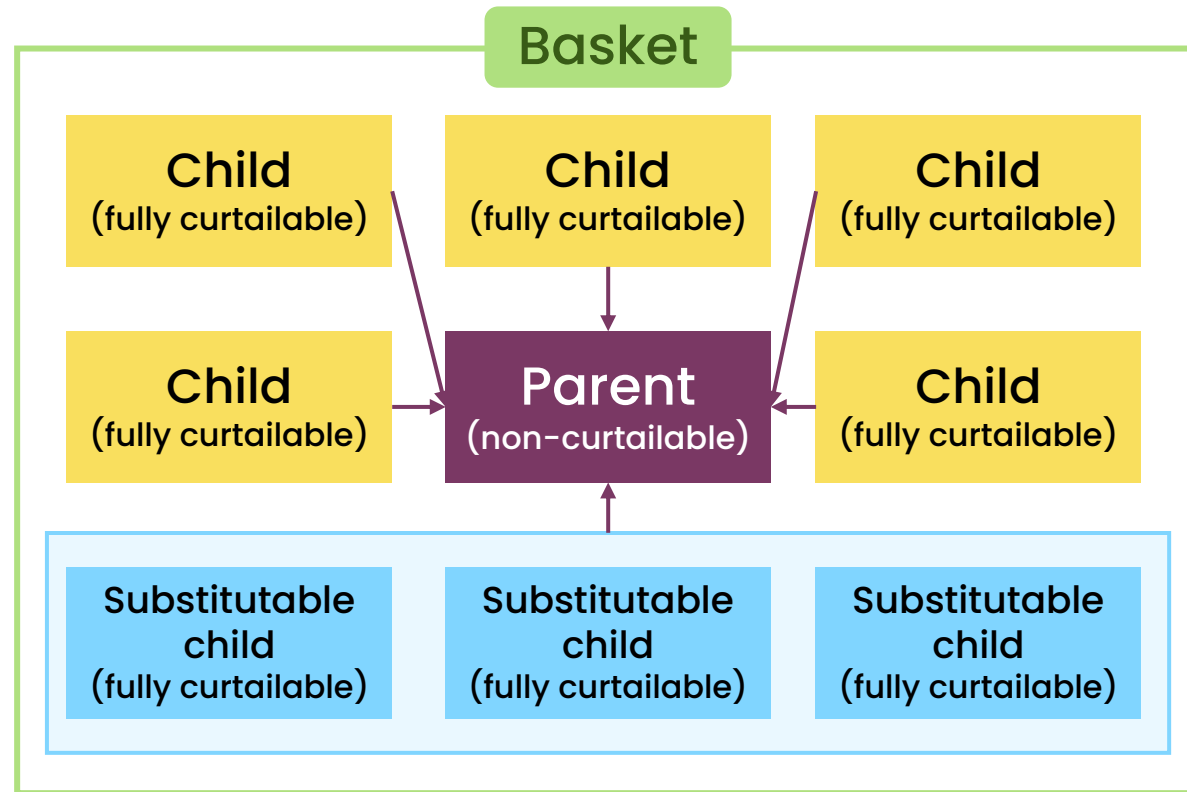**Market Welfare**

- $Market\ Welfare = CS + PS = £1800/h.$
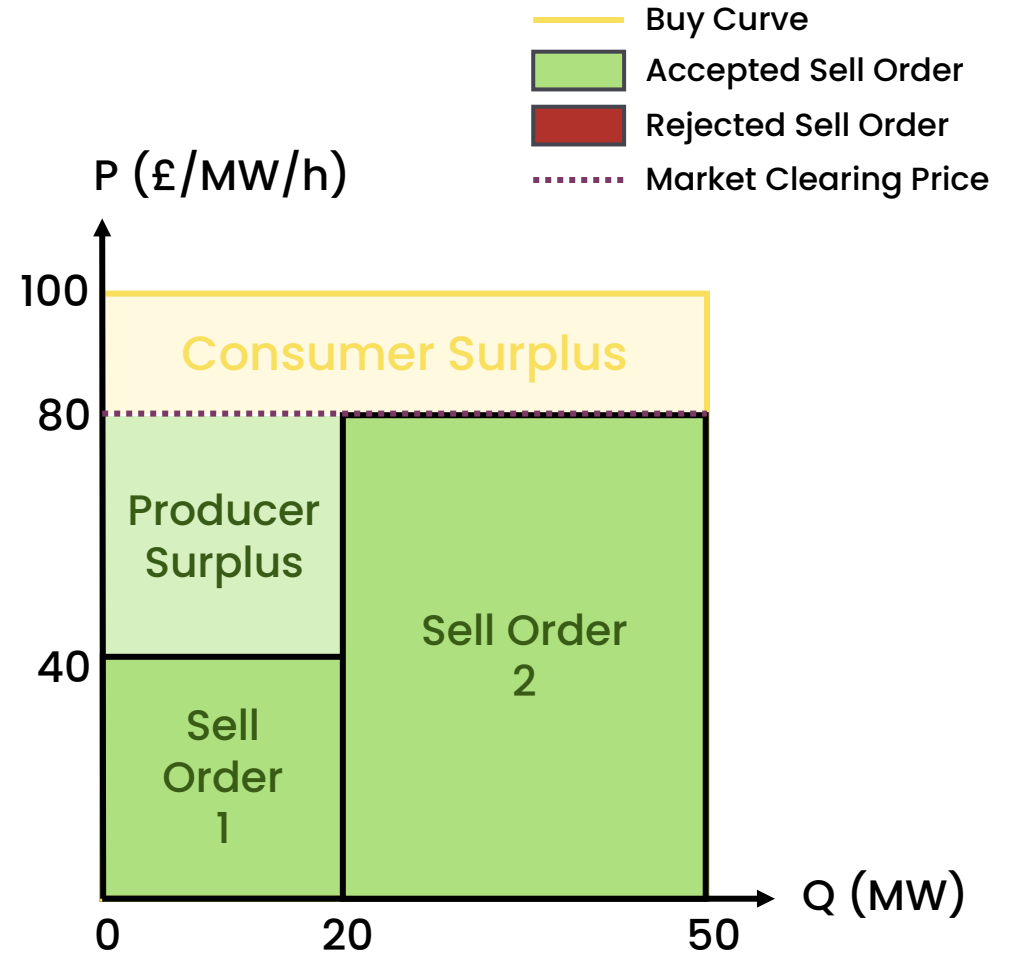
Auction and Order Features

➢ Basket

➢ Curtailability

➢ Linking: Parent and Child Blocks

➢ Minimum Acceptance Ratio

➢ Splitting

➢ Co-optimisation (Definitions and Numerical Examples)

Basket

In EAC, co-optimisation is implemented by using mutually exclusive *baskets*.

Basket

Child (fully curtailable)	Child (fully curtailable)	Child (fully curtailable)
Child (fully curtailable)	Parent (non-curtailable)	Child (fully curtailable)
Substitutable child (fully curtailable)	Substitutable child (fully curtailable)	Substitutable child (fully curtailable)

Note: Although a basket is defined only on a single service window, it may be "looped" to any other non-concurrent basket(s). This feature allows participants to build up offers that are defined over longer periods of time. Two or more baskets that are looped together are a "looped family".

- **Sell orders are grouped together into baskets.**
  - A basket is defined on **a single unit**.
  - Each basket has **a service type**:
    - I. For **EAC auction**, this is either "Frequency Response", "Quick Reserve", or "Slow Reserve".
    - II. For **Balancing Reserve (BR) auction**, this is "Balancing Reserve".
  - A basket is defined on **a single service window***.
  - Each **sell order** must be associated with **exactly one basket**, to which it belongs.
- **The baskets regulate which of the sell orders may or may not be accepted simultaneously.**
  - In particular, baskets are used to model mutual exclusivity between sets of orders.
  - Any two baskets are mutually exclusive if they are "concomitant", i.e., if they are defined on the same service window, or on service windows that overlap in any time period (for example, basket 1 covering time frame 03:00-07:00 is concomitant with basket 2 covering time frame 03:00-03:30 but not with basket 3 covering time frame 07:00-11:00).
  - If a basket is accepted, then any other basket with which it is mutually exclusive must be rejected.
- **A basket must contain** exactly **1** Parent Order. **A basket may contain** between **0** and **10** Child Orders, and additionally between **0** and **10** Substitutable Child Orders.

Curtailability

Non-curtailable order
An order which can only be fully accepted or fully rejected (i.e., the full offered volume must be taken, or the order rejected).

Curtailable order
An order which may be partially accepted (i.e., accepted for a smaller volume than the full offered quantity).

- Participants may wish to offer their capacity as "non-curtailable", meaning they require their order to be accepted for the entire offered quantity, or else rejected.

- Conversely, participants may be willing to have their offers curtailed, meaning that they may be willing to have their order cleared for a lower quantity than the total offered quantity. Participants who are willing to have their offer curtailed may require at least some minimum portion to be accepted, or they may be willing to be accepted for any quantity between 0 and the offered quantity.

- **In the EAC design, just as in the previous frequency response auction design (i.e., EPEXSPOT), Parent Orders are non-curtailable, and Child Orders are fully curtailable.**

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Linking: Parent and Child Blocks [1/2]

Parent order
A non-curtailable order whose acceptance is a pre-condition to acceptance of one or more other (child) orders in that Basket. A parent order may not have any linked child orders.

Child order
An order that can only be accepted if another order to which it is linked, the "parent order" is also accepted (i.e., the parent order can be accepted alone or the parent and child orders can be accepted together, but the child order cannot be accepted alone).

- Participants who want to offer their capacity as **non-curtailable** should use only parent orders.

- Participants who are willing to **be curtailed subject to the acceptance of minimum quantity** should use a parent order for the non-curtailable portion of the order, and child orders or substitutable child orders for the curtailable portion.

- Participants who wish to offer **fully-curtailable orders** (i.e., with no reserved minimum quantity) can use a parent order with an offered quantity of 0 MW, together with one or more child or substitutable child orders in the same basket.

- **In the EAC design, just as in the previous frequency response auction design (i.e., EPEXSPOT), Child Orders are fully curtailable. They can be accepted for any integer volume between 0 and the total offered quantity.**

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Linking: Parent and Child Blocks [2/2]

Consider a pair of parent-child orders...

The parent order is fully rejected.

P | Child — A child order cannot be accepted if its parent order is rejected.

A parent order is non-curtailable. It must either be:

fully accepted **fully rejected**

Parent **or** Parent

The parent order is fully accepted.

P | Child — A child order may be fully rejected.

P | Child — A child order may be partially accepted.

P | Child

P | Child — A child order may be fully accepted.

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Minimum Acceptance Ratio (MAR) is discontinued in the EAC Market Design

Minimum Acceptance Ratio (MAR)

MAR is the minimum percentage of an order that must be executed if the order is not fully rejected. For example, a MAR of 0.4 (or 40%) means that at least 40% of the offered volume must be executed or the order is fully rejected.

- MAR was frequently used in the previous frequency response auction (i.e., EPEXSPOT). In that auction design, all parent orders have a MAR of 1 and all child orders have a MAR of 0. Looped orders (i.e., C88 order type) can have a user-defined MAR between 0 and 1 (inclusive).

- This definition is no longer used in EAC (to simplify the auction design and to avoid volume rounding caused by using MAR), because an order with a non-binary MAR can be represented by a pair of parent and child orders. Please see the example below:

Order Structure in EAC

Order ID	Order Type	DCL	DCH	Price
P1	Parent	8	8	2.75
C1	Child	12	12	2.75

Order Structure in previous response auction (i.e., EPEXSPOT)

Order ID	Order Type	Volume	Price	MAR	Product	Looped Order
L1	C88	20	4.00	0.4	DCL	1001
L2	C88	20	1.50	0.4	DCH	1001

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Splitting [1/2]

Splitting

A unit has the opportunity (but not the obligation) to be accepted for different products in the same service window.

- The new market design for frequency response and reserve facilitates splitting through two different order structures[1]:

  a) By including more than one products in a single sell order, the provider can bundle products together and thus oblige splitting (subject to the acceptance of the sell order).

  b) By including different products in different sell orders but within the same basket, the provider can indicate a willingness (but not the requirement) to split.

- An unwillingness to split (i.e., a preference to not have different, heterogeneous products selected in the same service window) is expressed by offering only one single product in any basket.

Note: [1] The Balancing Reserve auction is not co-optimised with the co-optimised Dynamic Response and Quick Reserve auction (EAC auction) and therefore providers may not offer Balancing Reserve and Dynamic Response products in the same Sell Order or Basket. Providers must monitor their units' contracts from the morning BR auction before submitting Sell Orders for the afternoon EAC auction.

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Splitting [2/2]

Splitting within response

- Splitting is allowed between all frequency response products (i.e., amongst any combination of DCL, DCH, DML, DMH, DRL, and DRH).

Splitting within reserve

- Splitting is allowed between Balancing Reserve products (PBR and NBR), between Quick Reserve products (PQR and NQR), and between Slow Reserve products (PSR and NSR).

- Splitting is not allowed between different reserve services.

Splitting between response and reserve

- Splitting is allowed between Balancing Reserve product and response product in the opposite direction (i.e., PBR and DCH/DMH/DRH, NBR and DCL/DML/DRL).

Legend:
- Allowed (green)
- Not allowed (red)
- Not applicable (black)

Splitting Matrix			Response						Reserve					
			DC		DM		DR		BR		QR		SR	
			DCL	DCH	DML	DMH	DRL	DRH	PBR	NBR	PQR	NQR	PSR	NSR
Response	DC	DCL	Not applicable	Allowed	Allowed	Allowed	Allowed	Allowed	Not allowed	Allowed	Not allowed	Not allowed	Not allowed	Not allowed
		DCH	Allowed	Not applicable	Allowed	Allowed	Allowed	Allowed	Allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed
	DM	DML	Allowed	Allowed	Not applicable	Allowed	Allowed	Allowed	Not allowed	Allowed	Not allowed	Not allowed	Not allowed	Not allowed
		DMH	Allowed	Allowed	Allowed	Not applicable	Allowed	Allowed	Allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed
	DR	DRL	Allowed	Allowed	Allowed	Allowed	Not applicable	Allowed	Not allowed	Allowed	Not allowed	Not allowed	Not allowed	Not allowed
		DRH	Allowed	Allowed	Allowed	Allowed	Allowed	Not applicable	Allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed
Reserve	BR	PBR	Not allowed	Allowed	Not allowed	Allowed	Not allowed	Allowed	Not applicable	Allowed	Not allowed	Not allowed	Not allowed	Not allowed
		NBR	Allowed	Not allowed	Allowed	Not allowed	Allowed	Not allowed	Allowed	Not applicable	Not allowed	Not allowed	Not allowed	Not allowed
	QR	PQR	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not applicable	Allowed	Not allowed	Not allowed
		NQR	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Allowed	Not applicable	Not allowed	Not allowed
	SR	PSR	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not applicable	Allowed
		NSR	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed	Allowed	Not applicable

Co-optimisation

Co-optimisation

When a unit has capability to provide more than one of the services, the provider may wish to place multiple, alternative offers in the auction and let the auction clearing algorithm allocate the unit to the service that will clear the market most efficiently (i.e., best maximise market welfare, subject to the constraints). In contrast, without co-optimisation the provider has to choose in advance which of the various services to offer into the auction.

- Co-optimisation reduces risk for market participants while increasing overall market liquidity and reducing procurement costs.

- The new market design for frequency response and reserve implements co-optimisation by two different auction features: **"mutually-exclusive baskets"** and **"substitutable families"**.

- This document contains simple examples of implementing co-optimisation by baskets and more advanced examples of implementing co-optimisation by baskets and "substitutable families".

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Co-optimisation with Mutually Exclusive Baskets

Non-cooptimised auctions

DC

Sell Orders

DM

DR

QR

→ Auction runs →

Possible Clearing Outcomes

DM contracts awarded.

No contracts.
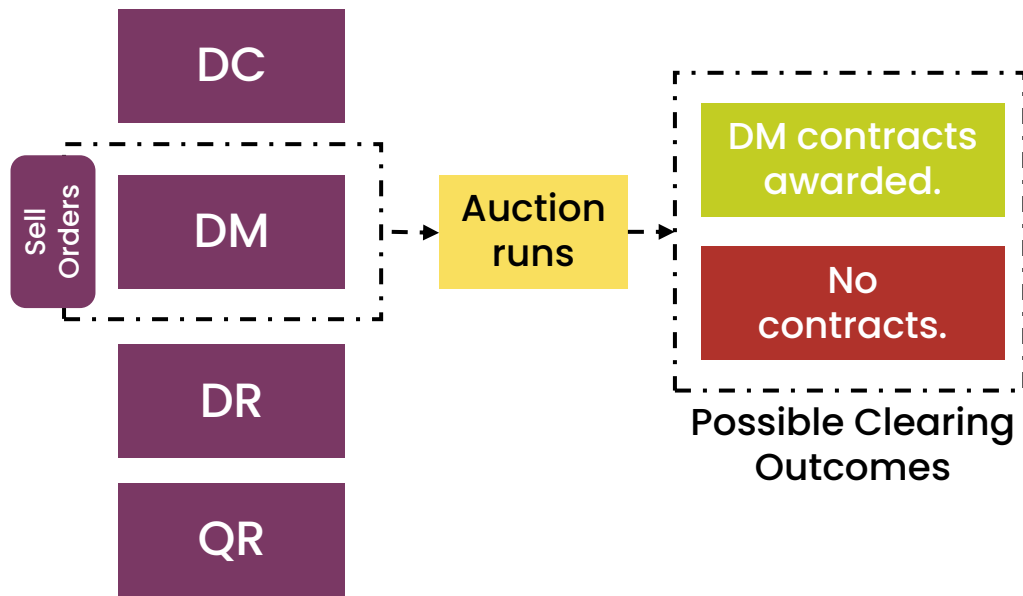
Only one service (i.e., either DC, DM, DR, or QR) can be offered into the auction. The provider has to choose in advance which of the various services to offer into the auction.

EAC auction (with co-optimisation)

Sell Orders

Basket B1 DC

Basket B2 DM

Basket B3 DR

Basket B4 QR

→ Auction runs →

Possible Clearing Outcomes

DC basket (B1) is accepted.

DM basket (B2) is accepted.

DR basket (B3) is accepted.

QR basket (B4) is accepted.

All baskets are rejected. No contracts.
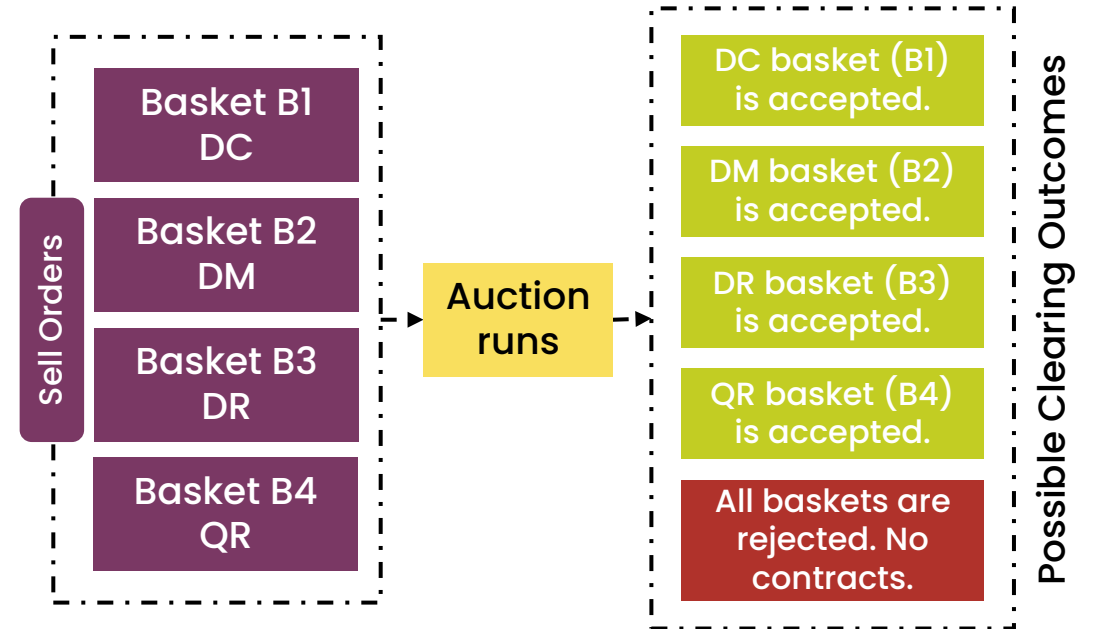
When a unit has the capability of providing more than one of the services, the provider can offer each service in a different basket. These baskets are mutually exclusive to each other, hence at most one basket will be selected. The auction clearing algorithm allocates the unit to the service that will clear the market most efficiently.

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Co-optimisation: Numerical Example 1

Numerical Example 1

Assume a unit is willing to offer either 100MW DCL at £2/MW/h or 100MW PQR at **£11.9**/MW/h, for delivery period 11:00-15:00.

There are two more participants in the co-optimised response and reserve market. Market Participant 1 (MP1) offers 100MW DCL at £1/MW/h, and Market Participant 2 (MP2) offers 100MW PQR at £1/MW/h, for the same delivery period.

The requirement for 11:00-15:00 is 200MW DCL at £10/MW/h, and 200MW PQR at £20/MW/h.

If the unit is allocated to DCL, the market welfare is increased by (the blue area)

$$(£10 - £2) \times 100MW \times 4h = £3200$$

If the unit is allocated to PQR, the market welfare is increased by (the pink area)

$$(£20 - £11.9) \times 100MW \times 4h = £3240$$

As per market design, the auction clearing algorithm allocates the unit to the product that will clear the market most efficiently (i.e., best maximise market welfare, subject to the constraints), in this example, the unit will be allocated to **PQR** market (and the market clears at **£11.9**/MW/h).

Note: Please see slide 24 for a table for sell orders and a table for buy orders. All numbers are for illustrative purpose only.

Delivery Period: 11:00-15:00

(EFA 4/Service Window 25-32)

Co-optimisation: Numerical Example 2

Numerical Example 2

Assume a unit is willing to offer either 100MW DCL at £2/MW/h or 100MW PQR at **£12.1**/MW/h, for delivery period 11:00-15:00.

There are two more participants in the co-optimised response and reserve market. Market Participant 1 (MP1) offers 100MW DCL at £1/MW/h, and Market Participant 2 (MP2) offers 100MW PQR at £1/MW/h, for the same delivery period.

The requirement for 11:00-15:00 is 200MW DCL at £10/MW/h, and 200MW PQR at £20/MW/h.

If the unit is allocated to DCL, the market welfare is increased by (the blue area)
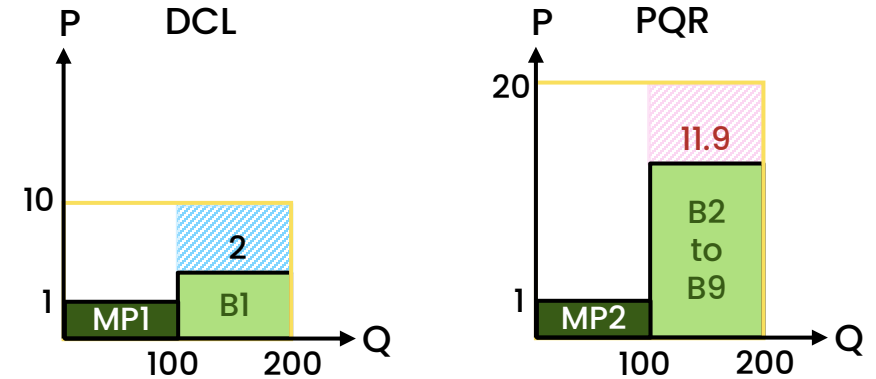
$$(£10 - £2) \times 100MW \times 4h = £3200$$

If the unit is allocated to PQR, the market welfare is increased by (the pink area)

$$(£20 - £12.1) \times 100MW \times 4h = £3160$$

As per market design, the auction clearing algorithm allocates the unit to the product that will clear the market most efficiently (i.e., best maximise market welfare, subject to the constraints), in this example, the unit will be allocated to **DCL** market (and the market clears at **£2**/MW/h).

Note: Please see slide 24 for a table for sell orders and a table for buy orders. All numbers are for illustrative purpose only.

Delivery Period: 11:00-15:00
(EFA 4/Service Window 25-32)
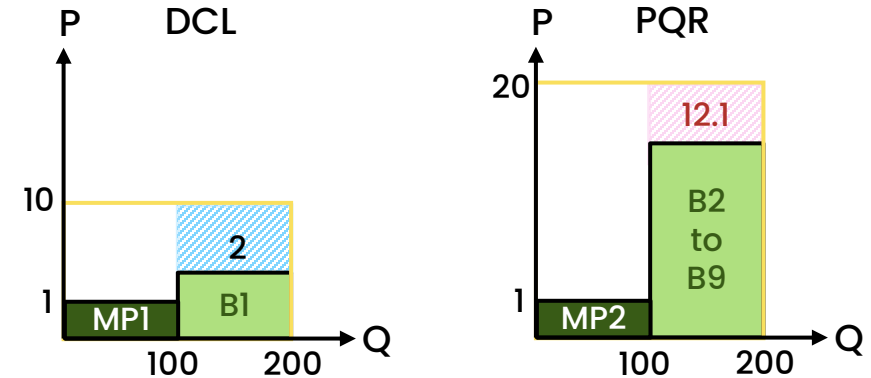
Co-optimisation: Numerical Example 3

Numerical Example 3

Assume a unit is willing to offer either 100MW DCL at £2/MW/h or 100MW PQR at **£12**/MW/h, for delivery period 11:00-15:00.

There are two more participants in the co-optimised response and reserve market. Market Participant 1 (MP1) offers 100MW DCL at £1/MW/h, and Market Participant 2 (MP2) offers 100MW PQR at £1/MW/h, for the same delivery period.

The requirement for 11:00-15:00 is 200MW DCL at £10/MW/h, and 200MW PQR at £20/MW/h.

If the unit is allocated to DCL, the market welfare is increased by (the blue area)

$$(£10 − £2) × 100MW × 4h = £3200$$

If the unit is allocated to PQR, the market welfare is increased by (the pink area)

$$(£20 − £12) × 100MW × 4h = £3200$$

As per market design, the auction clearing algorithm allocates the unit to the product that will clear the market most efficiently (i.e., best maximise market welfare, subject to the constraints), in this example, the algorithm is indifferent between the two options. The unit may be allocated to either one of the market.

Note: Please see slide 24 for a table for sell orders and a table for buy orders. All numbers are for illustrative purpose only.

Delivery Period: 11:00-15:00

(EFA 4/Service Window 25-32)

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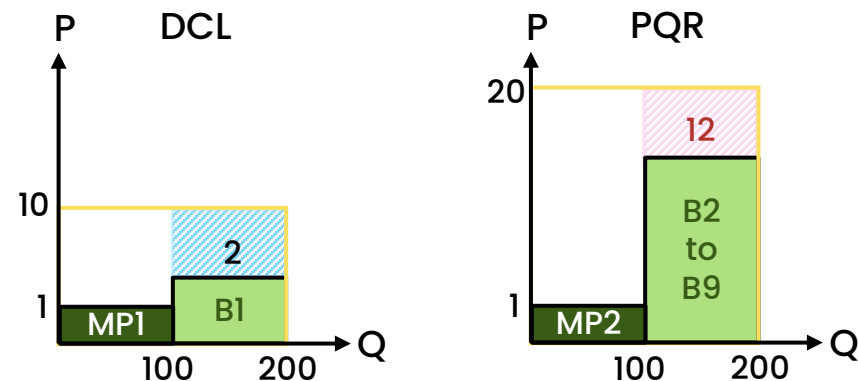
Co-optimisation: Sell and Buy Orders for Numerical Examples 1-3

Sell Orders (for Numerical Example 1-3)

Assume a unit is willing to offer 100MW DCL at £2/MW/h or 100MW PQR at **£11.9/£12.1/£12**/MW/h, for delivery period 11:00-15:00.

Basket ID	Service Window	Order ID	Order Type	DCL	PQR	Price No.1	Price No.2	Price No.3
B1	EFA 4	1	Parent	100		2	2	2
B2	25	2	Parent		100	11.9	12.1	12
B3	26	3	Parent		100	11.9	12.1	12
B4	27	4	Parent		100	11.9	12.1	12
B5	28	5	Parent		100	11.9	12.1	12
B6	29	6	Parent		100	11.9	12.1	12
B7	30	7	Parent		100	11.9	12.1	12
B8	31	8	Parent		100	11.9	12.1	12
B9	32	9	Parent		100	11.9	12.1	12

Buy Orders (for Numerical Example 1-3)

The requirement for 11:00-15:00 is 200MW DCL at £10/MW/h, and 200MW PQR at £20/MW/h.

Service Window	Order ID	Product	Quantity	Price
EFA 4	1	DCL	200	10
25	2	PQR	200	20
26	3	PQR	200	20
27	4	PQR	200	20
28	5	PQR	200	20
29	6	PQR	200	20
30	7	PQR	200	20
31	8	PQR	200	20
32	9	PQR	200	20

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Co-optimisation: Numerical Example 4

Numerical Example 4

Assume a unit is willing to offer 50MW for either DCL, DML, DRL or PQR at £2/MW/h, for delivery period 11:00-15:00.

For simplicity, assume there are no other participants in the co-optimised response and reserve market.

The requirement for the same delivery period is 100MW DCL at £25/MW/h, 100MW DML at £20/MW/h, 100MW DRL at £15/MW/h, and 100MW PQR at £10/MW/h.

The market welfare is:

- W_1: $(£25 - £2) \times 50MW \times 4h = £4600$ if the unit is allocated to DCL
- W_2: $(£20 - £2) \times 50MW \times 4h = £3600$ if the unit is allocated to DML
- W_3: $(£15 - £2) \times 50MW \times 4h = £2600$ if the unit is allocated to DRL
- W_4: $(£10 - £2) \times 50MW \times 4h = £1600$ if the unit is allocated to PQR

As per market design, the auction clearing algorithm allocates the unit to the product that will clear the market most efficiently (i.e., best maximise market welfare, subject to the constraints), in this example, the unit will be allocated to DCL market (and the market clears at £2/MW/h).

Note: Please see next slide for a table for sell orders and a table for buy orders.

Delivery Period: 11:00-15:00
(EFA 4/Service Window 25-32)
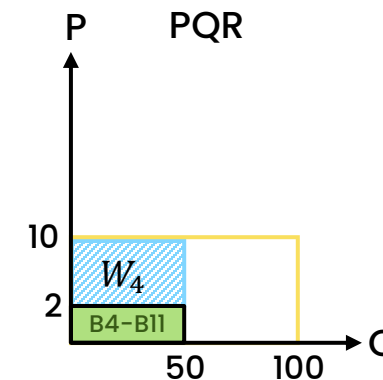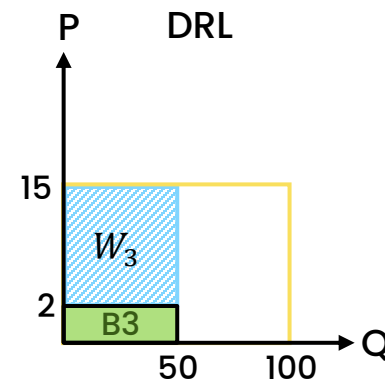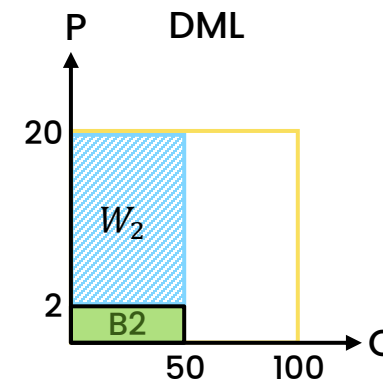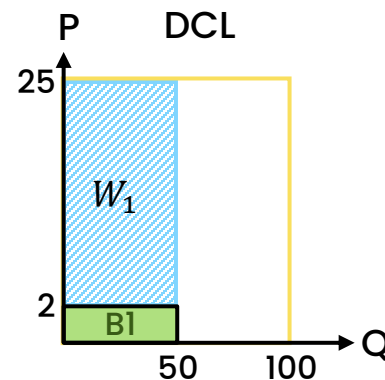
Co-optimisation: Sell and Buy Orders for Numerical Example 4

Sell Orders (for Numerical Example 4)

Assume a unit is willing to offer 50MW for either DCL, DML, DRL or PQR at £2/MW/h, for delivery period 11:00-15:00.

Basket ID	Service Window	Order ID	Order Type	DCL	DML	DRL	PQR	Price
B1	EFA 4	1	Parent	50				2
B2	EFA 4	2	Parent		50			2
B3	EFA 4	3	Parent			50		2
B4	25	4	Parent				50	2
B5	26	5	Parent				50	2
B6	27	6	Parent				50	2
B7	28	7	Parent				50	2
B8	29	8	Parent				50	2
B9	30	9	Parent				50	2
B10	31	10	Parent				50	2
B11	32	11	Parent				50	2

Buy Orders (for Numerical Example 4)

The requirement for the same delivery period is 100MW DCL at £25/MW/h, 100MW DML at £20/MW/h, 100MW DRL at £15/MW/h, and 100MW PQR at £10/MW/h.

Service Window	Order ID	Product	Quantity	Price
EFA 4	1	DCL	100	25
EFA 4	2	DML	100	20
EFA 4	3	DRL	100	15
25	4	PQR	100	10
26	5	PQR	100	10
27	6	PQR	100	10
28	7	PQR	100	10
29	8	PQR	100	10
30	9	PQR	100	10
31	10	PQR	100	10
32	11	PQR	100	10

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EAC Sell Order Structure

Simple Examples

List of Examples

1. A non-curtailable offer for a single product

2. A non-curtailable offer for two products

3. A non-curtailable offer for more than two products

4. A fully-curtailable offer for a single product

5. A partially-curtailable offer for a single product

6. A fully-curtailable offer for two products (independent clearing)

7. A fully-curtailable offer for two products (proportional clearing)

8. A simple example of co-optimisation within a service with baskets

9. A simple example of co-optimisation across services with baskets

10. A common strategy in the previous frequency response (i.e. EPEXSPOT) market

Examples of order construction in the new EAC auction look like this.

Order ID	Order Type	DCL	Price
P1	Parent	20	10.00

Examples of order construction in the previous (i.e., EPEXSPOT) auction for frequency response look like this.

Order ID	Order Type	Volume	Price	Product
P1	C01	20	10.00	DCL

Note: The following examples are all defined on a single service window. Linked services windows ("multi-period blocks") are also possible in the EAC market design. These will be explained in the next section.

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Example 1: A non-curtailable offer for a single product

Scenario

A participant wants to offer a fixed amount of 20MW for Product X.

The unit's marginal cost of providing Product X is £10/MW/h.

The participant requires payment of at least $20MW \times 10£/MW/h = 200£/h$ for the entire order.

Order features

✓ Non-curtailable orders

Order ID	Order Type	X	Price
P1	Parent	20	10.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X can be

i) either one of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) either one of the Quick Reserve products (PQR, NQR)
iii) either one of the Slow Reserve products (PSR, NSR)
iv) either one of the Balancing Reserve products (PBR, NBR).

Possible clearing outcomes

- Because the order is a Parent order, it is must either be fully rejected (Outcome 1) or fully accepted (Outcome 2).

- If the order is accepted, the participant will receive the market clearing price for Product X (£/MW/h) x 20 MW.

- The minimum revenue if the order is accepted is £200/h.

Possible Outcome	Executed Volume X	Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
1	0	0.00	0.00
2	20	200.00	10.00

Order structure in previous frequency response auction (i.e., EPEXSPOT)

- Non-curtailable orders are of type "C01"

Order ID	Order Type	Volume	Price	Product
P1	C01	20	10.00	DCL

Example 2: A non-curtailable offer for two products

Scenario

A participant wants to offer 20MW Product X and 20MW Product Y as a bundle, at £5.00/MW/h.

The participant requires payment of at least $(20MW + 20MW) \times 5£/MW/h = 200£/h$ for the entire order.

Order features

✓ Non-curtailable orders

✓ Multiple products in a single order

Notes

- The offered quantities may be the same (as in this case, a "symmetric offer") or different

- The entire order is offered at a single price (£/MW/h)

Order ID	Order Type	X	Y	Price
P1	Parent	20	20	5.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be
i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) two Quick Reserve products (PQR, NQR)
iii) two Slow Reserve products (PSR, NSR)
iv) two Balancing Reserve products (PBR, NBR).

Possible clearing outcomes

- Because the order is a Parent order, it must either be fully rejected (Outcome 1) or fully accepted (Outcome 2).

- If the order is accepted, the participant will receive at least £200/h.

Possible Outcome	Executed Volume		Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
	X	Y		
1	0	0	0.00	0.00
2	20	20	200.00	5.00

Order structure in previous frequency response auction (i.e., EPEXSPOT)

- An order is defined on a single product only

- Two orders may be "looped" together into a single bundle

- Looped orders are of type C88

- C88 orders specify a MAR (minimum acceptance ratio)

Order ID	Order Type	Volume	Price	MAR	Product	Looped ID
L1	C88	20	5.00	1	DCL	1001
L2	C88	20	5.00	1	DCH	1001

Example 3: A non-curtailable offer for more than two products

Scenario

A participant wants full acceptance of 30MW DCL, 10MW DCH, 20MW DML, 4MW DMH, and 18MW DRH. The average cost is £1.99/MW/h.

The participant requires payment of at least $(30MW + 10MW + 20MW + 4MW + 18MW) \times £1.99/MW/h = 163.18£/h$ for the entire bundle.

Order features

✓ Non-curtailable orders

✓ Multiple products in a single order

✓ Multiple services delivered simultaneously by a single unit

✓ Non-symmetric volumes

Notes

- The entire order is offered at a single price (£/MW/h)

- Simultaneous delivery of multiple services will be subject to updated service terms

Order ID	Order Type	DCL	DCH	DML	DMH	DRH	Price
P1	Parent	30	10	20	4	18	1.99

Variations

This example can only be applied to the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH).

Possible clearing outcomes

- Because the order is a Parent order, it must either be fully rejected (Outcome 1) or fully accepted (Outcome 2).

- If the order is accepted, the participant will receive at least £163.18/h.

Possible Outcome	Executed Volume					Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
	DCL	DCH	DML	DMH	DRH		
1	0	0	0	0	0	0.00	0.00
2	30	10	20	4	18	163.18	1.99

Order structure in previous frequency response auction (i.e., EPEXSPOT)

- This strategy cannot be modelled in the previous frequency response auction (i.e. EPEXSPOT) because:

  - Different frequency response services (DC/ DM/ DR) are not permitted to be offered by the same unit in the same service window

  - C88 orders may loop only two orders

Example 4: A fully-curtailable offer for a single product

Scenario

The participant offers 20MW Product X and is willing to be accepted for any integer amount between 0MW and 20MW.

The participant requires payment of at least $2£/MW/h$ for each MW accepted.

Order features

✓ Fully-curtailable orders

Notes

- In the EAC, fully-curtailable orders are modelled with a Child order for the full volume, linked to a Parent order with 0 volume.

Order ID	Order Type	X	Price
P1	Parent	0	0.00
C1	Child	20	2.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X can be
i) either one of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) either one of the Quick Reserve products (PQR, NQR)
iii) either one of the Slow Reserve products (PSR, NSR)
iv) either one of the Balancing Reserve products (PBR, NBR).

Possible clearing outcomes

- The child order can be accepted at any integer amount between [0, 20]. It can be rejected, partially-accepted, or fully-accepted.

- If the order is accepted, the participant will receive at least £2/MW/h per MW cleared.

Possible Outcome	Executed Volume X	Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
1	0	0.00	0.00
2	1	2.00	2.00
3	2	4.00	2.00
4	3	6.00	2.00
…	…	…	…
21	20	40.00	2.00

Order structure in previous frequency response auction (i.e., EPEXSPOT)

- Child orders are of type "C02"

Order ID	Order Type	Volume	Price	Product	Linked Order
P1	C01	1	2.00	DCL	
C1	C02	19	2.00	DCL	P1

Example 5: A partially-curtailable offer for a single product

Scenario

A 20MW unit wants to participate in the Product X market. Its marginal cost of providing DCL is as follows:

- £1/MW/h for the first 10MW
- £2/MW/h for the next 10MW

The participant is willing to offer any integer amount between 10MW and 20MW, conditional on the profit being non-negative.

Order features

✓ Parent-child links

Order ID	Order Type	X	Price
P1	Parent	10	1.00
C1	Child	10	2.00

Notes

- The non-curtailable quantity is offered as a Parent order and the curtailable quantity is offered as a Child order

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Variations

This is a general example and can be applied to all products in any EAC auctions. Product X can be
i) either one of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) either one of the Quick Reserve products (PQR, NQR)
iii) either one of the Slow Reserve products (PSR, NSR)
iv) either one of the Balancing Reserve products (PBR, NBR).

Possible clearing outcomes

- A child order may be accepted only if its linked parent order is accepted. A child order must be rejected if its linked parent order is rejected.

- The child order can be accepted at any integer amount between [0, 10].

- The total offer (including parent and child orders) can therefore be fully rejected, or else accepted between [10,20].

Possible Outcome	Executed Volume X	Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
1	0	0.00	0.00
2	10	10.00	1.00
3	11	12.00	1.09
4	12	14.00	1.17
...	...	...	...
12	20	30.00	1.50

Order structure in previous frequency response auction (i.e., EPEXSPOT)

Order ID	Order Type	Volume	Price	Product	Linked Order
P1	C01	10	1.00	DCL	
C1	C02	10	2.00	DCL	P1

Example 6: A fully curtailable order for two products (independent clearing)

Scenario

A participant has a constant marginal cost of £4/MW/h for providing Product X and a constant marginal cost of £1.5/MW/h for providing Product Y.

The participant is willing to be accepted for any integer amount between 0MW and 2MW for Product X and/or Product Y, conditional on the profit being non-negative.

Order features

✓ Fully-curtailable orders

✓ Multiple children on a single parent

Order ID	Order Type	X	Y	Price
P1	Parent	0	0	0.00
C1	Child	2	0	4.00
C2	Child	0	2	1.50

Order structure in previous frequency response auction (i.e., EPEXSPOT)

Order ID	Order Type	Volume	Price	Product	Linked Order
P1	C01	1	4.00	DML	
C1	C02	1	4.00	DML	P1
P2	C01	1	1.50	DMH	
C2	C02	1	1.50	DMH	P2

Possible clearing outcomes

- The two child orders are independent of each other. Each one of the two child order can be accepted at any integer amount between [0, 2].

- The minimum revenue (per hour) is calculated as follows:

$$executed\ volume_{DML} \times 4£ + executed\ volume_{DMH} \times 1.5£$$

Possible Outcome	Executed Volume		Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
	X	Y		
1	0	0	0.00	0.00
2	0	1	1.50	1.50
3	0	2	3.00	1.50
4	1	0	4.00	4.00
5	1	1	5.50	2.75
6	1	2	7.00	2.33
7	2	0	8.00	4.00
8	2	1	9.50	3.17
9	2	2	11.00	2.75

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH), ii)two Quick Reserve products (PQR, NQR), iii) two Slow Reserve products (PSR, NSR), iv) two Balancing Reserve products (PBR, NBR).

Example 7: A fully curtailable order for two products (proportional clearing)

Scenario

A participant has a constant marginal cost of £4/MW/h for providing Product X and a constant marginal cost of £1.5/MW/h for providing Product Y.

The participant is willing to be accepted for up to 2MW Product X and up to 2MW Product Y.

<u>The participant only wants to be accepted for the same amount of Product X and Product Y.</u>

The participant requires payment of at least $(4 + 1.5) \times \frac{1}{2} = 2.75 £/MW/h$.

Order ID	Order Type	X	Y	Price
P1	Parent	0	0	0.00
C1	Child	2	2	2.75

Compare this example with **Example 6** to see the difference between the following two order structures:

- **Independent clearing:** multiple children defined on single products
- **Proportional clearing:** one child defined on multiple products

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH), ii)two Quick Reserve products (PQR, NQR), iii) two Slow Reserve products (PSR, NSR), iv) two Balancing Reserve products (PBR, NBR).

Possible clearing outcomes

- The child order can be accepted at any integer amount between [0, 2].

- Product X and product Y must be accepted to the same proportion:

$$accepted\ volume_{DML} = accepted\ volume_{DMH}$$

- If the order is accepted, the participant will receive at least £2.75/MW/h.

Possible Outcome	Executed Volume		Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
	X	Y		
1	0	0	0.00	0.00
2	1	1	5.50	2.75
3	2	2	11.00	2.75

Order structure in previous frequency response auction (i.e., EPEXSPOT)

- A looped order with a MAR of 0 is fully-curtailable

Order ID	Order Type	Volume	Price	MAR	Product	Looped ID
L1	C88	2	4.00	0	DML	1001
L2	C88	2	1.50	0	DMH	1001

Example 8: A simple example of co-optimisation within a service with baskets

Scenario

A participant wants to offer two non-curtailable orders:

- O1: 20MW Product X at £2/MW/h
- O2: 20MW Product Y at £5/MW/h

The participant is indifferent to one, the other, or both orders being accepted. Possible clearing outcomes include:

1. Only O1 is fully-accepted
2. Only O2 is fully-accepted
3. Both O1 and O2 are fully-accepted
4. Both orders are rejected

Compare the above to **Example 2**, where both looped orders must be accepted or both rejected.

The exact equivalent structure in the EAC would require three baskets: accept one product, or the other, or both. As these baskets are all defined on the same period, at most one of them would be accepted.

Basket ID	Service Window	Order ID	Order Type	X	Y	Price
B1	1	P1	Parent	20		2.00
B2	1	P2	Parent		20	5.00
B3	1	P3	Parent	20	20	10.00

Note: This strategy cannot be modelled in the previous frequency response auction because mutually-exclusive offers are not part of the market design.

Possible clearing outcomes

- If a basket is accepted, then any other basket with which it is mutually exclusive must be rejected.
  - → B1, B2 and B3 are mutually to each other (because they are all defined on the same service window) hence at most one basket can be accepted.
- The auction algorithm will select the basket that clears the market most efficiently.

Possible Outcome	Accepted Basket	Executed Volume		Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
		X	Y		
1	-	0	0	0.00	0.00
2	B1	20		40.00	2.00
3	B2		20	100.00	5.00
4	B3	20	20	400.00	10.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be
i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) two Quick Reserve products (PQR, NQR)
iii) two Slow Reserve products (PSR, NSR)
iv) two Balancing Reserve products (PBR, NBR).

Example 9: A simple example of co-optimisation across services with baskets

Scenario

A 20MW unit wants to participate in the response markets. Its marginal cost of providing each service is as follows:

- **DCL:** £2/MW/h, up to 20MW
- **DML:** £5/MW/h, up to 20MW
- **DRL:** £10/MW/h, up to 10MW

Order features

✓ Non-curtailable orders
✓ Mutually exclusive baskets

Basket ID	EFA	Order ID	Order Type	DCL	DML	DRL	Price
B1	1	P1	Parent	20			2.00
B2	1	P2	Parent		20		5.00
B3	1	P3	Parent			10	10.00

Notes

- We introduce the idea of baskets as one way to represent co-optimised offers. Baskets group one or more orders together. Baskets defined on the same service window are mutually-exclusive: at most, one of them can be accepted.

- This strategy cannot be modelled in the previous frequency response auction because mutually-exclusive offers are not part of the market design. A participant must therefore choose, in advance of the auction, which of the three services to offer.

Possible clearing outcomes

- If a basket is accepted, then any other basket with which it is mutually exclusive must be rejected.
  - → B1, B2 and B3 are mutually to each other (because they are all defined on the same service window) hence at most one basket can be accepted.
- The auction algorithm will select the basket that clears the market most efficiently.

Possible Outcome	Accepted Basket	Executed Volume			Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
		DCL	DML	DRL		
1	-	0	0	0	0.00	0.00
2	B1	20			40.00	2.00
3	B2		20		100.00	5.00
4	B3			10	100.00	10.00

Variations
This example can only be applied to the co-optimised Response and Reserve products (DCL, DCH, DML, DMH, DRL, DRH, PQR, NQR, PSR, NSR).

Example 10: A common strategy in the previous frequency response market [1/2]

Scenario

In the previous frequency response auction (i.e., EPEXSPOT), we often see offers like:

Order ID	Order Type	Volume	Price	Product
P1	C01	10	8.00	DCL
P2	C01	10	6.00	DCH

These are two unlooped parent orders. Both are non-curtailable.

The participant is indifferent to one, the other, or both orders being accepted. Possible clearing outcomes include:

1. Only P1 is fully-accepted
2. Only P2 is fully-accepted
3. Both P1 and P2 are fully-accepted
4. Both orders are rejected

Compare the above to **Example 2**, where both looped orders must be accepted or both rejected.

Order ID	Order Type	Volume	Price	MAR	Product	Looped ID
L1	C88	20	5.00	1	DCL	1001
L2	C88	20	5.00	1	DCH	1001

Example 2

Scenario

The exact equivalent structure in the EAC would require three baskets: accept one product, or the other, or both:

Basket ID	EFA	Order ID	Order Type	DCL	DCH	Price
B1	1	P1	Parent	10		8.00
B2	1	P2	Parent		10	6.00
B3	1	P3	Parent	10	10	7.00

Because these baskets are all defined on the same time period, at most one of them would be accepted.

This approach is possible but not recommended. Units may submit a maximum of 25 baskets per auction (not per period).

Alternative approaches are illustrated on the next slide:

Variations
This is an extended example of Example 8 in the context of response products. This example can be generalised and can be applied to all products in any EAC auctions. The two products can be i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH), ii)two Quick Reserve products (PQR, NQR), iii) two Slow Reserve products (PSR, NSR), iv) two Balancing Reserve products (PBR, NBR).

Example 10: A common strategy in the previous frequency response market [2/2]

Approach 1

A participant wants to offer 10MW DCL and 10MW DCH.

The participant requires to be fully accepted for DCL, and is willing to be accepted for DCH in any amount between [0,10].

Order ID	Order Type	DCL	DCH	Price
P1	Parent	10	0	8.00
C1	Child	0	10	6.00

Approach 2

A participant wants to offer 10MW DCL and 10MW DCH.

The participant requires to be fully accepted for one of these products, and is willing to be accepted for the other product in any amount between [0,10].

Basket ID	EFA	Order ID	Order Type	DCL	DCH	Price
B1	1	P1	Parent	10		8.00
		C1	Child		10	6.00
B2	1	P2	Parent		10	6.00
		C2	Child	10		8.00

Possible clearing outcomes in EAC for Approach 1

Possible Outcome	Executed Volume		Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
	DCL	DCH		
1	0	0	0.00	0.00
2	10	0	80.00	8.00
3	10	1	86.00	7.82
4	10	2	92.00	7.67
...	...	...	...	...
12	10	10	140.00	7.00

Possible clearing outcomes in EAC for Approach 2

Possible Outcome	Accepted Baskets	Executed Volume		Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
		DCL	DCH		
1	-	0	0	0.00	0.00
2		10	0	80.00	8.00
3	B1	10	1	86.00	7.82
...		...	...	...	...
12		10	10	140.00	7.00
13		0	10	60.00	6.00
14	B2	1	10	68.00	6.18
...		...	...	...	...
23		10	10	140.00	7.00

EAC Sell Order Structure

Advanced Examples

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List of Examples [1/2]

Co-optimisation and Splitting

1. Baskets (without splitting)
2. Baskets (with splitting)
   a) Splitting between two response products
   b) Splitting across all response products
3. Substitutable child order (with splitting)
   a) Splitting between two products (with a zero MW parent)
   b) Splitting between two products (with a non-zero MW parent)
4. Child order (with splitting)

Examples of order construction in the new EAC auction look like this.

Order ID	Order Type	DCL	Price
P1	Parent	20	10.00

All examples in this section cannot be modelled in the previous (i.e., EPEXSPOT) auction for frequency response because co-optimisation/splitting is not an available feature.

All examples in this section cannot be modelled in the STOR auction because co-optimisation/splitting is not an available feature.

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Example 1: Co-optimised response offers with baskets (no splitting) [1/2]

Scenario

A unit wants to participate in the co-optimised response and reserve markets. Its marginal cost of providing 1MW two-sided service is as follows:

- **DC:** £2/MW/h for the first 10MW and £5/MW/h for the next 10MW
- **DM:** £5/MW/h for the first 10MW and £7/MW/h for the next 10MW
- **DR:** £10/MW/h for the first 5MW and £15/MW/h for the next 5MW

The participant wants to offer at least 50% capacity (for each side) for a single service, and is willing to offer the remaining 50% capacity as a fully curtailable order.

Order features

✓ Parent-child links (incl. non-curtailable and curtailable orders)

✓ Mutually exclusive baskets

Basket ID	EFA	Order ID	Order Type	DCL	DCH	DML	DMH	DRL	DRH	Price
B1	1	P1	Parent	10	10					2.00
		C1	Child	10	10					5.00
B2	1	P2	Parent			10	10			5.00
		C2	Child			10	10			7.00
B3	1	P3	Parent					5	5	10.00
		C3	Child					5	5	15.00

Variations
This example can only be applied to the co-optimised Response and Reserve products (DCL, DCH, DML, DMH, DRL, DRH, PQR, NQR, PSR, NSR).

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Example 1: Co-optimised response offers with baskets (no splitting) [2/2]

Possible clearing outcomes

- If a basket is accepted, then any other basket with which it is mutually exclusive must be rejected.

→ B1, B2 and B3 are mutually to each other (because they are all defined on the same service window) hence at most one basket can be accepted.

Possible Outcome	Accepted Basket	Executed Volume						Minimum Revenue (£)	Minimum Revenue in £/MW/h
		DCL	DCH	DML	DMH	DRL	DRH		
1	–	0	0	0	0	0	0	0.00	0.00
2		10	10					40.00	2.00
3		11	11					50.00	2.27
4	B1	12	12					60.00	2.50
...		...	...					...	...
12		20	20					140.00	3.50
13				10	10			100.00	5.00
14				11	11			114.00	5.18
15	B2			12	12			128.00	5.33
...				...	...			...	...
23				20	20			240.00	6.00
24						5	5	100.00	10.00
25						6	6	130.00	10.83
26	B3					7	7	160.00	11.43
...						...	...	...	...
29						10	10	250.00	12.50

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Example 2a: Splitting between two response products with baskets

Scenario

A unit wants to participate in the response markets. Its marginal cost of providing each service is as follows:

- **DCL:** £2/MW/h, up to 20MW
- **DMH:** £-5/MW/h, up to 20MW
- **DRH:** £-10/MW/h, up to 10MW

The participant wants to offer 20MW DCL as a bundle. Conditional on the full acceptance of the 20MW DCL order, the participant is willing to offer either DMH or DRH as a curtailable order.

Order features

✓ Parent-child links (incl. non-curtailable and curtailable orders)

✓ Mutually exclusive baskets

✓ Splitting (different directions)

Basket ID	EFA	Order ID	Order Type	DCL	DMH	DRH	Price
B1	1	P1	Parent	20			2.00
		C1	Child		20		−5.00
B2	1	P2	Parent	20			2.00
		C2	Child			10	−10.00

Variations
This example can only be applied to the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH).

Possible clearing outcomes

- If a basket is accepted, then any other basket with which it is mutually exclusive must be rejected.

→ B1 and B2 are mutually to each other (because they are all defined on the same service window) hence at most one basket can be accepted.

Possible Outcome	Accepted Basket	Executed Volume			Minimum Revenue (£/h)	Minimum Revenue in £/MW/h
		DCL	DMH	DRH		
1	–	0	0	0	0.00	0.00
2		20			40.00	2.00
3		20	1		35.00	1.67
4	B1	20	2		30.00	1.36
…		…	…		…	…
22		20	20		−60.00	−1.50
23		20			40.00	2.00
24		20		1	30.00	1.43
25	B2	20		2	20.00	0.91
…		…		…	…	…
33		20		10	−60.00	−2.00

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Example 2b: Splitting across all response products with baskets [1/2]

Scenario

A unit wants to participate in the response markets. Its marginal cost of providing each service is as follows:

- **Low**
  - **DCL:** £2/MW/h, up to 10MW
  - **DML:** £12/MW/h, up to 10MW
- **High**
  - **DCH:** £-2/MW/h, up to 20MW
  - **DMH:** £-5/MW/h, up to 20MW
  - **DRH:** £-10/MW/h, up to 10MW

The participant wants to offer 10MW DCL and 10MW DML as a bundle. Conditional on the full acceptance of the bundle, the participant is willing to offer either DCH, DMH or DRH as a curtailable order.

Order features

- ✓ Parent-child links (incl. non-curtailable and curtailable orders)
- ✓ Mutually exclusive baskets
- ✓ Splitting (same and different directions)

Basket ID	EFA	Order ID	Order Type	DCL	DCH	DML	DMH	DRH	Price
B1	4	P1	Parent	10		10			7.00
		C1	Child		20				-2.00
B2	4	P2	Parent	10		10			7.00
		C2	Child				20		-5.00
B3	4	P3	Parent	10		10			7.00
		C3	Child					10	-10.00

Variations
This example can only be applied to the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH).

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Example 2b: Splitting across all response products with baskets [2/2]

Possible clearing outcomes

- If a basket is accepted, then any other basket with which it is mutually exclusive must be rejected.
- → B1, B2 and B3 are mutually to each other (because they are all defined on the same service window) hence at most one basket can be accepted.

Possible Outcome	Accepted Basket	Executed Volume					Minimum Revenue (£)	Minimum Revenue in £/MW/h
		DCL	DCH	DML	DMH	DRH		
1	–	0	0	0	0	0	0.00	0.00
2		10		10			140.00	7.00
3		10	1	10			138.00	6.57
4	B1	10	2	10			136.00	6.18
...		...	...	...			...	...
22		10	20	10			100.00	2.50
23		10		10			140.00	7.00
24		10		10	1		135.00	6.43
25	B2	10		10	2		130.00	5.91
...		...		...	...		...	...
43		10		10	20		40.00	1.00
44		10		10			140.00	7.00
45		10		10		1	130.00	6.19
46	B3	10		10		2	120.00	5.45
...		...		...		...	...	...
54		10		10		10	40.00	1.33

Example 3a: Splitting between two products with substitutable child orders [1/2]

Scenario

A unit wants to participate in the response/reserve markets. Its marginal cost of providing each product is as follows:

- Product X: £2/MW/h, up to 10MW
- Product Y: £10/MW/h, up to 5MW

The participant is willing to offer either Product X or Product Y as fully curtailable orders, and is willing to offer <u>any mix</u> between Product X and Product Y.

Order features

- ✓ Fully curtailable orders
- ✓ Splitting (same or different directions)

Basket ID	Service Window	Order ID	Order Type	X	Y	Price
B1	5	P1	Parent	0		0.00
		S1	Substitutable	10		2.00
		S2	Substitutable		5	10.00

Variations
This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be
i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) two Quick Reserve products (PQR, NQR)
iii) two Slow Reserve products (PSR, NSR)
iv) two Balancing Reserve products (PBR, NBR).

Example 3a: Splitting between two products with substitutable child orders [2/2]

Possible clearing outcomes

- All substitutable child orders in a basket form a single Substitutable Family. The sum of the acceptance ratios in a Substitutable Family must be less than or equal to 1.

- In this example, the acceptance of the two substitutable child orders is subject to constraint: $x_{S1} + x_{S2} \leq 1$, where x_{S1}, x_{S2} are the acceptance ratios for order S1, S2, respectively.

- The top right matrix shows the valid combinations of the acceptance ratios for order S1, S2. Invalid combinations are coloured in black, as the sum of x_{S1}, x_{S2} is greater than 1.

- The bottom right matrix is the payoff/revenue matrix for all possible clearing outcome.

  1) The first column is the executed volume (in MW) for order S1, the second column is the acceptance ratio for order S1.

  2) The first row is the executed volume (in MW) for order S2, and the second row is the acceptance ratio for order S2.

  3) Values in the green cells represents the minimum revenue in £/h.

Valid combinations of acceptance ratios for order S1, S2

S2\S1	X	0	1	2	3	4	5	6	7	8	9	10
Y	AR	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
2	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
3	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
4	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
5	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0

Payoff matrix

S2\S1	X	0	1	2	3	4	5	6	7	8	9	10
Y	AR	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	0.0	0	2	4	6	8	10	12	14	16	18	20
1	0.2	10	12	14	16	18	20	22	24	26		
2	0.4	20	22	24	26	28	30	32				
3	0.6	30	32	34	36	38						
4	0.8	40	42	44								
5	1.0	50										

Example 3b: Splitting between two products with substitutable child orders [1/3]

Scenario

A unit wants to participate in the response/reserve markets. Its marginal cost of providing each product is as follows:

- Product X: £-5/MW/h, up to 21MW
- Product Y: £-10/MW/h, up to 10MW*

The unit also has a start up/fixed cost of £40. The participant is willing to offer either Product X or Product Y as fully curtailable orders and is willing to provide these two products for <u>any mix</u>.

Order features

✓ Parent-child links (incl. non-curtailable and curtailable orders)

✓ Splitting (same or different directions)

Basket ID	Service Window	Order ID	Order Type	X	Y	Price
B1	5	P1	Parent	1		40.00
		S1	Substitutable	20		-5.00
		S2	Substitutable		10	-10.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH), ii)two Quick Reserve products (PQR, NQR), iii) two Slow Reserve products (PSR, NSR), iv) two Balancing Reserve products (PBR, NBR).

Compare this example with the two examples below to see the difference between the following three order structures:

1) Offering splitting by submitting substitutable child orders (in one basket)

2) Offering splitting by submitting child orders (in multiple baskets)

Basket ID	Service Window	Order ID	Order Type	X	Y	Price
B1	5	P1	Parent	1		40.00
		C1	Child	20		-5.00
B2	5	P2	Parent	1		40.00
		C2	Child		10	-10.00

Example A

3) Offering splitting by submitting child orders (in one basket)

Basket ID	Service Window	Order ID	Order Type	X	Y	Price
B1	5	P1	Parent	1		40.00
		C1	Child	10		-5.00
		C2	Child		5	-10.00

Example B (Advanced Example 4)

Note: Suppose this unit is an energy limited asset and needs to de-rate its capacity by 50% to provide Product Y. No de-rating is required for providing Product X.

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Example 3b: Splitting between two products with substitutable child orders [2/3]

Possible clearing outcomes (for this example)

- All substitutable child orders in a basket form a single Substitutable Family. The sum of the acceptance ratios in a Substitutable Family must be less than or equal to 1.

- In this example, $x_{S1} + x_{S2} \leq 1$, where x_{S1}, x_{S2} are the acceptance ratios for order S1, S2, respectively.

- See right-hand side for payoff matrix for this example:

  1) The first column is the executed volume (in MW) for order S1, the second column is the acceptance ratio for order S1.

  2) The first row is the executed volume (in MW) for order S2, and the second row is the acceptance ratio for order S2.

  3) Values in the green or red cells represents the minimum revenue in £/h.

  4) The payoff is 0 if the entire basket is rejected. This outcome is omitted from the payoff matrix for simplicity.

S1/S2	Y	0	1	2	3	4	5	6	7	8	9	10
X	AR	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	0.00	40	30	20	10	0	−10	−20	−30	−40	−50	−60
1	0.05	35	25	15	5	−5	−15	−25	−35	−45	−55	
2	0.10	30	20	10	0	−10	−20	−30	−40	−50	−60	
3	0.15	25	15	5	−5	−15	−25	−35	−45	−55		
4	0.20	20	10	0	−10	−20	−30	−40	−50	−60		
5	0.25	15	5	−5	−15	−25	−35	−45	−55			
6	0.30	10	0	−10	−20	−30	−40	−50	−60			
7	0.35	5	−5	−15	−25	−35	−45	−55				
8	0.40	0	−10	−20	−30	−40	−50	−60				
9	0.45	−5	−15	−25	−35	−45	−55					
10	0.50	−10	−20	−30	−40	−50	−60					
11	0.55	−15	−25	−35	−45	−55						
12	0.60	−20	−30	−40	−50	−60						
13	0.65	−25	−35	−45	−55							
14	0.70	−30	−40	−50	−60							
15	0.75	−35	−45	−55								
16	0.80	−40	−50	−60								
17	0.85	−45	−55									
18	0.90	−50	−60									
19	0.95	−55										
20	1.00	−60										

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Example 3b: Splitting between two products with substitutable child orders [3/3]

Possible clearing outcomes (for Example A)

- The matrix on the right-hand side is the payoff matrix for **Example A**.

    1) The first column is the executed volume (in MW) for order C1, the second column is the acceptance ratio for order C1.

    2) The first row is the executed volume (in MW) for order C2, and the second row is the acceptance ratio for order C2.

    3) Values in the green or red cells represents the minimum revenue in £/h.

    4) The payoff is 0 if the entire basket is rejected. This outcome is omitted from the payoff matrix for simplicity.

- C1 and C2 are child orders and there is no substitution between the two orders, therefore, each order can be accepted up to 100%. However, C1 and C2 are mutually exclusive to each other (as they belong to two mutually exclusive baskets, B1 and B2), they cannot be accepted simultaneously.

C1/C2	Y	0	1	2	3	4	5	6	7	8	9	10
X	AR	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	0.00	40	30	20	10	0	−10	−20	−30	−40	−50	−60
1	0.05	35										
2	0.10	30										
3	0.15	25										
4	0.20	20										
5	0.25	15										
6	0.30	10										
7	0.35	5										
8	0.40	0										
9	0.45	−5										
10	0.50	−10										
11	0.55	−15										
12	0.60	−20										
13	0.65	−25										
14	0.70	−30										
15	0.75	−35										
16	0.80	−40										
17	0.85	−45										
18	0.90	−50										
19	0.95	−55										
20	1.00	−60										

This area is infeasible because basket B1 and B2 are mutually exclusive to each other. Once a basket is accepted, the other basket must be fully rejected.

This area may be unlocked by submitting substitutable child orders. Please see previous slide for a use case.

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Example 4: Splitting across multiple products with child orders [1/2]

Scenario

A unit wants to participate in the response markets. Its marginal cost of providing each service is as follows:

- Product X: £-5/MW/h, up to 21MW
- Product Y: £-10/MW/h, up to 10MW*

The unit also has a start up/fixed cost of £40. The participant is willing to offer either Product X or Product Y as fully curtailable orders and is willing to mix up these two services. But the participant decides to use child orders rather than substitutable child orders.

Order features

✓ Parent-child links (incl. non-curtailable and curtailable orders)

✓ Splitting (same or different directions)

Variations
This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be
i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) two Quick Reserve products (PQR, NQR)
iii) two Slow Reserve products (PSR, NSR)
iv) two Balancing Reserve products (PBR, NBR).

Basket ID	Service Window	Order ID	Order Type	X	Y	Price
B1	5	P1	Parent	1		40.00
		C1	Child	10		-5.00
		C2	Child		5	-10.00

Note: Suppose this unit is an energy limited asset and needs to de-rate its capacity by 50% to provide Product Y. No de-rating is required for providing Product X.

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Example 4: Splitting across multiple products with child orders [2/2]

Possible clearing outcomes

- The matrix on the right-hand side is the payoff matrix for this example:

  1) The first column is the executed volume (in MW) for child order C1, the second column is the acceptance ratio for child order C1.

  2) The first row is the executed volume (in MW) for child order C2, and the second row is the acceptance ratio for order child C2.

  3) Values in the green or red cells represents the minimum revenue in £/h.

  4) The payoff is 0 if the entire basket is rejected. This outcome is omitted from the payoff matrix for simplicity.

- C1 and C2 are child orders and there is no substitution between the two orders, therefore, each order can be accepted up to 100%. C1 and C2 are also not mutually exclusive to each other (as they belong to the same basket, B1) hence can be accepted simultaneously.

Payoff matrix

C1/C2	Y	0	1	2	3	4	5	6	7	8	9	10
X	AR	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
0	0.0	40	30	20	10	0	−10					
1	0.1	35	25	15	5	−5	−15					
2	0.2	30	20	10	0	−10	−20					
3	0.3	25	15	5	−5	−15	−25					
4	0.4	20	10	0	−10	−20	−30					
5	0.5	15	5	−5	−15	−25	−35					
6	0.6	10	0	−10	−20	−30	−40					
7	0.7	5	−5	−15	−25	−35	−45					
8	0.8	0	−10	−20	−30	−40	−50					
9	0.9	−5	−15	−25	−35	−45	−55					
10	1.0	−10	−20	−30	−40	−50	−60					
11	1.1											
12	1.2											
13	1.3											
14	1.4											
15	1.5											
16	1.6											
17	1.7											
18	1.8											
19	1.9											
20	2.0											

These grey areas may be technically feasible for the unit but is currently infeasible due to the order structure.

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List of Examples [2/2]

Looping of baskets

5. Looped baskets with parent orders

   a) Baskets defined on a single product (one-sided)

   b) Baskets defined on two products

   c) Mutually exclusive looped baskets (full overlap)

   d) Mutually exclusive looped baskets (partial overlap)

   e) Baskets defined on different products

6. Looped baskets with more complex order types

   a) Parent and child orders in consecutive service windows

   b) Looped baskets with child and substitutable child orders

Examples of order construction in the new EAC auction look like this.

Order ID	Order Type	DCL	Price
P1	Parent	20	10.00

Examples of order construction in the previous (i.e., EPEXSPOT) auction for frequency response look like this.

Order ID	Order Type	Volume	Price	Product
P1	C01	20	10.00	DCL

All examples in this section cannot be modelled in the STOR auction because co-optimisation/splitting is not an available feature.

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Example 5a: Baskets defined on a single product (one-sided)

Scenario

A participant wants to offer 20MW Product X, for 3 consecutive service windows, and expects to receive at least £10/MW/h. The entire order must be either fully accepted or fully rejected.

Order features

✓ Looped baskets

✓ Non-curtailable orders

Order structure in EAC auction

Basket			Order			
Basket ID	Service Window	Loop Family ID	Order ID	Order Type	X	Price
B1	1	F1	P1	Parent	20	10.00
B2	2	F1	P2	Parent	20	10.00
B3	3	F1	P3	Parent	20	10.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X can be
i)   either one of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) either one of the Quick Reserve products (PQR, NQR)
iii) either one of the Slow Reserve products (PSR, NSR)
iv) either one of the Balancing Reserve products (PBR, NBR).

Order structure in previous frequency response auction (i.e., EPEXSPOT)

Order ID	Order Type	EFA 1	EFA 2	EFA 3	Price	MAR	Product
P1	C01	20	20	20	10.00	1	X

Note: The clearing outcome is binary as all orders form an all-or-nothing order family.

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Example 5b: Baskets defined on two products

Scenario

A participant wants to offer 20MW for Product X and 20MW for Product Y, for 3 consecutive service windows, and expects to receive at least £10/MW/h. The entire order must be either fully accepted or fully rejected.

Order features

✓ Looped baskets

✓ Non-curtailable orders

Order structure in EAC auction

	Basket			Order			
Basket ID	Service Window	Loop Family ID	Order ID	Order Type	X	Y	Price
B1	1	F2	P1	Parent	20	20	10.00
B2	2	F2	P2	Parent	20	20	10.00
B3	3	F2	P3	Parent	20	20	10.00

Variations
This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be
i) any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) two Quick Reserve products (PQR, NQR)
iii) two Slow Reserve products (PSR, NSR)
iv) two Balancing Reserve products (PBR, NBR).

Note: The clearing outcome is binary as all orders form an all-or-nothing order family.

Order structure in previous frequency response auction (i.e., EPEXSPOT)

Order ID	Order Type	EFA 1	EFA 2	EFA 3	Price	MAR	Product	Linked Order
P1	Parent	20	20	20	10.00	1	X	L001
P2	Parent	20	20	20	10.00	1	Y	L001

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Example 5c: Mutually exclusive looped baskets (full overlap)

Scenario

A participant wants to offer either 20MW Product X at £10/MW/h for service window 40 to 43 as an all-or-nothing bundle or 10MW Product Y at £5/MW/h for service window 40 to 43 as an all-or-nothing bundle

Order features

✓ Looped baskets

✓ Non-curtailable orders

Order structure in EAC auction

Basket			Order				
Basket ID	Service Window	Loop Family ID	Order ID	Order Type	X	Y	Price
B1	40	F3	P1	Parent	20		10.00
B2	41	F3	P2	Parent	20		10.00
B3	42	F3	P3	Parent	20		10.00
B4	43	F3	P4	Parent	20		10.00
B5	40	F4	P5	Parent		10	5.00
B6	41	F4	P6	Parent		10	5.00
B7	42	F4	P7	Parent		10	5.00
B8	43	F4	P8	Parent		10	5.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X and Product Y can be

i)   any two of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)

ii) two Quick Reserve products (PQR, NQR)

iii) two Slow Reserve products (PSR, NSR)

iv) two Balancing Reserve products (PBR, NBR).

Order structure in previous frequency response auction (i.e., EPEXSPOT)

• This strategy cannot be modelled in the previous frequency response auction because mutually-exclusive offers are not part of the market design

• A participant must therefore choose, in advance of the auction, which service to offer.

Note: Looped family F3 and looped family F4 are mutually exclusive to each other as both family are defined on the same service window 40 to 43. At most one family will be accepted.

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Example 5d: Mutually exclusive looped baskets (partial overlap)

Scenario

A participant wants to offer 20MW Product X at £10/MW/h for any three consecutive service windows within service windows 40 to 43. The participant wants to offer everything as an all-or-nothing bundle.

Order features

✓ Looped baskets

✓ Non-curtailable orders

Order structure in EAC auction

Basket			Order			
Basket ID	Service Window	Loop Family ID	Order ID	Order Type	X	Price
B1	40	F5	P1	Parent	20	10.00
B2	41	F5	P2	Parent	20	10.00
B3	42	F5	P3	Parent	20	10.00
B4	41	F6	P4	Parent	20	10.00
B5	42	F6	P5	Parent	20	10.00
B6	43	F6	P6	Parent	20	10.00

Variations

This is a general example and can be applied to all products in any EAC auctions. Product X can be

i) either one of the Dynamic Response products (DCL, DCH, DML, DMH, DRL, DRH)
ii) either one of the Quick Reserve products (PQR, NQR)
iii) either one of the Slow Reserve products (PSR, NSR)
iv) either one of the Balancing Reserve products (PBR, NBR).

Note: Looped family F5 and looped family F6 are mutually exclusive to each other as both families cover the same service windows 41 and 42. At most one family will be accepted.

Order structure in previous frequency response auction (i.e., EPEXSPOT)

- This strategy cannot be modelled in the previous frequency response auction because mutually-exclusive offers are not part of the market design

- A participant must therefore choose, in advance of the auction, which service to offer.

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Example 5e: Baskets defined on different products

Scenario

A participant wants to offer

- 50MW DRL and 50MW DRH for EFA 1 and EFA 3

- 50MW PQR and 50MW NQR for service window 9 and 10

- 50MW PSR and 50MW NSR for service window 11 and 12.

The participant is only willing to offer all above services as an all-or-nothing bundle, and expects to receive at least £8700 (or £8.7/MW/h) for the entire bundle.

Order features

✓ Looped baskets

✓ Non-curtailable orders

Note: [1] The clearing outcome is binary as all orders form an all-or-nothing order family. [2] This strategy cannot be modelled in the previous (i.e., EPEXSPOT) auction for frequency response.

Basket			Order								
Basket ID	Service Window	Loop Family ID	Order ID	Order Type	DRL	DRH	PQR	NQR	PSR	NSR	Price
B1	23:00–03:00	F7	P1	Parent	50	50					10.00
B2	03:00–03:30	F7	P2	Parent			50	50			5.00
B3	03:30–04:00	F7	P3	Parent			50	50			4.00
B4	04:00–04:30	F7	P4	Parent					50	50	2.00
B5	04:30–05:00	F7	P5	Parent					50	50	3.00
B6	07:00–11:00	F7	P6	Parent	50	50					10.00

Variations

This example can only be applied to the co-optimised Response and Reserve products (DCL, DCH, DML, DMH, DRL, DRH, PQR, NQR, PSR, NSR).

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Example 6a: Parent and child orders in consecutive service windows

Scenario

A participant wants to offer a fixed quantity of 20MW DCL for EFA 1. Conditional on being accepted for EFA 1, the participant is willing to offer any integer quantity between 0MW to 20MW for DML, for the next EFA. The marginal cost is £5/MW/h for DCL and £7/MW/h for DML.

Order features

✓ Looped baskets

✓ Non-curtailable orders

✓ Fully-curtailable orders

Order structure in EAC auction

Basket			Order							
Basket ID	EFA	Loop Family ID	Order ID	Order Type	DCL	DCH	DML	DMH	DRL	DRH	Price
B1	1	F8	P1	Parent	20						5.00
B2	2	F8	P2	Parent			0				0.00
			C2	Child			20				7.00

Order structure in previous frequency response auction (i.e., EPEXSPOT)

Order ID	Order Type	EFA 1	EFA 2	EFA 3	EFA 4	EFA 5	EFA 6	Price	MAR	Product	Linked Order
P1	C01	20						5.00	1	DCL	
C1	C02		20					7.00	0	DML	P1

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Example 6b: Looped baskets with child and substitutable child orders [1/2]

Scenario

A participant wants to offer response services for three consecutive service windows, EFA 1 to EFA 3. The participant wants to offer at least 10MW DCL for each EFA. Conditional on the acceptance of the 10MW DCL offer for EFA 1 to 3, the participant is willing to offer:

- **EFA 1:** Either up to 10MW DCL, or 10MW DML or 5ML DRL as curtailable orders. The participant can offer any mix of DCL, DML and DRL.

- **EFA 2:** (1) up to 10MW two-sided DC, and/or (2) up to 5MW DRL

- **EFA 3:** (1) up to 10MW DCL, and/or (2) up to 10MW two-sided DC or 10MW two-sided DM. The participant can offer any mix between DC and DM.

Order features

✓ Looped baskets

✓ Non-curtailable orders

✓ Child and substitutable child orders

Note: This strategy cannot be modelled in the previous (i.e., EPEXSPOT) auction for frequency response.

Basket			Order								
Basket ID	EFA	Loop Family ID	Order ID	Order Type	DCL	DCH	DML	DMH	DRL	DRH	Price
B1	1	F9	P1	Parent	10						2.00
			S11	Substitutable	10						1.00
			S12	Substitutable			10				5.00
			S13	Substitutable					5		8.00
B2	2	F9	P2	Parent	10						2.00
			C21	Child	10	10					-1.00
			C22	Child						5	-8.00
B3	3	F9	P3	Parent	10						2.00
			C31	Child		10					-1.00
			S31	Substitutable	10	10					0.50
			S31	Substitutable			10	10			1.50

Variations

This example can only be applied to the co-optimised Response and Reserve products (DCL, DCH, DML, DMH, DRL, DRH, PQR, NQR, PSR, NSR).

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Example 6b: Looped baskets with child and substitutable child orders [2/2]

Possible clearing outcomes

There are many possible clearing outcomes for this example. Let x_o be the acceptance ratio of order o, once all looped baskets are accepted (i.e., $x_{P1} = x_{P2} = x_{P3} = 1$), the clearing of the remaining orders should satisfy:

- Child orders:

$$0 \leq x_{C21} \leq 1$$
$$0 \leq x_{C22} \leq 1$$
$$0 \leq x_{C31} \leq 1$$

- Substitutable child orders:

$$0 \leq x_{S11} + x_{S12} + x_{S13} \leq 1$$
$$0 \leq x_{S31} + x_{S32} \leq 1$$

Legend:
- **Basket**
- **Parent**
- **Child**
- **Substitutable Child**

By looping baskets B1, B2, and B3, parent orders P1, P2 and P3 form an all-or-nothing family, which can only be either fully rejected or fully accepted.
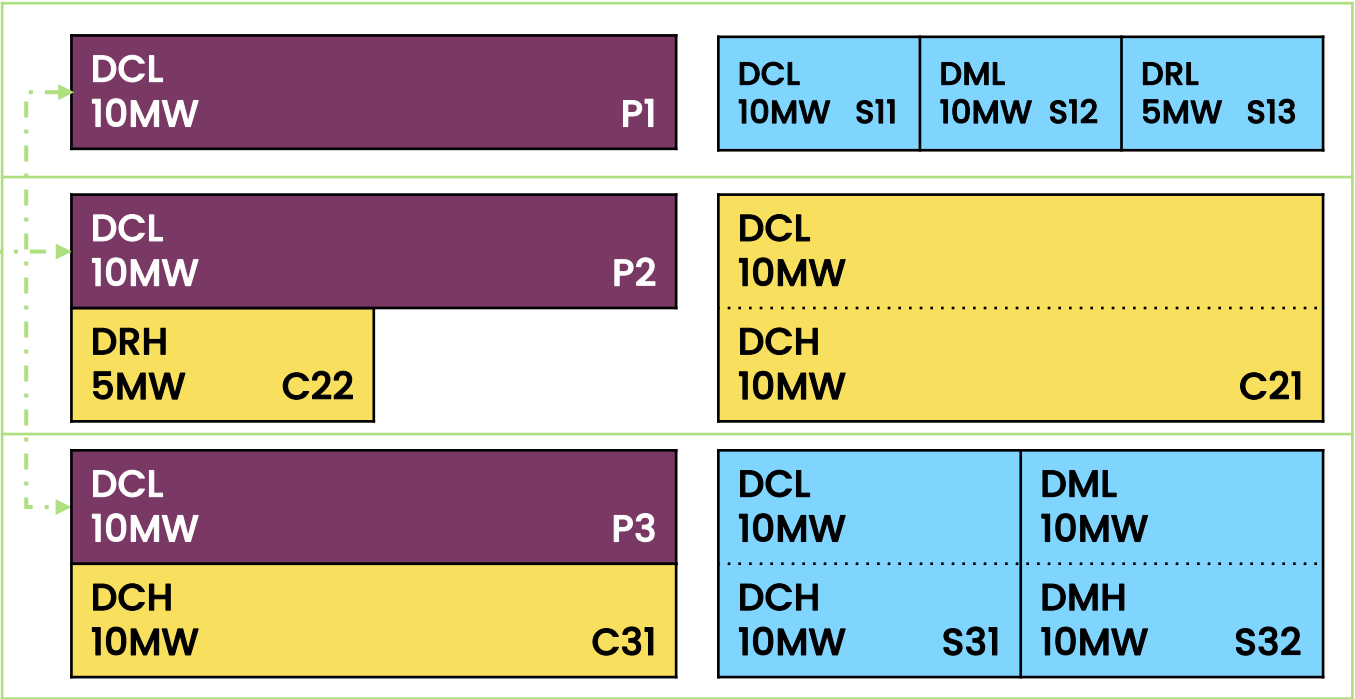
Market Clearing Rules: More Definitions

➢ Paradoxical Acceptance

➢ Paradoxical Rejection

What is Paradoxical Acceptance?

Paradoxical Acceptance

An order which is (fully or partially) accepted while its total surplus (including transfers of surpluses from/to other orders via links and surplus transferred to its substitutability group) is negative.

The order is accepted despite being "out-of-the-money"

This section help to answer the following questions:

1) Why sell orders are not allowed to be paradoxically accepted?

2) Why buy orders are allowed to be paradoxically accepted?

3) How is overholding implemented through the paradoxical acceptance of buy orders?
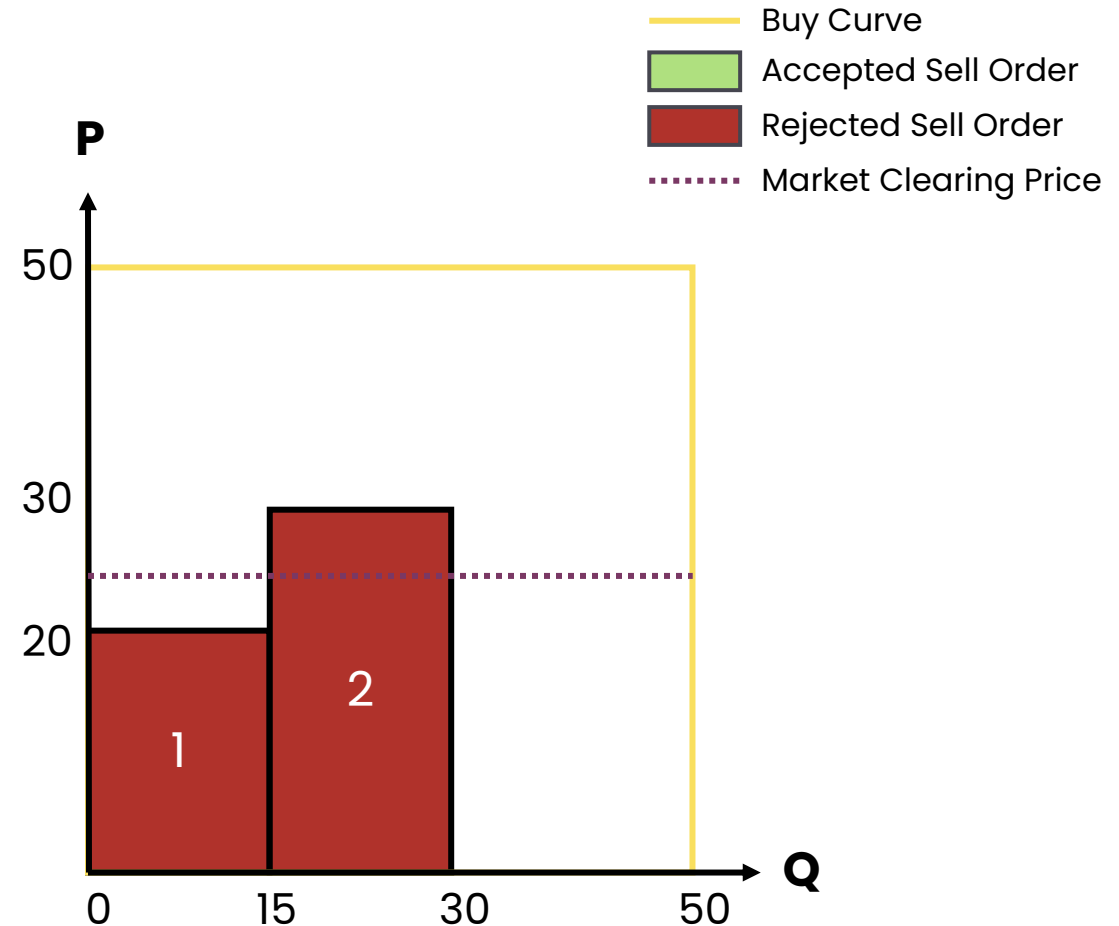
What is Paradoxical Acceptance?

Example 1

If we accept both Sell Order 1 and 2 and set the clearing price at £28…

- Sell Order 2 is paradoxically accepted. Because the order is "out-of-the-money", accepting the order at this clearing price generates negative surplus for the seller.

- Order prices should reflect seller's (minimum) requirement to be paid. **Therefore, sell orders are not allowed to be paradoxically accepted.**

Unit ID	Order ID	Order Type	Product	Volume	Price
U_01	1	Parent	A	15	20
U_02	2	Parent	A	15	30

Note: This solution maximises market welfare but violates market clearing rules. The expected clearing result is to accept both orders and the clearing price should be £30.
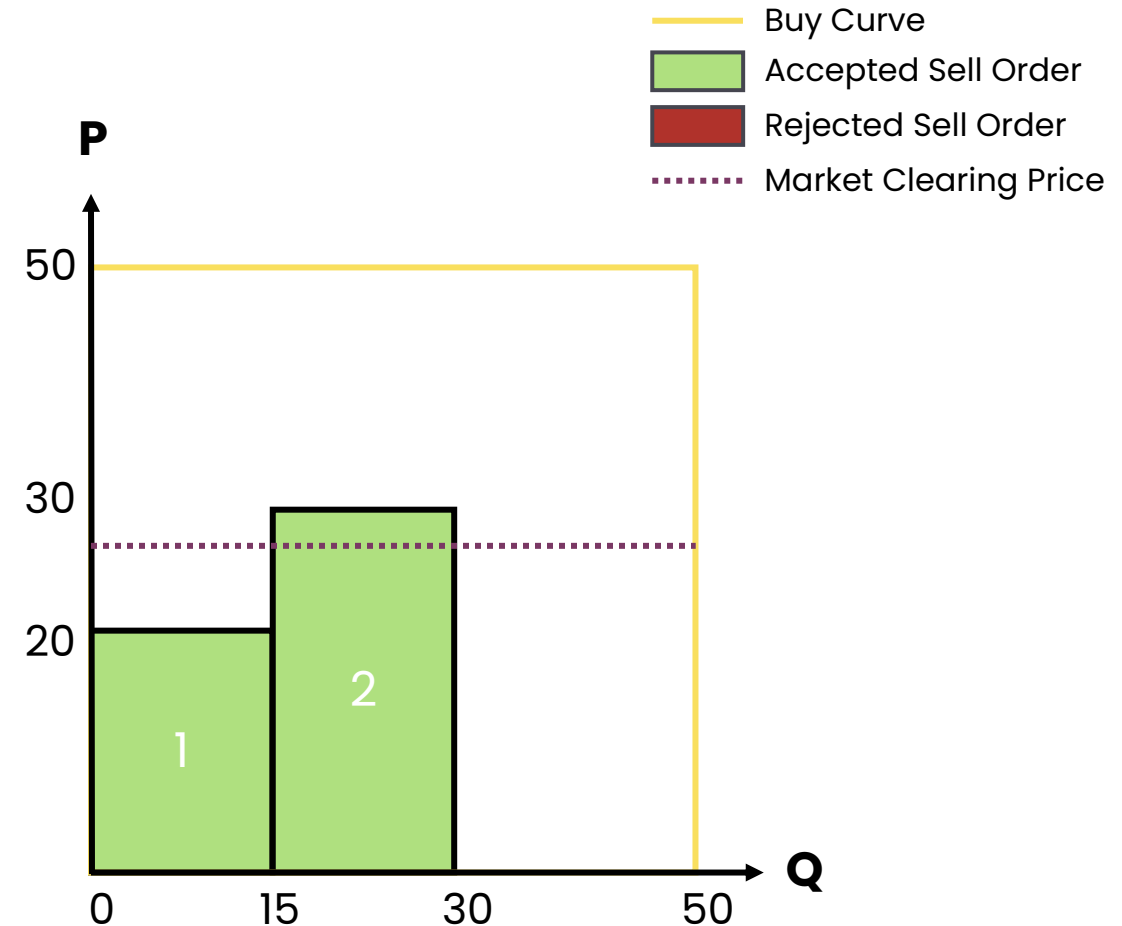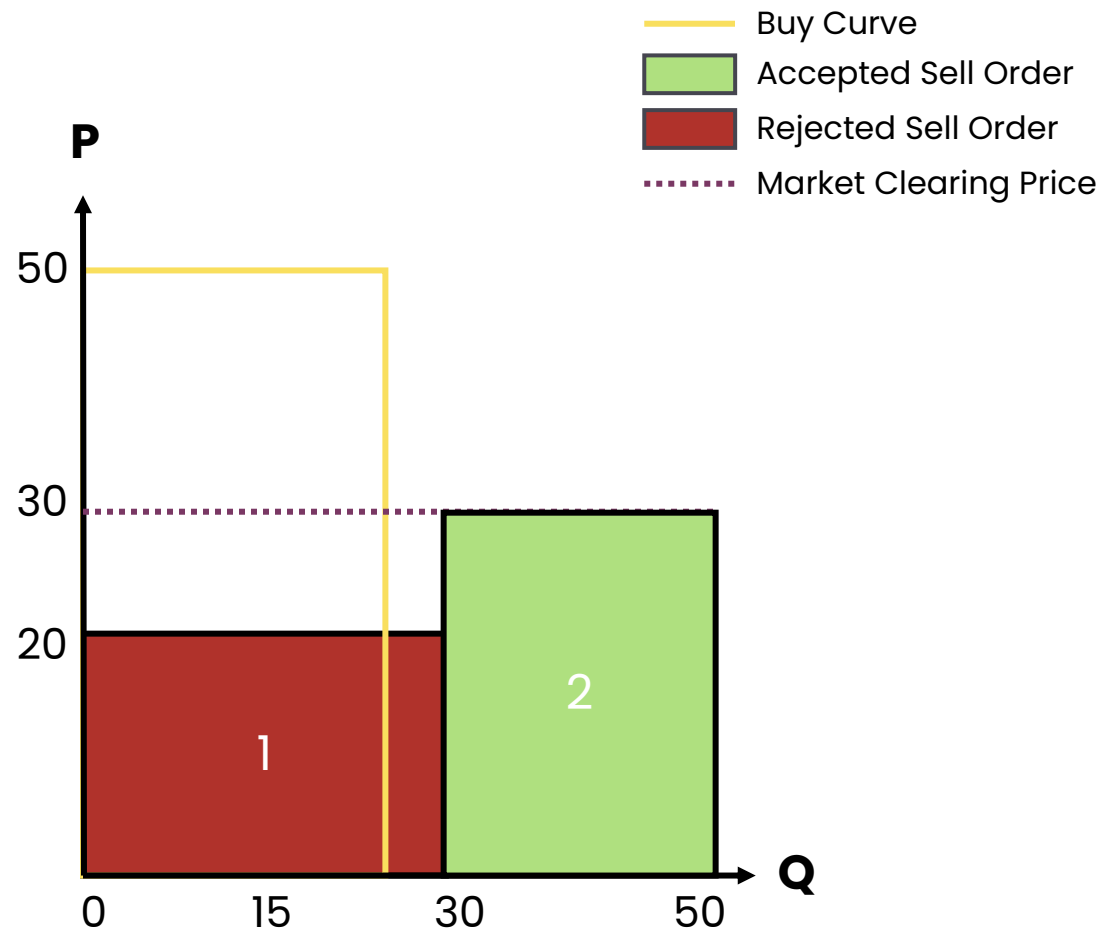
What is Paradoxical Acceptance?

Example 2a

If we accept both Sell Order 1 and 2 and set the clearing price at £51...

- The buy order, with a bid price of £50, is paradoxically accepted and generates negative surplus for the buyer.

- In this case, allowing buy orders to be paradoxically accepted does not provide good value.

- Why are buy orders still allowed to be paradoxically accepted? Please see next slide for an example.

Unit ID	Order ID	Order Type	Product	Volume	Price
U_01	1	Parent	A	15	20
U_02	2	Parent	A	15	30

Note: This solution maximises market welfare but violates market clearing rules. The expected clearing result is to accept both orders and the clearing price should be £30.

Legend:
- Buy Curve
- Accepted Sell Order
- Rejected Sell Order
- Market Clearing Price
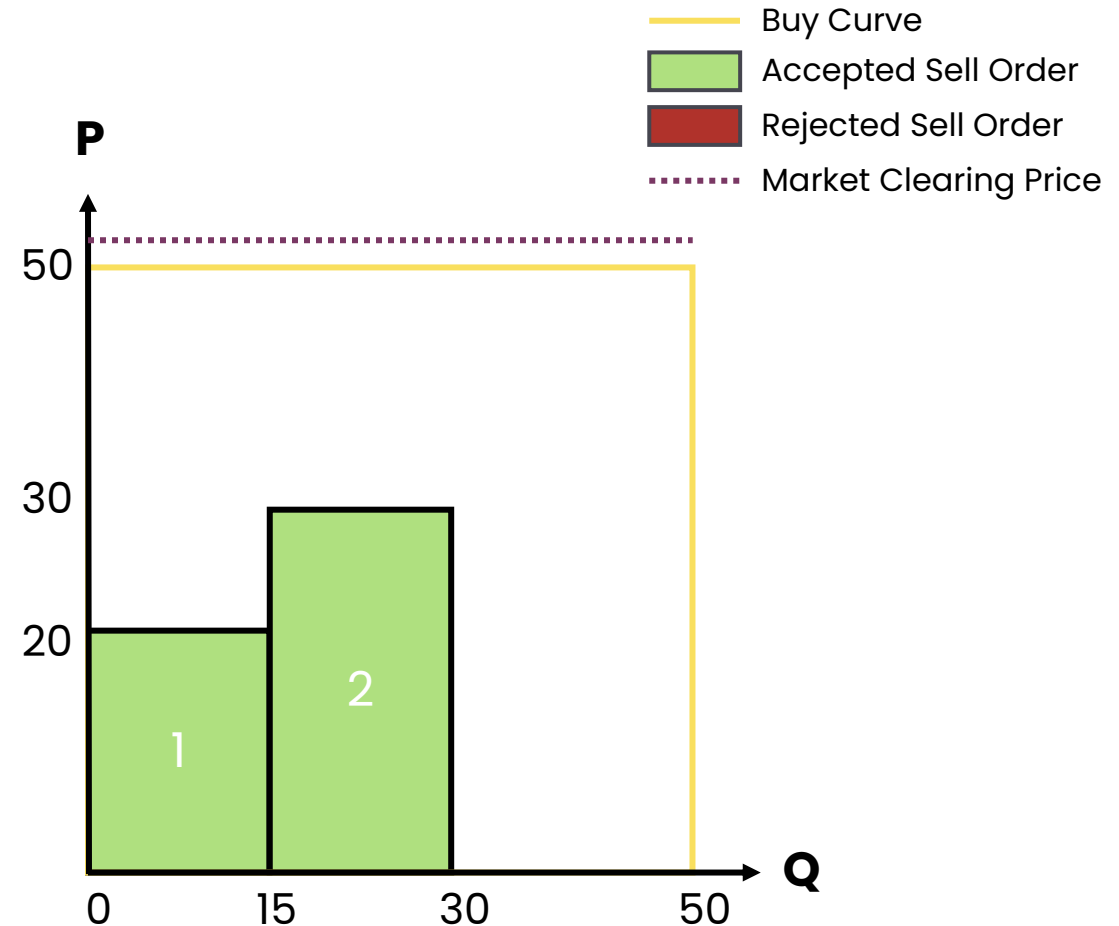
What is Paradoxical Acceptance?

Example 2b (Overholding)

We have an elastic buy curve that consists of two buy orders:

- **Buy Order 1:** 25MW, £50

- **Buy Order 2:** 25MW, £25

Accepting both orders generates the maximum welfare:

→ As illustrated in Example 1, sell orders are not allowed to be paradoxically accepted, the clearing price needs to be at least £30. If the clearing price is £30, accepting Buy Order 1 generates a positive surplus of £500/h, (partially) accepting Buy Order 2 generates a negative surplus of -£25/h, therefore Buy Order 2 is (partially) paradoxically accepted.

If buy orders cannot be paradoxically accepted, the optimal solution is to accept Sell Order 1 and reject Sell Order 2. The market clearing volume is 15MW. Total market welfare is £450/h.

If buy orders are allowed to be paradoxically accepted, the optimal solution is to accept both sell orders, fully accept Buy Order 1 and accept 20% (i.e., 5MW) of Buy Order 2. The market clearing volume is 30MW. The total market welfare is £625/h.

Unit ID	Order ID	Order Type	Product	Volume	Price
U_01	1	Parent	A	15	20
U_02	2	Parent	A	15	30
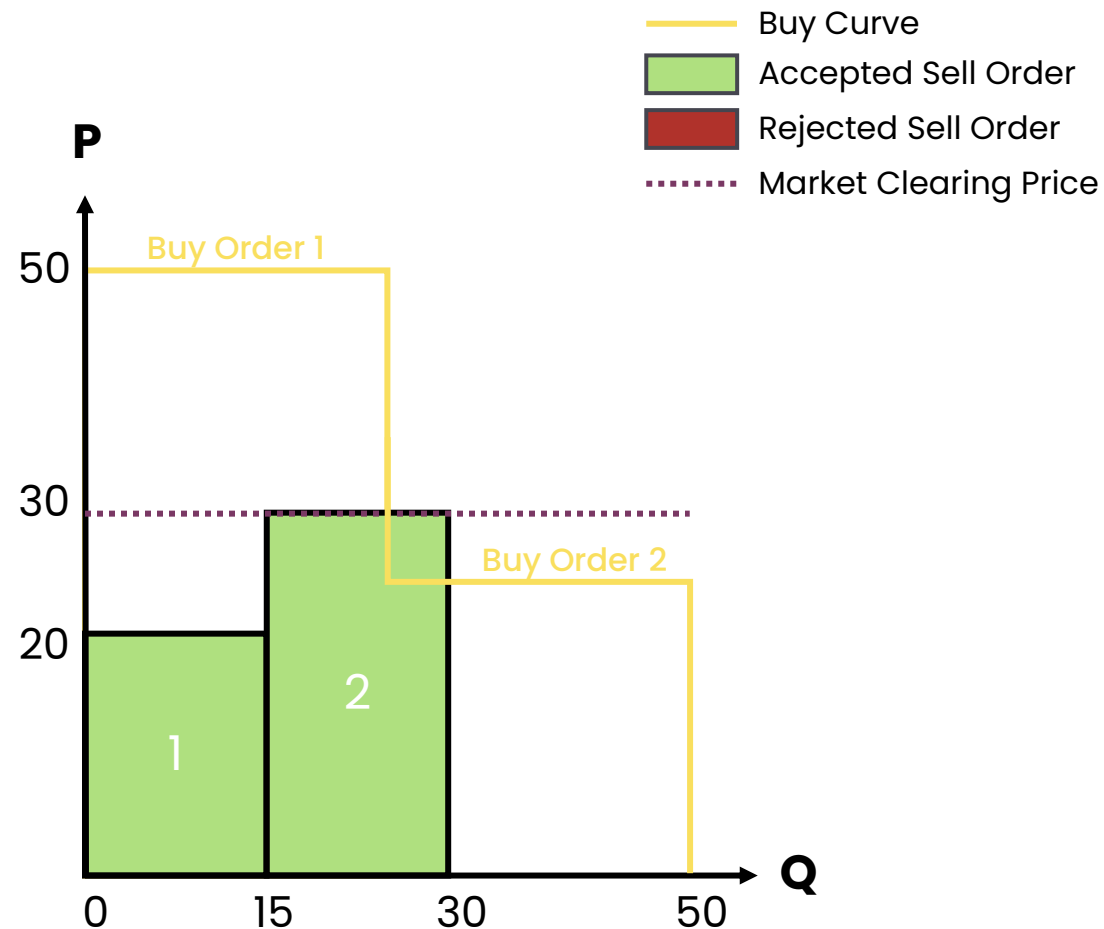
What is Paradoxical Rejection?

Paradoxical Rejection

An order which is (fully or partially) rejected while its total surplus (including the surplus transferred to its substitutability group) would be positive if it was accepted.

This section helps to answer the following questions:

Why sell orders are allowed to be paradoxically rejected?

- Allowing paradoxical rejection of sell orders (especially the non-curtailable ones) benefits market welfare maximisation. Not allowing (non-curtailable) sell orders to be paradoxically rejected may lead to infeasible solutions. Please see example 5.

Note: Buy orders are allowed to be paradoxically rejected both in the pre-EAC response auction design (i.e., EPEXSPOT) and in the EAC design in order to reduce procurement costs. As no changes are made on this rule, this rule is not discussed in details in this document.

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What is Paradoxical Rejection?

Example 3

If we reject Sell Order 2 and set the clearing price at £45…

- Sell Order 2 is paradoxically rejected. Because the order is "in-the-money", accepting the order would generate positive surplus.

Unit ID	Order ID	Order Type	Product	Volume	Price
U_01	1	Parent	A	15	20
U_02	2	Parent	A	15	30

Note: This solution does not maximise market welfare. The expected clearing result is to accept both orders and the clearing price should be £30.
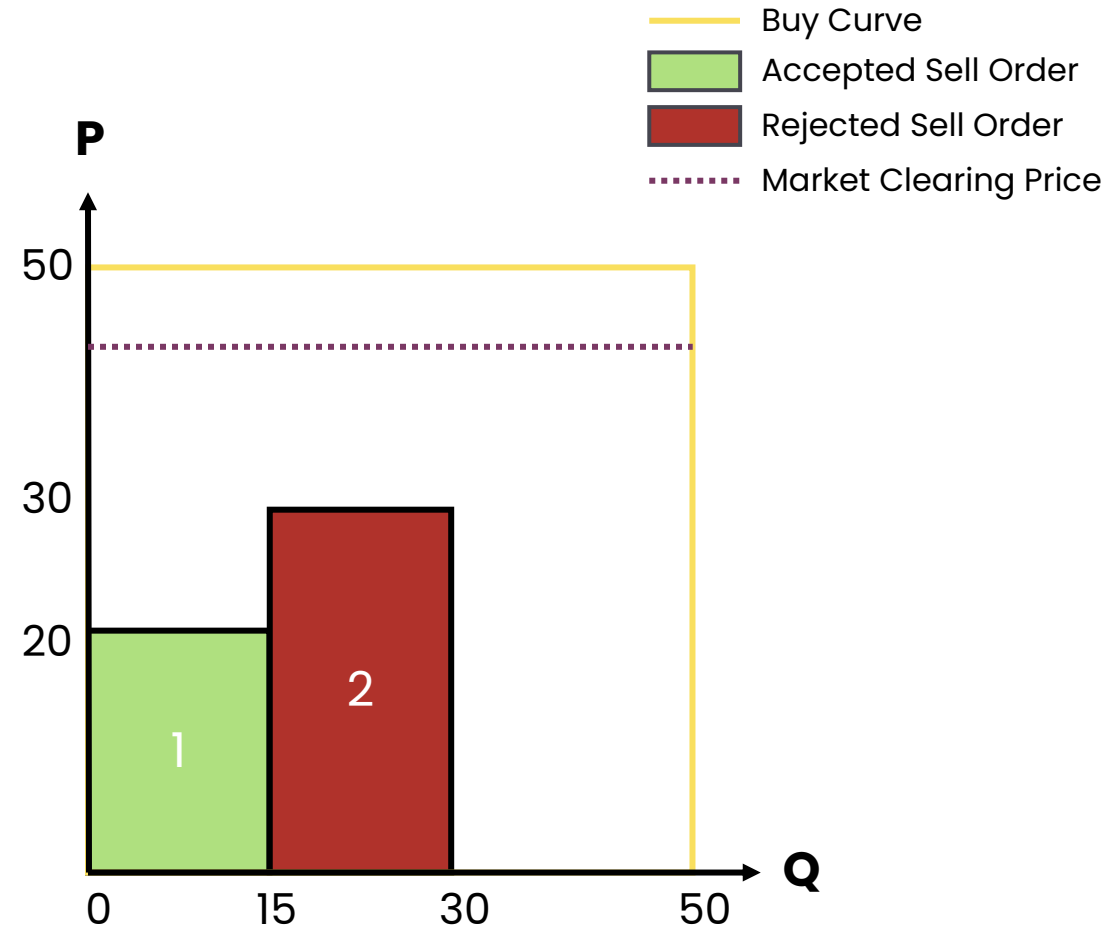
What is Paradoxical Rejection?

Example 4

If we reject both Sell Order 1 and 2 and set the clearing price at £25...

- Sell Order 1 is paradoxically rejected because the order is "in-the-money", accepting the order would generate positive surplus.

- Sell Order 2 is not paradoxically rejected because the order is "out-of-the-money", accepting the order would generate negative surplus

Unit ID	Order ID	Order Type	Product	Volume	Price
U_01	1	Parent	A	15	20
U_02	2	Parent	A	15	30

Note: This solution does not maximise market welfare. The expected clearing result is to accept both orders and the clearing price should be £30.

What is Paradoxical Rejection?

Example 5

In this example, both sell orders are non-curtailable orders.

We cannot accept Sell Order 1 because the offered volume of Sell Order 1 (30MW) is greater than the NESO requirement (25MW). Accepting Sell Order 2 alone can meet the requirement and the market clearing price needs to be at least £30 (to avoid paradoxical acceptance of Sell Order 2). However, Sell Order 1 has to be paradoxically rejected.

If sell orders are not allowed to be paradoxically rejected, there is no feasible solutions. The cleared volume is 0MW.

Allowing paradoxical rejection of sell orders (especially when they are non-curtailable) benefits market welfare maximisation. Not allowing (non-curtailable) sell orders to be paradoxically rejected may lead to infeasible solutions.

Type	Unit ID	Order ID	Order Type	Product	Volume	Price
Buy	–	a	–	A	25	50
Sell	U_01	1	Parent	A	30	20
Sell	U_02	2	Parent	A	25	30

Paradoxical Acceptance & Rejection Summary

Orders	Paradoxical	Clearing Rules	Order Surplus[1]	Order Virtual Surplus	Order Price v.s. Clearing Price	
Buy	Acceptance	Allowed[2]	Negative	Negative	Out-of-the-money	Order Price < Clearing Price
Buy	Rejection	Allowed	0	Positive	In-the-money	Order Price > Clearing Price
Sell	Acceptance	Not allowed	Negative	Negative	Out-of-the-money	Order Price > Clearing Price
Sell	Rejection	Allowed	0	Positive	In-the-money	Order Price < Clearing Price

Note:

[1] $Buy\ Order\ (Actual)\ Surplus = (Buy\ Order\ Price - Market\ Clearing\ Price) \times Executed\ Volume \times Duration$

$Sell\ Order\ (Actual)\ Surplus = (Market\ Clearing\ Price - Sell\ Order\ Price) \times Executed\ Volume \times Duration$

[2] In previous response auction design (i.e., EPEXSPOT), buy orders are not allowed to be paradoxical accepted. In the EAC, NESO may allow buy orders to be paradoxically accepted to allow overholding.

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Surplus Sharing

Surplus sharing within orders and baskets

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Calculation of Surplus for a Sell Order

The surplus of a sell order can be calculated as:

$$\left[\text{Clearing Price of Product} - \text{Offer Price of Sell Order}\right] \times \text{Contracted Quantity of Product}$$

For example, suppose we have the following sell order:

Unit ID	Loop Family	EFA	Basket ID	Order ID	Order Type	Quantity (MW)						Price (£)
						DCL	DCH	DML	DMH	DRL	DRH	
U-01		2	55	1	Parent					5		2.00

Suppose further that the market clearing price of **DRL** in this period is £10.00.

Then the surplus of this sell order is:

£(10.00 − 2.00) x 5 = £40.00 (/h)

> ### *Definition of Sell Order Surplus*
>
> *The surplus of a sell order is the difference between:*
>
> *(i) the minimum payment the seller requires for acceptance of the sell order, as implied by the offer price, and*
>
> *(ii) the actual settlement the seller will receive, based on the market clearing prices.*
>
> *This definition of surplus is the same for Parent, Child, and Substitutable Child Orders*

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Calculation of Surplus for a Sell Order

The surplus of a sell order can be calculated as:

$$\left[\text{Clearing Price of Product} - \text{Offer Price of Sell Order}\right] \times \text{Contracted Quantity of Product}$$

For example, suppose we have the following sell order:

Unit ID	Loop Family	EFA	Basket ID	Order ID	Order Type	Quantity (MW)						Price (£)
						DCL	DCH	DML	DMH	DRL	DRH	
U-01		2	55	1	Parent					5		2.00

Suppose further that the market clearing price of **DRL** in this period is £10.00.

Then the surplus of this sell order is:

$$£(10.00 - 2.00) \times 5 = £40.00 \ (/h)$$

DRL, EFA 2

P (£/MW/h)

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Calculation of Surplus for a Sell Order With Multiple Products

The surplus of a sell order can be calculated as:

$$\left[\text{Clearing Price of Product 1} - \text{Offer Price of Sell Order} \right] \times \text{Contracted Quantity of Product 1}$$

$$+ \left[\text{Clearing Price of Product 2} - \text{Offer Price of Sell Order} \right] \times \text{Contracted Quantity of Product 2}$$

$$\cdots$$

$$+ \left[\text{Clearing Price of Product N} - \text{Offer Price of Sell Order} \right] \times \text{Contracted Quantity of Product N}$$

> **A sell order can be defined on more than one product.**
>
> *Each product can have a unique quantity. The order has a single price.*
>
> *The surplus of the order is the sum of the surplus for all the products in the order.*

For example, suppose we have the following sell order:

Unit ID	Loop Family	EFA	Basket ID	Order ID	Order Type	Quantity (MW)						Price (£)
						DCL	DCH	DML	DMH	DRL	DRH	
U-01		2	55	1	Parent		6			5		2.00

Suppose further that the market clearing price of **DRL** in this period is £10.00, and the market clearing price of **DCH** is £3.00.

Then the surplus of this sell order is:

£(3.00 − 2.00) x 6 + £(10.00 − 2.00) x 5 = £46.00 (/h)

Surplus for DCH   Surplus for DRL

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What is Surplus Sharing

Surplus Sharing

Sell orders cannot be Paradoxically Accepted.

- **A sell order can be accepted only if its surplus is greater than or equal to zero.**

- *A sell order must make at least as much revenue as required by its offer price.*

Surplus can be shared between within and between sell orders. A sell order with surplus greater than zero can donate its "excess" surplus to another sell order to compensate for negative surplus.

Transfers of surplus can happen in either of the following scenarios:

A. Surplus can transfer within any sell order that is defined on multiple products

B. Surplus can transfer within a family of looped baskets

C. Surplus can also transfer from Child or Substitutable Child Orders the Parent Order

Note: The feature of surplus sharing is not new in EAC. In the previous Daily Dx Frequency Response Auctions (i.e., EPEXSPOT), the market design allowed surplus sharing from a Child Order to a Parent Order, within periods of a Multi-Period Block, and between Looped (C88) Orders.

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A. Surplus Sharing within a Sell Order which is Defined on Multiple Products

Parent | DCL 5MW | DCH 10MW

Child | DCL 5MW | DCH 10MW

Substitutable Child | DCL 5MW | DCH 10MW

Legend:
- Parent
- Child
- Substitutable child
- Transfer of surplus

If an order is defined on more than two products, surplus may transfer between any two products. For example, surplus may transfer from DCH to DCL, from DRL to DCL, and from DRH to DCL.
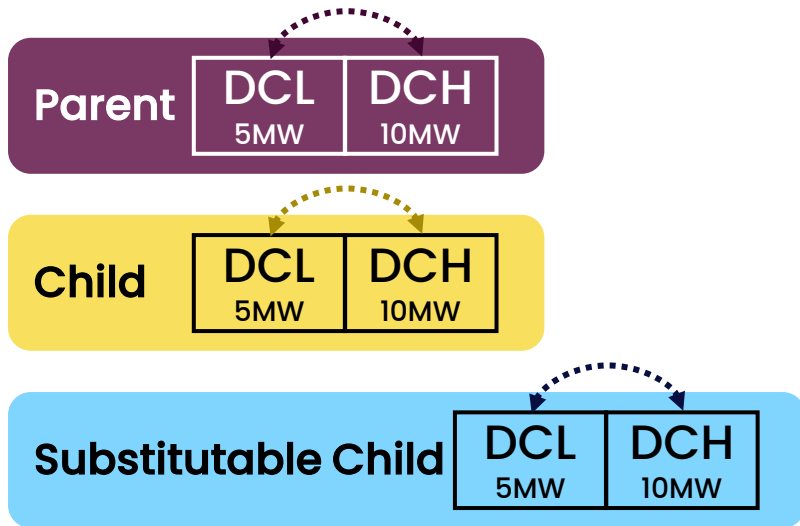
If an order is defined on two products, surplus may transfer from one product to the other. In the three examples, surplus may transfer from DCL to DCH, or from DCH to DCL.

Child | DCL 5MW | DCH 10MW | DRL 10MW | DRH 10MW

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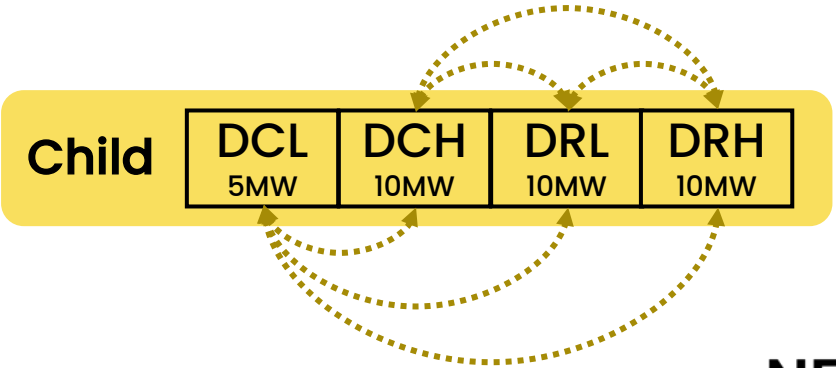
Acceptance of a Child or Substitutable Child Order

Market Clearing Rules

For a Child Order or Substitutable Child Order to be accepted, the total surplus of the order must be greater than or equal to zero.

The individual surplus of each product does not need to be non-negative.

A Child Order or a Substitutable Child Order defined on multiple products can be accepted, even if some products in the order have negative surplus.

For example, suppose we have the following sell order shown below.

Suppose further that the market clearing price of **DRL** in this period is £10.00, and the market clearing price of **DCH** is £3.00.

Then the surplus with respect to **DCH** is:

$$£(3.00 − 4.00) \times 6 = −£6.00$$

And the surplus with respect to **DRL** is:

$$£(10.00 − 4.00) \times 5 = £30.00$$

The total surplus of the sell order is:

$$−£6.00 + £30.00 = £24.00$$

The sell order can be accepted.

Unit ID	Loop Family	EFA	Basket ID	Order ID	Order Type	Quantity (MW)						Price (£)
						DCL	DCH	DML	DMH	DRL	DRH	
U−01		2	55	1	Child		6			5		4.00

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Acceptance of a Child or Substitutable Child Order
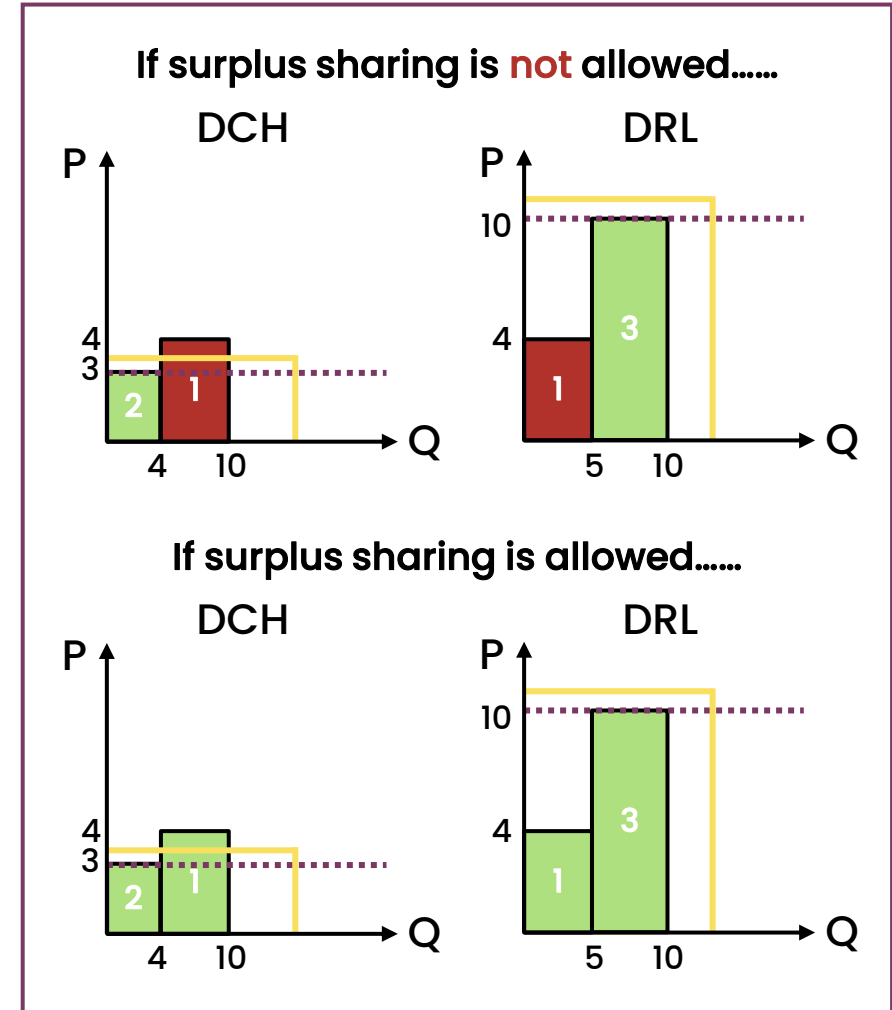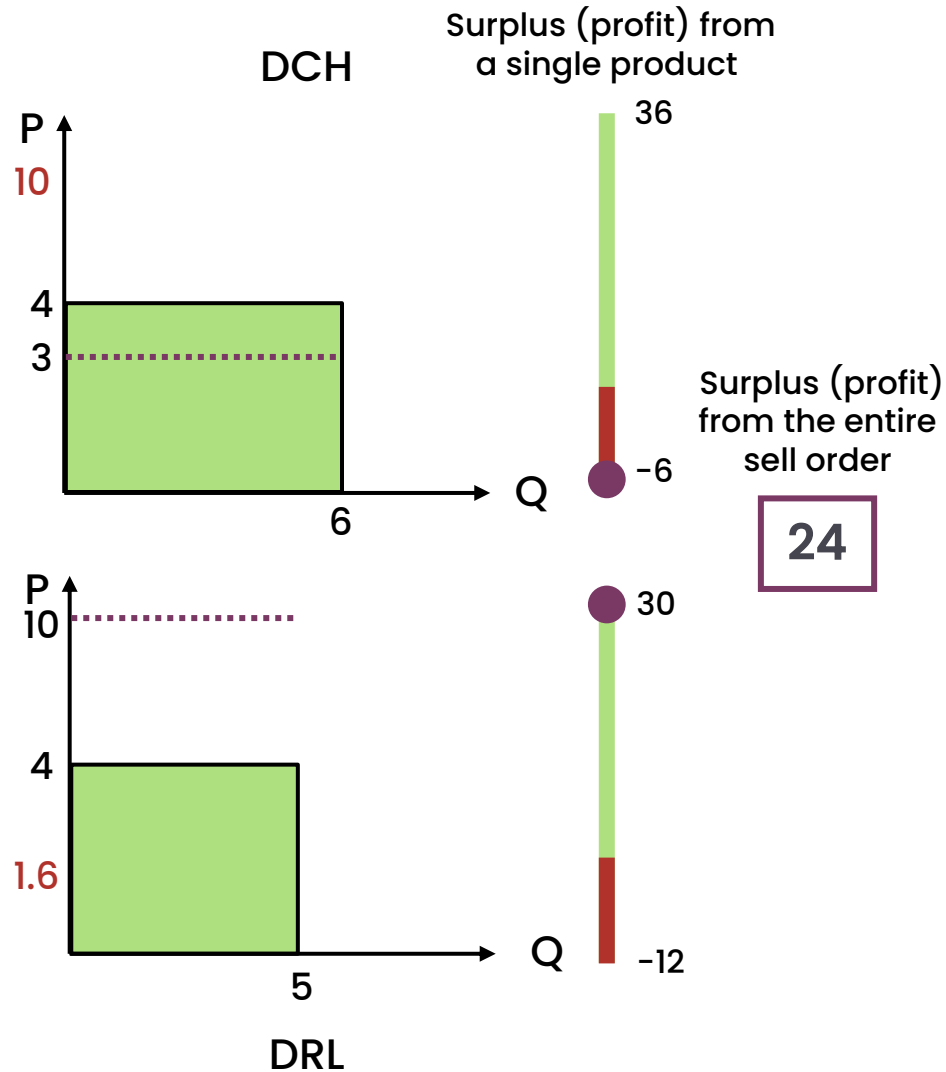
B. Surplus Sharing within a Family of Looped Baskets

Market Clearing Rules

A Parent Order with negative surplus can be accepted when it is in a Basket that is part of a Looped Family, and the total surplus of all accepted orders in all Baskets in the Looped Family is greater than or equal to zero.

A Basket which is part of a Looped Family cannot be accepted unless all the Baskets in the Looped Family are accepted.

A Basket can share surplus with other Baskets in its Looped Family

Basket Family

- Basket 1
- Basket 2

Basket Family

- Basket 1
- Basket 2
- Basket 3

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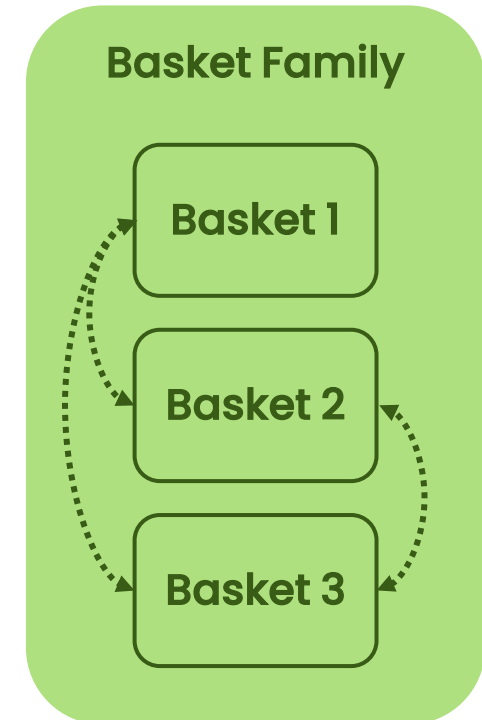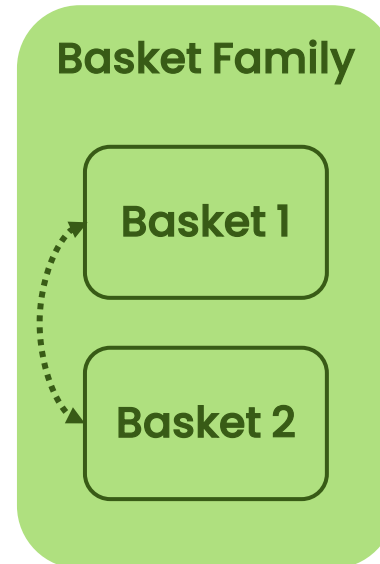
Acceptance of a Looped Family of Baskets

For example, suppose we have the Looped Family of Baskets shown below.

As before, the market clearing price of **DRL** in this period is £10.00, and the market clearing price of **DCH** is £3.00.

Then the surplus of the Parent Order in **Basket 55** is:

$$£(3.00 - 4.00) \times 6 = -£6.00$$

And the surplus of the Parent Order in **Basket 56** is:

$$£(10.00 - 2.00) \times 5 = £40.00$$

The total surplus of both Baskets in the Looped Family is:

$$-£6.00 + £40.00 = £34.00$$

So the Parent Orders in Basket 55 and Basket 56 can both be accepted together.

Unit ID	Loop Family	EFA	Basket ID	Order ID	Order Type	Quantity (MW)						Price (£)
						DCL	DCH	DML	DMH	DRL	DRH	
U-01	16	2	55	1	Parent		6					4.00
U-01	16	3	56	4	Parent					5		2.00

If surplus sharing is **not** allowed......

If surplus sharing is allowed......
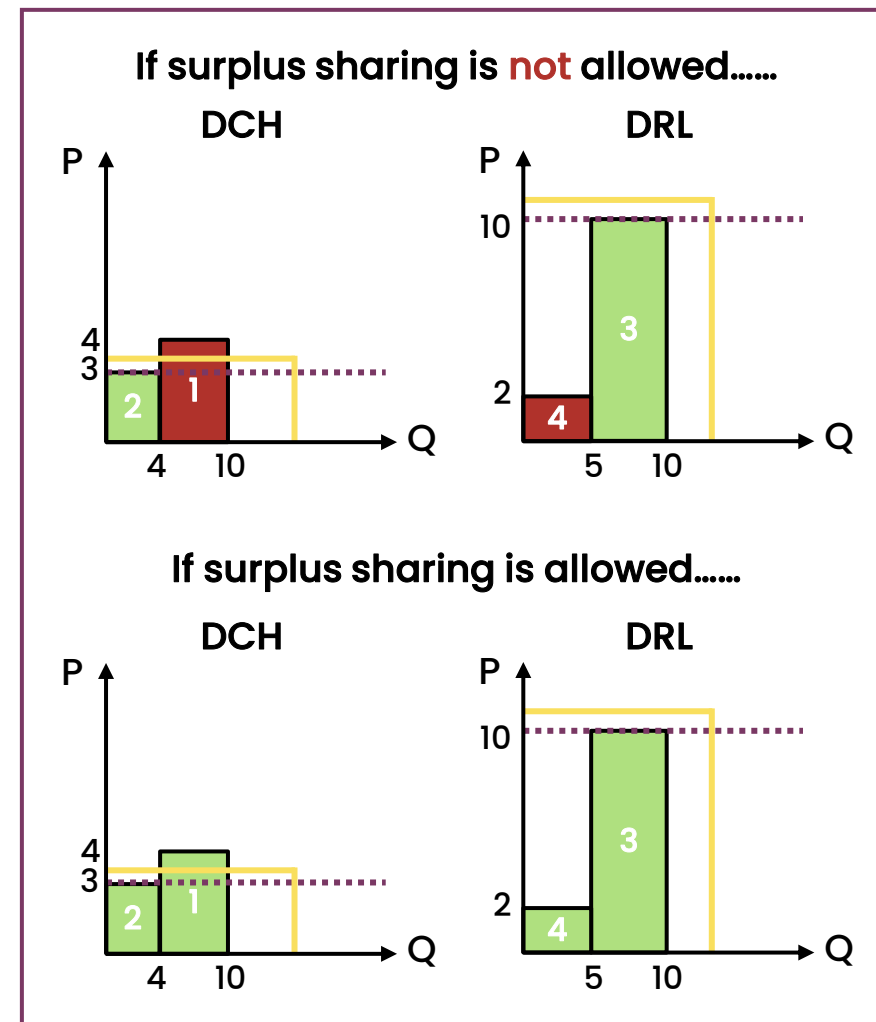
C. Surplus Sharing from a Child or Substitutable Child Order to its Parent Order

Market Clearing Rules

For a Parent Order to be accepted, the surplus of the Basket must be greater than or equal to zero.

The surplus of Basket is the total of the surplus of the Parent Order plus the surplus of all accepted Child Orders and Substitutable Child Orders in the Basket.

A Child Order or Substitutable Child Order can transfer surplus to its Parent.

The Parent Order may have negative surplus on its own, yet still be accepted, if it receives surplus.

A Child Order or Substitutable Child Order cannot be accepted unless the Parent Order in the Basket is accepted.
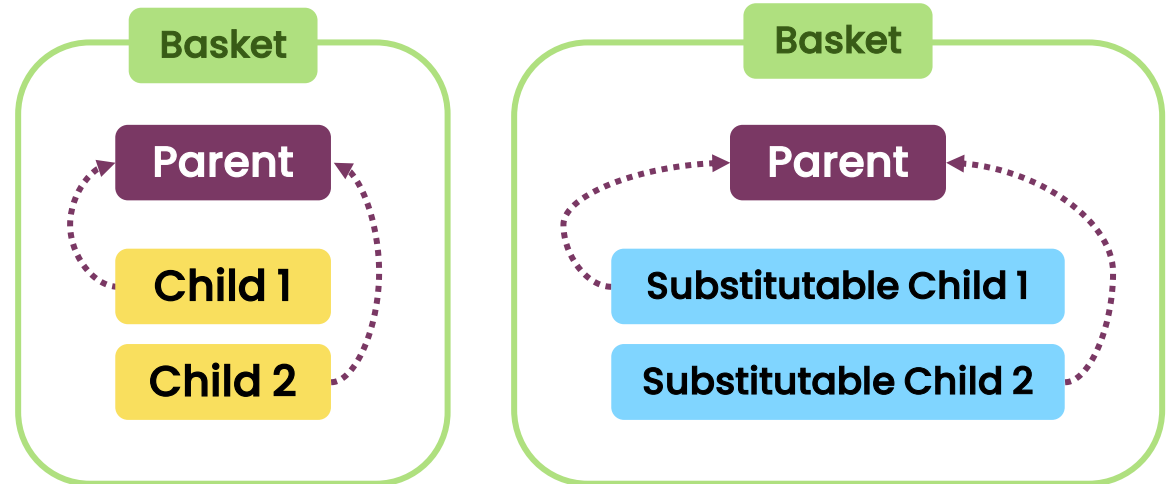
Acceptance of a Parent Order

For example, suppose we have the sell order shown below.

As before, the market clearing price of **DRL** in this period is £10.00, and the market clearing price of **DCH** is £3.00.

Then the surplus of the Parent Order is:

$$£(3.00 − 4.00) \times 6 = −£6.00$$

So this Parent Order cannot be accepted by itself. But the surplus of the Child Order is:

$$£(10.00 − 2.00) \times 5 = £40.00$$

The total surplus of the Basket is:

$$−£6.00 + £40.00 = £34.00$$

The Parent Order and the Child Order can both be accepted together.

Unit ID	Loop Family	EFA	Basket ID	Order ID	Order Type	Quantity (MW)						Price (£)
						DCL	DCH	DML	DMH	DRL	DRH	
U-01		2	55	1	Parent		6					4.00
U-01		2	55	4	Child					5		2.00

If surplus sharing is not allowed……

DCH   DRL

If surplus sharing is allowed……

DCH   DRL

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Preventing Sell Orders from Sharing Surplus [1/4]

Basket Family
Basket 1   Basket 2
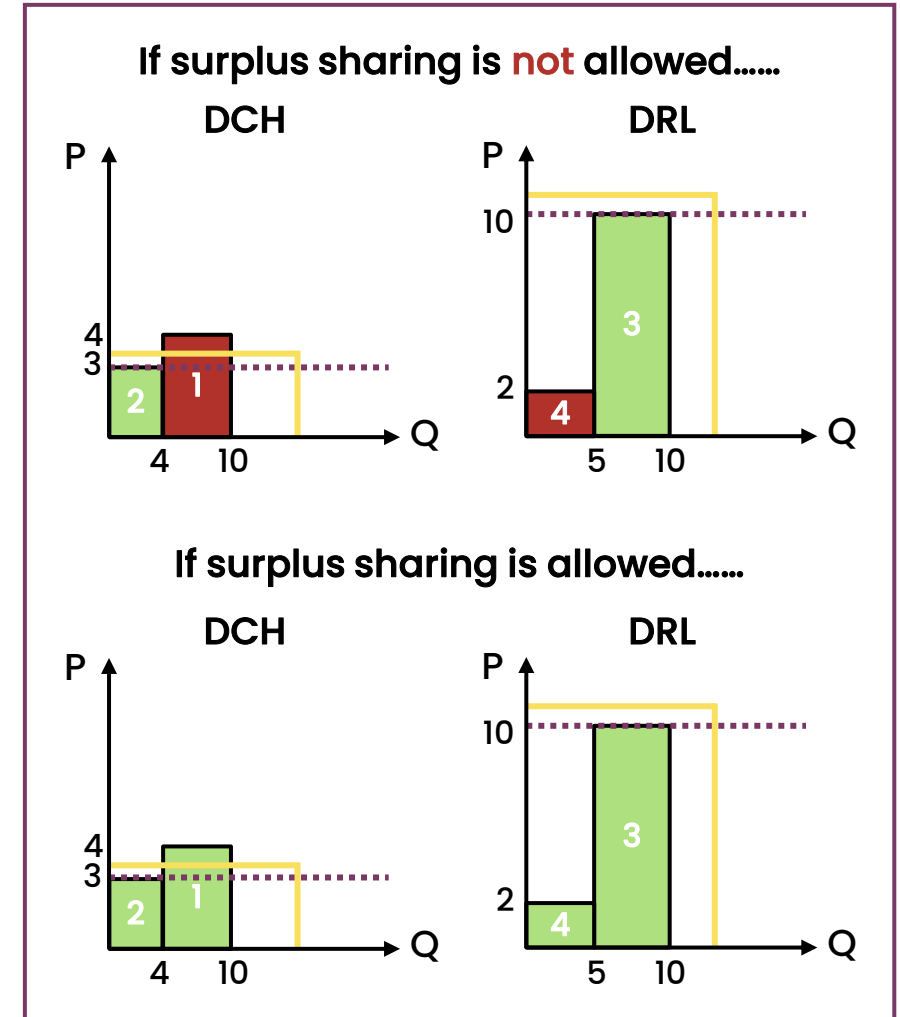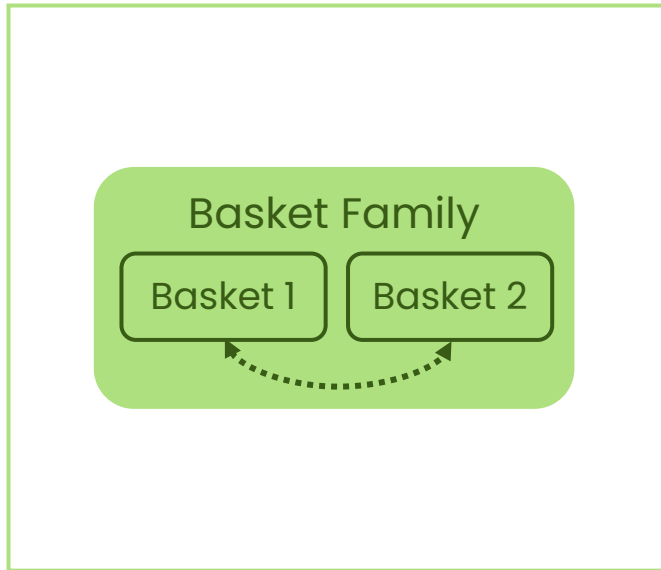
Unloop all baskets

Basket 1   Basket 2
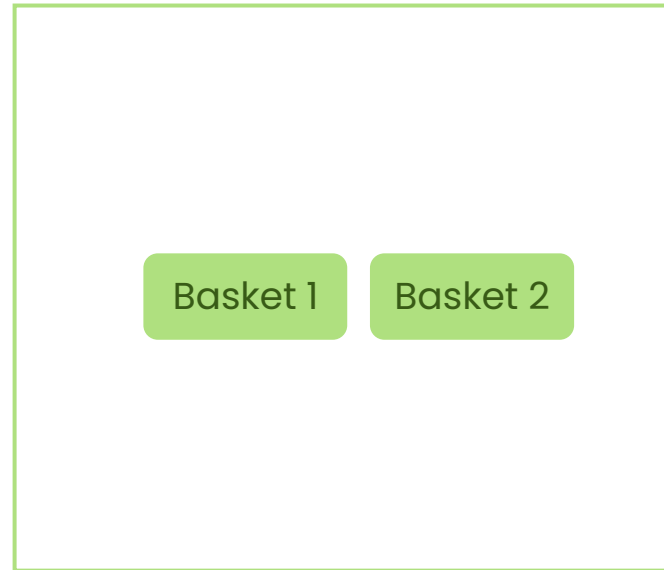
Preventing Sell Orders from Sharing Surplus [2/4]
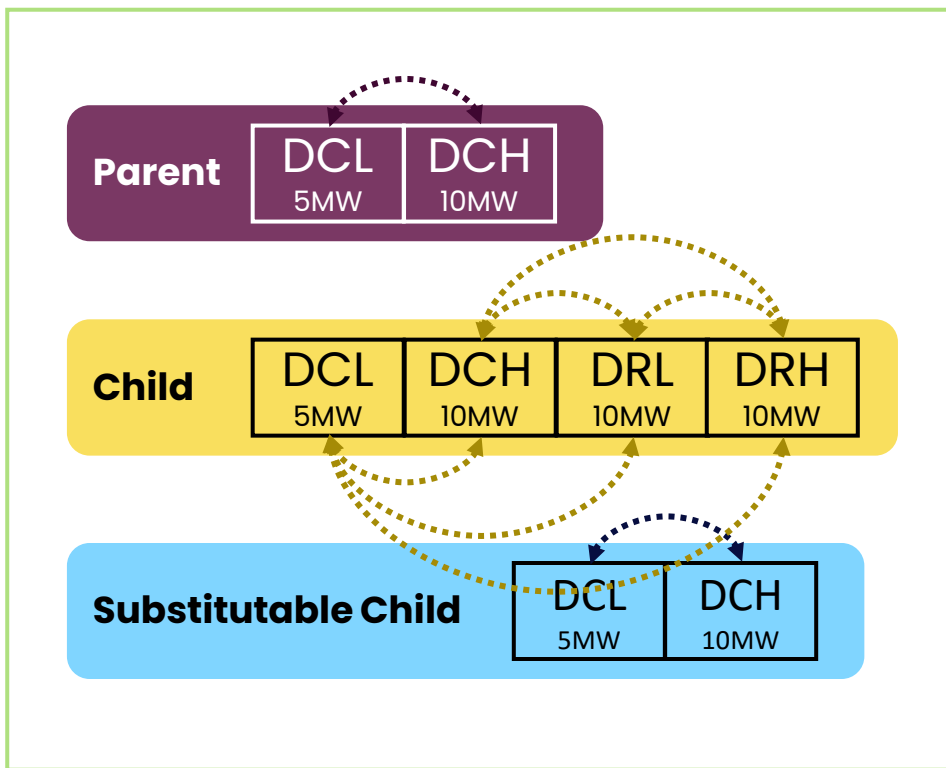
Each sell order is only defined on 1 product only
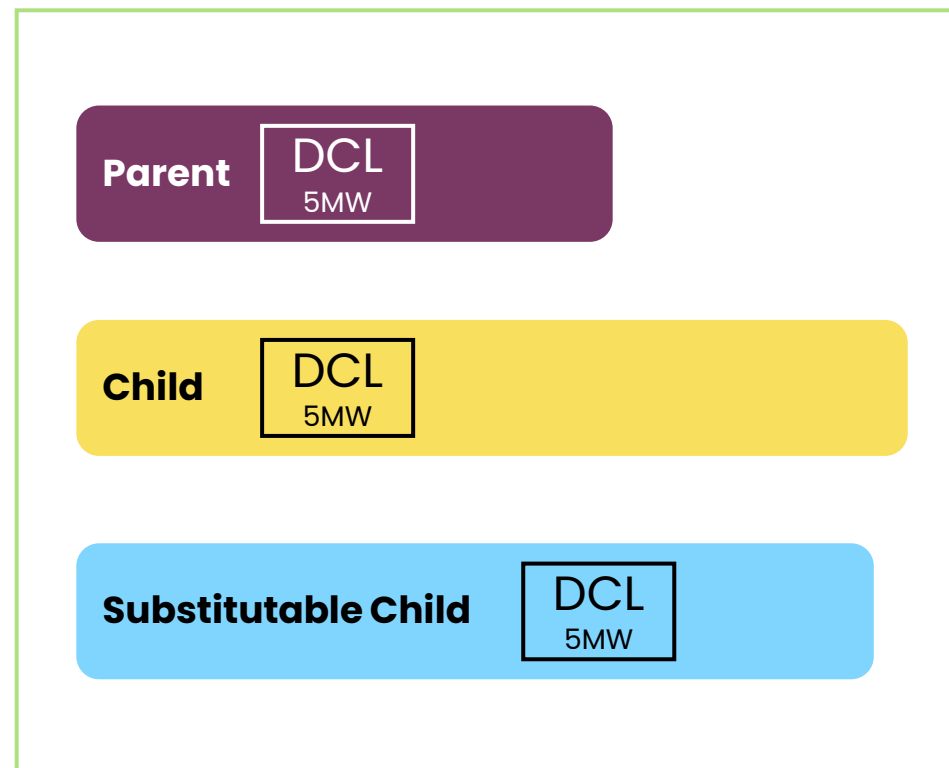
Preventing Sell Orders from Sharing Surplus [3/4]

Child Orders and Substitutable Child Orders cannot receive surplus from another sell order.

But the different products within each order can share surplus.

If a Child Order or Substitutable Child Order is defined on a single product only, then there will be no surplus sharing.

Sell Order Strategy

Offer a Basket containing:

- A 0 MW Parent Order; and

- One or more Child or Substitutable Child Orders, each defined on only a single product.

Note: The entire Basket will be fully curtailable.

If an order is accepted, the market clearing price will never be below the offer price of the order.

Option 1

Basket	
Parent	Any 0MW
Child 1	DCH 2MW
Child 2	DMH 3MW
Substitutable Child 1	DCL 20MW
Substitutable Child 2	DRL 10MW
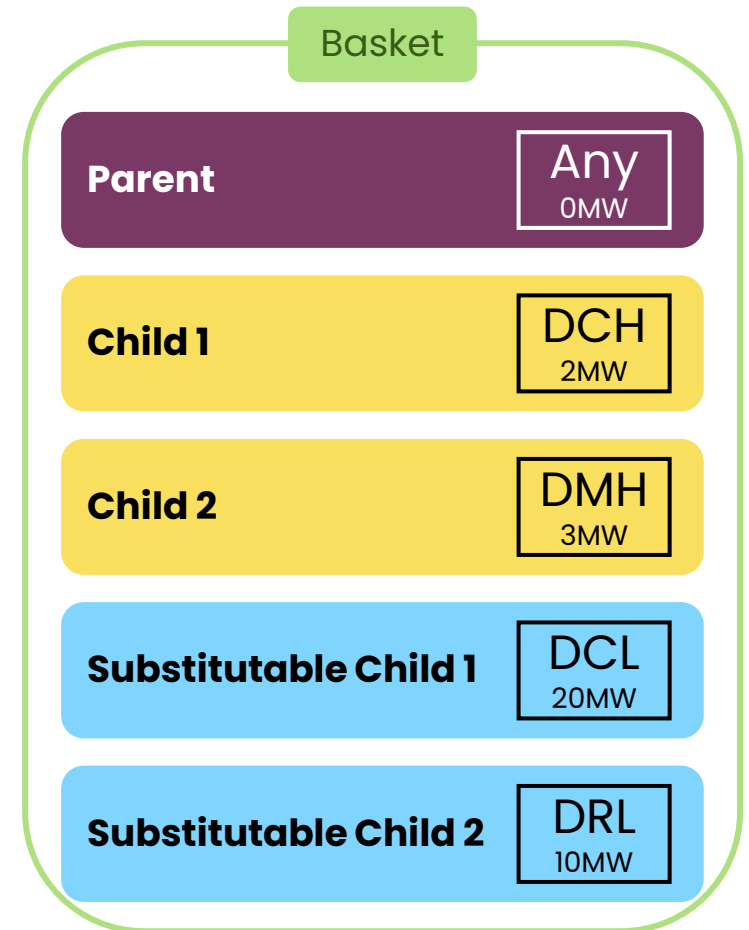
Preventing Sell Orders from Sharing Surplus [4/4]

A Parent Order is always non-curtailable. It must be accepted for the full offered quantity, or rejected.

A Parent Order can receive surplus from a Child Order or a Substitutable Child Order.

Child Orders cannot receive surplus from another sell order.

Sell Order Strategy

Offer a Basket defined on only one product. The Basket will contain orders (one Parent Order, and zero or more Child Orders) each defined on the same product.

Note: there can be no splitting (not even between HF and LF products of the same service).

The provider can control the curtailability of the offer.

The market clearing price will never be below the offer price of the cheapest accepted sell order.

Option 2

Basket

Parent	DCL 5MW

Child 1	DCL 2MW

Child 2	DCL 8MW

Child 3	DCL 10MW

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Case Studies

With historical auction data...

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EAC Case 1: EFA 5, DCH, Auction Date 7/Nov/2023

This auction cleared at £-7.56/MW/h despite all sell orders were offered above the price. This is due to the surplus sharing between looped sell orders:

- All executed DCH sell orders were offered in baskets that also offered DCL. Either the sell orders looped DCH and DCL (two or more products in the same order) or had parents defined on DCH and children defined on DCL.

- As per market design, surplus can transfer within a looped order (this feature exists since EPEX and is kept in EAC). For a looped sell order that is defined on product A and product B, it is possible accept the entire order when the part on product A is out-of-the-money whilst the part on product B is in-the-money, if the entire sell order has non-negative surplus. For example, basket 37859 only has a parent order, this order has a surplus of 1939.52 in DCL and a surplus of -1629.76 in DCH, the order has a total surplus of 309.76.

- Surplus can also transfer from child orders to parent orders (but not from parent orders to child orders; this feature also exists since EPEX and is kept in EAC). It is possible to accept a parent that is out-of-the-money if its children are deeply in-the-money so that the entire parent-children family has non-negative surplus. For example, basket 37654 has a parent order and three child orders, the parent order has a negative surplus of -137.04, three child orders have total surplus of 513.36, hence the entire basket has a total (positive) surplus of 376.32.

Note: The parent order of basket 36895 has 0 surplus which was likely to be the marginal order and set the clearing prices.

2023-11-07, DCH, EFA 5: 615MW cleared at -7.56£/MW/h
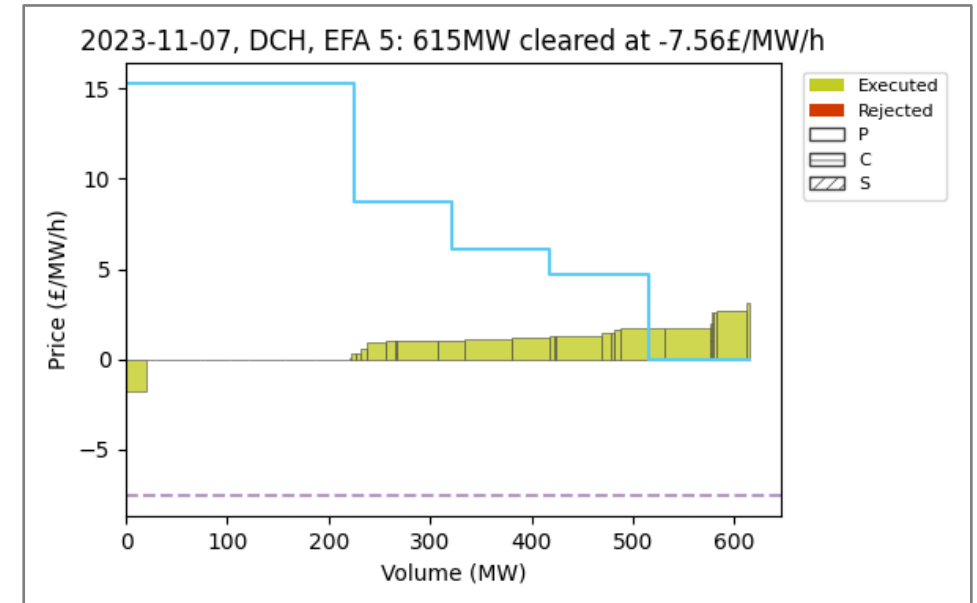
Appendix

A. Auction Overview

B. Service Windows

C. Specification of Baskets and Orders

D. Market Clearing Rules explained in Plain English

E. Differences between Sell Order Types

F. Rejection Codes

G. Useful Links

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Appendix A

Auction Overview

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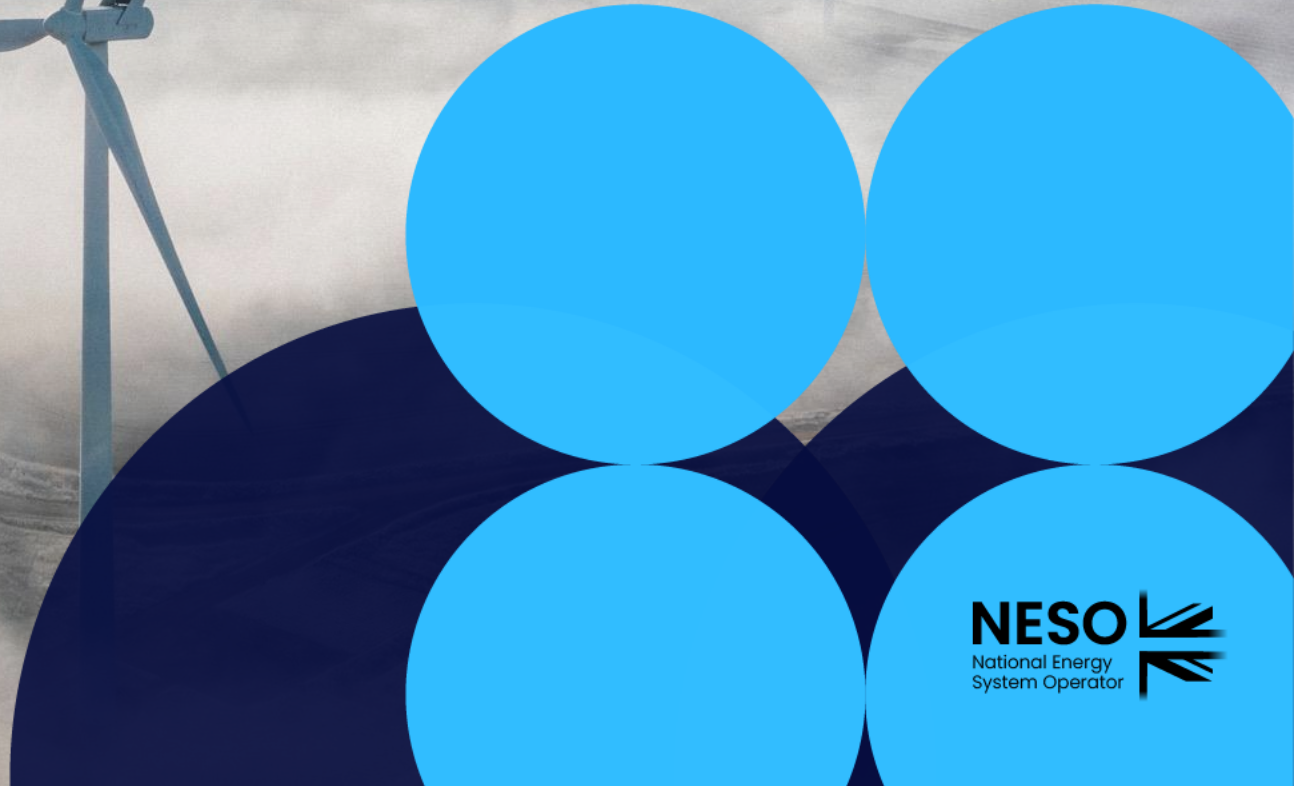
Auction Overview

Design	EAC Auction	Balancing Reserve Auction

Services Auctioned	• The **EAC Auction** is used for the clearing of capacity (availability) for the following services:
	   ○ **Frequency Response Services:** Dynamic Containment (DC), Dynamic Moderation (DM), and Dynamic Regulation (DR).
	   ○ **Reserve Services:** Quick Reserve (QR), Slow Reserve (SR).
	 • For every service, there are 2 product directions.
	   ○ **Low (L) and High (H)** Products for <u>Response Services</u> (resulting in DRL and DRH, DML and DMH, DCL and DCH).
	   ○ **Positive (P) and Negative (N)** Products for <u>Reserve Services</u> (resulting in PQR and NQR, PSR and NSR).
		• The **Balancing Reserve Auction** is used for the clearing of capacity (availability) for the following services:
		   ○ **Reserve Services:** Balancing Reserve (BR)
		 • For every service, there are 2 product directions.
		   ○ **Positive (P) and Negative (N)** Products for <u>Reserve Services</u> (resulting in PBR and NBR).

Auction Frequency	• DC, DM, DR, QR and SR will be procured in a single, simultaneous **day-ahead auction** held <u>daily</u>.	• BR will be procured in a single, simultaneous **day-ahead auction** held <u>daily</u>.
Auction Design	• **Auction type:** Closed double-sided auction. • **Objective function:** Maximisation of social welfare. • **Pricing:** Uniform clearing price per product for each service window. • **Locational granularity:** GB synchronous area. • **Overholding** allowed (cleared quantity may exceed NESO bid quantity). • **Procurement:** Capacity (MW).	

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Auction Overview

Design	Co-optimised Response & Reserve Auction		Balancing Reserve Auction
	Response	**QR**	
Auction Timing			
Gate Opening	08:00 BST/GMT D-15		08:00 BST/GMT D-15
Gate Closure	14:00 BST/GMT D-1		08:15 BST/GMT D-1
Publication of Results on UI	By 14:30 BST/GMT D-1		By 08:30 BST/GMT D-1
Publication of Results on Data Portal	By 15:00 BST/GMT D-1		By 08:45 BST/GMT D-1
Sell Order Design			
Number of Baskets per Unit per EFA day	25	100	100
Number of Parent Orders per Basket	Must be 1	Must be 1	Must be 1
Number of Child Orders per Basket	No more than 10	No more than 10	No more than 10
Number of Substitutable Child Orders per Basket	No more than 10	No more than 10	No more than 10
Technical Parameters			
Technical Minimum Prices (£/MW/h)	-20	0	0
Technical Maximum Prices (£/MW/h)	999.99	999.99	10000
Minimum Contract Size (MW)	1	1	1

Note: "D" stands for "delivery date".

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Appendix B

Service Windows

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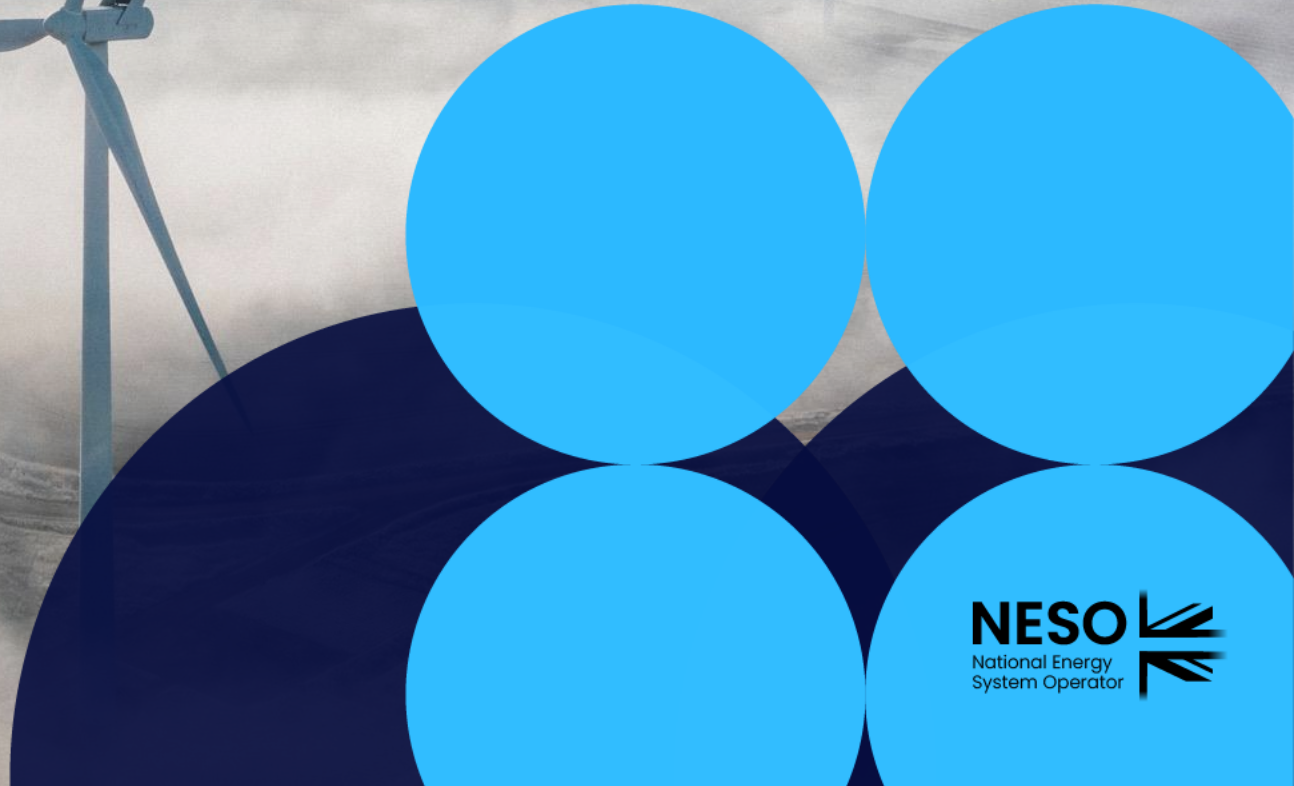
Service Windows

DC, DM, DR	Quick Reserve	Slow Reserve	Balancing Reserve
six 4-hour EFA blocks • EFA 1: 23:00–03:00 • EFA 2: 03:00–07:00 • EFA 3: 07:00–11:00 • EFA 4: 11:00–15:00 • EFA 5: 15:00–19:00 • EFA 6: 19:00–23:00	**forty-eight 30-minute blocks** • 23:00–23:30, 23:30–00:00, 00:00–00:30, 00:30–01:00, 01:00–01:30; 01:30–02:00, 02:00–02:30, 02:30–03:00 • 03:00–03:30, 03:30–04:00, 04:00–04:30, 04:40–05:00, 05:00–05:30, 05:30–06:00, 06:00–06:30, 06:30–07:00 • 07:00–07:30, 07:30–08:00, 08:00–08:30, 08:30–09:00, 09:00–09:30, 09:30–10:00, 10:00–10:30, 10:30–11:00 • 11:00–11:30, 11:30–12:00, 12:00–12:30, 12:30–13:00, 13:00–13:30, 13:30–14:00, 14:00–14:30, 14:30–15:00 • 15:00–15:30, 15:30–16:00, 16:00–16:30, 16:30–17:00, 17:00–17:30, 17:30–18:00, 18:00–18:30, 18:30–19:00 • 19:00–19:30, 19:30–20:00, 20:00–20:30, 20:30–21:00, 21:00–21:30, 21:30–22:00, 22:00–22:30, 22:30–23:00		

Note: The Slow Reserve service window is subject to change.

Service Windows

Clocks go forward (March)

GMT

| 23:00 | 23:30 | 00:00 | 00:30 | 01:00 | 01:30 | 02:00 | 02:30 | 03:00 | 03:30 | 04:00 | 04:30 | 05:00 | 05:30 | 06:00 | 06:30 | 07:00 | 07:30 | 08:00 | 08:30 | 09:00 | 09:30 | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 | 16:30 | 17:00 | 17:30 | 18:00 | 18:30 | 19:00 | 19:30 | 20:00 | 20:30 | 21:00 | 21:30 | 22:00 |

Local Time

| 23:00 | 23:30 | 00:00 | 00:30 | 02:00 | 02:30 | 03:00 | 03:30 | 04:00 | 04:30 | 05:00 | 05:30 | 06:00 | 06:30 | 07:00 | 07:30 | 08:00 | 08:30 | 09:00 | 09:30 | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 | 16:30 | 17:00 | 17:30 | 18:00 | 18:30 | 19:00 | 19:30 | 20:00 | 20:30 | 21:00 | 21:30 | 22:00 | 22:30 | 23:00 |

BR

| 1 | 2 | 3 | 4 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |

DC, DM, DR

| EFA 1 | | | | | | EFA 2 | | | | | | | | EFA 3 | | | | | | | | EFA 4 | | | | | | | | EFA 5 | | | | | | | | EFA 6 | | | | | | | |

QR

| 1 | 2 | 3 | 4 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |

SR

| 1 | 2 | 3 | 4 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |

Note: The Slow Reserve service window is subject to change.

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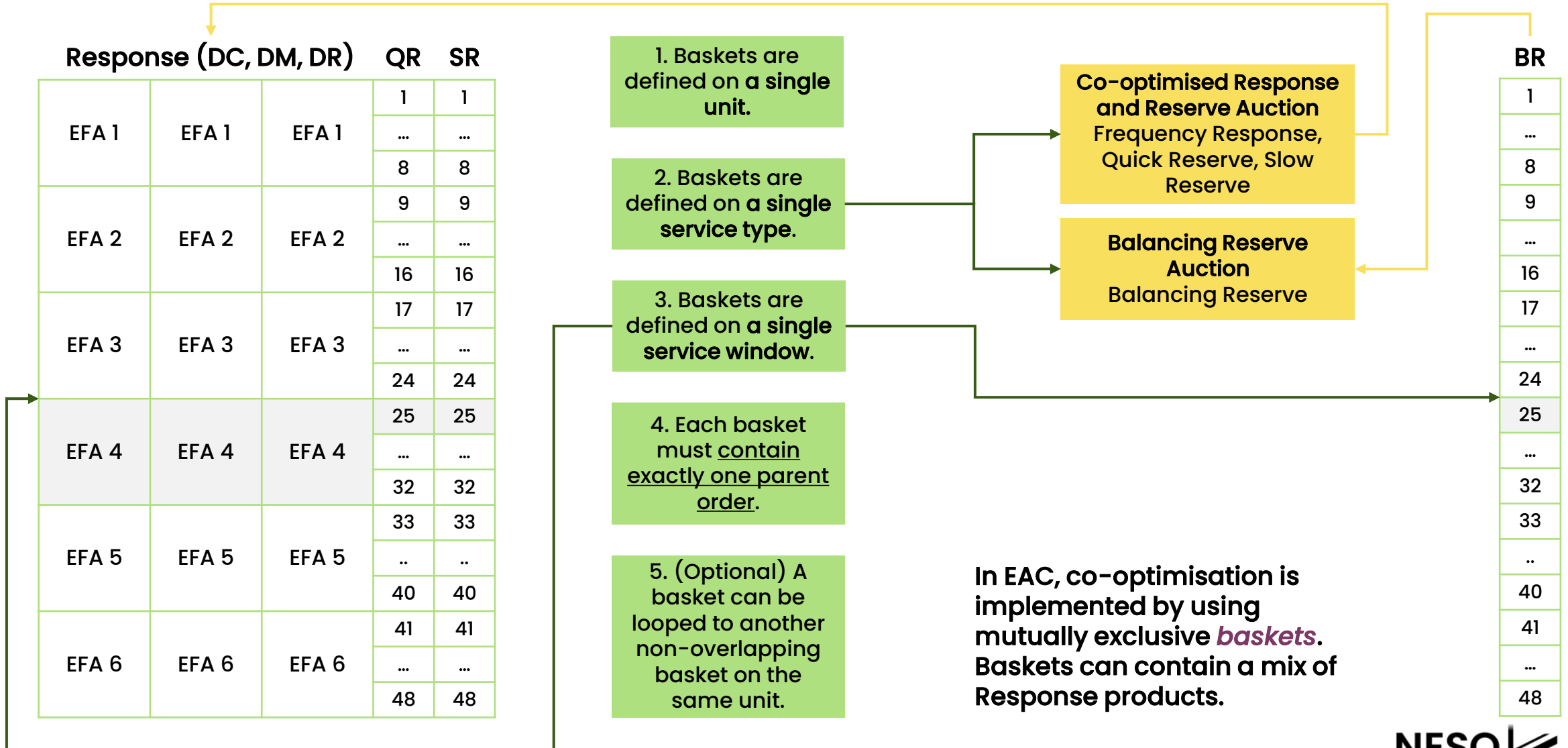
Service Windows

Clocks go back (October)

Note: The Slow Reserve service window is subject to change.

Appendix C

Specification of Baskets and Orders

Specification of a Basket

Response (DC, DM, DR)			QR	SR
EFA 1	EFA 1	EFA 1	1	1
			…	…
			8	8
EFA 2	EFA 2	EFA 2	9	9
			…	…
			16	16
EFA 3	EFA 3	EFA 3	17	17
			…	…
			24	24
EFA 4	EFA 4	EFA 4	25	25
			…	…
			32	32
EFA 5	EFA 5	EFA 5	33	33
			..	..
			40	40
EFA 6	EFA 6	EFA 6	41	41
			…	…
			48	48

BR
1
…
8
9
…
16
17
…
24
25
…
32
33
..
40
41
…
48

1. Baskets are defined on **a single unit.**

2. Baskets are defined on **a single service type.**

3. Baskets are defined on **a single service window.**

4. Each basket must contain exactly one parent order.

5. (Optional) A basket can be looped to another non-overlapping basket on the same unit.

Co-optimised Response and Reserve Auction Frequency Response, Quick Reserve, Slow Reserve

Balancing Reserve Auction Balancing Reserve

In EAC, co-optimisation is implemented by using mutually exclusive *baskets*. Baskets can contain a mix of Response products.

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Specification of a Basket

Element	Comment
Basket ID	Each basket has a unique identifier
Unit	A basket is associated with delivery of ancillary services from a single unit.
Service Type	• **Co-optimised Response and Reserve Auction:** either "Frequency Response", or "Quick Reserve", or "Slow Reserve". • **Balancing Reserve Auction:** "Balancing Reserve".
Service Window	A single service window, consistent with the service type.
Loop Family ID	A basket may be looped to any non-concomitant basket(s).
Sell Orders	A set of sell order IDs that are contained in the basket

1) **Unit:** A unit is identified to the auction by a unique Unit ID. Each unit is prequalified for the provision of some or all of the different products. Baskets and orders may be defined only on products for which the unit is prequalified. In each auction, a unit can submit at most **25** baskets for Response products, **100** baskets for Quick Reserve products, **100** baskets for Slow Reserve products, and **100** baskets for Balancing Reserve products.

2) **Service Type:** A basket is defined on a single service type common to each order contained in the basket. The service type is **either Frequency Response, or Quick Reserve, or Slow Reserve** for the Co-optimised Response and Reserve Auction and is **Balancing Reserve** for Balancing Reserve Auction. Inside a basket, orders can only indicate offered quantities form products from the chosen service type. Consequently, a basket can only contain products for which splitting is allowed.

3) **Service Window:** A basket is defined on a single service window common to each order contained in the basket. The service window must be compatible with the products covered by the service type. The exclusivity relationships between baskets are fully determined by their service window. No information about mutual exclusivity is required from the user.

4) **Loop Family ID (optional):** A basket may optionally be looped to one or more (non-concomitant) baskets. For the avoidance of doubts, a basket may loop to a basket of a different service type.

5) **Sell Orders:** A basket must contain exactly 1 Parent Order. A basket may contain between zero and 10 Child Orders, and additionally between 0 and 10 Substitutable Child Orders. Each sell order is associated with exactly 1 basket.

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Specification of a Sell Order

Element	Comment
Sell Order ID	Each order has a unique identifier
Order Type	Either "Parent", "Child", or "Substitutable Child".
Offered Quantities	A set of product/quantity pairs, representing the offer of capacity for the various products corresponding to the Service Type of the basket.
Price	A single price, in £/MW/h.

1) **Order Type:** A sell order must be a Parent Order, a Child Order, or a Substitutable Child Order.

2) **Offered Quantities:**

   A. Valid products for a sell order include:

      a) DCL, DCH, DML, DMH, DRL, DRH, PQR, NQR, PSR, and NSR for the co-optimised response and reserve auction.

      b) PBR and NBR for Balancing Reserve auction.

   B. The offered products must be consistent with the service type of the basket. For example, if the service type is Frequency Response, then the service window must be an EFA period, and offered quantities would be specified for DCL, DCH, DML, DMH, DRL, and DRH. An order is not allowed to specify product–volume pairs for products for which its unit is not qualified.

   C. All offered quantities are integer MWs. The offered quantity for a product may be zero. The offered quantities with respect to a Parent Order may be zero for all products (i.e., all quantities in the order may be zero). A Child Order and a Substitutable Child Order must have at least one product with a positive offered quantity.

3) **Price:** The price is expressed in pounds and pence (multiple of 0.01 £/MW/h). The price must be between the market's minimum and maximum prices. For the avoidance of doubt, the price of a sell order may be negative.

Mutual Exclusivity of Baskets [1/4]

A basket is mutually exclusive with all other concurrent baskets (i.e., defined on the same delivery period or a portion of the delivery period). The participant does not indicate which baskets are mutually exclusive. The EAC platform determines this from the service type and delivery periods of each basket.

Scenario 1

23:00-03:00 EFA 1 B1	23:00-03:00 EFA 1 B2	23:00-03:00 EFA 1 B3

- B1, B2, and B3 are mutually exclusive to each other.

Scenario 2

23:00-03:00 EFA 1 B4	23:00-23:30 B5	23:00-23:30 B6
	...	...
03:00-07:00 EFA 2 B7	03:00-03:30 B8	03:00-03:30 B9
	...	...

- B4, B5, and B6 are mutually exclusive to each other.
- B7, B8, and B9 are mutually exclusive to each other.
- → You can have B4+B8, etc.

Scenario 3

Overlapping periods 07:00-07:30

- B10, B12, and Loop-B are mutually exclusive to each other.
- B10, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, B13, and Loop-B are mutually exclusive to each other.
- → You can have B10+B11, B10+B13, B12+Loop-A, etc.

Mutual Exclusivity of Baskets [2/4]

A basket is mutually exclusive with all other concurrent baskets (i.e., defined on the same delivery period or a portion of the delivery period). The participant does not indicate which baskets are mutually exclusive. The EAC platform determines this from the service type and delivery periods of each basket.

Scenario 1

23:00-03:00 EFA 1 B1	23:00-03:00 EFA 1 B2	23:00-03:00 EFA 1 B3

- B1, B2, and B3 are mutually exclusive to each other.

Scenario 2

23:00-03:00 EFA 1 B4	23:00-23:30 B5	23:00-23:30 B6
	...	...
03:00-07:00 EFA 2 B7	03:00-03:30 B8	03:00-03:30 B9
	...	...

- B4, B5, and B6 are mutually exclusive to each other.
- B7, B8, and B9 are mutually exclusive to each other.
- → You can have B4+B8, etc.

Scenario 3

Overlapping periods 09:00-11:00

- B10, B12, and Loop-B are mutually exclusive to each other.
- B10, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, B13, and Loop-B are mutually exclusive to each other.
- → You can have B10+B11, B10+B13, B12+Loop-A, etc.

Mutual Exclusivity of Baskets [3/4]

A basket is mutually exclusive with all other concurrent baskets (i.e., defined on the same delivery period or a portion of the delivery period). The participant does not indicate which baskets are mutually exclusive. The EAC platform determines this from the service type and delivery periods of each basket.

Scenario 1

23:00-03:00 EFA 1 B1	23:00-03:00 EFA 1 B2	23:00-03:00 EFA 1 B3

- B1, B2, and B3 are mutually exclusive to each other.

Scenario 2

23:00-03:00 EFA 1 B4	23:00-23:30 B5	23:00-23:30 B6
	...	...
03:00-07:00 EFA 2 B7	03:00-03:30 B8	03:00-03:30 B9
	...	...

- B4, B5, and B6 are mutually exclusive to each other.
- B7, B8, and B9 are mutually exclusive to each other.
→ You can have B4+B8, etc.

Scenario 3

07:00-11:00 EFA 3 B10
07:00-07:30 B12
09:00-13:00 Looped Family Loop-A
07:00-15:00 Looped Family LOOP-B
11:00-15:00 EFA 4 B11
13:00-13:30 B13

Overlapping periods 11:00-13:00

- B10, B12, and Loop-B are mutually exclusive to each other.
- B10, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, B13, and Loop-B are mutually exclusive to each other.
→ You can have B10+B11, B10+B13, B12+Loop-A, etc.

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Mutual Exclusivity of Baskets [4/4]

A basket is mutually exclusive with all other concurrent baskets (i.e., defined on the same delivery period or a portion of the delivery period). The participant does not indicate which baskets are mutually exclusive. The EAC platform determines this from the service type and delivery periods of each basket.

Scenario 1

23:00-03:00 EFA 1 B1	23:00-03:00 EFA 1 B2	23:00-03:00 EFA 1 B3

- B1, B2, and B3 are mutually exclusive to each other.

Scenario 2

23:00-03:00 EFA 1 B4	23:00-23:30 B5	23:00-23:30 B6
	...	...
03:00-07:00 EFA 2 B7	03:00-03:30 B8	03:00-03:30 B9
	...	...

- B4, B5, and B6 are mutually exclusive to each other.
- B7, B8, and B9 are mutually exclusive to each other.
→ You can have B4+B8, etc.

Scenario 3

07:00-11:00 EFA 3 B10
11:00-15:00 EFA 4 B11
09:00-13:00 Looped Family Loop-A
07:00-07:30 B12
07:00-15:00 Looped Family LOOP-B
13:00-13:30 B13

Overlapping periods 13:00-13:30

- B10, B12, and Loop-B are mutually exclusive to each other.
- B10, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, Loop-A, and Loop-B are mutually exclusive to each other.
- B11, B13, and Loop-B are mutually exclusive to each other.
→ You can have B10+B11, B10+B13, B12+Loop-A, etc.

Summary of Sell Order Features

Previous Frequency Response (i.e., EPEXSPOT) Sell Order Design	EAC Sell Order Design
Parent order • Non-curtailable (i.e., MAR=1). • 1 parent order per service window, per product, per unit.	**Parent order** • Non-curtailable (i.e., MAR=1). • 1 parent order per basket (a basket is defined on a service window and a unit). • A parent order can be defined on multiple products. All products in the parent order must be either accepted or rejected.
Child order • Fully-curtailable (i.e., MAR=0). • A child must be defined on a single product. • A parent order can only have at most one child per service window. • A child and its linked parent can be defined on the same or different service windows.	**Child order** • Fully-curtailable (i.e., MAR=0). • A child order can be defined on multiple products. • A parent order can have multiple children per basket. • A child and its linked parent must be defined on the same service window.
No splitting	**Substitutable child order** • Fully-curtailable (i.e., MAR=0). • This order type can be used for (continuous) splitting. • A substitutable child and its linked parent must be defined on the same service window.
No co-optimisation	**Baskets** • Each basket must be defined on a single unit, a single service window, a service type and a parent order. • This feature is designed to allow mutually exclusivity (e.g., co-optimisation).
Looped order • Looped orders have same actual acceptance ratio (AAR).	**Parent/Child/Substitutable child order (for the same service window)** • All products defined in a sell order must be accepted for the same proportion. **Looped baskets (for consecutive or non-consecutive service windows)** • The parent orders of looped baskets must be either accepted or rejected.
Multi-period order • Multi-period order has same actual acceptance ratio (AAR).	**Looped baskets** • The parent orders of looped baskets must be either accepted or rejected.

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Appendix D
Market Clearing Rules Explained in Plain English

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Market Clearing Rules Explained in Plain English

Paragraph	Market Clearing Rule	Plain English Explanation
9.2.1	The **Acceptance Ratio** of a **Parent Order** is either one (1) or zero (0).	A parent order is non-curtailable. Either all products in the sell order must be accepted for the full offered quantity, or else the order must be rejected.
9.2.2	The **Acceptance Ratio** of a **Child Order** is between zero (0) and one (1) inclusive.	A child order is curtailable, and may be partially accepted (i.e., the contracted quantities may be less than the offered quantities). If there is more than one product in the order, then all products are accepted for the same proportion (subject to the rounding rules).
9.2.3	The sum of the **Acceptance Ratios** of all **Substitutable Child Orders** in a **Basket** is between zero (0) and one (1) inclusive.	A substitutable child order is curtailable and may be partially-accepted. Within an order, the products are accepted in proportion. The substitutable child orders in a single basket are not independent of each other: the acceptance of one of them will limit the potential of the others to be accepted.
9.2.4	The **Acceptance Ratio** of a **Buy Order** is between zero (0) and one (1) inclusive.	A buy order is curtailable and may be accepted for a smaller quantity than the bid quantity.
9.2.5	The sum of the **Acceptance Ratios** of all **Buy Orders** that are members of the same **Buy Order Substitutable Family** is between zero (0) and one (1) inclusive.	Buy orders that are members of the same buy order substitutable family are not independent of each other: the acceptance of one of them will limit the potential acceptance of the others.
9.2.6	The **Acceptance Ratio** of a **Child Order** or **Substitutable Child Order** is less than or equal to the **Acceptance Ratio** of the **Parent Order** in its **Basket.**	A child order or a substitutable child order can be accepted only if the parent order in its basket is accepted.
9.2.7	The **Acceptance Ratios** of the **Parent Orders** in each **Basket** of a **Loop Family** are equal.	When two or more baskets are looped together, either all the parent orders of the baskets must be accepted, or else all rejected.
9.2.8	The sum of the **Acceptance Ratios** of the **Parent Orders** in any two **Baskets** which are **Concomitant** is less than or equal to one (1).	If two baskets are defined on the same service window or overlapping service windows, then their parent orders cannot both be accepted.

Note: The paragraph number refers to *Response Services Procurement Rules*, *Balancing Reserve Service Procurement Rules*, and *Quick Reserve Service Procurement Rules (Consultation)*. The paragraph number may vary in different procurement rules.
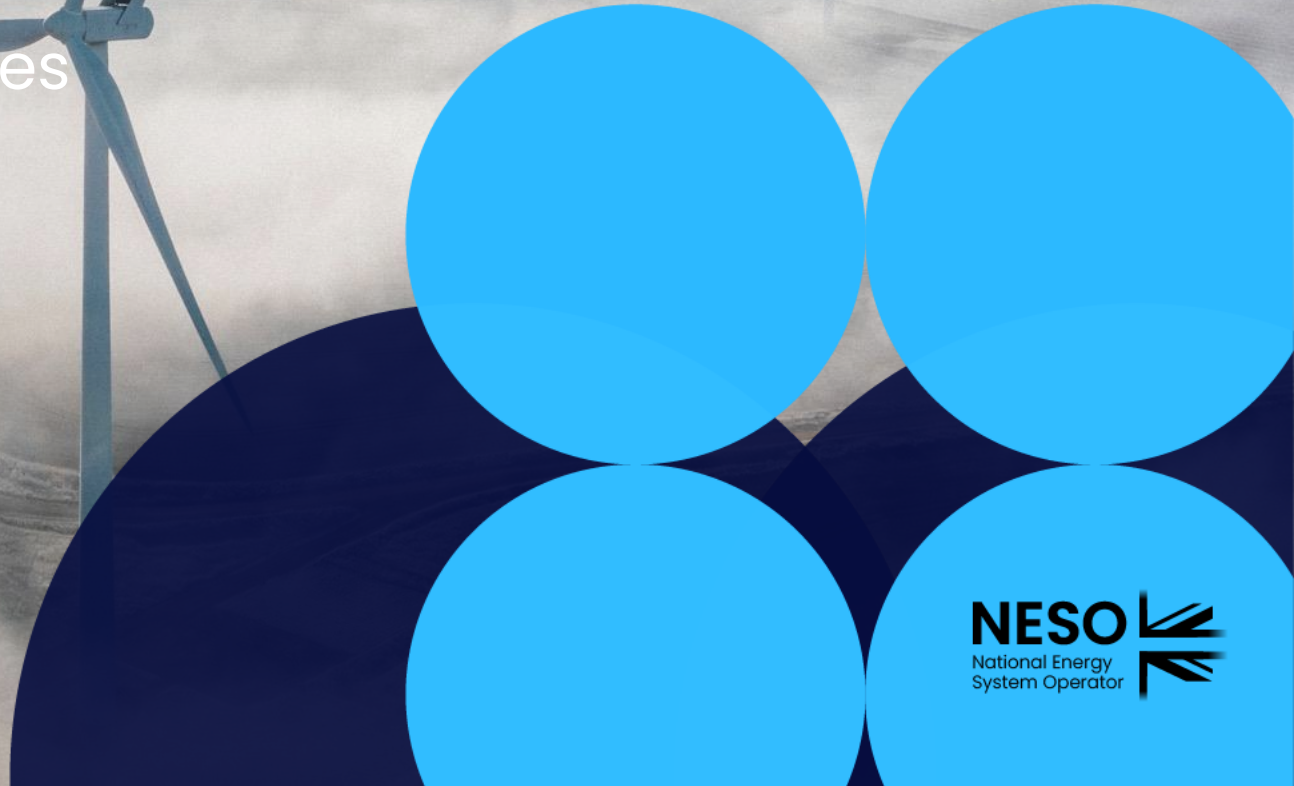
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Market Clearing Rules Explained in Plain English

Paragraph	Market Clearing Rule	Plain English Explanation
9.2.9	The **Acceptance Ratio** of a **Child Order** or **Substitutable Child Order** is greater than zero (0) only if its **Order Surplus** is greater than or equal to zero (0).	A child order or substitutable child order cannot be accepted if it is out-of-the-money. The offer price of the order must be less than or equal to the weighted average clearing prices of the accepted products (i.e., weighted by the contracted quantities of the order).
9.2.10	The **Acceptance Ratio** of a **Parent Order** in a **Basket** that is not a member of a **Loop Family** is equal to one (1) only if the sum of the **Order Surplus** of all **Sell Orders** in the **Basket** is greater than or equal to zero (0).	A parent order can be accepted if it is at-the-money or in-the-money. Accepted child orders or substitutable child orders can donate surplus to the parent order in their basket, so that an out-of-the-money parent can be accepted if its basket is in-the-money overall.
9.2.11	The **Acceptance Ratio** of a **Parent Order** in a **Basket** that is a member of a **Loop Family** is equal to one (1) only if the sum of the **Order Surplus** of all **Sell Orders** in all the **Baskets** that comprise the **Loop Family** is greater than or equal to zero (0).	An in-the-money basket can donate surplus to an out-of-the-money basket in its loop family, so that the whole loop family can then be accepted.
9.2.12	The **Acceptance Ratio** of a **Buy Order** that has a **Paradoxical Acceptance Indicator** equal to "False" may be greater than zero (0) only if its **Order Surplus** is greater than zero (0).	A buy order with paradoxical acceptance indicator equal to "False" can be accepted only if the market clearing price is less than or equal to the bid price.
9.2.13	For any **Auction Product** and **Service Window**, the sum across all **Sell Orders** of the **Matched Quantity** is equal to the sum across all **Buy Orders** of the **Matched Quantity**.	The quantity of accepted sell orders is matched to the quantity of accepted buy orders.
9.2.14	For the avoidance of doubt, a **Sell Order** or a **Buy Order** with an **Order Surplus** greater than zero (0) may have an **Acceptance Ratio** less than one (1) ("**paradoxically rejected**"), and a **Buy Order** with an **Order Surplus** less than zero (0) that has a **Paradoxical Acceptance Indicator** equal to "True" may have an **Acceptance Ratio** greater than zero (0) ("**paradoxically accepted**").	Sell orders and buy orders may be paradoxically rejected, i.e., they may be rejected despite being in-the-money. A sell order is never paradoxically accepted, i.e., it is never accepted when it is out-of-the-money. But if a buy order has a paradoxical acceptance indicator equal to "True", then it may be paradoxically accepted (i.e., it may be accepted despite the clearing price being above its bid price).

Note: The paragraph number refers to _Response Services Procurement Rules_, _Balancing Reserve Service Procurement Rules_, and _Quick Reserve Service Procurement Rules (Consultation)_. The paragraph number may vary in different procurement rules.

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Appendix E

Differences between Sell Order Types

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Differences between Sell Order Types

Paragraph	Parent	Child	Substitutable Child
8.4.5	Exactly 1 per basket	Between 0 and 10 per basket	Between 0 and 10 per basket
8.3	Sell order may have no Auction Products	Sell order must have at least one Auction Product	Sell order must have at least one Auction Product
8.6.1	All Offered Quantities considered for Validation of Capacity	All Offered Quantities considered for Validation of Capacity	Only the largest Offered Quantity per Auction Product from amongst the Substitutable Family is considered for Validation of Capacity
9.2.1, 9.2.2	Non-curtailable	Curtailable	Curtailable
9.2.6	Must be accepted for any children to be accepted.	Can only be accepted if its parent is accepted	Can only be accepted if its parent is accepted
9.2.3	Acceptance ratio is independent of other orders in the basket.	Acceptance ratio is independent of other Children in the Basket	Sum of acceptance ratios of all Substitutable Children in Basket is <= 1.
9.2.9	Surplus can be negative. Can receive transfer of surplus from Child or Substitutable Child.	Surplus always >= 0. Can transfer surplus to Parent.	Surplus always >= 0. Can transfer surplus to Parent.
9.3	Matched quantities are always integers (no rounding required).	Matched quantity rounded to nearest integer	Matched quantity rounded down to nearest integer.

Note: The paragraph number refers to _Response Services Procurement Rules_, _Balancing Reserve Service Procurement Rules_, and _Quick Reserve Service Procurement Rules (Consultation)_. The paragraph number may vary in different procurement rules.

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Appendix F

Rejection Codes
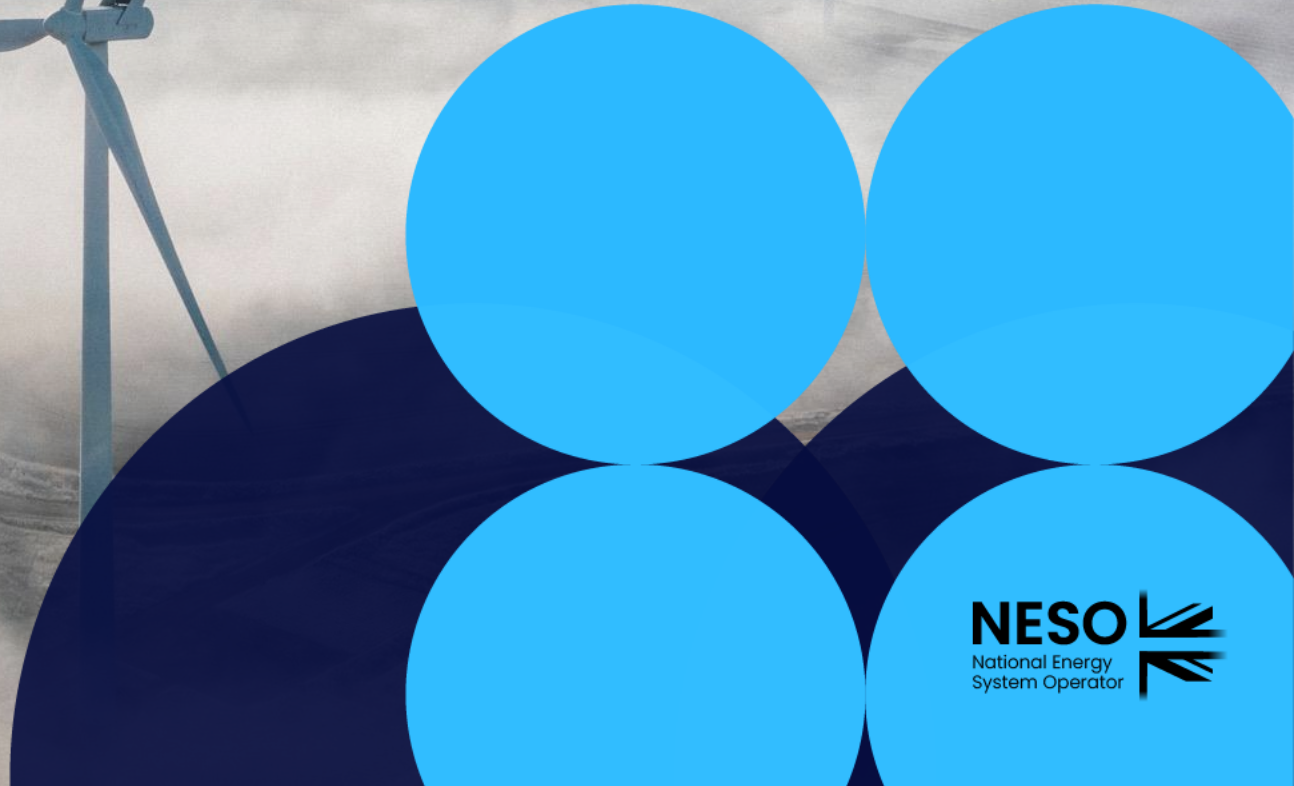
Rejection Codes

Code	Description
11	Basket rejected because too expensive.
12	Basket rejected because other looped baskets are too expensive.
13	Basket rejected to accept other more profitable basket(s) concomitant to this basket or to any basket looped to this one.
14	Basket paradoxically rejected.
21	Child order (partially) rejected because too expensive.
22	Child order rejected because its parent order is rejected.
23	Substitutable child order (partially) rejected because other substitutable children are accepted and bring more value.
24	Child order (partially) paradoxically rejected.
31	Buy order (partially) rejected because priced too low.
32	Buy order (partially) rejected because other buy orders from its substitutability family are accepted and bring more value.
33	Buy order (partially) paradoxically rejected.
34	Buy order (fully or partially) rejected because other joined orders are priced too low.

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Appendix G
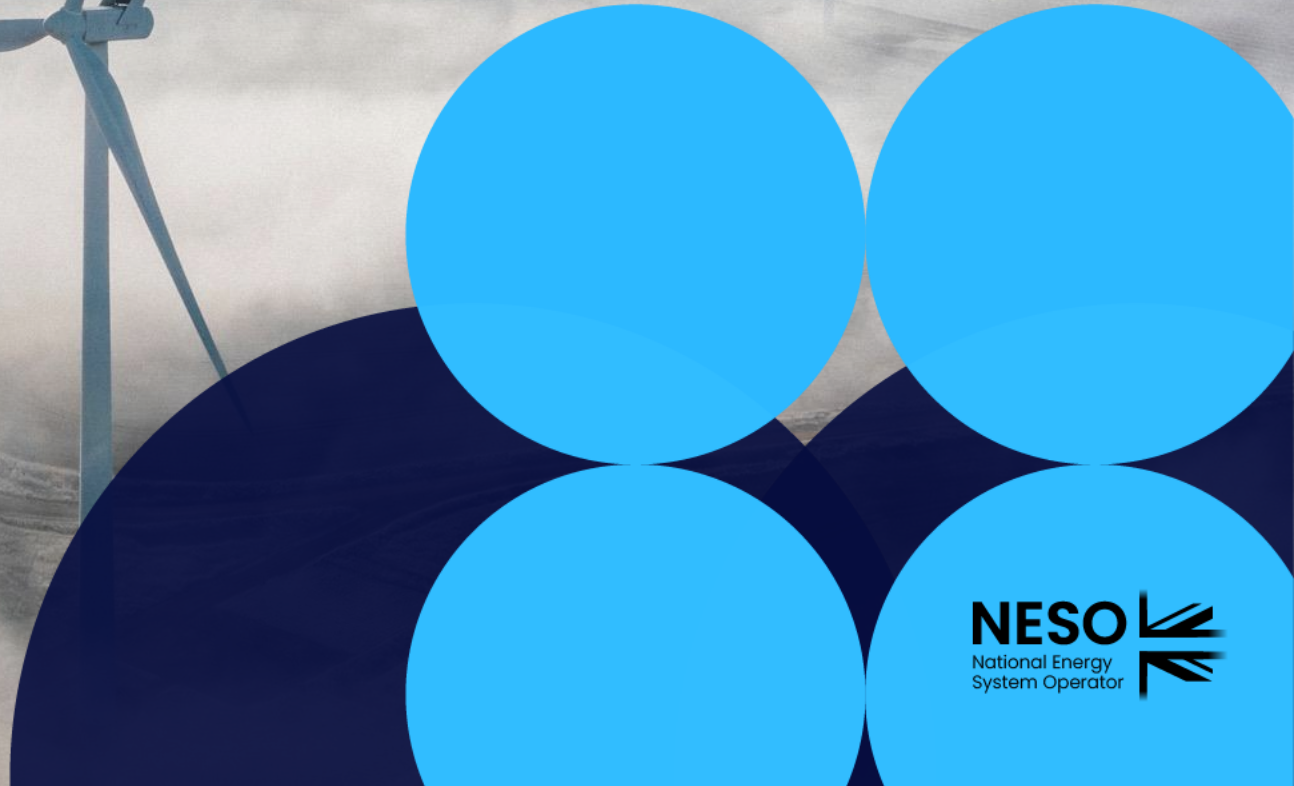
Useful Links

Useful Links

Market Design Documents

- [Market Design Report (N-SIDE)](#)
- [Market Design Explainer](#)
- [EAC API Documentation](#)

Auction Results

- [EAC Auction Results](#)
- [BR Auction Results](#)

Service Requirements

- [Dynamic Containment Requirements 4 Day Forecast](#)
- [Dynamic Moderation Requirements](#)
- [Dynamic Regulation Requirements](#)
- [Balancing Reserve Requirements Forecast](#)

General Information

- [Enduring Auction Capability (EAC) Webpage](#)
- [Dynamic Response (DC, DM, DR) Webpage](#)
- [Balancing Reserve (BR) Webpage](#)
- [Quick Reserve (QR) Webpage](#)
- [Slow Reserve (SR) Webpage](#)
- [Ancillary Services Important Industry Notifications](#)

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