Department for
Energy Security
& Net Zero

Review of Electricity Market Arrangements

Alternative Capacity Market Auction Designs

A report to the Department for Energy Security and Net Zero

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Executive Summary

1.1 Context

The Government has set an objective to decarbonise the electricity system by 2035 subject to maintaining security of supply. To achieve this, it is consulting on wide ranging reforms to the electricity market under its Review of Electricity Market Arrangements (REMA).

The Capacity Market (CM) is a key mechanism within the existing market design. By offering long term contracts to capacity holders for providing capacity to meet peak demand periods, the CM supports investment in new capacity and retain existing capacity that is needed to meet peak demand conditions.

However, the Department for Energy Security and Net Zero (DESNZ) is now considering how the CM can be better aligned with decarbonisation objectives. As part of this, it is assessing if and how the CM auction should be designed to deliver more low carbon capacity in general, and more specifically to deliver flexible low carbon capacity that can support intermittent renewable generation in a mass low carbon power system. Reform of the CM will ultimately need to be positioned in the wider context of market reform and the specific role that the CM will play alongside other market mechanisms.

1.2 This study

DESNZ asked Baringa to assess three high-level auction designs to consider how they could support objectives to decarbonise capacity and deliver low carbon flexibility. These auction designs are:

1. **A split auction**: In which technologies with different characteristics are procured through wholly separate auctions and with independent target capacities and clearing mechanisms.
2. **A single auction with multiple clearing prices**: In which technologies with different characteristics participate in a single auction but with a mechanism to allow for different clearing prices to be determined for capacity with different characteristics. For example, this could be achieved by defining a minimum or maximum amount of capacity with a certain characteristic.
3. **A single auction with multipliers**: In which technologies with different characteristics participate in a single auction and with a single clearing price, but in which technologies with certain characteristics have a multiplier applied to the clearing price in the auction to reflect their additional value in delivering a decarbonised (and/or flexible) electricity system.

Of relevance, but not directly in scope of this study, is wider consideration of the CM being undertaken by DESNZ through a separate consultation. Of most relevance are proposals to reduce the emissions intensity limits within the CM, with the intended effect of limiting operating hours of unabated gas capacity that participates beyond 2035.

1.3 Approach and methodology

Our approach is centred around qualitative assessment, drawing on our team's understanding of market and auction design, auction theory and insight from international auction design where possible.

To support the qualitative assessment, we have also carried out illustrative auction modelling. This modelling helps to demonstrate possible auction outcomes under each design. Given the early stage of development of CM reform, our modelling represents a small number of many possible designs and conditions. Different design choices for key parameters within each auction design and under alternative scenarios could result in quite different outcomes.

As DESNZ continues to develop wider policy in parallel with the CM, our assessment is limited to outcomes within the CM specifically. Interactions with other market mechanisms that will exist within a future electricity market design are not captured. The potential for societal benefits of reform from accelerated decarbonisation are not monetised.

Rather the modelling is intended to illustrate the auction dynamics and provide indications of how CM auction outcomes might differ for different types of capacity under different auction designs.

Our approach is summarised in Figure 1.

Figure 1: Summary of our approach

1. Agree desirable features for a future Capacity Market
2. Identify key research questions for the analysis
3. Form outline of alternative auction designs - obtain insights from auction theory and international practice. Conduct an initial screening of options
4. Identify role for supporting quantitative analysis and design illustrative CM models to support research questions
5. Carry out further qualitative analysis and targeted quantitative analysis to inform assessment
6. Final assessment of design options and assessment against desirable criteria
7. Deliver report summarising findings

1.4 Key findings

The appropriate auction design choice should be made in the context of the objective that DESNZ decides upon for the auction. An objective to send signals for low carbon capacity in general would have different implications for auction design than an objective to send signals for specific forms of low carbon flexibility.

The objective of incorporating signals for low carbon capacity into the CM auction is to maximise the proportion of capacity which is met by low carbon technologies, subject to ensuring value for money. There is no specific volume of need but rather a desire to maximise low carbon capacity.

In the case of flexibility, there is more of a specific need such that the marginal benefit of flexible capacity demonstrates diminishing returns. In other words, once sufficient flexibility of the desired type is present in the market, further flexible capacity is less valuable.

Thus, for flexibility, volume certainty is an important objective for the auctioneer who may wish to provide strong signals for additional capacity up to the given level of need without overpaying for additional flexibility beyond this. Our analysis demonstrates that a split auction or an auction with multiple clearing prices are better able to provide volume certainty than an auction with multipliers given the control that the auctioneer has over target volumes under either approach.

Our modelling reflected the uncertainty for the auctioneer over auction outcomes where multipliers are used. Under the assumptions used for our modelling, even a relatively high multiplier did not lead to a substantial volume of new-build low carbon capacity, whether flexible or not, clearing in the auction. Actual results will reflect a different set of conditions. However, this finding demonstrates the lack of control that the auctioneer has over volumes of capacity that will clear in an auction with multipliers relative to the alternative auction designs.

Volume certainty may not be as necessary where the auctioneer is seeking to maximise low carbon capacity without any flexibility objectives. However, split auctions and auctions with multiple clearing prices also have the benefit of allowing the market to reveal the cost of delivering a desired level of additional low carbon capacity unlike multipliers in which the auctioneer must take a view on the additional value delivered to set the multiplier.

There are also disadvantages of split auctions and auctions with multiple clearing prices for low carbon capacity. These options place importance on the ability of the auctioneer to define target low carbon capacity with a reasonable degree of confidence. Setting target capacity too low risks missing out on additional value for money low carbon capacity. Setting target capacity too high risks very high clearing prices, or even failure to clear the auction, resulting in high costs to consumers, and in some cases additional security of supply risk.

Furthermore, split auctions increase concentration of auction competition as they split liquidity between each auction. An auction with multiple clearing prices also increases concentration within a sub-set of the auction.

A split auction or auction with multiple clearing prices may therefore be most effective where there is a relatively clear and competitive pipeline of low carbon projects that are expected to participate in future auctions. This provides information for the auctioneer to set parameters appropriately to reflect this supply potential and helps to deliver competitive pressure within the auction.

On the other hand, an auction with multipliers can be designed to provide strong and consistent signals for low carbon capacity where the pipeline is less certain and/or is more nascent.

A split sequential auction in which unsuccessful low carbon capacity can compete in the second 'remainder' auction is conceptually very similar to an auction with multiple clearing prices for low carbon capacity. Both allow scarcity for low carbon capacity to be reflected in a higher clearing price but also allow for low carbon capacity and carbon emitting plant to compete to deliver overall target capacity.

Relative to a split auction, an auction with multiple clearing prices may have the further advantage of allowing all capacity to compete within a single auction, which has practical advantages and, in some cases, may deliver some additional competitive pressure within the overall auction.

1.5 Recommended next steps

Before developing CM design in detail, DESNZ must determine the specific role that the CM is intended to play within the wider electricity market.

A key consideration is the nature of system stress event that the CM is designed to cover. As we explore in the report, the nature of system stress events will change as we develop a mass low carbon power system. As well as the need to cover peak demand, system stress events may be driven by sustained periods of low renewables output due to climatic conditions. The parameters of the existing CM (e.g., de-rating factors and delivery penalties) are not designed with this nature of system stress in mind. A reformed CM must reflect the changing nature of system stress in its high-level design and within the set of parameters that are included.

Determining the role of the CM also requires an assessment of which market mechanisms are best able to deliver cost-effective low carbon capacity and flexibility.

In the case of response time flexibility services, the key question is whether explicit signals in the CM would duplicate or distort signals which will be sent elsewhere in the future market design, e.g., within the wholesale market, balancing markets, ancillary and flexibility services markets.

At least within the existing market design, the gap in signals for capacity that can sustain output over a long duration appears more obvious. However, the role of the CM in delivering signals for sustained response should reflect decisions elsewhere. Of particular relevance are revenue certainty mechanisms (e.g., cap and floor mechanisms) being considered for some forms of low carbon capacity including hydrogen to power, carbon capture and storage and long duration storage.

We modelled a sensitivity to consider the possibility that these forms of capacity are supported elsewhere but continue to participate in the CM (effectively as price takers). This sensitivity illustrates a potential scenario in which an increasingly small sub-set of capacity that bids into the CM is dependent on the CM as an investment signal and is therefore likely to set the price.

This starts to question whether the CM continues to remain a relevant/appropriate mechanism for sending investment signals.

Questions that should frame the role of the CM include:

- To what extent is the CM providing the sole investment signal to investors and for what technologies is this the case?
- What role will other mechanisms such as balancing and ancillary services, and flexibility markets play in sending signals to flexibility providers? How do these signals interact with any flexibility signals that DESNZ is considering sending through the CM?
- Would a national CM remain consistent with a more localised wholesale market? What impacts would this design have on CM outcomes?
- How will explicit signals for decarbonisation interact with stronger emissions intensity limits in the CM, if these are introduced?

After determining the specific objectives of the CM, DESNZ can decide upon a suitable auction design to support these objectives. The analysis in this report can support this decision. The report summarises the conditions under which different design choices may be more or less suitable and provides an initial assessment of key parameters within a reformed CM.

More detailed impact assessment should be undertaken once DESNZ has developed a small number of detailed options, and alongside analysis of wider reform packages that are developed within REMA. Whole system assessment of costs and benefits, including carbon emission impacts should support DESNZ's decision making at this stage.

After a detailed auction design has been determined and key parameters within the auction decided upon, DESNZ (or a delegated body) will need to run the CM auctions. This will involve drawing on analysis from key stakeholders such as the FSO to determine auction specific parameters. These auction parameters will include auction price caps, target capacities and demand curves, both for the overall auction and for specific requirements for low carbon capacity and/or low carbon flexibility.

2. Context

2.1 The Review of Electricity Market Arrangements

In its Review of Electricity Market Arrangements (REMA), the Department for Energy Security and Net Zero (DESNZ) is consulting on wide ranging reforms to the electricity market arrangements of Great Britain (GB). The core objective of REMA is to facilitate the full decarbonisation of the electricity system by 2035, subject to maintaining security of supply.

Beneath this core objective, REMA also aims to:

- Deliver a step change in the rate of deployment of low carbon technologies and reduce GB's dependence on fossil fuelled generation.
- Provide the right signals for flexibility across the system.
- Facilitate consumers to take greater control of their electricity use by rewarding them through improved price signals, whilst ensuring fair outcomes.
- Optimise assets operating at local, regional, and national levels.
- Ensure that the security of the system can be maintained at all times.

In the context of the energy crisis and the impact on the price paid for energy, the Government has a broader emerging objective to decouple the electricity price that consumers pay from global gas prices.

2.2 The Capacity Market

The GB Capacity Market (CM) was introduced as part of the Government's package of Electricity Market Reform, with the first CM auction held in 2014.

The CM was developed to enhance security of electricity supply. It achieves this by providing a fixed, 'bankable' payment to capacity (whether generation, storage, DSR or interconnection) that can respond when notified by the electricity system operator (ESO) during periods of system stress.

These payments are additional to revenues that capacity providers can make through participation in other markets such as the wholesale, balancing and ancillary services markets. Payments are intended to reflect the 'missing money' of electricity market participants – i.e., the revenues needed to recover up front and ongoing costs, not recovered in other markets. 15-year agreements are available for new capacity, providing long term payment certainty. Since its inception, thirteen CM auctions have been held[1].

The GB CM is a descending clock, pay as clear auction. The auction starts at a price cap, as set out in the Auction Guidelines[2]. In each round the price is reduced by a set decrement of 5 £/kW/yr. The auction is split into a T-4 and T-1 auction, four years and one year ahead of

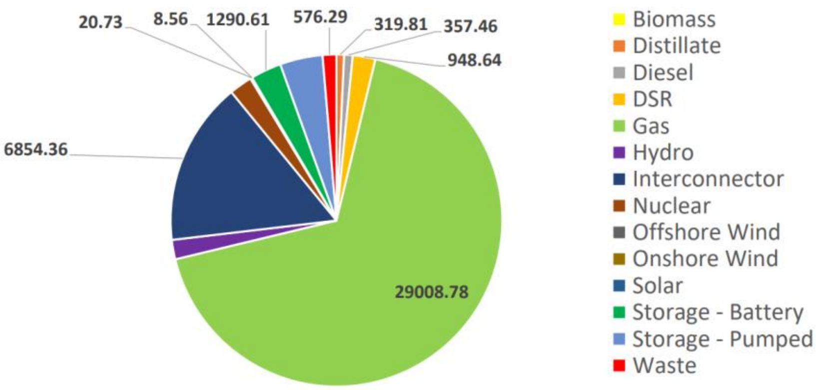
[1] Including the TR-2016 auction and all auctions held to time of writing.
[2] BEIS letter to NGESO - Table of 2022 CM Parameters.pdf (emrdeliverybody.com)

delivery, respectively. The T-4 auction is intended to allow for investment in new-build capacity but allows existing capacity to also enter. The T-1 auction is used to meet remaining required capacity closer to the delivery year. Lengths of agreements vary depending on the class of asset. New build plants are able to agree 15-year contracts, refurbished plants can agree 3-year contracts and existing plants can agree 1-year contracts. The most recent auction (T-4) took place in February 2023, for delivery year (DY) 2026/27 and with a price cap of 75 £/kW/yr. 43,000 MW of capacity was awarded capacity agreements at a clearing price of 63 £/kW/yr[3], significantly higher than the clearing price observed in previous auctions. The majority of capacity agreements were for 1-year contracts (c. 40,000 MW).

The current GB CM design is designed to be technology neutral though this does not mean that all technologies are treated equally. Capacity is de-rated to reflect the expected potential of each type of technology to provide capacity during times of system stress. These de-rating factors are generally set at a technology level. I.e., there is no differentiation in de-rating factors between capacity of the same type. As well as de-rating factors, non-delivery penalties are applied to capacity that cannot respond during a system stress event.

The primary objective of the CM has been to ensure security of supply. Other than de-rating factors and non-delivery penalties, the CM therefore includes no explicit incentives that differentiate for low carbon generation or for the ability to provide flexibility. As a result, a significant proportion of capacity contracts in the DY 2026/27 auction were awarded to gas-fired generators (Figure 2).

Figure 2: Capacity Awarded by Primary Fuel Type (MW)



Before participating in a CM, potential bidders need to pre-qualify capacity for which they are seeking CM contracts. Participants receiving low carbon support (e.g., Renewables Obligation, CfD or small-scale FiT) and capacity outside of GB are not currently eligible to participate in the CM.

[3] EMR Portal - T4(DY26-27) (emrdeliverybody.com)

2.3 Emerging challenges

The CM is currently designed to be technology neutral. It rewards capacity availability from different technology types regardless of associated carbon emissions and other characteristics such as response time or the potential duration of response[4][5].

Delivering a fully decarbonised electricity system by 2035 will require a significant increase in the scale-up of low carbon generation. Deployment of large volumes of low carbon flexibility will also be needed to facilitate mass low carbon power, avoiding the need for dispatch of carbon emitting generation during periods of low renewable output.

As part of REMA, DESNZ is considering whether the design principles surrounding the CM auctions should be revised to support the REMA objectives. In particular, DESNZ is exploring ways in which the CM could encourage the deployment of greater amounts of low-carbon and flexible capacity.

The changing nature of system stress events

The CM is currently designed to meet system stress events which are driven by peak periods of electricity demand. This logic was driven by an electricity market in which flexible forms of capacity were relatively abundant, and the need to deal with low periods of renewables output was limited, such that peak demand periods have represented the time when security of supply (in terms of generation adequacy) has been at greatest risk.

However, in a world of mass low carbon power in which a large proportion of supply is variable, a new form of system stress event emerges. At times when renewables output is low, the supply margin may fall because of low supply instead of, or as well as, high demand. More rapid swings in supply and demand compound the challenge since resources must react quickly, and sometimes need to ramp up over very short periods of time. This raises potentially fundamental questions about the design of the CM to cope with this new form of system stress event.

2.4 This study

This study focusses on three alternative designs for a CM auction which may be designed to support delivery of low carbon and flexibility objectives:

1. **A split auction**: In which technologies with different characteristics are procured through wholly separate auctions and with independent target capacities and clearing mechanisms.

2. **A single auction with multiple clearing prices**: In which technologies with different characteristics participate in a single auction but with a mechanism to allow for different clearing prices to be determined for capacity with different characteristics. For example, this could be achieved by defining a minimum or maximum amount of capacity with a certain characteristic.

[4] Though it is worth noting that capacity is de-rated to reflect its expected potential to contribute at times of system stress.

[5] Low carbon capacity which receives other forms of support (e.g., renewables obligation certificates (ROCs) or contracts for difference (CfDs) are not eligible for the CM, however their contribution to meeting demand at peak is deducted from the capacity requirement calculated for the CM.

3. **A single auction with multipliers**: In which technologies with different characteristics participate in a single auction and with a single clearing price, but in which technologies with certain characteristics have a multiplier applied to the clearing price in the auction to reflect their additional value in delivering a decarbonised (and flexible) electricity system.

The CM also contains several detailed parameters such as target capacity definition, de-rating methodologies, auction price caps, and non-delivery incentives which are all relevant design considerations where future auctions may be split more by technology. In this report, we consider the implications of the high-level auction designs set out above for key parameter definition within the auction. We do not carry out a full review of the parameters themselves.

For each auction design, we consider and assess the main design choices including the auction format, bidding and clearing approach and consider parameter definition at a high-level. We assess the potential implications of each design on auction outcomes as well as risks and unintended consequences.

We define several desirable objectives against which we appraise each auction design. However, auction designs are at an early stage of development. Qualitative and quantitative appraisal is therefore made at an equally high-level, incorporating several assumptions and reflecting unknowns of detailed auction design. It is also developed in isolation of CM design, without reflecting the full extent of interaction between the CM and other market mechanisms.

The content of this report does not form a full impact assessment which would need to be carried out following further design development and in the context of wider market reform.

2.4.1 Interactions with other areas of the market

The CM currently plays a specific role in the electricity market and interacts with several other mechanisms which have different objectives. The scope of REMA is broad. The review is considering a wide range of options across the breadth of electricity market design. This includes the potential for fundamental reforms to the market such as locational pricing. REMA also includes alternative mechanisms to secure capacity, in particular reliability options, supplier obligations and strategic reserves.

There is an open question regarding whether explicit long term investment signals for low carbon and flexible capacity should be incorporated into the CM or whether these signals are best sent through other mechanisms. Interactions with wider mechanisms are important to consider avoiding duplication of benefits, and to avoid the potential for remaining gaps in signals. This report does not seek to answer those questions but instead sets out considerations regarding alternative designs of a CM auction to achieve such objectives.

Design of the CM must consider interactions with other existing mechanisms as well as those which are being developed through REMA, in particular procurement of Balancing Services by the ESO. In Table 1, we outline the existing and potential mechanisms that are intended to provide signals related to capacity adequacy, operability, energy duration and low carbon power deployment.

Table 1: Existing/potential mechanisms with related objectives

	Capacity adequacy	Operability	Energy duration	Low carbon
Existing mechanisms	Existing CM	Balancing and ancillary services contracts Local flexibility markets		Renewables Obligation Certificates (ROCs, no longer open to new projects) CfDs UK Emissions Trading Scheme Emissions Performance Standards
Market/policy mechanisms under consideration	Reliability options Strategic reserves Targeted tender	Dedicated support scheme	Cap and floor (C&F) contracts for long duration storage	Revised CfDs – potentially including 'non price factors' to reflect supply chain and operability benefits C&F or dispatchable power agreement (DPA) for new capacity (e.g., CCUS, hydrogen)

Interactions with these mechanisms and with other areas of the market raise several design considerations. Whilst these interactions are not directly in scope for investigation for this project, we outline key potential considerations relating to existing and potential market design in Table 2.

Table 2: Interactions with existing and potential market design

Market area	Interaction
Balancing Services	How would a flexibility signal in the CM change the need for the ESO to forward contract to ensure sufficient capacity is on the system to meet its needs for Balancing Services? Would flexibility signals in the CM be designed to send signals relating to the range of services that the ESO requires to operate the grid? Is there a risk of introducing a 'double reward' for some of the services provided by flexibility?
Renewables participation	Would existing renewable generation, no longer operating under the Renewables Obligation or CfD, be eligible for minimum low carbon requirement in an Optimised CM?
Distributed resources	Distributed, flexible resources may take on non-firm access to use the grid. Would such resources be eligible as flexible capacity in a CM? How would their non-firm agreements be reflected?
Business support models (CCUS, hydrogen, long duration storage)	Several technologies may receive future policy support – e.g., C&F payments. Would these technologies still be eligible for the CM? If not, how much low carbon capacity would be eligible for the CM that does not receive support elsewhere?
Enhanced balancing services	REMA is exploring enhanced balancing services that may allow/require the system operator to provide stronger signals to low carbon capacity in the balancing market and ancillary services If developed, these signals could interact with those intended to be sent through a reformed CM that seeks to support flexible low carbon capacity.
Locational pricing	Would a national CM remain consistent with a more locational wholesale market? What impacts would a locational wholesale market have on CM outcomes?

2.4.2 Ongoing reform to the CM

In parallel with its consultation on reform to the CM under REMA, DESNZ is also consulting on short term reform to the CM to maintain security of supply[6] while delivering other objectives including decarbonisation. The consultation is considering more limited adjustments to the

[6] The consultation can be found at the following link: [Capacity Market 2023 consultation (publishing.service.gov.uk)]

existing CM design but with some interaction between those potential reforms and the stated objectives of this assessment. Of particular note, the consultation includes the following:

- Strengthening the non-delivery penalty regime to send a clear signal to capacity providers about the importance of delivery during a system stress event.

- Changes which are intended to align the CM with net zero objectives, including:

    - Reducing the carbon emissions intensity limits applicable to new build plants from 1 October 2034.
    - Requesting views on the creation of pathways to allow CM contract holders to leave multi-year CM contracts early to decarbonise, subject to security of supply considerations.
    - Allowing low carbon capacity with low capital expenditure to access multi-year agreements of three years without needing to meet capital expenditure thresholds.

The consultation notes that implementation of any reform is subject to further, more detailed analysis. It will also require parliamentary time to be secured for secondary legislation to make the required changes. Nevertheless, we may expect the changes signalled in this consultation to be delivered in the relatively near term whereas changing the auction design of the CM as considered in this report may take several years to implement.

2.4.3 Out of scope

DESNZ has defined several considerations as out of scope of our assessment.

Changes to auction design parameters to reflect the changing nature of system stress events

In Section 2.3 we discussed the changing nature of system stress events. While these will constitute important considerations for any future design of CM, the potential for re-definition of parameters within the CM to account for such system stress events is not within the scope of this report.

Differentiation by location

In its REMA consultation, DESNZ include considerations regarding sending locational investment signals through the CM, e.g., by splitting the CM into multiple auctions for capacity in different parts of the country. Decarbonising transmission constraints is challenging as constraint management requires ramping up and down capacity in short timescales following gate closure. Without reform to locational signals, there is a risk that decarbonised and flexible resources could be deployed but in locations that are less beneficial and therefore sub-optimal from a total system cost perspective. DESNZ is continuing to explore locational signals and reforms to balancing markets within REMA. However, DESNZ did not include differentiation by location within the scope of this study.

Ongoing review of the CM

This report does not consider the proposals set out within the open letter on reform to the CM as summarised above, in particular the proposed reforms to emissions intensity limits that

DESNZ is considering. Where relevant, we take the existing CM design as the counterfactual 'status quo' without reflecting the changes proposed.

Whole system impacts

The changes to the CM explored in this report would result in impacts stretching well beyond the narrow scope of the CM. Introducing low carbon signals into the CM would be designed with the objective of accelerating the transition to net zero, supporting investment cases in low carbon capacity and resulting in societal benefits through reduced carbon emissions. Even where this results in an increase in the direct costs of the CM, it may reduce the costs of deploying low carbon capacity elsewhere in the market.

Signals for flexibility would be intended to ensure that security of supply continues to be delivered in a mass low carbon power system. While the costs of the CM itself may increase relative to the counterfactual, it may deliver societal value through low carbon security of supply. It may also reduce the extent of costs appearing in other areas of the market such as balancing services and flexibility markets.

Given that REMA is continuing to consider wider market design, the scope of the analysis in this report is limited to the direct impacts on CM outcomes. Particularly where we present quantitative analysis from our illustrative modelling, it is important to note wider interactions and scope for benefits and costs elsewhere in the market.

3. Approach

3.1 Summary of approach

Our approach combines qualitative assessment of the high-level design options with targeted use of auction modelling where this can support our consideration of specific research questions. Our approach is summarised in Figure 3.

Figure 3: Summary of our approach

1. Agree desirable features for a future Capacity Market
2. Identify key research questions for the analysis
3. Form outline of alternative auction designs - obtain insights from auction theory and international practice. Conduct an initial screening of options
4. Identify role for supporting quantitative analysis and design CM models to support research questions
5. Carry out further qualitative analysis and targeted quantitative analysis to inform assessment
6. Final assessment of design options and assessment against desirable criteria
7. Deliver report summarising findings

In the remainder of this section, we set out the agreed desirable features for the purpose of this research project and key research questions.

3.2 Desirable features

The REMA objectives are general to the re-design of the electricity market rather than particular to the CM. To allow for a more informed assessment of the options available we have developed and agreed with DESNZ a set of ‘desirable features’ that should exist within a future CM, consistent with the overarching REMA objectives. These desirable features are as follows:

1. **REMA objective: Ensure that the security of the system can be maintained at all times.**
    a. Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output
    b. Supporting investment cases in capacity with characteristics which support security

2. **REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB's dependence on fossil fuel generation.**
    a. Providing appropriate economic signals for investment in low carbon capacity
3. **REMA objective: Provide the right signals for flexibility across the system.**
    a. Providing appropriate economic signals for investment in low carbon flexibility
    b. Enabling participants to reap the benefits they bring for the wider energy system
4. **Additional objective: Cost-effective provision of energy security for consumers**
    a. Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary
    b. Minimising the cost of implementing and operating the auction
    c. Ensuring complementarity between the CM and other mechanisms within the electricity market such as DPA, revenue cap and floor arrangements, balancing services and renewables support mechanisms.
5. **Additional objective: Avoiding creation of unnecessary risk and uncertainty**
    a. Minimising unintended consequences from auction design
    b. Adaptability of auction design to market and technological evolution

3.3 Key research questions

To develop and appraise a set of 'strawman' auction designs, we agreed a set of research questions with DESNZ. We apply these research questions to each of the three high-level design options (a split auction, an auction with multiple clearing prices, and an auction with multipliers) in the remainder of this report:

- What is the most suitable auction format and why? This includes:
    - The bid submission/determination approach – e.g., 'sealed bid' vs 'descending clock'
    - The clearing mechanism – e.g., 'Pay as Bid' vs 'Pay as Clear' and 'First Price' vs 'Second Price' auctions
- What would the relative merits and disadvantages of each of the three auction designs be?
- Should there be multiple rounds of the auction? How should these be designed and sequenced?
- How would the design of the auction impact on competition and on the overall cost to consumers?
- What are the interactions with wider market design and policy?
- What are the implications for detailed parameters such as:
    - Eligibility criteria
    - Target capacity and demand curves
    - De-rating factors

  - Non-delivery penalties
  - Price caps
- How would auction specific parameters be determined? E.g.:
  - For a split auction, how would the target capacity in each auction be determined?
  - For a multiple clearing price auction, on what basis would the clearing prices be determined?
  - For a single auction with multipliers, how would the value of the multipliers be determined?

We also explore a set of research questions relating to the potential outcomes from the auction, including:

- What are the expected outcomes from each auction design, e.g., regarding the cleared capacity mix and the associated clearing price?
- Which auction designs are most suited to which objectives/outcomes and why?
- Which technologies are likely to win contracts in the auction?
- How would the auction design impact on bidding behaviour?
- What challenges exist with implementing and running the auctions?
- What potential exists for unintended consequences?

3.4 Summary of approach for quantitative analysis

3.4.1 Scope and objectives

Within our analysis of future CM design options, quantitative analysis plays a supporting role to illustrate the impacts of different auction design. This report does not represent a full impact assessment for a specific design at this stage. A full impact assessment would require additional detail on the auction design and would need to be undertaken alongside an impact assessment of wider REMA reform options At this high-level stage of auction design, the objective of our modelling is to illustrate and inform some of the findings from our qualitative assessment of auction design. Outcomes from the modelling are heavily impacted by auction design choices and modelling assumptions that we make, e.g., regarding target capacities and demand curves, eligibility and the overall supply pool of capacity. Changing the set-up of the auction parameters and assumptions would inevitably result in a different set of outcomes.

In practice, any of the three auction designs being considered could be designed to deliver different levels of ambition for decarbonisation and contribution to low carbon flexible capacity. The target capacities for a split auction or auction with multiple clearing prices could be set to deliver a significant majority of low carbon potential. Multipliers could place a lot of value on delivery of low carbon capacity with some similarities in outcome. However, in either case, this would result in a higher cost of the CM as higher priced capacity clears in the auction. In practice, the auction designer would need to make a trade-off between objectives to maximise low carbon capacity against the higher costs of the CM that would result from greater ambition.

For our modelling purposes, we play the role of the auctioneer and establish a hypothetical level of ambition for each auction. But taking a different view on the tradeoff of auction objectives would inevitably lead to different outcomes.

For this reason, we caution against drawing direct conclusions from modelling outcomes that are not placed in the context of our qualitative assessment. Instead, insight from the modelling is used to support and illustrate, or revise, conclusions that have already been drawn. The modelling can also add insight regarding the potential magnitude of impacts under a given set of conditions and assumptions.

Our model provides a platform that allows comparison of different auction designs based on key metrics which we design to assess the impact of design choices on the set of desirable features that we set out above.

We provide further detail on the analytical approach for modelling of the auction designs in 0.

3.4.2 Modelled auction designs

Our modelling assumes that all participants have perfect foresight, and that all capacity of the same technology type has equivalent costs in any given year.

Additional modelling considerations for the three potential designs under review are as follows:

1. **Split auction**:
    a. Each split auction is considered as an independent auction for capacity with different characteristics. Eligibility for a particular split is determined for each technology type and the characteristics they provide. Auction splits are considered mutually exclusive – i.e., capacity can only participate in one split auction.
    b. The auction designer sets the parameters of each auction separately. These parameters include the target capacity, expected clearing price and any price caps separately for each auction. In each case one auction is defined as the 'remainder' auction. This represents the auction for capacity that does not have the desirable characteristic. Target capacity for this split auction is set to achieve overall target capacity after incorporating the output capacity from all other split auctions.
    c. Capacity receives the clearing price from the auction in which they clear.

2. **Multipliers**:
    a. Capacity with different characteristics participate in the same single auction but technologies that offer desired characteristics will receive an augmented clearing price determined by the multiplier.
    b. Auction design maintains the same target capacity as the single auction. In addition, the auction designer must define multipliers for each desired characteristic and categorise technology types as eligible for each characteristic by their ability to provide these desired characteristics.
    c. We assume that eligible bidders are perfectly rational in reflecting the multiplier in their bid price. Bid prices of participants are divided by the relevant multiplier. Post auction, successful plants with the desired characteristic receive the clearing price multiplied by the associated multiplier.

3. **Auctions with multiple clearing prices (we model auctions with minima)**:
   a. Different technologies compete to fulfil an overall capacity requirement with additional constraints on minimum targets for certain capacity characteristics. The auction does not clear unless minimum targets are met as well as the overall target capacity.
   b. The auction design maintains the same target capacity as the single auction. In addition, the auction designer must define minimum capacity targets for desired characteristics and categorise technology types as eligible based on their ability to provide these desired characteristics.
   c. Capacity with the desirable characteristic that clears the auction will receive the higher of the clearing price which exists for the overall auction or for the minimum requirement.

3.4.3 Key outputs and metrics

The outcome of each auction provides the clearing price, cumulative de-rated capacity, marginal plant, and the full cleared supply stack along with their initial bids. From this, several other outputs are derived to support the assessment and comparison between auction designs:

1. De-rated capacity mix of the cleared supply, either by technology type or by desirable characteristic, e.g., proportion of low carbon capacity, across the time horizon. This provides a comparable metric across auction designs to analyse their effectiveness in attracting capacity with desirable characteristics or delivering a step change in the rate of deployment of a particular technology.

2. Total cost to consumer to ensure supply in a particular year. This is a summation of each cleared plant's de-rated capacity multiplied by its contracted price for that year. This includes the contribution of multi-year agreements for new build plants.

3. Inframarginal rent provides an assessment of the economic rent arising from the auction, i.e., how much additional profit the plant is receiving above its bid price. This is calculated as the summation across the supply stack of the de-rated capacity multiplied by the difference between the agreement price the plants receive and their initial bid. Plants already under contract from previous auctions are excluded from our calculation of inframarginal rent in any given year.

4. The Herfindahl-Hirschman Index (HHI)[7] provides an indicative measure of market concentration of capacity. In this case, for simplicity to illustrate the impact of different market designs on auction liquidity, we assume that each capacity provider is a different entity, providing a relatively simple measure of how concentrated the auction is. Market designs with a higher HHI are at greater risk of strategic bidding. Common ownership would increase the HHI.

[7] See short description of the HHI here: https://www.justice.gov/atr/herfindahl-hirschman-index

3.4.4 Key assumptions and limitations

The modelling outcomes are highly dependent on the inputs and assumptions that we build into the model, for example, target capacity and demand curve, de-rating factors, assumed costs and revenues for less established technologies, etc.

The technology supply pool

One important limitation in assessing modelling outcomes relates to the technology 'supply pool'. To analyse the effectiveness of different market designs, we needed to construct a 'potential supply pool' – i.e., capacity that could in theory win a CM contract depending on the specific design of the CM but would not win a CM contract, and as a result, may not be deployed in the market under other designs. The supply pool is intended to represent a sensible but sufficiently diverse range of technologies that can bid into the CM, along with a suitable estimate of their expected costs and revenues from the energy and other markets. To develop this potential supply pool, we take outputs from Baringa's system modelling. In Baringa's modelling, long-term capacity investment and retirement decisions are based on projected profitability, expected decarbonisation trajectory and capacity margin targets. These include announced and committed projects and retirements in the nearer term.

In practice, the deployment of capacity from new technologies will depend on a much wider range of factors than are captured in the scope of this modelling exercise. This includes technological readiness, alleviation of commercial barriers and wider financing support and global supply chains. New technologies will also respond to a broad range of signals beyond the CM including the design of the wholesale and balancing markets, connection policy and commercial opportunities to deliver flexibility.

For that reason, this project cannot forecast the technology mix that will be deployed in the future and how it will be impacted by the CM in isolation. Whether or not the potential supply pool that we include in our modelling can be delivered in the future will depend on a large number of factors beyond CM design.

Instead of asking which technologies can be deployed as a result of CM design, this project explores how CM design would affect the technologies that clear in the auction, assuming a common potential supply pool is able to be deployed in theory under any auction design. In practice, the supply pool will inevitably be different to that we assume. However, insight regarding the potential impact of auction design to impact on the type of capacity that wins a CM contract, the clearing price and other auction outcomes remains. It is this broader insight that we encourage those reading this report to focus on.

Low carbon and flexibility capability

We classify eligibility of different technology types as low carbon[8], potential providers of sustained duration response of greater than four hours, and potential providers of response time (ESO response and reserve services). We agreed the eligibility assumptions with DESNZ.

[8] For both new build and existing capacity

The provisional definitions outlined in the Table 3 below have been mapped out and used for the purposes of the modelling to help illustrate results and are a starting point for further policy exploration.

Table 3: Technology definitions

Type	Category	Low Carbon	Low Carbon Sustained Response	Low Carbon Response and Reserve
Battery 0.5 - 3hr duration	Battery	Yes	No	Yes
Battery 4 - 6hr duration	Battery	Yes	Yes	Yes
Biogas and Biomass (inc CCS)	Bio	Yes	Yes	No
DSR	DSR	Yes	No	Yes
EfW	Gas	No	No	No
Gas CCGT, OCGT, CHP	Gas	No	No	No
Gas CCS	CCS	Yes	Yes	Yes
Hydro	Hydro	Yes	No	No
Hydro Pumped Storage	Hydro	Yes	Yes	Yes
Interconnector	Interconnector	No	No	No
Nuclear	Nuclear	Yes	Yes	No
Wind	Wind	Yes	No	No
H2 CCGT	Hydrogen	Yes	Yes	Yes
H2 OCGT	Hydrogen	Yes	Yes	Yes
Longer duration batteries	LDS	Yes	Yes	Yes
Longer duration, low efficiency (6hr)	LDS	Yes	Yes	No
Longer duration, low efficiency (12 hr)	LDS	Yes	Yes	No
Established longer duration storage (medium)	LDS	Yes	Yes	No
Established longer duration storage (long)	LDS	Yes	Yes	No

Capacity targets are based on the Baringa Reference Case projections for demand, including assumptions for the electrification of heat, transport, and hydrogen electrolysis. The peak demand is defined as the annual maximum of the fixed demand share, i.e., the portion that is inflexible to price signals. For auctions with multiple targets, e.g., in a split auction or an auction with minima, target capacity has been set to balance competing objectives of maximising deployment of desired forms of capacity while maintaining competitive pressures. I.e., we have avoided setting target capacity to deliver all desirable capacity irrespective of price[9].

Whole system/whole economy impacts

The scope of this study is limited to CM auction outcomes. The analysis presented in this report reflects only the modelled outcomes on the CM, and under the set of assumptions made for modelling purposes. In practice, interactions between the CM and other market mechanisms will lead to a much broader range of impacts from CM reform. For example, a CM design which increases the costs from the CM may support delivery of flexible low carbon power and reduce costs in other areas such as the wholesale or balancing markets, especially within a mass low carbon power system. Beyond the energy markets are wider non-monetary

[9] We note that the auctioneer would need to make a similar subjective call-in practice. E.g., would they prefer to procure more low carbon capacity at a very high price or limit costs to consumers while accepting less than the full potential of low carbon capacity.

costs to consumers, e.g., those related to carbon emissions that are not quantified in this report.

Wider assumptions

Other key assumptions and limitations include the following:

1. We assume no strategic bidding; all plants are expected to bid according to their profitability gap and there is no consideration of multi-unit bids. The HHI index and the marginal delta metrics provide an indication of where the auction may be more at risk of the clearing price being artificially increased by bidders strategically withdrawing capacity.

2. Our model does not differentiate between auctions run at different periods ahead of delivery i.e., separate T-1 and T-4 auctions. Though this may impact the clearing price that the T-1 plants would receive, as there is no defined eligibility rule for participation in either auction this simplification is justified in this illustrative modelling.

3. All new build capacity of the same technology type is assumed to have the same CAPEX, fixed operation and maintenance costs, additional revenues, and technical life. This reduces variation in bid price; however, these are common value inputs that are predominantly influenced by uncertain external factors.

4. There is no feedback loop from the outcome of the auction to the modelling of the power price projections, therefore the energy market revenues are not influenced by the decision to "build" any of the additional plants specified in the expanded generator pool.

3.4.5 Summary of results from modelling of single auction

In Sections 5 and 6, we evaluate the use of a split auction, auction with multiple clearing prices and auction with multipliers for delivering additional low carbon and flexible capacity in the CM. We compare this against the status quo in which a single auction continues to exist.

Under this single auction, and with the potential supply pool as defined above, we observe auction results which lead to a cleared CM supply stack as shown in Figure 4.

In Figure 5 we show the breakdown by flexibility characteristics, with low carbon capacity that could be designed to provide sustained response of four hours or more, response time services and those that can provide both.

In Figure 6 we show the proportion of cleared capacity that is delivered by new capacity contracts and subsequently capacity that is under a 15-year contract. We treat all price takers as 'existing' capacity in this chart. For the purposes of our modelling, this includes new interconnection, DSR and offshore wind at the end of its CfD contract period in addition to capacity that enters into the CM as existing plant at the end of its initial 15-year contract period.

In Figure 7 we show the clearing price of the CM auction over the period under our modelling. This is intended to reflect a modelled counterfactual against which alternative auction designs can be tested. It is not intended to backcast or forecast actual CM auction clearing prices and should not be interpreted as projected clearance prices under business-as-usual.

Several mechanisms affect the trends observed for the CM clearing price over time:

- Our wholesale market reference case scenario reflects falling load factors for unabated gas capacity over time. All else equal this would imply increasing clearing prices as unabated gas recoups less revenue from the CM.
- However, our reference case scenario assumes that capacity in the wholesale market is able to recover large levels of revenue from some periods, particularly where hydrogen capacity sets the price and incorporating assumptions of relatively high hydrogen commodity prices. These inframarginal revenues from the wholesale market would reduce clearing prices in the CM, all else equal.
- Finally, we also observe merit order effects. As new forms of capacity become sufficiently competitive to clear in the CM, they push some more expensive unabated gas capacity out of merit.

Figure 4: Single auction cleared supply stack

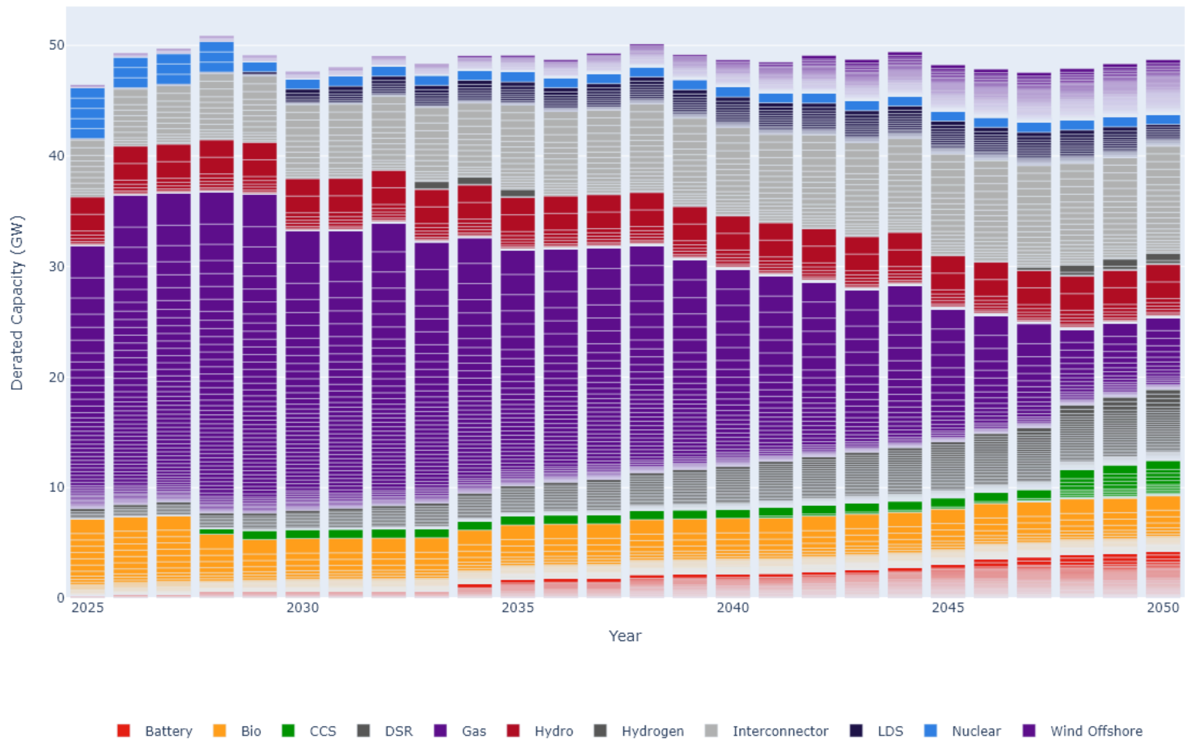


Figure 5: Single auction cleared capacity by potential low carbon flexibility

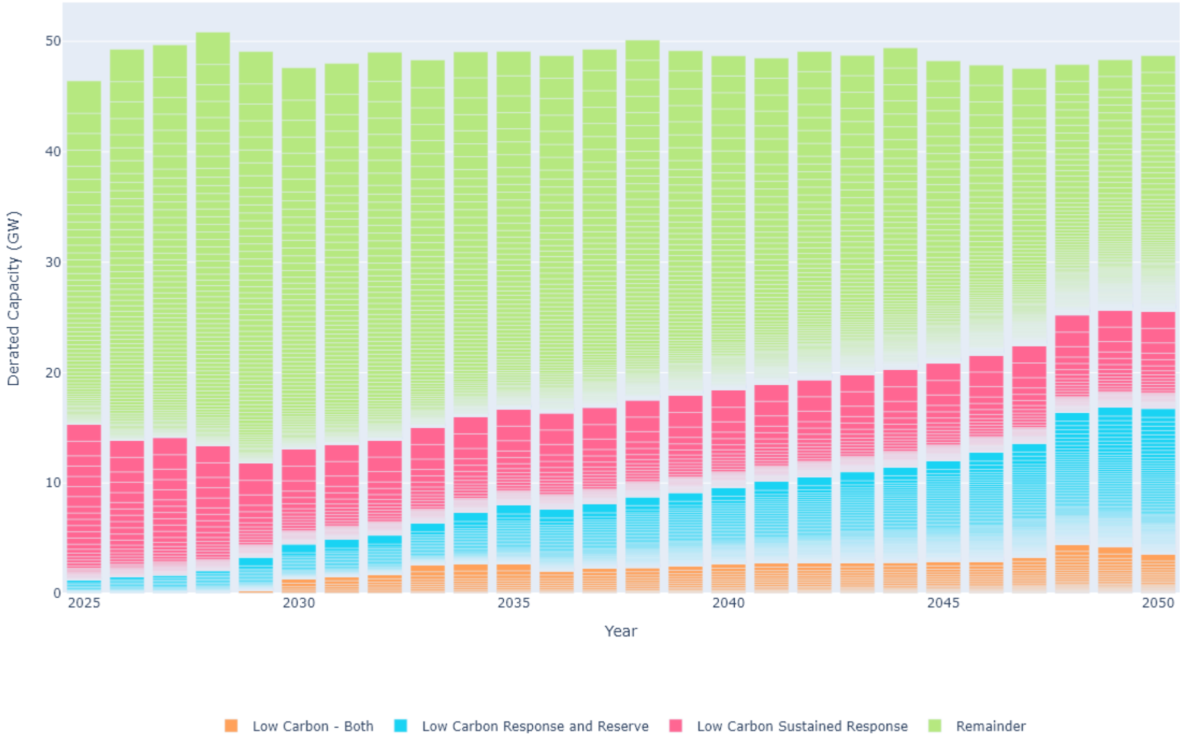


Figure 6: New capacity, capacity under contract and existing capacity in single auction

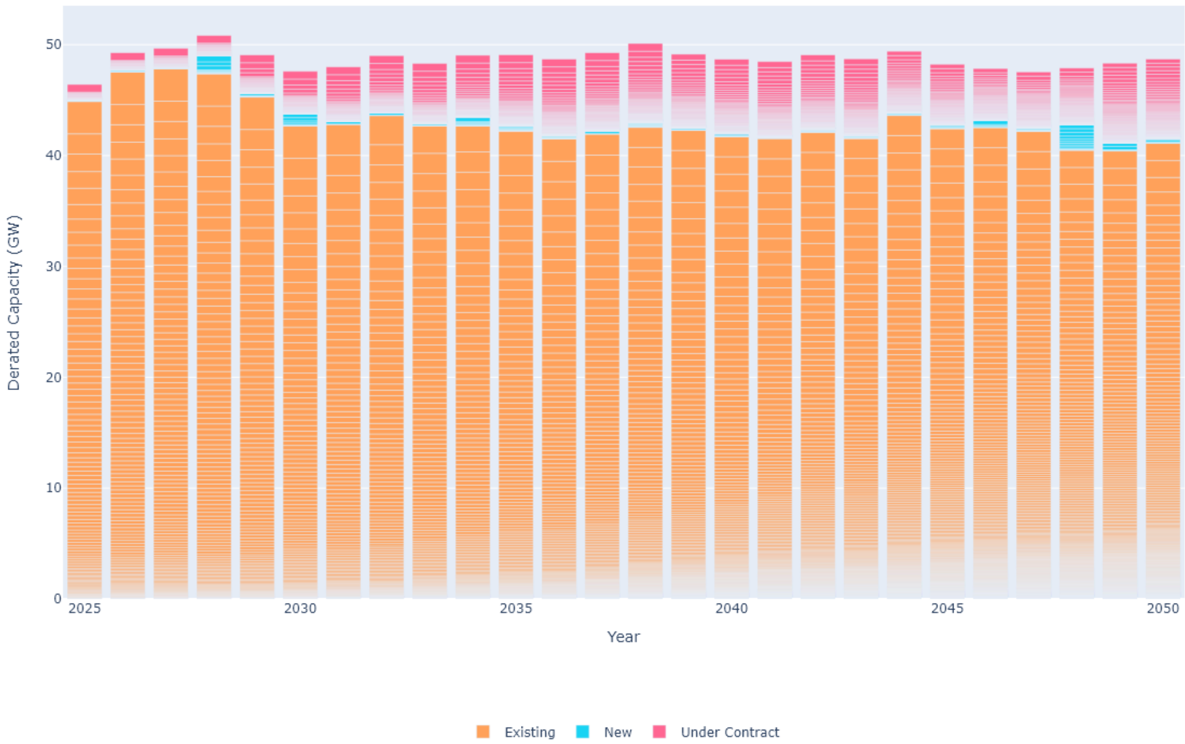


Figure 7: Clearing price under single auction

4. CM auction design

4.1 Summary of international CM auction designs

While a full case study assessment of international CM designs is out of scope, we have reviewed a selection of international CM designs. We provide a summary of key characteristics of these international CM designs in Table 4. A fuller summary of international CM designs is provided in 0.

Table 4: Overview of international capacity auctions

Auction	Bidding method	Clearing mechanism	Payment	Differentiated auctions/prices
ISO-NE Forward Capacity Market (FCM)	Descending clock	Variable sloping demand curve	Pay as clear with additional 'Pay-for-Performance' (PFP)[10]	System wide price with two sub-zones.
NYISO Installed Capacity Market (ICAP)	Sealed bid	Linearly sloping demand curve	Pay as clear	New York control area with three subzones
PJM Reliability Pricing Model (RPM)	Sealed bid	Kinked sloping demand curve	Pay as clear	System wide price with 12 locational delivery area subzones
MISO Planning Resource Auction (PRA)	Sealed bid	Vertical demand curve	Pay as clear	10 local resource zones all with individual requirements
Belgian Capacity Mechanism (CM)	Sealed bid	Algorithm	Pay as clear with a payback obligation principle (excessive revenue)	Considered by the algorithm
Single electricity market (SEM) Capacity Revenue Market (CRM) (Ireland and Northern Ireland)	Sealed bid (with second step of offset locational requirements)	Linearly sloping demand curve	Pay as clear (but with pay as bid to satisfy minimum capacity in constrained areas)	Separate locational element with separate auction mechanism for two additional sub-zones

[10] PFPs were introduced to strengthen the delivery incentives for capacity holders to make sure that they are able to fulfil their obligations. They provide both an upside and downside incentive for delivery of capacity in a system stress event.

Across the international case studies that we have considered, the most common format is a sealed bid with only the ISO-NE Forward Capacity Mechanism (FCM) using a descending clock.

The four ISOs in the US that operate capacity markets use one system curve for the ISO that specifies a price for each capacity level for the region as a whole. Zonal demand curves are also used to reflect the additional congestion price to be paid on top of the system capacity price for specific constrained capacity zones. This has the effect of creating separate clearing prices for different zones, with the level of distinction between zones varying slightly between ISOs.

Under current designs, we have not found evidence of CM auctions which distinguish between low carbon and capacity or flexible and non-flexible capacity, and which treat the two differently in terms of clearing capacity or clearing price.

4.2 High-level auction design options

In this section we summarise and discuss the three high-level auction design options included within this study. We also provide examples of where these auction designs are used in practice.

4.2.1 Split auctions

Description of a split auction

In a split auction, independent auctions are used to procure capacity with different characteristics. The auctioneer sets the parameters of each auction without any interaction between them. Parameters defined in each auction include target capacity, eligibility criteria and clearing price caps.

Examples of split auctions in practice

International examples of split auctions include the GB CfD auctions, the original proposal for the Irish SEM CRM design (which was not taken forward) and the MISO PRA.

In the first case, a split auction was chosen to allow capacity at different maturity levels to compete separately (separate technology pots), providing more opportunity for less mature technologies to benefit from a CfD. In the remaining examples, consideration of a split auction has been driven by physical constraints which limit the extent to which separate regions can be considered a single capacity market.

- **GB CfD auctions** include separate pots, as well as minima and maxima for different technology types. For example, in allocation round four (AR4), there were three pots[11]. Pot 1 included Solar PV, Onshore Wind and Energy from waste, Pot 2 included Tidal Stream, Floating Offshore Wind and Remote Island Wind and Pot 3 contained Offshore

[11] Contracts for Difference: draft budget notice for the fourth allocation round, 2021 (publishing.service.gov.uk)

wind[12] (now moved to a 'mature pot'). In the 2019 evaluation of the CfD Scheme[13], most developers supported having separate pots for emerging technologies.

- **The SEM** committee (Ireland) considered a number of options for locational procurement of capacity, including split auctions in multiple zones. The proposal was to split the capacity market into two or more sub-markets. However, the SEM committee concluded that the capacity requirement should be determined for the SEM as a whole, with minimum requirements rather than split auctions used to meet locational capacity objectives[14]. Respondents to the consultation highlighted the increased complexity of splitting the auction by geographical zone and the ability of the whole-island approach to mitigate market power. It was also assumed that the North-South interconnector would resolve constraints reducing the need for zonal capacity requirements.

- **In the MISO PRA**, each of the ten zones in the MISO region operates a separate pot, with distinct clearing prices. This has led to significant variation between regions with zones 1-7 (MISO North) hitting the price cap in the 2022-23 auction, while zones 8-10 (MISO South) had very low prices. MISO South had excess capacity to export, which would have reduced the clearing price in MISO North below the cap, but it was constrained by an export limit of 1.9 GW[15].

In the examples discussed above, a split auction is justified by differentiation of separable capacity types, either to facilitate emergence of less mature technologies, or given constraints which imply separable locational markets.

4.2.2 Single auction with multiple clearing prices

Description of a single auction with multiple clearing prices

In a single auction with multiple clearing prices, all capacity competes to fulfil an overall capacity requirement. However, separate clearing prices may be determined for specific sub-sets of technologies. There are several ways in which separate clearing prices could be defined.

Perhaps the most straightforward is to set a minimum requirement for capacity with a desirable characteristic. As well as the overall capacity requirement, the auction needs to fulfil the minima. As the minima is designed to reflect scarce characteristics, it will often clear at a higher clearing price. Desirable capacity that clears will do so at the higher of the overall auction clearing price or the clearing price set by the minima. This sends a signal to the market for capacity with the desirable characteristic.

Alternatives options for deriving multiple clearing prices to reflect specific characteristics include:

- **Maxima**: All capacity competes in the overall auction. However, a maximum threshold is applied to capacity with an 'undesirable' characteristic (e.g., carbon

[12] Contracts for Difference: draft budget notice for the fourth allocation round, 2021 (publishing.service.gov.uk)
[13] CfD_evaluation_phase_1_final_report.pdf (publishing.service.gov.uk)
[14] SEM-15-103 CRM Decision 1_0.pdf (semcommittee.com)
[15] Analysis of the MISO 2022/23 Planning Resource Auction | ICF

emitting) that the auctioneer wishes to limit (and therefore would likely clear at a lower price).

- **Ex post approaches**: The auctioneer takes all bids in the auction, specifying a requirement for information regarding certain technology characteristics. The auction designer retains an element of judgement in determining the combination of bids that provides the best value-for-money, taking a range of objectives into account. This may mean some capacity with certain characteristics clearing the auction where it is judged to provide beneficial characteristics, even if it is more expensive than alternatives. This could lead to multiple clearing prices associated with separate desirable characteristics. At the extreme, it could result in a PaB approach.
- **Complex combinatorial approaches**: Like an ex-post approach, a combinatorial auction would take into account the combination of a range of technology characteristics that each participant could provide. However, in this case, the combination of requirements from the auction designer would be determined ahead of the auction and codified into an algorithm that optimises to find the lowest cost solution to meet the desired combination of characteristics. This could result in multiple clearing prices associated with separate desirable characteristics. At the extreme, it could result in a PaB approach. These approaches are likely to be based on a sealed bid auction format.

In the remainder of this report, we focus on auctions with minimum capacity requirements for certain desirable characteristics. The intuition for an auction with maximum limits on certain capacity would be similar in most cases. Subjective and complex combinatorial approaches may become more necessary as the number of interacting minima/maxima increases. Within the definition of a relatively limited number of desirable characteristics that we consider in this report, we would not expect these auction designs to be necessary or beneficial. Avoiding complex and subjective auction design options supports simplicity and transparency of auction design.

Examples of auctions with multiple clearing prices in practice

- **The GB CfD auctions** employ maxima and minima for different technology types within separate split auctions. The maxima and minima produce separate clearing prices for those technologies. For example, in AR4, minima were applied to tidal energy, floating offshore wind (FLOW) and maxima applied to onshore wind and solar. The FLOW minima demonstrated one risk with this approach as only two projects, potentially leading to artificially high clearing prices. Neither of the maxima that were applied to onshore wind and solar were biting constraints.[16]

- **The French Seabed leasing auctions** use a combination of attributes to identify winners. The factors are compared separately, and each applicant given a score. This has the result of setting different award prices to each participant, and each participant is paid as they bid. There are three criteria that are assessed:
    - Economic and financial value (75%) – The economic and financial value is calculated from the value of the bid and the robustness of contractual and financial arrangements.
    - Consideration of environmental issues (15%) – Environmental impact of the project is assessed based on specific criteria.

[16] DESNZ is also consulting on reforms to the CfD auctions, including the potential to incorporate non-price factors into their design.

  - Consideration of local content (10%) – The percentage of design and installation services that the applicant proposes to undertake by local SMEs.

- **The PJM Reliability Pricing Model (RPM)** is split into several locational delivery areas (LDAs)[17]. LDAs which are constrained use a separate demand curve and can receive a higher clearing price. In last year's auction four LDAs received a 'locational price adder' representing the difference between clearing prices in the constrained LDA and the immediate higher level LDA[18].

- **The Belgian Capacity market** employs an algorithm that considers a set of predefined locational grid constraints that limit the selection of units and selects the combination of available bids that maximises economic surplus. The auction algorithm is implemented by a third-party organisation with little information published on how it functions. The detail of the algorithm is out of scope of the independent auditor report of the auction[19].

4.2.3 Single auction with multipliers

Description of a single auction with multipliers

In a single auction with multipliers, capacity with different characteristics would compete in a single auction. However, eligible capacity would benefit from a multiplier to the clearing price it receives if it clears in the auction[20].

In practice, we would expect an auction with multipliers to proceed as follows:

1. A desirable characteristic is identified, and a suitable multiplier defined.
2. The auction progresses as usual, and a clearing price is determined.
3. Capacity with the desirable characteristic that clears in the auction receives the clearing price multiplied by the agreed multiplier.

A rational bidder in a competitive auction should reflect the clearing price multiplier in their bid price. If successful in the auction, they would receive 'Clearing Price X Multiplier'. In turn, a rational bidder would submit a bid of 'Original Bid Price / Multiplier' such that they would receive the same effective clearing price if they are the marginal plant.

This would have two impacts on outcomes for eligible bidders:

1. They should be more likely to clear in the auction as they submit a lower bid price to reflect the clearing price multiplier they will receive if they clear. This may also have the consequence of lowering the clearing price for the auction, where these bidders become marginal or inframarginal.

2. They will receive a multiple of the clearing price, thus allowing for higher revenues and so sending a signal to investors that this form of capacity brings additional value.

[17] PJM Manual 18: PJM Capacity Market
[18] PJM 2023/2024 RPM Base Residual Auction Results
[19] Belgian Capacity Remuneration Mechanism Y-4 2025-2026 Auction: Independent Auditor Report (creg.be)
[20] Alternatively, non-desirable capacity could face a negative multiplier, leading to its bid becoming less competitive. The effects would be similar.

There may appear to be a question about how multipliers interact with de-rating factors. From a bidder's perspective, the impact of each may be similar. The bidder's revenue and hence bid price is dictated by the combination of capacity volumes and prices. A de-rating factor is a multiplier on the volume of capacity while a multiplier affects the price received.

However, there is an important difference from the auctioneer's perspective. The level of the de-rating factor affects how much capacity needs to be procured in the auction. The multiplier does not affect the volume of cleared capacity, only the price paid for that capacity.
Variants exist in which the multipliers are linked to certain outcomes in the market. For example, the scalars used in the Irish DS3 (ancillary) services are linked to the prevalence of renewable output on the system at the time that the service is needed. The scalar for a given service is greater in periods of high renewable output.

Multipliers can be applied across a relatively large number of characteristics relatively easily and without impacting on the competitiveness of the auction. For this reason, the inclusion of multipliers may be a relatively simple solution for valuing a wide range of characteristics. The I-SEM DS3 Auctions apply scalars to four features, with the purpose of 'increasing the efficiency and reliability of the procurement design by ensuring that the correct signals are provided for system services providers'[21].

Examples of single auctions with multipliers

Examples of auctions that use multipliers or scalers include a proposed design for the Irish CRM and the Irish DS3 auctions.

- **The Irish CRM** considered locational price adjustment to reflect locational constraints. The SEM Committee proposed adjusting the price of individual capacity bids to reflect the consequential costs of choosing one provider over another. However, this price adjustment was considered challenging to implement and it was not introduced.

- **The Irish DS3 auctions**: The scalars in the Irish DS3 auctions reduce the level of payment to service providers where it is identified that value is not delivered to the consumer and increase the level of payment to services that are considered to deliver additional value to the consumer. Four types of scalars were developed: performance, scarcity, product and volume scalars. EirGrid set out a detailed description of the scalars and proposals for how they are set in a consultation[22].

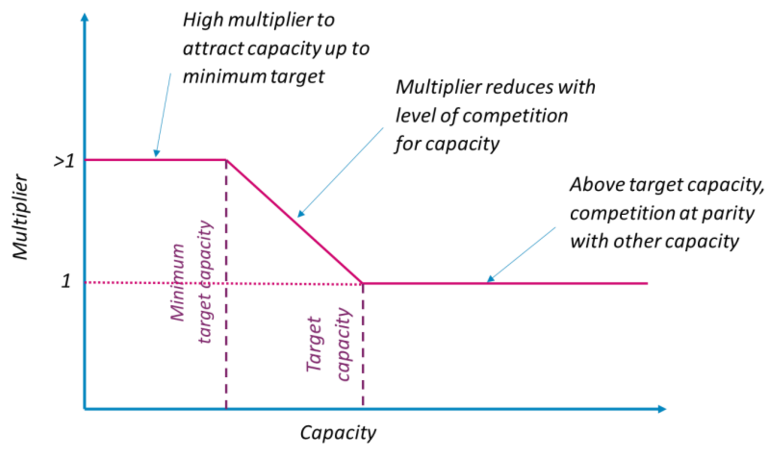
4.2.4 Combinations and variants

We also identify several auction designs which combine properties of the main design options summarised above. We summarise these options in Table 5.

[21] SEM-14-108 DS3 System Services Decision Paper
[22] Consultation on DS3 System Services Contracts for Regulated Arrangements

Table 5: Combined/variant auctions

Combined auction design	How would it work?
Split low carbon/carbon auction with minimum requirement for flexible characteristics within the low carbon auction	Separate auctions would be run for carbon and low carbon capacity, potentially sequenced to procure low carbon capacity as a priority. Within one or both auctions, a minima would be introduced for certain flexibility characteristics. Flexibility would either have to be procured from only the low carbon auction or minima would need to be specified across both auctions.
Split low carbon/carbon auction with multipliers for flexibility within the low carbon auction	Separate auctions would be run for carbon and low carbon capacity, potentially sequenced to procure low carbon capacity as a priority. Within one or both auctions, multipliers would be introduced for certain flexibility characteristics.
Minima for low carbon capacity with multipliers for flexibility	Rather than a split auction, low carbon capacity could be delivered using minima in a single auction. This minimum requirement could be combined with multipliers for flexibility (either all capacity or only low carbon capacity) to encourage the provision of more flexible plant.
'Sliding scale' multipliers	The auctioneer would set a minimum target and a target for capacity with certain characteristics (e.g., low carbon). Multipliers would be applied to capacity with these characteristics, but the applied multiplier would be determined after the auction has been run based on the level of competition. A multiplier would be set at one level at the minimum target capacity. The multiplier would reduce as the volume of desirable capacity increased up to a desirable target capacity from which point the multiplier would remain equal to 1 (i.e., no additional value signal). This approach has the benefit of providing a signal for a certain type of capacity, but which reflects the observed extent of competition. This can benefit the auctioneer where they lack information regarding the potential future pipeline of projects. On the other hand, it transfers uncertainty to auction participants. At the time of the auction, bidders do not know the value of the multiplier they will ultimately face. Their participation in the auction will therefore reflect their view on the level of competition for capacity with the desirable

Combined auction design	How would it work?
	characteristic and their risk appetite. This may lead to conservative bidding in which they enter a bid which assumes a multiplier of 1, thus reducing the likelihood that they would clear in the auction. We provide an illustration of this option in Figure 8. **Figure 8: Illustration of 'sliding scale' multipliers approach** 

4.3 Wider parameters

As well as the three high-level auction designs which are the focus of this report, there are several design parameters that will also need to be carefully considered within a future CM design. Given interactions with a future CM design, we provide a summary of key considerations and interactions with high-level auction design in the following sections.

4.3.1 Payment approach

Three options exist regarding the payment approach for cleared capacity:

- Pay-as-bid (PaB) in which cleared capacity receives payment at the level of its bid;
- First price Pay-as-Clear (FPPaC) in which all cleared capacity receives the price of the highest successful participant; and
- Second price Pay-as-Clear (SPPaC) in which all cleared capacity receives the price of the lowest unsuccessful participant.

The existing GB CM uses a FPPaC design.

Auction theory suggests that a PaB auction design sends the least appropriate incentives to auction participants to enter into the auction at their true costs. Auction participants have an interest in approximating the clearing price and increasing their bid above actual costs in an attempt to clear the auction with as high a bid as possible. Auction outcomes can therefore depend on the risk appetite of participants rather than their actual costs, reducing efficiency of outcomes. This disadvantage of the PaB mechanism is reflected in the international CMs we have reviewed in which all of the CM auctions are PaC[23].

However, it is worth noting that several other auctions use a PaB format. For example, many international CfD auction designs are PaB. PaB auction designs become increasingly necessary as agreements between the bidder and counterparty become increasingly bespoke – e.g., considering non-price factors. In practice, PaB auctions may also have the advantage of limiting inframarginal rent to some degree. Where bidders have a broad range of intended bid prices, those that are inframarginal receive their bid price rather than the full inframarginal rent up to the clearing price. Even allowing for some degree of ‘bidding up’, and lack of information for bidders coupled with an element of risk aversion suggests there may be some overall savings in costs.

A FPPaC auction creates much stronger incentives for truthful bidding. The incentive for participants to increase their bid is reduced because all participants receive the clearing price regardless of their own price submission. However, Aures[24] suggests that a FPPaC auction maintains some incentives for strategic bidding at the margins. As the marginal bidder only receives a profit if their bid exceeds their true costs, this design continues to introduce some incentive for participants to price their capacity above their own costs, close to their expectation of the lowest unsuccessful bid. Therefore, the outcomes of the auction may remain dependent to some extent on risk appetite.

For this reason, Aures suggests that a SPPaC auction is the most incentive compatible. As the clearing price is completely independent of the price of any participants who clear the auction, bidders have the incentive to enter into the auction at their true costs.

Both a FPPaC and SPPaC auction lead to a higher level of inframarginal rent (assuming lack of information and risk aversion) than a PaB design but reduce much of the risk of inefficiency of auction outcomes. Bidders have less to gain from bidding strategically and therefore the merit order is largely driven by the actual cost base of capacity rather than an internal view of strategy and risk appetite.

The GB CfD Auctions use FPPaC. Some developers (particularly those that were unsuccessful in applying for CfDs) have raised concerns over the pay-as-clear mechanism. They suggest that a pay-as-clear structure can lead to the submission of bids that are priced unrealistically low and that contracts are then awarded to projects that are ultimately financially unviable[25]. It has been suggested that pay-as-clear has not resulted in strategic bidding in the offshore wind auctions which are more established. However, concerns have been raised regarding how auctions for smaller scale and other emerging technologies may have been affected.

Whichever auction approach is chosen to send signals to low carbon (flexible) capacity, an approach which is successful in driving more desired capacity will almost certainly increase the clearing price for the relevant capacity. Under a PaC approach, this will lead to an increase in inframarginal rent for low carbon (flexible) capacity that clears below the clearing price, including some proportion that would have cleared in the CM absent of any reform. A PaB mechanism may reduce some of this ‘windfall profit’ for such capacity, though is unlikely to eradicate this additional profit if we assume strategic bidding to uplift bids towards the clearing

[23] In the case of the SEM, the ‘whole market’ auction is PaC, however the locational element of the auction is PaB.
[24] See here
[25] CfD_evaluation_phase_1_final_report.pdf (publishing.service.gov.uk)

price. This may influence DESNZ's decision on whether it is preferable to move towards a PaB payment approach when introducing a reformed CM.

Drawing on international precedent suggests that a PaC approach may remain applicable unless DESNZ identifies significant opportunity for reducing inframarginal rent from the auction under a PaB design, thus reducing costs. However, DESNZ should carefully consider the potential for unintended consequences in moving to a PaB design which is highly likely to introduce incentives for strategic bidding and may therefore introduce risks of inefficient outcomes from the auction.

4.3.2 Auction format

A second key design consideration is the auction format. In the context of CMs, the choice is between a sealed bid, a descending clock auction (or 'Dutch auction') and an ascending clock auction (or 'English auction'). In a sealed bid auction, no information regarding the bids submitted is revealed to auction participants during the auction. The only information that bidders receive is the clearing price upon auction completion. The MISO planning resource auction (PRA) uses single bid auction format as it 'minimizes the ability for participants to signal or game the auction' and 'provides efficient market-clearing prices'[26].

In a descending clock auction, the auctioneer begins the auction at a high price and gradually reduces the price in repeated rounds. As the price reduces, bidders begin to drop out of the auction at a price in which they are no longer willing to offer their capacity. This is repeated until the auction discovers the minimum price at which there is sufficient capacity to clear the auction.

An ascending clock auction works in the opposite direction. The auctioneer starts at a low price and gradually increases the price in repeated rounds. Participants enter into the auction when they are willing to offer capacity at the given price until sufficient capacity is cleared.

The Department for Energy and Climate Change (DECC) decided to use a descending clock format for the existing GB CM. DECC set out the following as perceived advantages of a descending clock format relative to sealed bid[27]:

- *Providers (in particular, new entrants) face considerable uncertainty when estimating capacity costs.*
- *Estimates of capacity costs involve 'common values': many aspects of costs will be similar across projects (e.g., how much energy revenue they will receive); however, each provider will each have their own estimates of these costs.*
- *Where common values are significant, sealed bid auctions have a tendency to lead to the 'winner's curse' – the successful participant(s) are often those who have overestimated revenue/underestimated costs, not the most efficient providers.*
- *The ability to observe the behaviour of participants in previous rounds in a descending clock auction, and adapt bidding behaviour on this basis, mitigates this risk, and should increase the likelihood that the most efficient providers win capacity agreements.*

[26] MISO L100 - Resource Adequacy training
[27] Electricity Market Reform: Capacity Market – Detailed Design Proposals: Here

However, the majority of CM auctions that we have assessed in our international review use a sealed bid design. The exception is the ISO NE FCM which uses a descending clock design in rounds, seeking to capture the benefits of both sealed bid and descending clock auctions, on the basis that neither format is likely to produce higher or lower clearing prices[28]. Risks of a descending clock auction are mitigated by the 'hybrid' round format as *'the round structure in the hybrid DCA (descending clock auction) hampers the ability of the bidders to determine when exiting the auction will set [the] price.'*

Decisions regarding whether to choose a descending clock or sealed bid auction format generally depend on the relative benefits and risks of providing additional information to bidders regarding the bids of others. This depends on the balance of two conditions:

1. **Common value uncertainty**: Common value inputs affect many/all auction participants and are influenced by uncertain external factors (e.g., future electricity prices). Where these common value inputs are unknown, bidders face common uncertainty over their 'missing money'. This can lead to the 'winner's curse' in which auction outcomes are partly dictated by each bidder's perception of an uncertain common input rather than by a consistent valuation of missing money. The winner's curse can lead to a situation in which the successful bidder is the one with the most optimistic view of the uncertain input rather than an inherent cost advantage. This can lead to inefficient outcomes from the auction and, in the case of the CM, can increase the risk of non-delivery.

   A descending clock auction format can reduce this risk. By revealing information on the bids of other participants as the auction progresses, common information on uncertain input values is partially revealed, reducing the risk associated with the winner's curse.

2. **Pivotal bidding strategies**: In a descending clock auction, each bidding round reveals information to the market regarding the amount of capacity remaining in the auction at each possible clearing price. In relatively illiquid auctions in which there are large, indivisible multiunit bids and in which some participants have multiple units participating in the auction, the information provided to auction participants can reveal when a certain bidder becomes pivotal – i.e., the point at which their withdrawal from the auction would clear the auction. In this case, a bidder with multiple units is able to strategically withdraw some capacity from the auction above its actual willingness to accept the clearing price. By artificially increasing the clearing price, the participant may earn higher revenues for its other capacity that remains in the auction.

Considering the GB CM, Harbord and Pagnozzi[29] questioned whether a descending clock auction format was the most suitable choice for the GB auction. They presented the case of Colombia in which they identified evidence of pivotal bidding behaviour in the CM, leading to detrimental auction outcomes. Drawing lessons from international examples, they suggested that market conditions in GB were more suited to a sealed bid than descending clock auction design.

Notwithstanding bidding behaviour, an ascending clock auction with FPPaC is theoretically identical to a descending clock auction with FPPaC. The key difference is in the nature of information revealed to auction participants. In a descending clock format, information is revealed regarding capacity that is no longer willing to participate as the price reduces. In an

[28] ISO NE produced a discussion paper comparing Descending Clock Auctions with Sealed Bid for the FCM: 20160711-dca-v-sealed-bid.pdf (iso-ne.com)
[29] See here

ascending clock format, the information revealed regards the willingness of bidders to enter into the auction as the price increases.

A descending clock auction allows for a SPPaC payment approach whereas this is not possible with an ascending clock design.

When optimising the CM, DESNZ may consider the balance of merits of a sealed bid vs descending clock auction format. The literature is balanced on the benefits and both types of format are observed internationally. Where redesign of the auction reduces auction liquidity, this may increase the benefits of moving to a sealed bid auction format.

4.3.3 De-rating factors

De-rating factors are designed to reflect the expected capability of different technologies to respond during a system stress event. For example, the actual amount of capacity delivered by intermittent renewable capacity is likely to be a fraction of its nameplate capacity.

We do not identify a direct link between the high-level auction design and de-rating factors. Conceptually, the role of de-rating factors will be similar under a split auction, auction with multipliers and auction with multiple clearing prices.

There may appear to be a question about how multipliers interact with de-rating factors. From the perspective of a participant in the auction the two may be effectively equivalent as the participant’s revenue is dictated by the combination of capacity volumes and prices. A de-rating factor is a multiplier on the volume of capacity while a multiplier affects the price received.

However, there is an important difference from the auctioneer’s perspective. The level of the de-rating factor affects how much capacity needs to be procured in total while the level of the multiplier affects the price paid for that capacity.

While out of scope, we discussed the changing nature of system stress events in Section 2.4. As de-rating factors are designed to reflect the definition of a system stress event within the current design of the CM, the changing nature of system stress events could raise more fundamental questions for the role of, and determination of, de-rating factors. For example, a de-rating factor which reflects the capability of capacity to respond at times of peak demand will not appropriately reflect capability of the same capacity to respond to sustained periods of low renewables output.

4.3.4 Non-delivery penalties

As with de-rating factors, we do not consider that the role of non-delivery penalties is directly impacted by high-level auction design, whether a split auction, auction with multipliers or auction with minima.

However, non-delivery penalties are also designed to reflect the ability of capacity to provide output during a system stress event as currently defined in the CM. The changing nature of system stress events may therefore require DESNZ to reflect on the role of, and determination of non-delivery penalties to reflect this. For example, if changes to the CM are introduced to reflect emerging forms of system stress, non-delivery penalties may need to be separated between traditional and non-traditional forms of system stress, allowing differentiation of the capabilities of different types of capacity to respond to each event.

For example, capacity that receives a premium based on its sustained response capability must be exposed to appropriate non-performance penalties against that service requirement. The current annual cap on non-delivery penalties may not be sufficient.

4.3.5 Carbon intensity limits

Under the current CM design, new capacity is able to win 15-year contracts while refurbished capacity can win 3-year contracts and existing capacity can win single year contracts. Given that new-build unabated gas capacity has been awarded 15-year contracts in recent T-4 auctions, CM agreements have already been entered into for new-build capacity for delivery beyond 2035.

In its recent consultation on reforms to the CM, the Government is consulting on measures to better align the CM with its low carbon objectives. This includes placing stricter emissions intensity limits on new and refurbished CM contract holders which will apply from October 2034 onwards. These limits would be set at a level of 100gCO_2/kWh, which DESNZ does not expect that unabated gas technology would be able to meet.

Capacity that does not meet these carbon intensity limits would be subjected to an annual emissions limit of 350kgCO_2/kW, designed to allow for operation as a peaking plant in a limited number of hours per year.

If introduced, these new measures may support a shift towards low carbon capacity in the CM given increasingly strong limitations on carbon emitting capacity that is contracted beyond 2035, without the possibility of retrofitting carbon capture and storage technology.

These measures would be compatible with any of the high-level auction design models which could further strengthen signals for low carbon capacity.

5. Targeting Low-Carbon Capacity

5.1 Designing an auction to target low carbon capacity

The current CM is designed to be technology neutral. Bidders compete for contracts which are based solely on the volume of reliable capacity they can offer, and at what price. DESNZ is now considering whether the CM should be aligned more explicitly with decarbonisation objectives by introducing signals for low carbon forms of capacity into the CM.

5.2 General design considerations

The following considerations would apply to the design of a CM which incorporated signals for low carbon capacity under most/all of the high-level auction designs.

5.2.1 Interactions with other market mechanisms

Today, the main signal for low carbon capacity in the electricity market is sent via contracts for difference (CfDs), carbon pricing, and the Government's Carbon Pricing Support.

Most low carbon technologies can compete in an auction for CfDs which provide a long-term guaranteed revenue stream by providing an agreed 'strike price' for export of power. Where the market price is above or below this strike price, generators are paid, or pay, the difference.

Electricity capacity that emits carbon upon dispatch must pay a charge on the carbon it emits under the UK Emissions Trading Scheme and Carbon Price Support[30]. This reduces the competitiveness over time for carbon emitting capacity to dispatch, which may also flow through to investment signals where sufficiently strong and predictable.

Historically, other mechanisms have been used to support low carbon generators, including the Renewables Obligation which provided subsidy support on top of the wholesale price, through a traded certificate scheme. Some low carbon generators do not receive any support or long-term revenue stabilisation and instead base their investment decisions on the combination of revenues they can receive, primarily from the wholesale or Power Purchase Agreement (PPA) market.

We assume that low-carbon signals in the CM would be sent alongside a continuation of the CfD as well as a continuation of UK carbon pricing. CfD contracts would be the primary support mechanism for mass low carbon generators (subject to other reforms being considered under REMA) and CfD contract holders would continue not to be eligible for the CM. Low carbon signals in the CM would be targeted at other low carbon forms of capacity including DSR, batteries, long duration storage technologies, CCS and hydrogen power plants, for example.

Our modelling results are affected by assumptions on whether or not LDS, CCS and hydrogen capacity are supported by additional support mechanism outside the CM. We assumed in our

[30] See here: https://www.gov.uk/government/publications/uk-emissions-trading-scheme-and-carbon-price-support-apply-for-compensation

central scenario that these forms of capacity do not receive long term revenue support elsewhere[31], reflecting a scenario where the CM is designed to play a bigger role in supporting these technologies.

We test this assumption through a sensitivity (0) in which we assume that these forms of capacity receive wider support. This is modelled by assuming that they are willing to bid into the CM as price takers.

Interconnectors continue to participate in the CM but are not categorised as low carbon within our modelling.

5.2.2 Eligibility

The auctioneer must set a limit on carbon intensity for capacity which is determined to be eligible as low carbon. If capacity such as CCS is intended to participate in the auction, this limit should allow for associated residual emissions. It would also allow for a small amount of natural gas blending with hydrogen fired power plants.

One option is to align eligibility for low carbon capacity with the emissions limits which DESNZ has consulted on as part of its review of the CM. This would introduce a limit of 100g CO_2/kWh emissions intensity for plant classified as low carbon.

While the CM consultation also includes proposals for a yearly emissions limit that would apply to plant that does not meet the emissions intensity limit, this is intended to allow participation of unabated gas plant that would run in a small number of hours in the year. We do not believe that this should be classified as low carbon capacity within the CM auction.

5.2.3 Contract length

CM contract lengths were originally designed in the context of conventional power plants. A 15-year contract was designed to strike an appropriate balance between providing long term revenue certainty and the potential for asset stranding given uncertainty about future pathways.

As a future CM is re-focussed on sending signals for the development of new, low carbon forms of capacity, there is a question about whether this contract length remains most appropriate.

The appropriate contract length may be influenced by several factors, including the nature of capacity that the auctioneer intends to target. Long lifetime, capital intensive plant may require a longer period of financial stability to make the project commercially viable. If the intention is for the CM to act as the main mechanism to provide this revenue certainty, this may imply longer contract durations, perhaps even stretching beyond a 15-year time horizon. However, if this form of capacity is provided with revenue stability elsewhere (e.g., through a revenue cap

[31] This reflects the fact that policy on support for such forms of capacity was still under consideration by DESNZ. Assumptions regarding alternative forms of support were agreed with DESNZ but do not necessarily reflect DESNZ policy positions at the time.

and floor agreement), the CM may act more as one amongst several potential sources of revenue, allowing for shorter contract durations driven by the needs of capacity that is not eligible for long term revenue stabilisation mechanisms. Depending on such choices, this may allow for contract lengths of less than the existing 15-year agreements for new-build capacity.

As we explore in more depth in Section 6.2, some forms of LDS capacity may require revenue certainty over a period beyond 15 years to provide sufficient investor certainty for capital intensive project development. For the purposes of our modelling, we retain a 15-year contract duration for new-build capacity but note that the assumption that this allows for delivery of LDS capacity may need to be tested further.

Finally, given objectives for full decarbonisation of the electricity system by 2035, DESNZ may wish to restrict provision of long-term agreements to carbon emitting plant that goes beyond this horizon. This may also be achieved through the more stringent emissions intensity limits proposed by DESNZ in its parallel consultation.

5.2.4 Target capacity and demand curves

Within a split auction or auction with minima for low carbon, specific target capacity and demand curve parameters need to be set for the low carbon part of the auction.

Maximising low carbon capacity within value for money constraints implies a shallow sloping demand curve accompanied by a conservative target capacity. This can mitigate the risk to the auctioneer of setting the target capacity at a sub-optimal level. The conservative target capacity mitigates the risk of a very high clearing price or an auction that does not clear. The shallow demand curve can allow value for money capacity to clear in the auction, even above target capacity.

Target capacity should be set taking into account the auctioneer’s projection of the low carbon supply pipeline. It should be set sufficiently below the pipeline of potential low carbon capacity to enhance competition for low carbon capacity contracts.

5.2.5 Price caps

Including signals for low carbon capacity in the CM may introduce a need to consider the appropriate price caps that should apply for eligible capacity.

The price cap in the CM is currently set as a multiple of the cost of a new entrant (CONE) CCGT, a technology that would not meet the low carbon criteria. This risks the price cap being set too low as it may not reflect the costs of entry for new forms of low carbon capacity.

Maintaining the logic of price cap within the CM, the price cap that is applied to low carbon capacity could be designed to reflect the CONE of the cheapest or most likely form of new-build capacity that can meet the requirements. This may evolve over time to reflect potential entry from CCS plant, hydrogen power stations, etc.

A higher price cap could be reflected in any of the three auction designs being considered. In a split auction, the low carbon auction would have a higher price cap than the carbon auction. In an auction with minima, the minima would be able to clear at a higher price. In an auction with multipliers, the multiplier could be reflected in the price cap such that eligible capacity could receive a higher clearing price.

5.2.6 Purchasing more expensive capacity

Regardless of the auction design, the objective is similar. In each case, the auction is being designed to provide an additional investment signal to a certain type of capacity, whether low carbon or flexible. This can only be achieved by agreeing CM contracts with capacity that would have been out of merit within the status quo single auction design. To achieve this objective, it is unavoidable that CM contracts will need to be agreed with more expensive plant and costs of the CM may increase relative to the status quo. This will not always be the case however, as auction design may also lead to lower inframarginal rent for some forms of capacity, reducing overall costs.

The overall impacts on auction cost will likely differ between auction designs, even if they achieve the exact same capacity mix. This is because each design has different implications for the inframarginal rent of other CM participants. A design which targets capacity providers with a desirable characteristic more effectively will limit the extent of inframarginal rent which is provided to other CM contract holders, therefore reducing the additional costs which fall onto consumers to achieve decarbonisation objectives.

While auction designs may increase costs of the CM, this is a narrow representation of overall impacts. Capacity market contracts provided to low carbon and flexible capacity through alternative CM designs may support more flexible management of the system overall, resulting in lower costs in other areas of the market such as balancing services or flexibility markets. They may also support faster and lower cost transition to a decarbonised system by sending clearer investment signals. Quantification of these wider impacts is not captured within our modelling of the CM. When considering the analysis in this report, it is important to note that these are focussed on CM outcomes without accounting for wider costs and benefits.

5.3 A low-carbon split auction

5.3.1 How a split low carbon auction would work

Conceptually, a split low carbon auction would be relatively straightforward. A targeted auction would be held for capacity which is classified as low carbon (existing and new capacity) with a second auction held in which remaining capacity is able to compete for CM contracts.

The parameters for each auction would be set independently with the objective of maximising the volume of low carbon capacity that receives a CM contract, subject to ensuring value for money. Remaining capacity would then 'make up the difference', ensuring that overall target capacity continues to achieve the required de-rated capacity margin.

Simultaneous or sequential?

A split auction could take place simultaneously or sequentially. For example, simultaneous split auctions could take place at T-4 and at T-1. Or auctions for new and refurbishing low carbon capacity could be held at both T-4 and T-1 with sequential auctions for remaining capacity held after the low carbon auction has cleared and results have been confirmed.

Alternatively, if the intention is to avoid the development of any new-build carbon plant, auctions multiple years ahead of delivery (e.g., T-4) could be targeted at low carbon capacity with remaining capacity only able to participate in auctions at T-1.

In the case of a simultaneous split auction, target capacity and other auction parameters would have to be specified ahead of the auction. Under a sequential split auction, the low carbon auction would take place first, providing information on the amount of low carbon de-rated capacity that has cleared the auction and allowing the parameters of the auction for remaining capacity to be set taking into account achieved low carbon capacity.

The remainder auction could be targeted only at capacity that has not participated in the initial low carbon auction. Alternatively, all capacity, including low carbon capacity that did not clear in the low carbon auction could be allowed to participate. The latter option has the benefit of providing further opportunities for low carbon capacity to clear. However, it raises two potential issues.

First, knowing that they are able to participate in a second auction, bidders may be more prepared to place strategic high bids, knowing that if they fail to clear, they will have a further opportunity to win a contract, and potentially with more information about competitor bidding behaviour.

Second, allowing all capacity to participate in the second auction could lead to a scenario in which low carbon capacity that fails to clear in the targeted low carbon auction could in some circumstances receive a higher clearing price in the second auction. While auction parameters should be designed with the intention of avoiding this outcome, it could lead to perceptions of unfairness and impact on incentives to participate in the first low carbon auction.

We consider that the opportunity to construct a second auction for remaining capacity based on information provided from the first low carbon auction is one of the main benefits of a split auction. Whether or not unsuccessful low carbon capacity from the first auction should be able to compete in the second remainder auction is more finely balanced. While this approach may support maximisation of low carbon capacity, it may have important unintended consequences.

Descending clock vs sealed bid

Splitting the auction may raise the potential for strategic bidding and pivotal bidding strategies as liquidity in each auction is lower than would have been the case in a single auction. The auctioneer’s assessment of expected liquidity ahead of each auction may help to inform whether the risk of strategic bidding within a descending clock auction format implies moving to a sealed bid auction.

What happens if the low carbon doesn’t clear?

Under a simultaneous split auction, it is likely that the auction will need to be re-run if insufficient eligible capacity bids within the price cap to clear the auction.

However, with a sequential split auction, the auctioneer may have the option to take all low carbon capacity that entered the auction and then re-define target capacity in the carbon auction to account for that outcome. While this provides a fallback to avoid re-running the auction, it is not a desirable outcome for the auctioneer. It may result in a very high clearing price in the low carbon auction (particularly if the position of market power for low carbon capacity is anticipated). However, it may be preferable to re-running the auction.

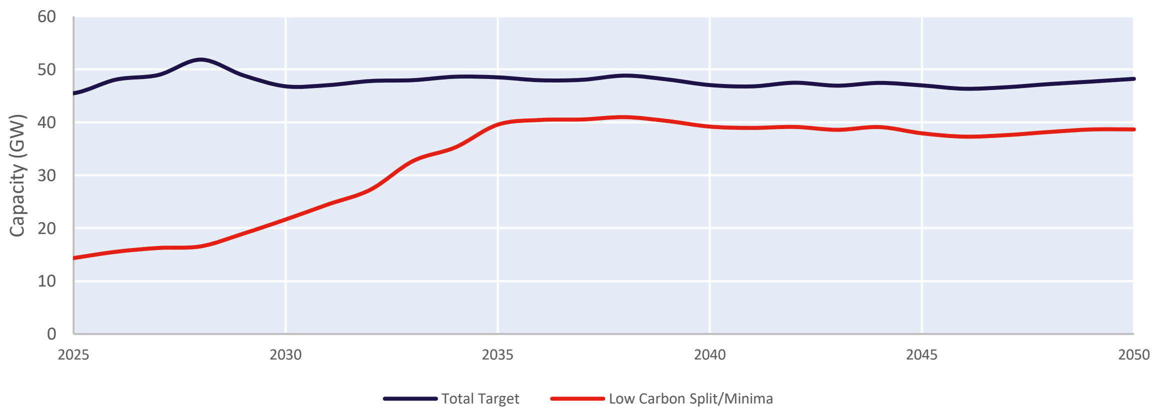
5.3.2 Evaluation of a split low carbon auction

Within a split auction for low carbon capacity, the auctioneer's objective would be to maximise contracting of low carbon capacity but while balancing this against objectives to retain competitive pressures and ensuring value for money.

In our modelling, when setting the target low carbon capacity, we consider the ability of a split auction to deliver a low carbon power system and hence prioritise this objective for the auctioneer. This represents an ambitious low carbon split auction target capacity (Figure 9) in which we set the low carbon capacity target at the lower of:

- 90% of the total low carbon supply pool available within our modelling methodology; or
- The total auction target capacity net of capacity provided by interconnection (i.e., allowing interconnectors to continue to clear).

Figure 9: Capacity Targets for Low Carbon Split Auction



1. ***REMA objective: Ensure that the security of the system can be maintained at all times.***
    a. *Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output*
    b. *Supporting investment cases in capacity with characteristics which support security*

So long as both split auctions clear, and assuming that de-rating factors and non-delivery penalties are set appropriately, a split auction should not directly impact on security of supply outcomes.

A split auction does introduce additional risk that the low carbon auction will not clear, e.g., if the auctioneer anticipates more low carbon capacity than exists in the market and sets the low carbon target capacity too high. As well as increasing the cost to consumers of clearing high priced capacity, this could impact on security of supply given that the lower target capacity in the carbon auction will have sent a market signal, potentially meaning that there is insufficient carbon capacity to fill the remaining capacity gap.

One form of split auction may have greater impacts on security of supply than others. We discussed the option of limiting the auction which is intended to facilitate new build capacity (e.g., T-4) to only low carbon capacity. Carbon capacity could only compete at T-1, limiting scope for new build carbon capacity. Over time, this approach may become more viable. However, the inherent security of supply risk associated with relying solely on new build low carbon capacity may be too significant in the near term while many forms of low carbon capacity develop in technological maturity.

2. ***REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB's dependence on fossil fuel generation.***

    a. *Providing appropriate economic signals for investment in low carbon capacity*

Subject to the potential capacity supply pool allowing for delivery of a high volume of low carbon capacity, our quantitative analysis supports the conclusion that a split low carbon auction could significantly increase the amount of low carbon capacity clearing in the CM relative to the status quo single auction. Under our modelling, we observe a step change in the delivery of low carbon capacity by 2035 relative to the status quo with this trend continuing over the remainder of the period. The remaining carbon capacity within the modelling is predominantly interconnection that is not assumed to be eligible for the low carbon split auction.

This does not mean that the CM alone can deliver this level of low carbon capacity. To do so would require the appropriate wider market design and conditions as well as sufficient technological and commercial viability to deploy such technologies at scale. However, the results indicate that if conditions are present to allow for such outcomes, a split low carbon auction can allow for a greater proportion of CM contracts to be met by low carbon capacity than observed under the counterfactual.

In Figure 10 we show the mix of carbon and low carbon capacity that clears under the single and split auction designs in our modelling out to 2050.

Figure 10: Low carbon and carbon capacity mix in our modelling of a low carbon split auction

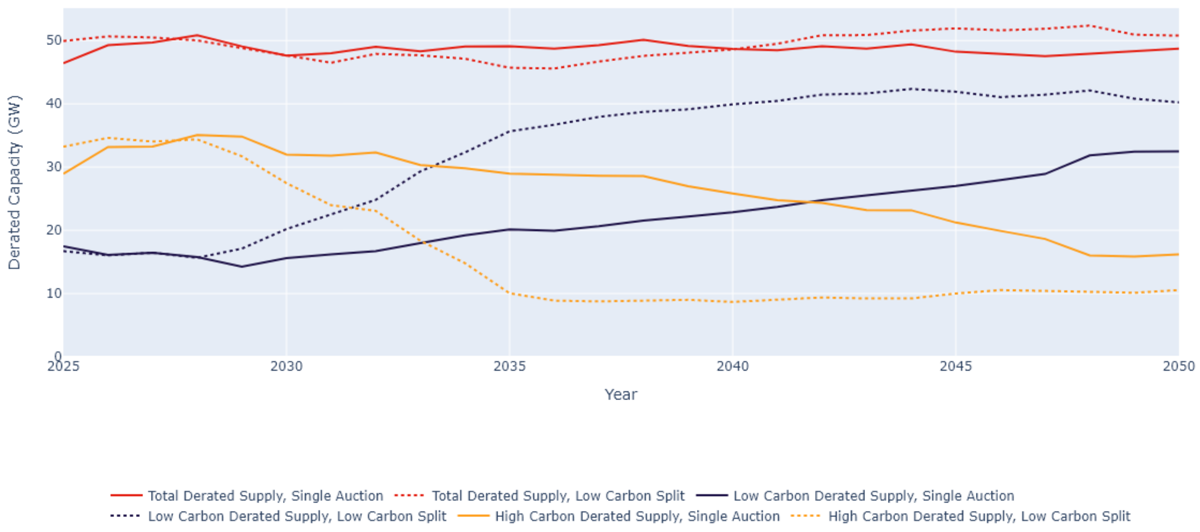
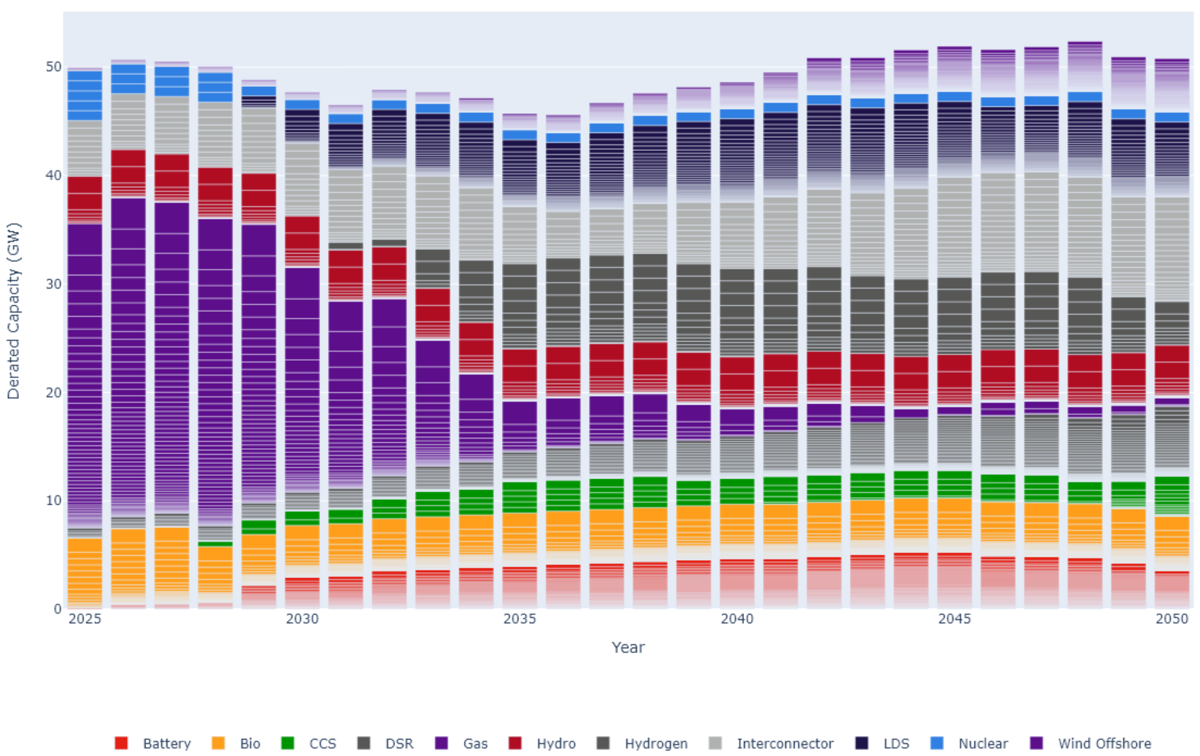


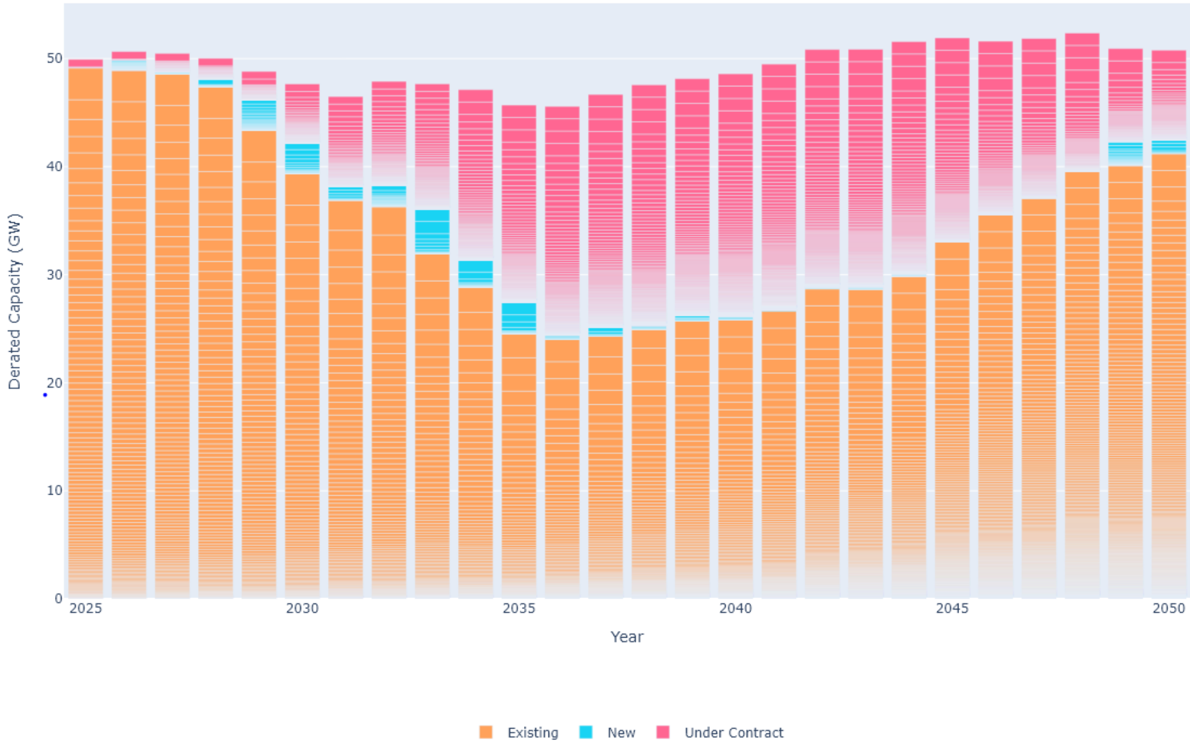
Figure 11 shows the breakdown of capacity. Relative to the single auction (Figure 4), the split auction delivers a significant additional volume of hydrogen, long duration storage and CCS capacity that clears the CM auction over time. While a small amount of unabated gas capacity continues to clear in the auction beyond 2035, the volume is much lower than in the single auction.

Figure 11: Breakdown of capacity under the low carbon split auction



In comparison to the single auction, the additional signals sent be the low carbon split auction supports additional investment in new-build capacity in early years, with much of this under contract and then becoming existing capacity in the CM towards the end of the period (Figure 12).

Figure 12: New-build capacity under the split low carbon auction



3. REMA objective: Provide the right signals for flexibility across the system.

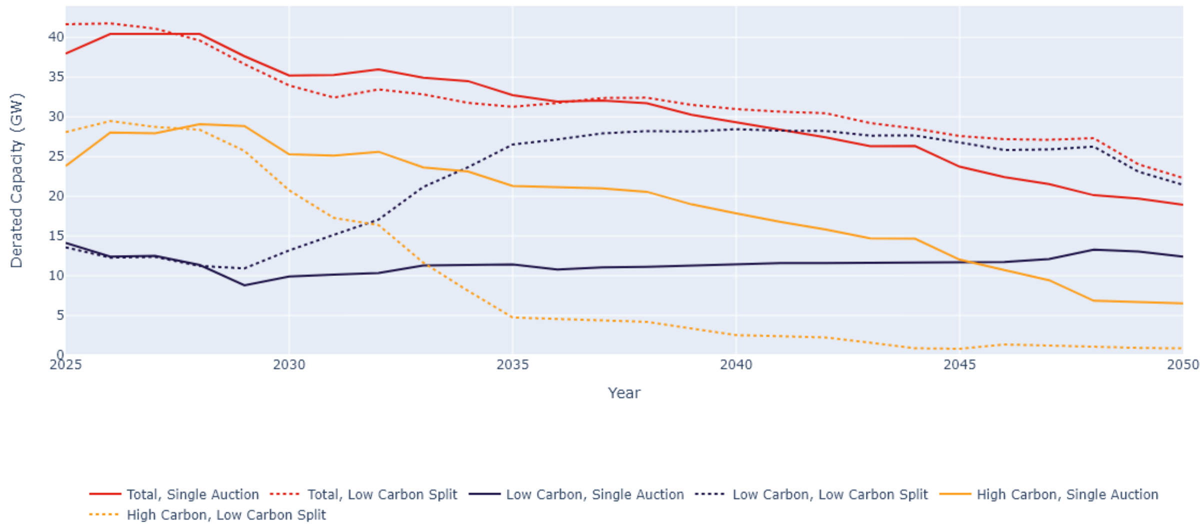
   a. Providing appropriate economic signals for investment in low carbon flexibility

   b. Enabling participants to reap the benefits they bring for the wider energy system

While a low carbon split auction does not send any explicit signals for flexibility, it can nevertheless impact on the amount of flexibility which is delivered indirectly by impacting on the capacity mix.

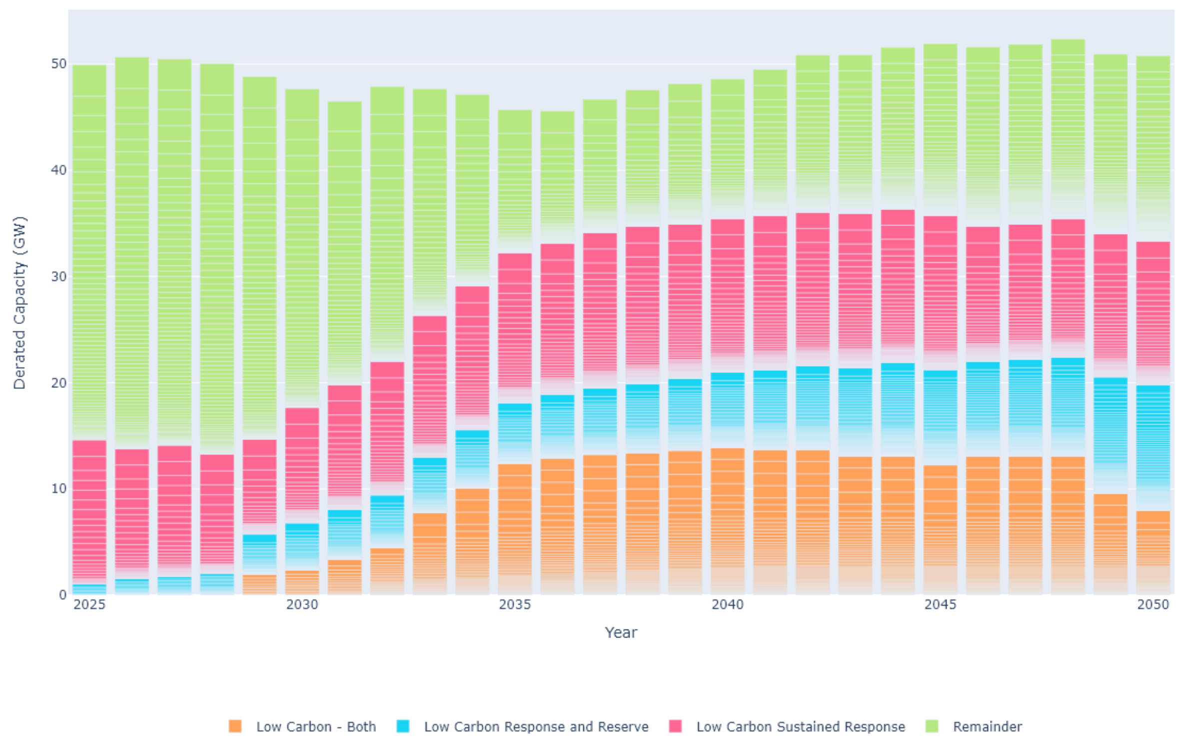
We observe a general trend for sustained response to fall over time in both the single and split low carbon auction (Figure 13). Under the split low carbon auction, the change in the capacity mix delivers a slightly lower level of sustained response between 2027 and 2036 as less unabated gas capacity is delivered. However, from 2036 onwards, more sustained response is delivered under the low carbon split auction as long duration storage, hydrogen and CCS bridges the gap in unabated gas. The low carbon split auction also significantly increases the proportion of sustained response delivered which is low carbon.

Figure 13: Sustained Duration Response capacity under Single and Split Low Carbon Auctions



The split low carbon auction continues to deliver capacity that may be designed to deliver response and reserve services, with the provision of these services by low carbon forms of capacity growing over time (Figure 14).

Figure 14: Derated capacity under low carbon split auction split by flexibility capability types



Whilst the split auction is likely to drive a reduction in the provision of unabated gas capacity, this also requires consideration of unintended consequences relating to services such as ramping and inertia.

4. ***Additional objective: Cost-effective provision of energy security for consumers***

    a. *Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary*

    b. *Minimising the cost of implementing and operating the auction*

    c. *Ensuring complementarity between the CM and other mechanisms within the electricity market such as revenue cap and floor arrangements, balancing services and renewables support mechanisms.*

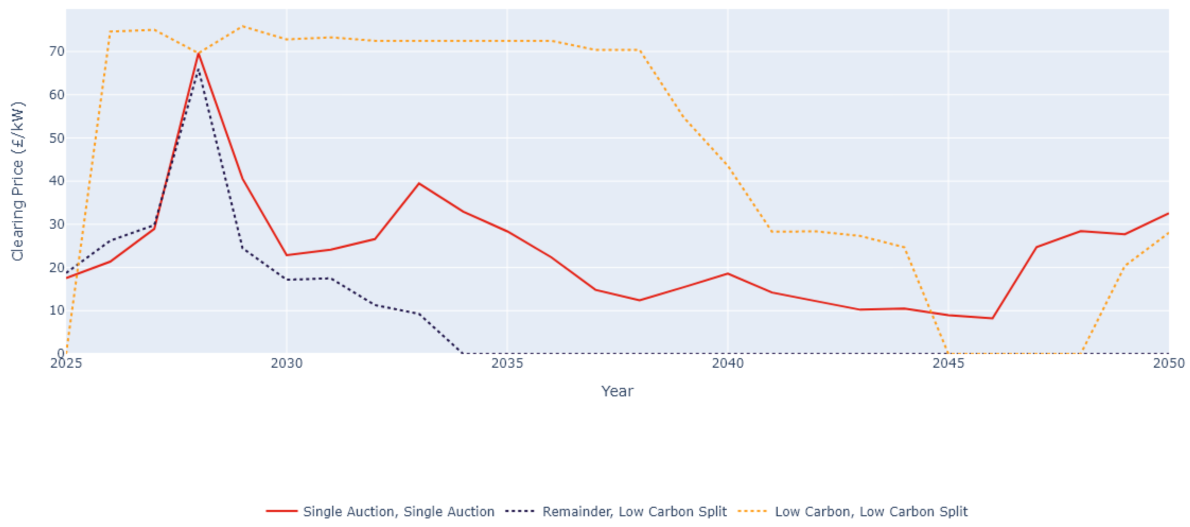
As the split auction targets an increase in low carbon capacity, it is likely to require procurement of more expensive capacity in the low carbon auction, at a higher clearing price than under the status quo. The inverse is true for the carbon auction where we would expect the auction to clear further down the merit order and therefore the clearing price to be lower. We generally observe this trend in our modelling of the split auction (Figure 15) with additional low carbon capacity leading to high clearing prices in the low carbon split auction for the much of the period, clearing at, or close to the price cap in many years at the start of the period.

The modelled scenario for the split low carbon auction represents one in which 2035 decarbonisation targets are met with deployment of a significant volume of new-build flexible low carbon technologies (hydrogen, LDS and CCS). This new build capacity means that only small volumes of capacity need to be procured through the carbon auction beyond 2035 and consist predominantly of interconnection with a small amount of unabated gas capacity. In our modelling, the small amount of unabated gas capacity is able to enter into the CM at a very low price. Some of this capacity has recouped up-front investment and receives inframarginal rent in the wholesale market in some periods, driven by a high hydrogen price[32]. This drives a clearing price of £0/kW in the carbon auction.

As has previously been noted, this outcome depends not only on CM design. It assumes that the wider market design, technological and commercial readiness of low carbon capacity allows for the potential supply pool included within our modelling.

[32] This is conditional on the set of assumptions used under Baringa's power system model.

Figure 15: Clearing price in the low carbon split auctions



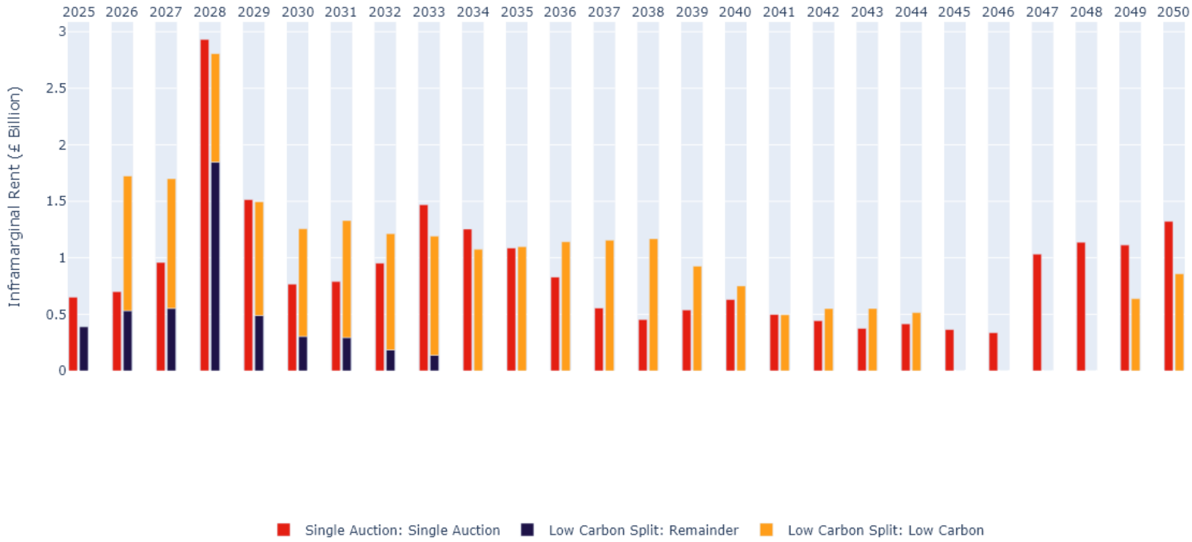
Inframarginal rent under a split auction will result from a balance of two opposing trends:

- Capacity that clears in the low carbon auction will often do so at a higher clearing price. A proportion of this capacity would have cleared in a single auction without any reform. This capacity will receive additional inframarginal rent relative to the counterfactual.
- Capacity that still clears in the carbon auction will generally do so at a lower clearing price, receiving less inframarginal rent than under the counterfactual.

Since the net impacts will depend on the two trends, it is not possible to draw a definite conclusion on the impacts of a split auction on inframarginal rent. Whether inframarginal rent increases or decreases relative to the status quo will be sensitive to the specific merit order and how this is affected by changes to the auction design.

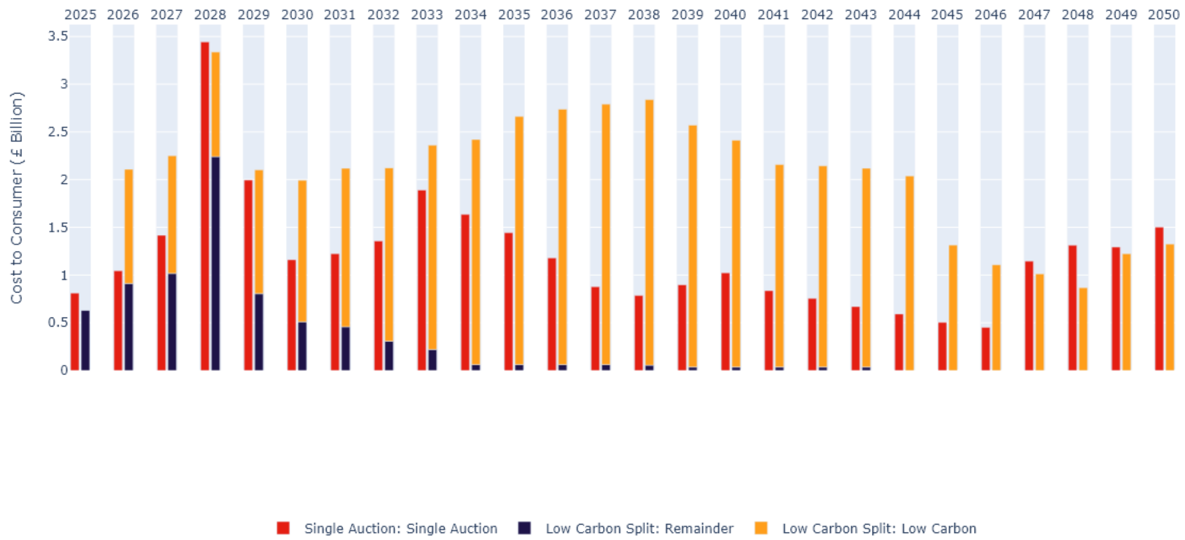
In our modelling of the split auction, the combination of these two trends slightly increases the overall level of inframarginal rent (Figure 16). Average annual inframarginal rent in the single auction is £0.89 billion. Average inframarginal rent in the low carbon split auction is £0.74 billion and, in the carbon auction, is £0.18 billion, leading to a total inframarginal rent of £0.92 billion under the split auction. Note that this assumes a £0/kW clearing price in many years of the carbon auction which is unlikely to be observed in practice.

Figure 16: Inframarginal rent under low carbon split auction



Our modelling scenario suggests that this combination of factors results in an increase in the costs of the CM under a split auction (Figure 17). Average annual cost of the CM under the single auction is £1.2 billion in our modelling. The average cost of the low carbon split auction is £1.74 billion, and the average cost of the carbon split auction is £0.29 billion, resulting in an average total cost of £2.03 billion. Much of this additional cost is observed around the middle of the period when the split auction leads to long term CM contracts being agreed with new-build low carbon capacity. As has previously been noted, this is a narrow assessment of costs. Cost increases in the CM may be balanced against cost decreases elsewhere in the market and on the speed and cost of achieving a decarbonised electricity system.

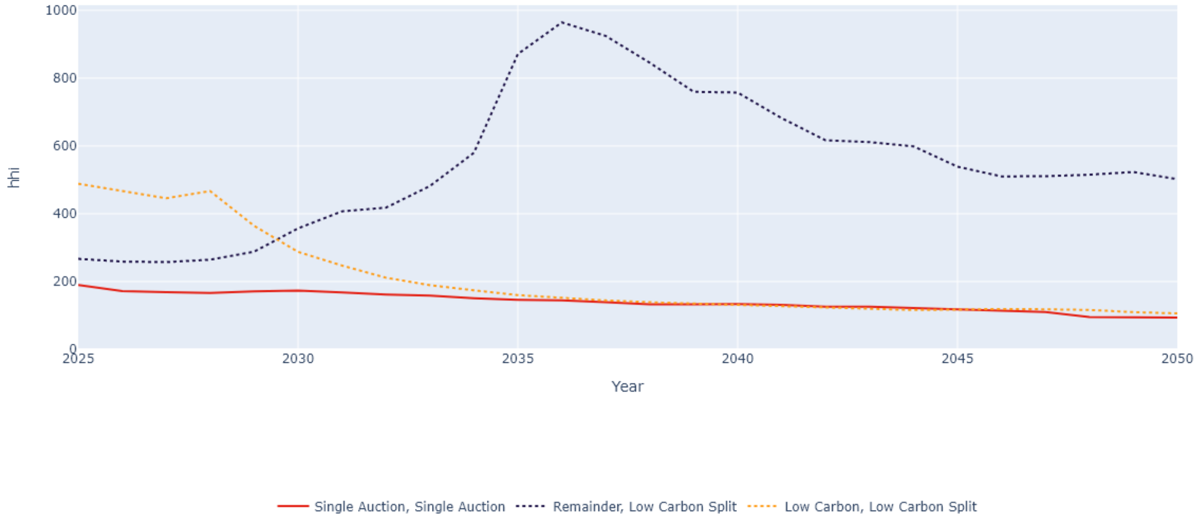
Figure 17: CM auction costs under a split auction



This modelled finding is expected to hold in a competitive auction with 'honest' bidding. However, splitting the auction would generally reduce liquidity in both auctions. We would expect the low carbon split auction to become increasingly competitive over time but with potential liquidity challenges in early years. Over time, less and less capacity may compete in the carbon auction, potentially introducing greater potential for strategic bidding which may increase the likelihood of strategic bidding behaviour. As previously noted, it is unlikely that the auction would clear very close to a price of £0/kW in practice.

The HHI metric in our modelling demonstrates this trend (Figure 18), with higher concentration of capacity in the carbon emitting auction in the middle and late parts of the period – predominantly interconnection and some remaining unabated gas capacity.

Figure 18: HHI under the low carbon split auction



The implementation and operation of either of the split auctions would have a similar resource burden to the single auction in the counterfactual. While there will be resource synergies between split auctions, running two auctions will introduce additional costs for the auctioneer and for participants in the market, many of whom will bid assets into both auctions.

The additional resource burden is most likely to result from the need to develop separate parameters for each auction. This can multiply the administrative challenge of determining separate target capacity and demand slopes for each. A particular challenge is setting the target capacity of the low carbon auction at an appropriate level which maximises low carbon capacity but retains competitive pressures. This will require an assessment of the low carbon capacity pipeline.

Considering complementarity with other mechanisms, this will depend more on auction parameters such as eligibility than it does on the high-level auction design. For modelling purposes we assume that the CM provides the primary investment signal to hydrogen, LDS and CCS plant.

However, it is possible that a cap and floor agreement could act to stabilise long term revenue while a CM contract provides a source of revenue within the cap and floor.

5. ***Additional objective: Avoiding creation of unnecessary risk and uncertainty***

    a. *Minimising unintended consequences from auction design*

    b. *Adaptability of auction design to market and technological evolution*

We previously discussed considerations regarding the provision of services currently delivered by gas fired generators and the potential reduction in auction liquidity from splitting the auction that could introduce more scope for strategic bidding.

An additional unintended consequence may result from the challenge in setting appropriate target capacity for the low carbon auction that maximises contribution of low carbon capacity while retaining competitive pressures. The challenge for the auctioneer is greater than under the counterfactual as this will need to be informed by a forward view of the low carbon capacity pipeline. We previously mentioned potential challenges for security of supply if the auctioneer sets a target capacity for low carbon capacity which is too high and is not delivered. At the same time, the auctioneer will want to deliver as much value for money low carbon capacity as possible. Setting a conservative target capacity with a shallow sloping demand curve can help to avoid suboptimal outcomes.

The most direct way to adapt the split auction over time is to adjust the target capacity and demand curves to reflect evolution of the expected low carbon supply pool. This approach is intended to allow more low carbon capacity to clear where there is plentiful supply potential but retain competitive pressures where the supply pool is more limited. The lead time ahead of delivery presents an additional challenge. The auctioneer must take a view on the potential capacity that could enter into the market several years ahead.

A final unintended consequence of a split auction may be in the signals it sends to participants. While a split auction would be designed with the expectation that the auction for low carbon capacity would clear at a price greater or equal to the auction for remaining capacity, this is not guaranteed. Depending on the target capacities set by the auctioneer, it is possible that this could be reversed with the low carbon auction clearing below the price of the remaining auction. This could become more likely over time if a reduction in liquidity in the remaining auction results in moving down the merit order and raises more risk of strategic bidding. While this outcome is not evident from our modelling, if it did occur, it could lead to questions of fairness and may introduce perverse signals/incentives which encourage carbon emitting rather than low carbon capacity.

5.4 An auction with minima for low carbon capacity

5.4.1 How an auction with minima for low carbon capacity would work

An auction with minima for low carbon capacity is conceptually similar to a split auction. Minima would be introduced into a single auction to reflect a minimum amount of low carbon capacity that would need to clear in the auction. This would allow for a higher clearing price for low carbon capacity, where needed to achieve the minimum capacity requirements. Almost equivalent would be an auction with maxima set for capacity which is not low carbon, leading to a single auction but with a constrained (lower) clearing price for carbon emitting plant.

Descending clock vs sealed bid

As with a split auction, introducing minima increases the risk of strategic bidding by reducing the liquidity of a part of the auction. However, one advantage over a split auction is that low carbon capacity would continue to compete with carbon capacity in the overall auction. This reduces the risk of strategic bidding in the carbon capacity auction, associated with reducing liquidity over time.

Nevertheless, given constraints applied to the low carbon part of the auction, an assessment of expected liquidity of low carbon capacity may help to inform whether a sealed bid design becomes preferable.

What happens if the minima does not clear?

As with a sequential split auction, the auction may not need to be re-run if the minima does not clear. While the minima can specify the volume of low carbon capacity that will clear if sufficient capacity enters the auction, there is a fallback option of clearing more carbon capacity if there is insufficient low carbon capacity present in the auction. This is not a desirable outcome for the auctioneer as it may result in a very high clearing price for the minima (particularly if the position of market power for low carbon capacity is anticipated). However, it may be preferable to re-running the auction.

5.4.2 Evaluation of a single auction with minima for low carbon capacity

As with a split auction for low carbon capacity, the auctioneer's objective for a low carbon minima would be to maximise contracting of low carbon capacity but while balancing this against objectives to retain competitive pressures and with possible constraints to ensure value for money.

For consistency, we set the low carbon minima equal to the target capacity for low carbon under the split auction. We set the price cap equal to that in the central auction. From a modelling perspective, this results in auction outcomes which are identical to the split auction. Capacity that is needed to meet the minima clears at a clearing price equivalent to that observed in the split auction. Remaining capacity clears at a lower clearing price, equivalent to that observed in the split auction. Results for inframarginal rent and auction cost are also identical.

Evaluation in this section therefore focusses on qualitative differences between the split and minima auctions that do not impact on modelling outcomes but may impact on auction outcomes in practice.

1. ***REMA objective: Ensure that the security of the system can be maintained at all times.***
    a. *Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output*
    b. *Supporting investment cases in capacity with characteristics which support security*

So long as both the minima and main auction clear, and assuming that de-rating factors and non-delivery penalties are set appropriately, a split auction should not directly impact on security of supply outcomes.

A minima auction introduces some risk that the minima will not clear, e.g., if the auctioneer anticipates more potential capacity than exists in the market. Similar to a split auction, this could impact on security of supply if the minima has the unintended consequence of discouraging carbon capacity from competing in the main auction given the market signal sent by the minima.

2. ***REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB's dependence on fossil fuel generation.***
    a. *Providing appropriate economic signals for investment in low carbon capacity*

As observed for the split auction, our quantitative analysis adds to the qualitative conclusion that an auction with minima has the potential to increase the amount of low carbon capacity that clears the CM relative to a single auction if the wider market conditions, technological and commercial readiness of such technology enables its deployment[33].

3. ***REMA objective: Provide the right signals for flexibility across the system.***
    a. *Providing appropriate economic signals for investment in low carbon flexibility*
    b. *Enabling participants to reap the benefits they bring for the wider energy system*

While a low carbon auction with minima does not send any explicit signals for flexibility, it can nevertheless impact on the amount of flexibility which is delivered indirectly by impacting on the capacity mix. As Under the modelled low carbon auction minima, we observe the same outcome to that discussed for a split auction. Less sustained response is delivered in the early part of the period, but more sustained response is delivered from around 2036 onwards. (Figure 13 and Figure 14).

As with a split auction, replacing conventional capacity in the supply mix may introduce additional challenges associates with retaining sufficient flexibility and operational capabilities currently provided by conventional power stations.

Some flexible capacity such as interconnection may not qualify for the low carbon auction. Some care may need to be taken that the design of the CM does not have the unintended consequence of crowding out desirable sources of flexibility that would otherwise participate in the CM.

4. ***Additional objective: Cost-effective provision of energy security for consumers***
    a. *Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary*
    b. *Minimising the cost of implementing and operating the auction*
    c. *Ensuring complementarity between the CM and other mechanisms within the electricity market such as revenue cap and floor arrangements, balancing services and renewables support mechanisms.*

[33] This assumes that there is an underlying pool of low carbon capacity that is available to bid into the CM.

Similar to a split auction, we would expect an auction with minima for low carbon capacity to lead to a higher clearing price for low carbon capacity and a lower clearing price for carbon capacity. The mechanism is similar. Where the minima leads to more low carbon capacity being procured, we move up the merit order to higher priced capacity. This reduces the amount of carbon capacity that is procured, lowering the clearing price for carbon capacity.

Supported by findings from our modelling, we would expect an auction with minima to lead to higher inframarginal rent for a proportion of low carbon capacity (that would have cleared in a single auction) and lower inframarginal rent for carbon capacity (Figure 16).

The overall impact on inframarginal rent, similar to the split auction, will depend on a number of factors.

Overall, the impact of an auction with minima for low carbon capacity will often be to increase the overall cost of procuring an equivalent level of capacity, all else being equal[34]. Our modelling scenario includes an expected increase in average annual costs from c. £1.2 billion per year to c. £2 billion per year (Figure 17, with much of this driven by long term CM agreements with new-build low carbon capacity around the middle of the period. As has been discussed previously, this represents a narrow consideration of cost limited only to the CM and not reflecting wider system benefits or consideration of impacts on the speed or costs of decarbonizing the electricity system.

One advantage of an auction with a minima in comparison to a split auction is that the former requires capacity that is not eligible for the minima to compete directly with capacity that is eligible. Even as less and less carbon capacity remains in the auction, this will place an additional constraint on the potential for strategic bidding.

The implementation and operation of an auction with a single minima should not require significantly more resource than the existing auction design. One advantage over a split auction is that only one auction needs to be run, reducing some time and resource required to physically run multiple auctions. The clearing algorithm should be relatively straightforward to develop, and we expect that a descending clock design would remain viable if preferred. The additional resource burden is most likely to result from the need to set the minima at an appropriate level which maximises low carbon capacity but retains competitive pressures. This will require an assessment of the low carbon capacity pipeline.

Considering complementarity with other mechanisms, this will depend more on auction parameters such as eligibility than it does on the high-level auction design. For modelling purposes, we assume that the CM provides the primary investment signal to hydrogen, LDS and CCS plant who bid into the CM as price makers.

However, it is possible that a cap and floor agreement could act to stabilise long term revenue while a CM contract provides a source of revenue within the cap and floor.

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[34] The cost over time and impacts on overall system costs will depend on a much wider set of considerations, including the changing risk profile for investment appetite for new unabated gas assets which is not captured in this modelling exercise.

Additional objective: Avoiding creation of unnecessary risk and uncertainty

a. *Minimising unintended consequences from auction design*

b. *Adaptability of auction design to market and technological evolution*

While reduced compared to a split auction, there remains some potential impact from reducing the broader services delivered by existing carbon emitting capacity. There is also some additional scope for strategic bidding of capacity that is eligible for the minima. Relative to the split auction, we noted reduced potential for strategic bidding for carbon emitting capacity.

A further unintended consequence may be the additional challenge in setting appropriate target capacity for the minima that maximises contribution of low carbon capacity while retaining competitive pressures. The challenge for the auctioneer is greater than under the counterfactual as this will need to be informed by a forward view of the low carbon capacity pipeline. We previously mentioned potential challenges for security of supply if the auctioneer sets a target capacity for low carbon capacity which is too high and is not delivered. At the same time, the auctioneer will want to deliver as much value for money low carbon capacity as possible. Setting a conservative target capacity with a shallow sloping demand curve for the minima can also help to avoid suboptimal outcomes.

The most direct way to adapt the minima over time is to adjust the target minima and demand curves to reflect evolution of the expected low carbon supply pool. This approach is intended to allow more low carbon capacity to clear where there is plentiful supply potential but retain competitive pressures where the supply pool is more limited. The lead time ahead of delivery presents an additional challenge. The auctioneer has to take a view on the potential capacity that could enter into the market several years ahead.

A minima auction has one further advantage over a split auction in that it eliminates the potential unintended consequence for the low carbon auction to clear below the auction for remaining capacity. Under the minima, low carbon capacity would receive the greater of the clearing price set under the minima or the overarching clearing price. Therefore, if the marginal unit of capacity in the overall auction happens to be a carbon emitting plant, all capacity would clear at the same price avoiding the potentially distortive signals to carbon vs low carbon capacity.

5.5 An auction with multipliers for low carbon capacity

5.5.1 How an auction with multipliers for low carbon capacity would work

In an auction with multipliers, a single CM auction is held, but low carbon capacity receives a defined multiple of the clearing price[35]. As this allows a single auction format to be retained, liquidity of the auction should be similar to that observed otherwise in theory.

[35] Alternatively, a negative multiplier could be applied to carbon capacity. Retaining the assumption that bidders would reflect this into their bids, the effect would be identical.

As low carbon capacity receives a multiplier of the clearing price if they are successful in the auction, a rational bidder should reflect this by bidding at a lower bid price (equal to their original bid price divided by the multiplier). They should therefore be more likely to clear in the auction.

We assume that the multiplier is also reflected in the CM price cap. I.e., capacity that is eligible for the multiplier can bid at the price cap. If the CM auction clears at the price cap, eligible capacity would receive the price cap multiplied by the multiplier.

Setting multipliers

There are two alternative concepts which could inform the setting of multipliers:

1. **Value-based**: Multipliers would be designed to reflect some estimate of the additional value delivered by low carbon capacity relative to carbon emitting capacity. For example, this could be designed to reflect the social cost of carbon in some way.

2. **Cost-based**: Multipliers would be designed to reflect the additional revenues that low carbon forms of capacity require to become competitive in the auction, e.g., by comparing the net present costs of a new entrant CCGT against the equivalent costs of a new entrant hydrogen or CCUS plant, for example.

Value-based multipliers may be academically preferable as they are justified on the basis that they reflect an externality that is not currently priced into the market. However, they may be difficult to estimate in practice and may afford less control over merit order impacts in comparison to the cost-based multiplier philosophy.

5.5.2 Evaluation of a single auction with multipliers

As discussed previously, multipliers for low carbon capacity could be ‘cost’ or ‘value’ based. Estimating an appropriate multiplier for low carbon capacity under either approach is beyond the scope of this project. To test the impact of multipliers on auction outcomes, we apply an illustrative multiplier of 2 to all eligible low carbon capacity in the auction.

1. ***REMA objective: Ensure that the security of the system can be maintained at all times.***

    a. *Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output*

    b. *Supporting investment cases in capacity with characteristics which support security*

Assuming that de-rating factors and non-delivery penalties are set appropriately, multipliers should not impact directly on security of supply. As all capacity competes together in the same auction, there is little impact on the likelihood of clearing the auction.

2. ***REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB’s dependence on fossil fuel generation.***

    a. *Providing appropriate economic signals for investment in low carbon capacity*

Our quantitative analysis shows that multipliers could lead to an increase in low carbon capacity as this capacity lowers its bid in the auction relacing some carbon capacity in the merit order. In Figure 19 and Figure 20 we show results from our modelling of a multiplier of 2 on cleared low carbon and carbon capacity. The increase is relatively small, particularly compared to that observed with ambitious target capacities for low carbon under the split and minima auctions. This results from the structure of the merit order. Our modelling suggests prevalence of a significant amount of carbon emitting capacity that is prepared to take a low clearing price in the CM. On the other hand, much of the new low carbon capacity has a bid price approaching or at the auction cap. Therefore, even with a multiplier of 2, this new build low carbon capacity is rarely able to become more competitive with majority of the carbon emitting part of the supply stack.

Assuming rational response of bidders to the multipliers, this suggests that multipliers may need to be relatively high to deliver a significant step change, at additional cost to consumers.

Figure 19: Capacity mix under an auction with multipliers for low carbon capacity

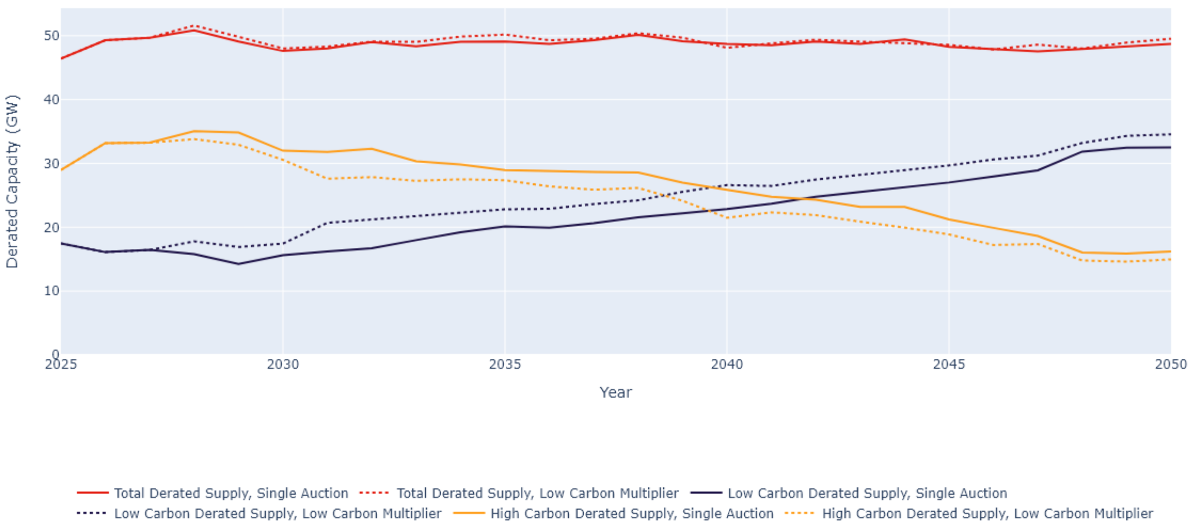
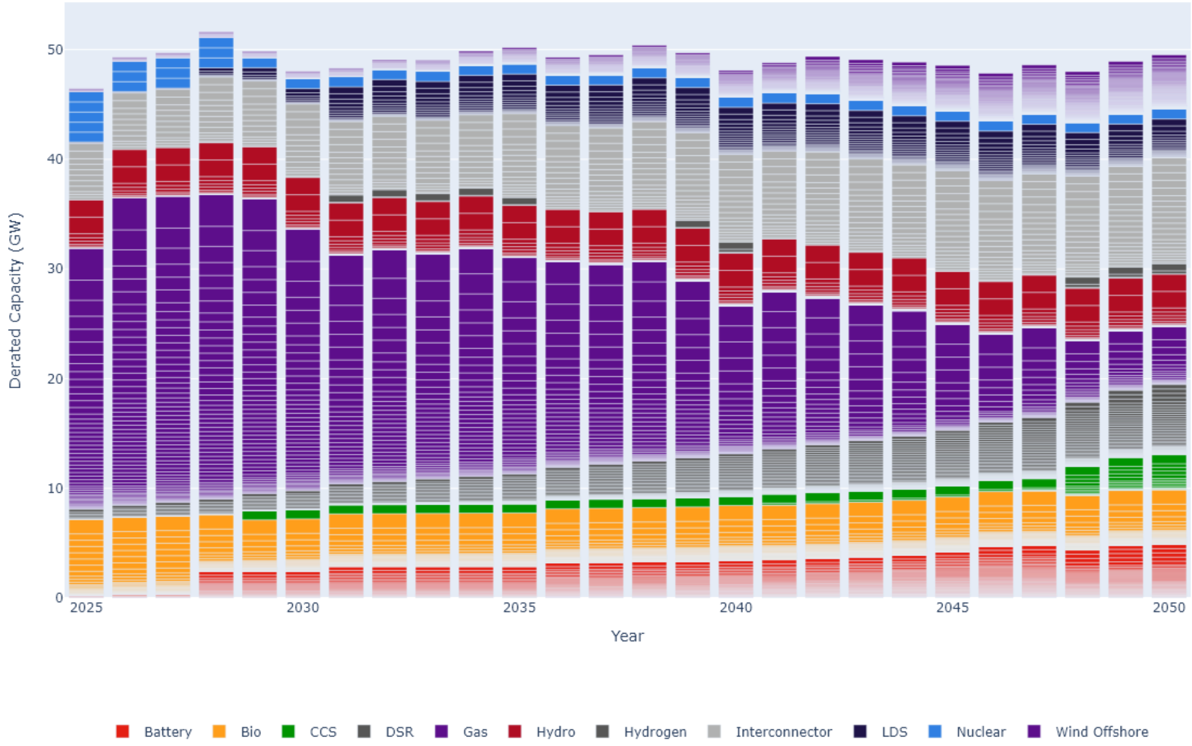
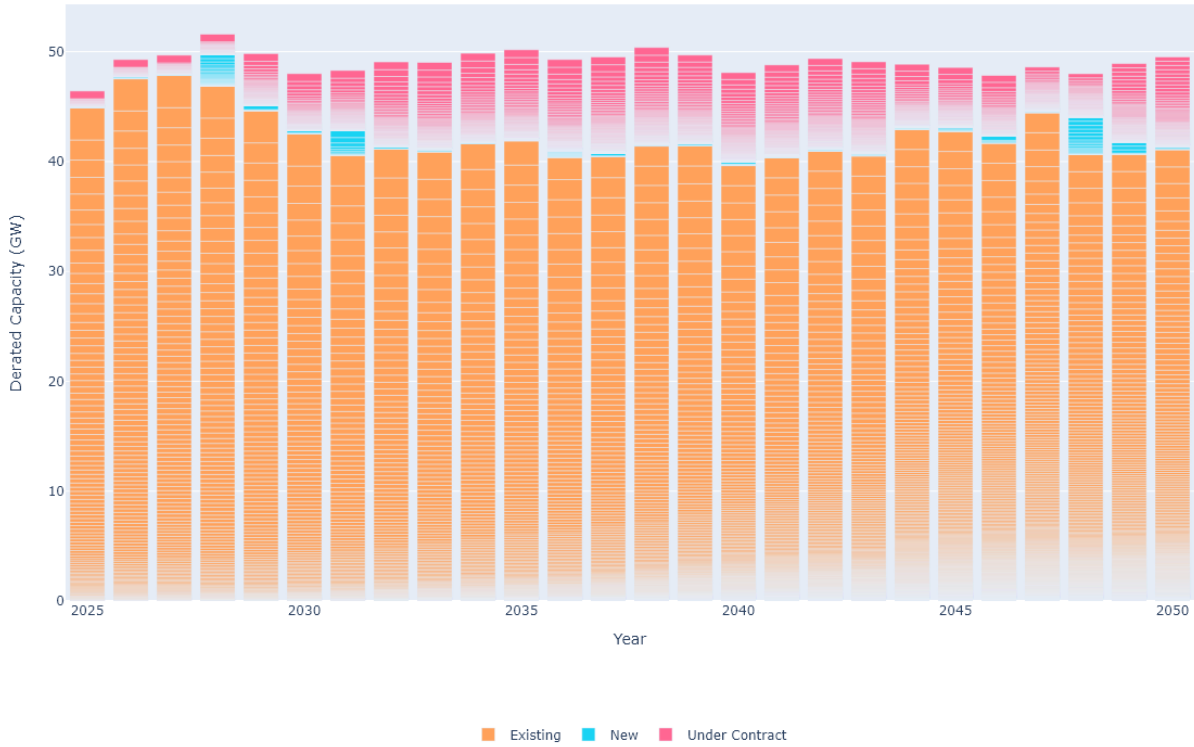


Figure 20: Capacity mix with multipliers for low carbon capacity



This is also reflected in the deployment of new build capacity. The change is limited relative to the outcomes we observed under the single auction (Figure 21).

Figure 21: New build capacity under auction with multipliers



This insight demonstrates the volume risk associated with multipliers for the auctioneer. Relative to a split auction and auction with minima, the auctioneer has less control over the volume of low carbon capacity that is likely to clear in the auction.

As noted, multipliers can theoretically be designed in a way that is 'value based' – which may include incorporating missing signals for low carbon capacity which reflect the value that society places on low carbon vs carbon capacity. If possible in practice, this form of signal would represent an economically efficient one with society then ambivalent between outcomes. However, it is impossible to estimate and reflect this signal perfectly in practice. A value based approach may also provide less flexibility to ensure delivery of a desired level of additional low carbon capacity, e.g. to meet decarbonization objectives.

3. REMA objective: Provide the right signals for flexibility across the system.

a. Providing appropriate economic signals for investment in low carbon flexibility

b. Enabling participants to reap the benefits they bring for the wider energy system

While a low carbon auction with minima does not send any explicit signals for flexibility, it can nevertheless impact on the amount of flexibility which is delivered indirectly by impacting on the capacity mix. Our modelling found a similar level of sustained response capacity that clears under the CM in either auction but with a small increase in the proportion of this coming from low carbon sources (Figure 22 and Figure 23).

Figure 22: Sustained response capacity mix under an auction with multipliers for low carbon capacity

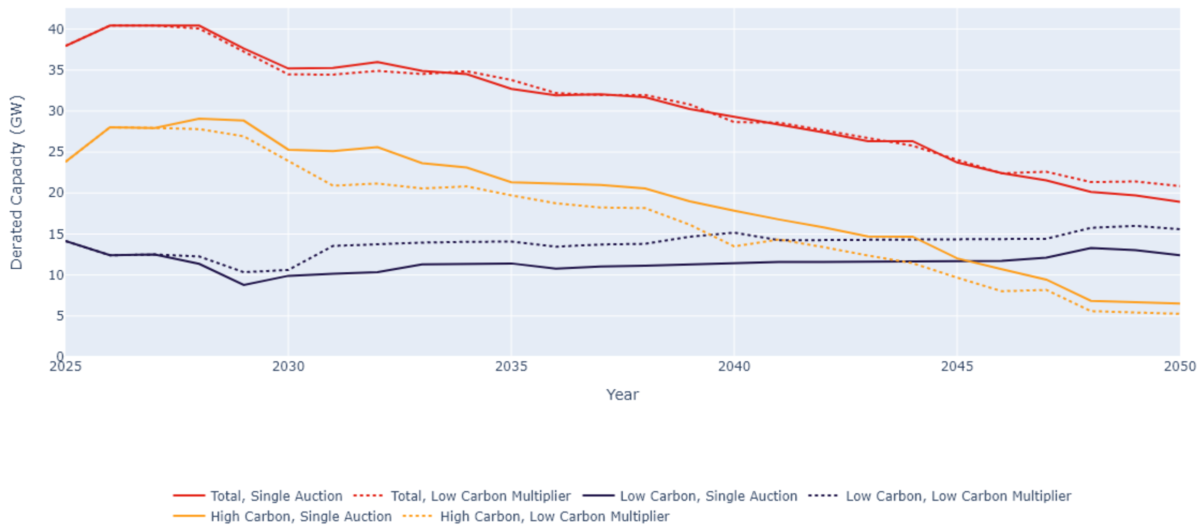
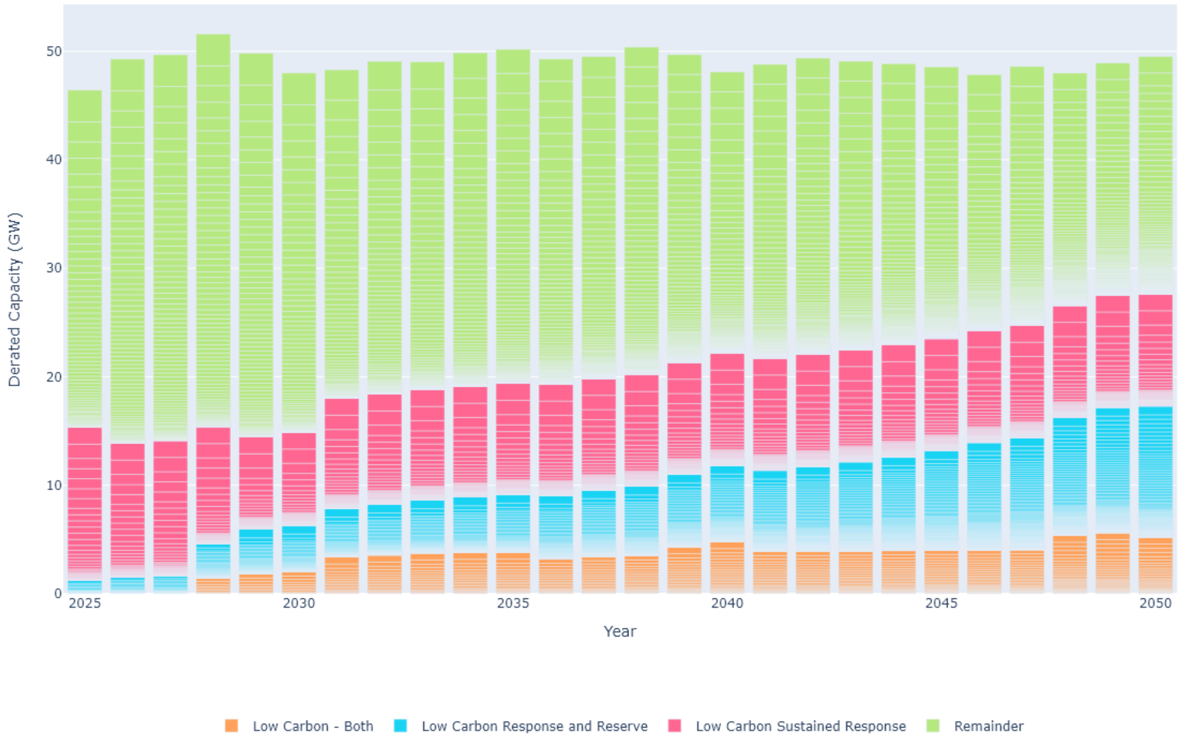


Figure 23: Sustained response and response time services under an auction with multipliers for low carbon capacity



Unabated gas capacity delivers other beneficial services to the market, not all of which are market based. To the extent that multipliers for low carbon capacity drive a reduction in the provision of unabated gas capacity, the unintended consequences relating to services such as ramping and inertia must also be considered.

4. ***Additional objective: Cost-effective provision of energy security for consumers***

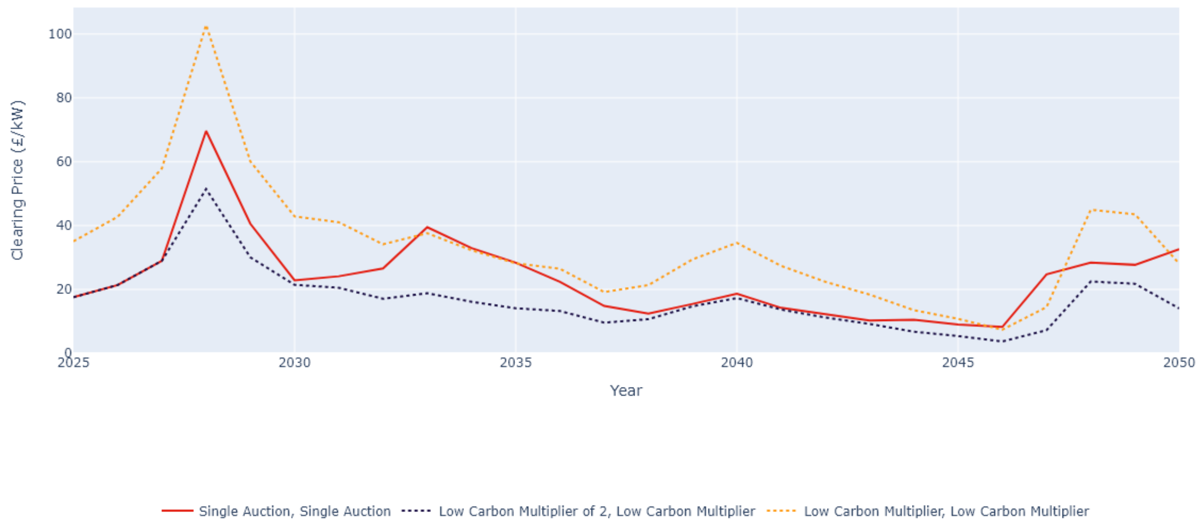
   a. *Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary*

   b. *Minimising the cost of implementing and operating the auction*

   c. *Ensuring complementarity between the CM and other mechanisms within the electricity market such as revenue cap and floor arrangements, balancing services and renewables support mechanisms.*

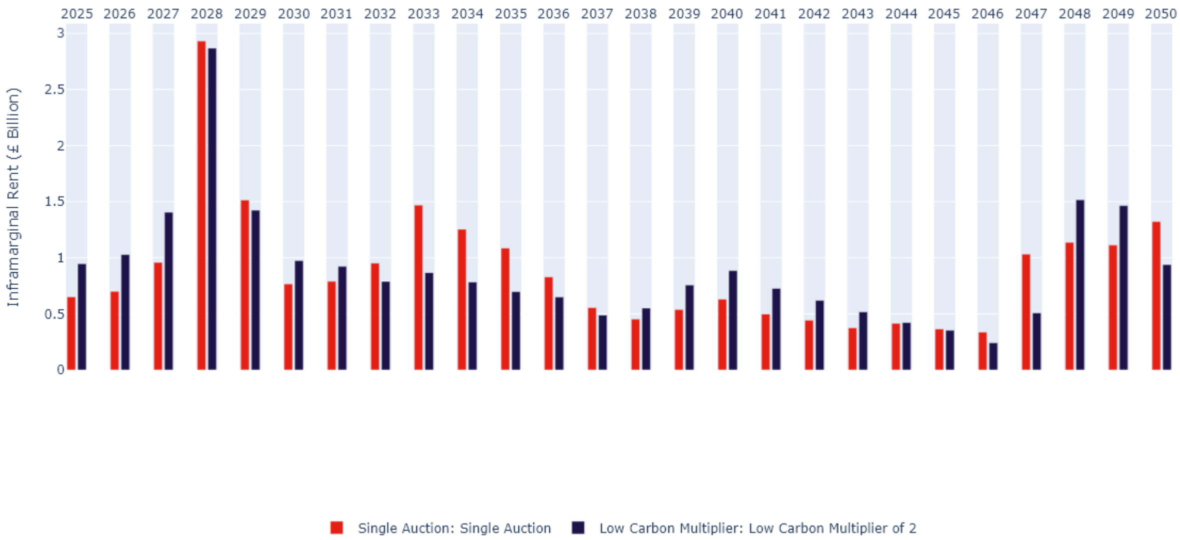
By sending a signal to low carbon capacity to bid at a lower price, multipliers are likely to lower the clearing price of the CM auction, and hence the price that carbon capacity receives. However, after incorporating the multiplier into the clearing price received by low carbon capacity, the ‘effective clearing price’ for such capacity will often be higher than that received by low carbon capacity in a single auction. This will not always be the case. Under the assumption that low carbon capacity will reflect the value of the multiplier in their bid price, the clearing price may tend towards the clearing price under the counterfactual where low carbon capacity represents the marginal unit in the auction. We observe this effect in our modelling (Figure 24). In some years, the clearing price after application of the multiplier is actually slightly lower than the single auction as new-build low carbon capacity reduces auction target capacity requirements relative to the counterfactual in later years.

Figure 24: Clearing price under auction with multipliers for low carbon capacity



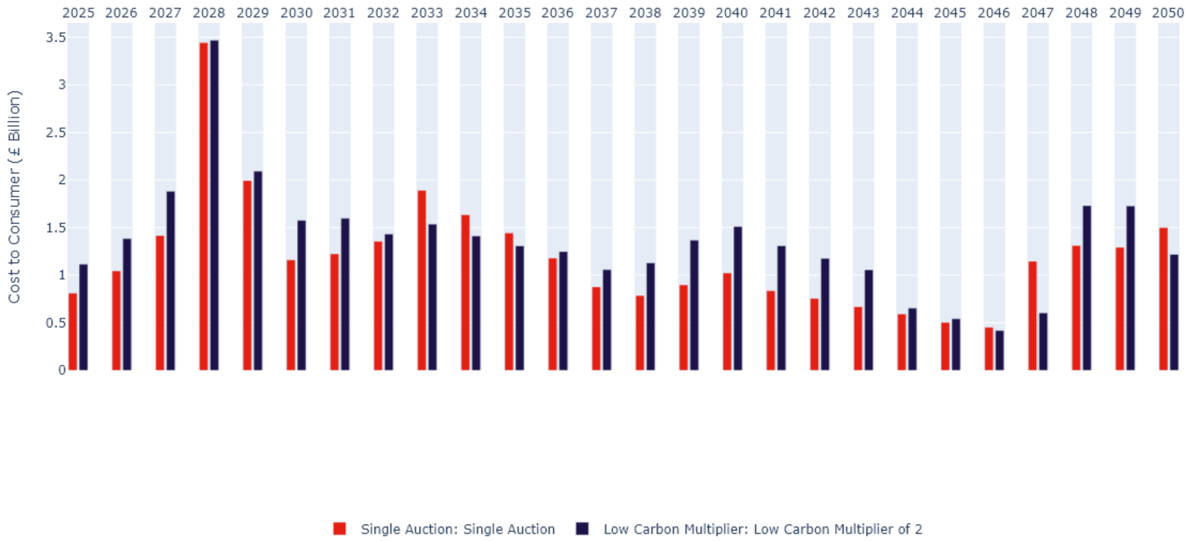
As with a split auction and auction with minima, we would expect an auction with multipliers to lead to higher inframarginal rent for low carbon capacity and lower inframarginal rent for carbon capacity. On balance it may be possible for this to either raise or lower the overall level of inframarginal rent. In our modelling scenario we find a very small increase in inframarginal rent, though not in all years. On average, annual inframarginal rent increases from £0.89 billion to £0.9 billion under the auction with multipliers.

Figure 25: Inframarginal rent under auction with multipliers for low carbon capacity



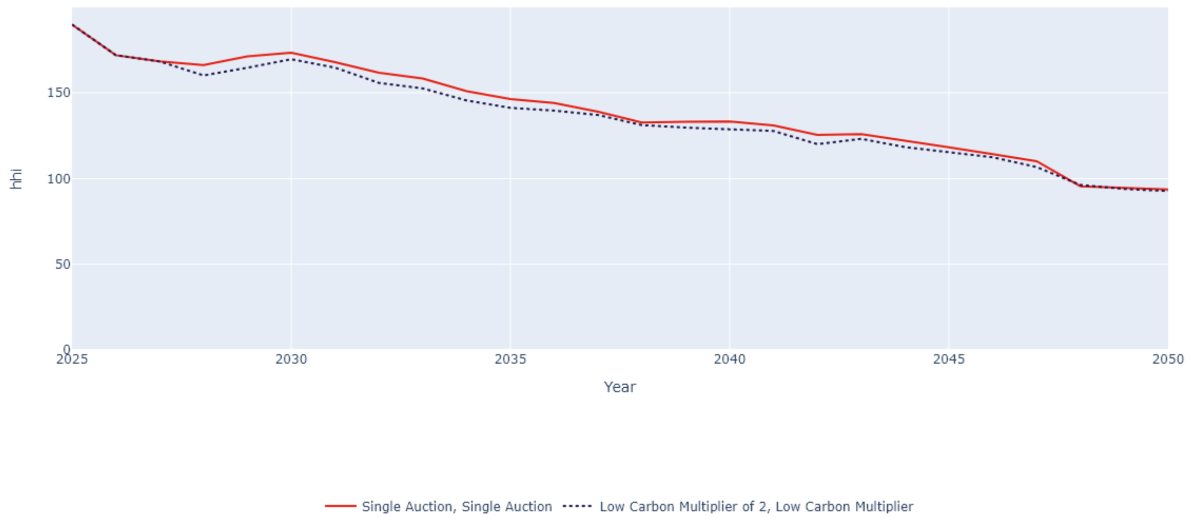
Overall, our modelling of an auction with an illustrative multiplier of two for low carbon capacity results in a similar level of total cost of the auction (Figure 26). Over the full period, the average annual cost of the auction increases from £1.2 billion to £1.37 billion. This results from the tradeoff between a small amount of additional higher priced low carbon capacity combined with additional inframarginal rent to low carbon providers against the reduction in inframarginal rent for carbon emitting capacity.

Figure 26: Cost of the auction with multipliers for low carbon capacity



Unlike a split auction, the use of multipliers does not separate auction liquidity and so should not have a significant impact on the potential for strategic bidding (Figure 27).

Figure 27: HHI under an auction with multipliers for low carbon capacity



Use of a single multiplier to reflect low carbon capacity should be easy to incorporate into a CM auction. The main additional implementation challenge will lie in the choice of an appropriate multiplier. As this will have a significant impact on auction outcomes, it is likely to be heavily debated by the industry. Both the ‘cost based’ and ‘value based’ approaches presented in this report are conceptually straightforward but challenging to implement in practice given imperfect information.

Considering complementarity with other mechanisms, this will depend more on auction parameters such as eligibility than it does on the high-level auction design For modelling purposes we assume that the CM provides the primary investment signal to hydrogen, LDS and CCS plant who are modelled as price makers.

However, it is possible that a cap and floor agreement could act to stabilise long term revenue while a CM contract provides a source of revenue within the cap and floor.

5. ***Additional objective: Avoiding creation of unnecessary risk and uncertainty***
    a. *Minimising unintended consequences from auction design*
    b. *Adaptability of auction design to market and technological evolution*

For a split auction we identified a challenge in setting an appropriate target capacity for low carbon, particularly given the need to do this several years in advance of delivery and for a range of capacity types. The use of multipliers reduces this challenge as the auctioneer avoids setting of a specific target capacity, instead allowing the market to determine the mix of capacity that clears in the CM.

On the other hand, multipliers provide a much less direct mechanism for setting a desired volume of low carbon capacity. As discussed elsewhere, the auctioneer faces ongoing volume uncertainty as to how much capacity will clear in the auction. The auctioneer also faces the challenge of defining multipliers. While they may be guided by the ‘cost based’ or ‘value based’ principles set out elsewhere, this is likely to be challenging to apply in practice with imperfect information.

5.6 Applicability of auction design options

The objective of incorporating signals for low carbon capacity into the CM auction is to maximise the proportion of capacity, which is met by low carbon technologies, subject to ensuring value for money.

Both a split sequential auction and an auction with minima could be designed to maximise target low carbon capacity using explicit auction parameters – e.g., by combining relatively low target capacity with ‘shallow sloping’ demand curves. Both options have the advantage of allowing the market to determine the additional cost of delivering the auctioneer’s desired volume of low carbon capacity. Relative scarcity is reflected in a higher clearing price while plentiful supply of low carbon capacity would be reflected in a clearing price which tends towards that observed for carbon emitting plant. The shallow sloping demand curve allows the auction to adjust to the prevalence of relatively low-priced capacity.

However, these options place importance on the ability of the auctioneer to define target low carbon capacity with a reasonable degree of confidence. Setting target capacity too low risks missing out on additional value for money low carbon capacity. Setting target capacity too high risks very high clearing prices, or even failure to clear the auction, resulting in high costs to consumers, and in some cases additional security of supply risk.

These options may therefore be most effective where there is a relatively clear pipeline of low carbon projects that are expected to participate in future auctions, allowing parameters to be set optimally to reflect this supply potential.

An auction with multipliers can be designed to provide strong and consistent signals for low carbon capacity. However, centrally determined multipliers which could have a significant impact on auction outcomes. As a result, multipliers maintain volume uncertainty regarding how much low carbon capacity will clear in the auction. If more low carbon capacity than expected clears, this will come at a cost to consumers given the multiple of the clearing price received by this capacity. If less low carbon capacity clears than expected, then the auctioneer may not achieve their objectives to maximise the amount of 'value for money' low carbon capacity.

In our modelling, we observed that multipliers may be limited in effectiveness where the signal sent is insufficient to make highly priced new-build low carbon capacity competitive relative to existing capacity that has recouped its up-front investment and is therefore able to bid into the CM more competitively. Even a relatively high multiple may not lead to new-build low carbon capacity clearing in the auction under such conditions. It may therefore be challenging to set multipliers to completely remove carbon capacity from the merit order over time.

On balance, we believe that the 'market based' determination of clearing prices within a split sequential auction or an auction with minima are more likely to result in value for money outcomes for consumers. They also provide more direct and predictable tools for the auctioneer to manage the volume of low carbon capacity clearing in the auction, providing more volume certainty.

A split sequential auction in which unsuccessful low carbon capacity can compete in the second 'remainder' auction is conceptually very similar to an auction with minima for low carbon capacity. Both allow scarcity for low carbon capacity to be reflected in a higher clearing price but also allow for low carbon capacity and carbon emitting plant to compete to deliver overall target capacity.

Relative to the minima auction, a split sequential auction may introduce more risk of unintended consequences as bidders with low carbon capacity may identify an opportunity to bid strategically in the first low carbon auction.

6. Targeting Flexible Low-Carbon Capacity

6.1 Designing an auction to target specific types of low carbon flexible capacity

In a mass low carbon power system, flexible capacity that is able to dispatch at short notice and to deliver electricity over a sustained period is essential to system management. The future capacity mix will also need to provide the combination of balancing services used by the electricity system operator (ESO, in future the Future System Operator (FSO)), to manage the system[36].

Several mechanisms exist which provide a range of revenue opportunities for some forms of flexibility in the existing market. These include the wholesale day-ahead and intraday markets, balancing and ancillary services markets and localised flexibility services. While the existing CM does not include an explicit signal for flexibility, de-rating factors and non-delivery penalties reflect the capability of capacity to provide capacity during a system stress event. Capacity that can flex up and down is generally better able to meet these requirements and this capability is generally reflected in de-rating factors.

No explicit markets or signals exist for energy dispatch which can be sustained over long periods of time, for example in response to periods of low renewables output. In such an event, the wholesale market price would rise, presenting revenue opportunities for capacity that can deliver sustained output during these periods. However, given that these represent low likelihood, high impact events, the ability to recoup high revenues during such periods may not send an appropriate investment signal.

Under REMA, DESNZ is considering the most appropriate market mechanisms for sending stronger signals for flexibility. This includes consideration of whether the CM should be designed to provide more explicit long-term investment signals for flexibility and if so, what form these signals should take.

6.1.1 What might flexibility in the CM look like?

Targeting of flexibility within the CM auction may be designed to reflect a range of characteristics:

- **Response time**: The ESO procures several services which enable it to respond to events close to real time. These are broken down into response services and reserve services:
  - **Response services**: There are three response services (Dynamic Containment (DC), Dynamic Moderation (DM) and Dynamic Regulation (DR)) with response

[36] More information on the balancing services used by the system operator is available here: [Balancing Services | ESO (nationalgrideso.com)]

times ranging from 'immediate' to <10 seconds. These services are used to maintain system frequency within necessary limits and to respond to faults which impact on frequency.

  - **Reserve services**: Reserve services are used by the ESO to manage longer term imbalances between supply and demand. The ESO has been developing a new suite of reserve services including Quick Reserve and Slow Reserve with response times between 1 minute and 15 minutes.

- **Ramp rate**: In parallel with the need for response and reserve services, some technologies on the system can respond quickly to system signals by changing output over a short period of time ('ramping'). Conventional power stations can ramp quickly, reducing the extent of balancing services that the ESO needs to procure. In the rest of this section, we group ramp rate provision into response time services as we would expect similar implications for auction design.

- **Sustained duration response**: In Section 2.3 we discussed the emerging challenge of meeting demand during sustained periods of low renewables output ('renewables droughts'), particularly as flexible unabated gas plant leaves the system. This will introduce a need for low carbon capacity that is able to provide a sustained response for several hours or even days to cover such periods. These forms of capacity could include long duration storage technologies, hydrogen power stations and gas fired generators fitted with CCUS technology.

- **Ancillary services**: In addition to the response and reserve services summarised above, the ESO procures a range of other ancillary services which help it manage the system. This includes reactive power and restoration services. In the future, the need for system services may evolve, for example to ensure sufficient inertia on the system. While we identify ancillary services for completeness, we do not consider them further in this report as they are out of scope.

6.1.2 Defining flexibility requirements

Signals for flexibility could in theory be introduced under any of the three auction design options. To do so would require some consideration of the volume of capacity that is needed to provide the desired range of characteristics.

Whichever approach is used, we anticipate a key role for the FSO to determine the primary tools it requires for operating a system and maintaining suitable system management tools. This would include response time, ramp rate capabilities and duration of response. To achieve this, the FSO would assess a range of scenarios to evaluate a range of needs under multiple system pathways. We would expect this to include use of the FES and other analytical tools to identify the nature of, and requirement for certain flexibility characteristics that could then be signalled within the CM for investment for these capacities.

To map this into target capacities in the CM, the auctioneer would need to balance commitment to procure sufficient capacity against locking in capacity in the context of future system uncertainty and technological evolution which could impact on the level and cost of flexibility requirements.

Response time

To ensure procurement of an appropriate mix of capacity for meeting the ESO's reserve and response requirements, the capacity mix will need to deliver sufficient volume across several response times. While the precise requirements would need to be defined by the FSO given wider system conditions, we draw on the ESO's existing procurement of balancing services[37] to provide an example of the volumes of capacity that they may seek to procure across response times (Table 6).

Table 6: Summary of ESO 'response time' requirements

Category	ESO balancing service	Response time	Pre/post fault	Target volume
Response	Dynamic Containment	Immediate	Post fault	Circa. 1 GW
	Dynamic Moderation	< 1 second	Pre fault	Circa. 300 MW
	Dynamic Regulation	< 10 seconds	Pre fault	Circa 300 MW
Reserve	Short Term Operating Reserve	< 20 mins	Pre fault	Circa 1.7 GW

It is beyond the scope of this project to assess how the ESO's response time requirements are likely to evolve over time and this may best be informed through engagement with the ESO to understand the implications of various future pathways. We note that a reduction in ramping capabilities may also impact on service requirements, with additional response time services potentially needed to deliver similar responsiveness requirements.

Sustained duration response

The volume of sustained response requirements in a future electricity system will be heavily dependent on the future decarbonisation pathway. We would expect the FSO to have an important role in determining an appropriate volume of sustained duration response that reflected a balance of pathways for a low carbon power system, analysis of weather patterns and the likelihood of sustained periods of low output from renewables. Incorporating sustained response requirements into the CM must also reflect temporal challenges, taking into account the lead time for development of capacity which can provide such a response and the uncertainty of future pathways which reduces closer to real time.

[37] See this link: ESO Data Portal: Ancillary Services | National Grid Electricity System Operator (nationalgrideso.com)

While we do not attempt to estimate the volume of sustained duration response or provide a firm view on the definition of sustained response that would need to be included within a future mass low carbon power system, we do provide a short summary of existing market analysis of the need for long duration storage which is likely to provide an important source of sustained duration response in Box 1 below:

Box 1: Existing market analysis of long duration storage requirements

LDS is likely to be an important provide of sustained response given its potential to withdraw excess capacity from the grid during high output/low demand periods and store this capacity over the course of a low output period. Other than LDS, capacity including nuclear, hydrogen and CCS power stations may also provide sustained response.

The FES (2022) vary in the amount of LDS incorporated into the grid depending on the future pathway. Including only pumped storage, LAES and CAES, the FES include somewhere between c. 3 GW and c. 8 GW of LDS capacity by 2030 and between c. 4 GW and c. 17 GW by 2050. The FES also include a significant volume of battery capacity by 2030 and 2050, some of which will extend beyond four hours energy storage duration.

Aurora[38] conducted research which set out to assess the value of long duration storage to manage a high renewables system. Aurora defined LDS as capacity which can store electricity for four hours or more. Their analysis suggested that up to 24 GW of LDS (eight times existing installed capacity) may be needed by 2035 to integrate renewables. They identified benefits from the development of large quantities of LDS including reduced carbon emissions of 10 $MtCO^2$ per year and reduced system costs of £1.13 billion per year.

6.2 General design considerations

The following considerations would apply to the design of a CM which incorporated signals for low carbon flexible capacity under most/all of the high-level auction designs.

6.2.1 Interactions with other market mechanisms

There are already several mechanisms in the energy market that are designed to send signals for capacity to provide different forms of flexibility. These mechanisms include:

- **The wholesale electricity market**: Flexible capacity can arbitrage between high price and low-price periods extracting more value from the wholesale market.
- **The balancing market**: The balancing market provides an opportunity for resources to monetise their flexibility by selling these services to the ESO. Flexible capacity is better equipped to balance positions.
- **Balancing and ancillary services markets**: The ESO procures a range of response and reserve services through balancing services markets. It also procures a range of wider ancillary services designed to help it manage the system. In some cases, the

[38] A summary of Aurora's research is available here: https://auroraer.com/media/long-duration-electricity-storage-in-gb/

ESO makes availability payments for the ability to draw on the service, and utilisation payments when the service is called upon.

- **Local flexibility markets**: Distribution System Operators are developing localised flexibility markets from which localised sources of flexibility can extract value.

Considering the need to send signals for response time and/or sustained duration response through the CM depends on two key questions:

1. What is the gap in the market that this signal is designed to address?
2. What are the impacts of introducing this signal on other areas of the market?

Response time characteristics

Introducing signals for response time into the CM would have strong interactions with the ESO's procurement of balancing services. The balancing services markets are designed to send relatively short-term operational signals but in setting a market-based price for the range of services, also send signals where provision of these services is scarce. In theory, where the ESO faces greater challenges in meeting requirements, the market will clear at a higher price and should signal opportunities for potential providers to enter into the market.

In determining whether to introduce long term signals for response time capabilities in the CM, the key question is therefore whether these shorter-term signals are sufficiently strong to send long-term investment signals for provision of the necessary range of services.

If response time signals were introduced into the CM, this could in turn, have significant implications for the role and design of the balancing services markets. Much of the value that service providers may expect to derive from providing such capabilities should already have been delivered through the CM which should in equilibrium cover the costs of the capability for providing such a service. Any remaining payments through the balancing services markets should then reflect the costs of operation to deliver the service.

It is worth noting that the direction of travel in the balancing services markets has been away from long term contracts and towards closer to real time procurement. While the ESO used to enter into long term contracts for some services (e.g., contracts of up to 15 years for Short Term Operating Reserve), the vast majority of service provision is now performed much closer to real time. The intention has been to avoid locking into potentially sub-optimal and inflexible long-term contracts.

Sustained Duration Response

Providers that are able to deliver a sustained duration response service are likely to build a business case by stacking revenues across multiple markets. They are likely to arbitrage within the wholesale market and may be able to provide balancing or ancillary services close to real time.

We have discussed elsewhere in this report the changing nature of system stress events as we move to a mass low carbon power system. Under such conditions, the wholesale market price should rise to reflect system conditions, providing market participants with the opportunity for inframarginal rents during such periods.

However, an explicit signal for capacity that can cover a prolonged renewables drought system stress event is currently lacking. Investors may not price in potential revenues during these relatively low likelihood events and similar arguments of missing money exist as were made for the case of traditional peak demand led system stress events at the time the CM was introduced.

A second key question is whether the signals from wholesale and other markets are sufficiently strong and certain to allow for investment, particularly in capital intensive capacity that requires long term investor confidence. By providing long term contracts to new build capacity, a reformed CM that incorporates explicit signals for sustained duration response could be designed to mitigate challenges faced by several technologies that may be well placed to deliver a sustained response.

6.2.2 Eligibility

Response time services

Balancing services are provided by a wide range of service providers, not all of whom participate in the CM or the energy markets. For example, some balancing and ancillary services are provided by electricity demand customers, network solutions and renewable generators who do not participate in the CM. Assuming these customers are not eligible to provide a response service in the CM, they may be at a disadvantage compared to balancing services providers who can participate in the CM. This could reduce the efficiency of existing balancing markets as some providers are less able to compete than others.

Response time services introduce a further complexity in that they are highly dynamic with balancing services procured across several blocks at the day-ahead stage. Some service providers can deliver services in some service periods but not in others. For example, their portfolio may mean that they can generally provide a frequency response service on a winter's evening but are less able to do so during the rest of the year. This raises a question about whether such a provider would be eligible for provision of flexibility within a reformed CM.

Sustained Duration Response

Eligibility for sustained duration response may be easier to define. The need for this form of flexibility is driven by the potential for low renewables output which could occur at any time throughout the year. Therefore, we assume that eligible capacity would need to be able to provide sustained output for a given period, designed to cover a system stress event which could occur at a random time.

The main questions relate to the duration for which output needs to be sustained and the amount of notice available ahead of the provision of output. In its analysis of LDS, Aurora defines 'long duration storage' as at least four hours of output. As well as power stations, pumped hydro, liquid and compressed air energy storage, this definition would allow for participation of large batteries that may contribute increasing volumes of capacity in future.

However, a definition of four hours duration may not reflect a sustained 'renewables drought' periods that may result in renewables output that is well below seasonal averages for a period of days or even weeks. The Climate Change Committee[39] considered a 'stress test' scenario

[39] Report available here: [Delivering a reliable decarbonised power system - Climate Change Committee (theccc.org.uk)]()

which included a 30-day wind drought period, though noting that this did not have any historical precedent. This may imply a need for longer duration of output capability beyond four hours.

This longer duration could be specified instead of a four-hour definition. Alternatively, multiple definitions could be used with a split auction, minima or multipliers applying to several durations. This could mean including multiple split auctions/minima covering several different durations of response. In the case of multipliers, lower value multipliers could be introduced for shorter duration response (e.g., 4-12 hours) with a higher multiplier available for sustained duration response capabilities of 12 hours or more. In the case of a split auction or minima, we note challenges that have already been discussed with reduced liquidity as auctions become more fragmented.

We would not expect a sustained response characteristic to be limited to LDS. A sustained response of four hours could also be delivered by several other capacity types including hydrogen power stations, CCUS and nuclear for example. Depending on if and how such technologies receive support elsewhere in the market, they may also be eligible as sustained response providers in the CM. If not, they would still be able to provide sustained response and so would net off the required sustained response capacity in the CM.

It is possible that multiple units of capacity of a shorter duration could be aggregated to provide a sustained response of greater length. For example, several four-hour duration batteries could develop a combined agreement to enable a sustained response over a 12-hour period, with their capacity de-rated accordingly. Subject to demonstrating compliance with the stated service requirements, and the inclusion of suitable de-rating and non-delivery arrangements, there are no obvious reasons why this form of agreement should not be eligible to provide a sustained response.

6.2.3 Contract length

Response time services

Over recent years, and under regulatory pressure, balancing services have been procured increasingly close to real time, with the objective of developing liquid balancing services markets to maximise competitive pressures and reduce costs of service provision. Close to real time service procurement is also an advantage in a quickly evolving and highly uncertain system in which service requirements may change significantly over the course of a few years. It also provides more opportunity for services such as DSR and renewables to participate.

If signals were introduced for flexibility characteristics that are already provided through balancing services, this would provide long term financial commitments to at least some providers. As the electricity market and technology develops over time, these commitments may be proved to be inefficient if they become less necessary than envisaged or if technology develops (or would have been developed) which could provide the same service more cost-efficiently. It may also introduce an unlevel playing field with some capacity receiving long term contracts for response time services while others do not.

If signals are introduced for such services through the CM, this logic suggests that those commitments should be short in length – e.g., a maximum of one year. However, this approach raises inconsistencies between the length of contracts for new-build capacity (currently 15 years) and the length of contracts for balancing services capabilities. If the CM contract was made shorter for new-build providers of such capacity, there would be little incentive to compete for response time provision in the CM.

Sustained Duration Response

Several of the technologies that can provide a sustained duration response may require long term revenue certainty to become financially viable. This holds for pumped storage, LAES and CAES for example, each of which are capital intensive projects with long lead times.

For these types of technology to compete, contracts awarded to sustained duration response providers can contribute to this long-term revenue certainty[40]. In its paper on the need for a revenue stabilisation mechanism, Drax[41] proposed the need for revenue certainty over a 25-year time horizon to spread the underwriting of the capital costs appropriately. If a CM is used as a substitute to a cap and floor mechanism, this may imply a desire for CM revenue certainty over a similar period.

However, arguments for contracts greater in length than the existing 15-year contracts provided to new-build capacity must be balanced against the risk of stranded assets given the increase in uncertainty over future pathways.

Not all providers of sustained duration response would require 25-year CM contracts which raises the possibility of providing 25-year contracts to LDS but shorter contracts to others. However, this would raise more significant concerns regarding fairness and competition given impacts on bid prices.

6.2.4 Lead time for new-build sustained duration response providers

Within the existing CM design, the T-4 auction is designed to enable the lead time needed to build a new plant following CM contract award.

The four-year lead time is broadly in line with that needed to build a combined-cycle gas turbine (CCGT) plant and was therefore deemed an appropriate period to attract new build capacity into the market. However, a future CM may need to attract a wider range of technologies to ensure low carbon flexibility. For example, DESNZ is considering the role that the CM should play in attracting investment for LDS. Technologies such as pumped-hydro, compressed air energy storage and liquid air energy storage require intensive geological design and are highly capital intensive with build times that are likely to extend beyond four years.

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[40] The extent of importance of revenue certainty awarded under CM contracts will depend on wider market design and policy, e.g., whether such forms of capacity receive a cap and floor on revenues.
[41] Report available here: [A4 Landscape Crop and Bleed (drax.com)](drax.com)

Drax suggest that the lead time for development of capital-intensive LDS capacity is of the order of 5-7 years[42]. The existing T-4 CM auction may therefore provide insufficient lead time ahead of delivery for these projects, either requiring investment at risk, or resulting in significant risk of non-delivery in initial years.

Extending auction lead time to 5-7 years would introduce new challenges as it would increase the extent of uncertainty ahead of delivery at the time of holding the auction, increasing the challenge of setting appropriate target capacities for example. It would also align less well with the lead time of some new-build projects, therefore reducing the potential for more nimble, shorter lead time projects to respond to need closer to delivery timescales.

In this context, one advantage of a sequential split auction design would be to allow separation of auction timings, e.g., with sustained duration response auctions held 5-7 years ahead of delivery, and further auctions held for remaining low carbon and carbon capacity at T-4 and T-1.

6.2.5 Target capacity and demand curves

Response time flexibility requirements are relatively fixed with diminishing marginal returns from additional capacity above a level necessary for the ESO to balance the system effectively.

While larger, the volume of sustained duration response on the system will also be relatively fixed, driven by the anticipated capacity gap during a period of low renewables output.

Within a split auction or in an auction with minima for flexibility characteristics, these diminishing marginal returns on additional capacity may imply the use of steep demand curves which reflect the limited value from procuring more capacity than is strictly needed.

At the same time, demand curves could be designed to factor in some of the future uncertainty and challenges with forecasting need well ahead of time. Reducing the steepness of the demand curve may allow some of this uncertainty to be reflected – i.e., allowing additional ‘value for money’ capacity beyond the minimum requirement to be contracted as a form of insurance policy where it is sufficiently cheap.

6.2.6 Price caps

If signals for flexibility are introduced in the CM, there may be a need to consider how price caps should apply to capacity that can deliver these services.

The price cap in the CM is currently set as a multiple of the cost of a new entrant (CONE) CCGT. Regardless of the flexibility requirement, a new entrant CCGT without carbon capture would not be eligible as it does not meet the low carbon criteria. This risks the price cap being set too low as it may not reflect the costs of entry for eligible new providers, needed to meet target capacity.

[42] Report available here: [A4 Landscape Crop and Bleed (drax.com)]()

Maintaining the logic of price cap within the CM, the price cap that is applied to low carbon, flexible capacity could be designed to reflect the CONE of the cheapest or most likely form of new-build capacity that is expected to be necessary to meet target capacity for flexibility requirements.

Alternatively, the price cap could be designed in some other way. For example, if applied to response characteristics, the price cap could be designed to reflect the cost of alternative options available to the FSO. E.g., in this case, the price cap may reflect the cost of procuring similar services from providers who are not eligible for the CM, or the estimated costs to consumers that would result from the FSO not having the desired level of flexibility available.

6.2.7 De-rating factors and non-delivery penalties

Within the current CM, de-rating factors are fixed per technology and are based on an estimate of the proportion of capacity that technology is able to export at the time of a defined system stress event. Non-delivery penalties are also fixed and are raised if the contract holder is unable to deliver its committed capacity volume within a system stress event, adjusted for several factors. Both de-rating factors and non-delivery penalties were introduced with respect to a system stress event which is focussed on periods of peak demand.

However, the value of both response time and sustained duration response capabilities is more evenly spread across the year. The ESO/FSO may require the range of balancing services in almost any period of the year. The risk of a renewables drought event is seasonally correlated to some degree but is still spread more evenly across multiple periods within the year than is the case for peak demand.

This raises a challenge for the Government in centrally determining a de-rating factor and non-delivery penalty approach that reflects actual capability to provide the relevant services at the time they are needed. A different approach may be needed if flexibility capabilities are introduced into the CM.

In the case of sustained duration response, an alternative may be to encourage CM participants who are eligible to express their own confidence in being able to provide sustained duration response throughout the year with sufficient warning. Non-delivery penalties would then apply if the service was required but could not be called upon. Both revenues and non-delivery penalties would reflect the extent of commitment to deliver during the system stress event. Several practical challenges exist, most notably regarding the moral hazard associated with low probability high impact events. It is beyond the scope of this project to explore this approach in depth, but it may be worthy of further exploration given the significance of challenges associated with establishing de-rating factors and non-delivery penalties as currently defined for response time and sustained duration response services.

An alternative may be to define de-rating factors that vary across the year to reflect the capability of technologies to provide different levels of flexibility throughout the year. More dynamic non-delivery penalties could also attempt to reflect the varying importance of flexible capacity at different times of year. However, dynamic de-rating factors and non-delivery penalties could quickly become rather complicated. Non-delivery penalty arrangements would also need to be reviewed, e.g., to remove any caps on non-delivery penalties that could eliminate incentives to provide sustained response services if and when a cap on penalties is reached.

6.3 A low carbon flexibility split auction

6.3.1 How a split auction would work

A split auction for low carbon flexibility could be constructed in several ways. At its simplest, two split auctions could take place, one for low carbon capacity with the desired flexibility characteristic and one for all remaining capacity, combining low carbon capacity without the flexibility characteristic and carbon emitting capacity.

Alternatively, the auction could be further disaggregated, e.g., to include:

- one auction for low carbon capacity that meets a specified flexibility characteristic;
- one auction for low carbon capacity that does not meet the specified flexibility characteristic; and
- one auction for remaining capacity (which could also allow for capacity that has not been successful in previous auctions to participate).

This could be taken further, e.g., to reflect different flexibility characteristics, e.g., with one or more auctions for capacity that can respond within a certain time horizon and one or more auctions for capacity that can sustain output for a given number of hours. At least in theory this could result in several auctions which are designed to map relatively closely to the FSO's expected requirements for operating a decarbonised power system and to incorporate signals for capacity that can sustain output across multiple durations.

While DESNZ has asked us to consider a flexibility auction which is limited to low carbon capacity, a flexibility auction would not have to be limited to low carbon. If low carbon signals are sent elsewhere, the CM could be designed to focus only on provision of flexibility capacity while remaining agnostic regarding whether this is delivered by carbon or low carbon capacity.

Simultaneous or sequential?

In Section 5.2 we set out our view that a sequential low carbon auction followed by a carbon auction would be the most appropriate design for a split low carbon/carbon auction.

In the case of further splitting of the auction, the arguments between a simultaneous and sequential design become more finely balanced. Sequencing of multiple auctions could have benefits, e.g., in mapping auction lead times more closely to that needed for various types of provider. However, it also increases the period over which repeated auctions must take place. We also consider that the target capacity for flexibility characteristics is relatively independent from market supply – i.e., the FSO will need a relatively fixed amount of responsive capacity regardless of how much is available in the market. This reduces the information value we identified within a sequenced split auction for low carbon capacity.

Disaggregation and alignment with need

As we set out previously, split auctions for flexibility may be delineated by several characteristics (response time, ramp rate, duration of response, etc). In each case, auctions could also be separated by capability (e.g., ability to respond within 10 seconds, ability to respond within 30 minutes, etc). This could lead to several split flexibility auctions, each reflecting different system flexibility requirements.

Multiple split auctions could also be designed to capture the requirement for provision of sustained response over multiple durations.

The target capacity in each auction would be defined by analysis conducted by the FSO of the volume of need for each type of service under a range of future pathways.

Disaggregation to reflect a wide range of needs would have several important disadvantages, however. Greater disaggregation of the auction would fragment auction liquidity, leading to higher clearing prices and greater opportunity for strategic bidding. More fragmented auctions also place a greater burden on the auctioneer to determine separate target capacities and demand curves for each, increasing the potential inefficiency of the auction design and requiring firmer information on the expected project pipeline.

Within a split auction format, these fragmentation issues introduce an important constraint on the extent to which characteristics can be delineated before fragmentation of the auction becomes suboptimal. In practice, even splitting the overall CM into three auctions may reduce liquidity significantly.

Descending clock vs sealed bid

The increased risk of strategic bidding as the auction is fragmented and liquidity is reduced may imply a need to consider whether a sealed bid auction format may become preferable to a descending clock format. The sealed bid design limits information provision to bidders, thus limiting their ability to develop optimal strategic bidding strategies.

6.3.2 Evaluation of a split flexibility auction

In theory, separate (and potentially multiple) split auctions could be developed for sustained duration response and response time services, with a third auction for those services who do not participate in either of the two. The response time split auction could be further disaggregated, e.g., into one auction for reserve services and a separate auction for response services or for multiple lengths of sustained duration response.

In the case of sustained duration response, auction design and outcomes would have similarities with a split auction for low carbon capacity. Using a definition of sustained response as capacity that is able to provide a sustained output for four hours or more, a large proportion of low carbon capacity that participates in the CM qualifies as low carbon sustained response.

However, for response time services, we identify a possible challenge for defining and running a split auction. Even if all response time services are aggregated into a single split auction, it is likely that a split auction for response time services would have a limited target capacity – a maximum of c. 3 GW in the near term.

In many years, competition for this limited capacity may lead to a low clearing price as we find when we model this auction design as a minima. It is quite possible that the clearing price in the response time auction could in fact be lower than that observed in the ‘remainder’ auction. Capacity that participates in the response time auction would also be eligible for the main auction. This could lead to perverse incentives for capacity which can meet response time requirements to withhold capacity from the response time auction. In doing so, it would benefit from the higher clearing price in the ‘remainder’ auction instead.

In years where eligible capacity is low relative to the target, increased concentration of the auction may lead to adverse auction outcomes with strategic bidding leading to high costs of clearing the auction.

For this reason, we do not expect a split auction for response and reserve services to be a viable option. For modelling purposes, we assume a split auction for low carbon sustained duration response with an additional auction for remaining capacity. We set the target capacity for low carbon sustained duration response capacity at 90% of all such capacity included in our potential supply stack but netting off interconnection capacity to allow it to continue to clear in the auction. We do not model a split auction for response and reserve services.

1. ***REMA objective: Ensure that the security of the system can be maintained at all times.***
    a. *Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output*
    b. *Supporting investment cases in capacity with characteristics which support security*

In the case that all split auctions clear, and assuming that de-rating factors and non-delivery penalties are set appropriately, a split auction should not directly impact on security of supply outcomes.

In the case of both response time and sustained duration response, the fact that an additional market signal is being sent to reflect the value of flexibility should not increase security of supply risk and may actively reduce it, where this signal is filling a gap in signals sent from elsewhere in the market.

In the case of low carbon capacity, the auctioneer’s objective is to maximise value for money low carbon capacity. This may introduce some security of supply risk if the auctioneer sets target capacity too high such that the low carbon auction does not clear.

In a low carbon split auction, the additional signal for low carbon capacity is not intended to meet an explicit need but rather a general desire to maximise low carbon capacity. However, for flexibility services, target capacity is driven by an explicit need rather than simply maximising capacity with flexibility characteristics. Given this, where the split auction fails to clear this reflects the fact that there is insufficient flexible capacity that is able to participate in the CM, even with the stronger signals incorporated into a CM which is designed to encourage flexibility.

In the case of response time services, there is an interaction with signals sent in the wider market. If the split auction for response time services did not clear, this may signal that the FSO needs to procure more services closer to real time through (forward) balancing services markets if they continue to exist in parallel with the reformed CM. As not all potential providers of balancing services would be captured within the CM, the FSO may need to adjust for flexibility that is expected to be provided by other technologies.

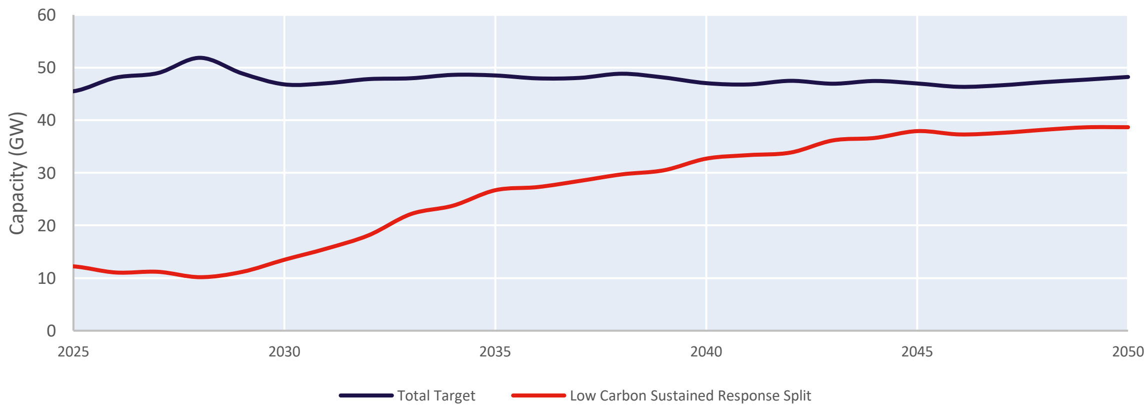
For sustained response services, target capacity will depend on the proportion of demand which is forecast to be met by variable generation in any given period, and the associated extent of risk of a fall in renewables output during that period. This should signal the extent of capacity shortfall that is needed to cover a renewables drought. If the auction does not clear, this implies that sustained duration capacity is unable to meet the potential shortfall in renewable capacity, therefore reflecting some security of supply risk if a renewables drought were to occur. This risk would be more significant within a single auction given that no explicit signals currently exist for sustained response.

The low carbon sustained response target capacity (Figure 28) was set at the lower of:

- 90% of the total supply pool available to provide low carbon sustained response within our modelling methodology; or
- The total auction target capacity net of capacity provided by interconnection (i.e., allowing interconnectors to continue to clear in the CM).

This reflects a desire to procure an increasing requirement for capacity to cover a renewables drought and for more of this to come for low carbon sources.

Figure 28 Capacity Targets for Low Carbon Sustained Response Split Auction used in quantitative analysis



When considering a split auction for low carbon capacity, we found that this could undermine the provision of flexibility that would be delivered by conventional generation. Split auctions targeting flexibility could be designed to reduce this risk, by sending explicit signals for flexibility from low carbon capacity that could help to replace that lost from conventional generation.

2. *REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB's dependence on fossil fuel generation.*

a. Providing appropriate economic signals for investment in low carbon capacity

Much of the low carbon capacity supply pool may be able to deliver low carbon sustained response under the definition of a sustained output for four or more hours used in this illustrative modelling. Assuming new low carbon technologies are technologically and commercially ready to participate in a market that supports their entry, a split auction for low carbon sustained response would also lead to more low carbon capacity clearing in the CM relative to the counterfactual (Figure 29 and Figure 30).

As the low carbon sustained response supply pool is a subset of all low carbon capacity, the displacement effect from carbon to low carbon capacity is likely to be lower than that observed in the low carbon split auction to some extent.

Figure 29: Capacity mix under sustained duration response split auction

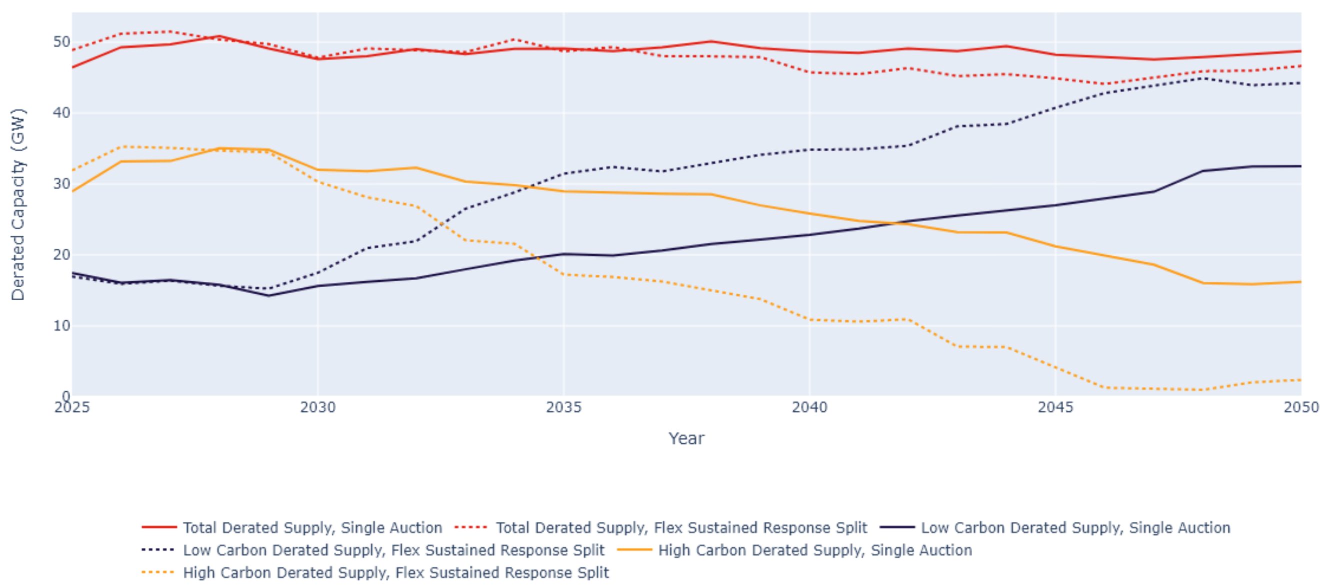
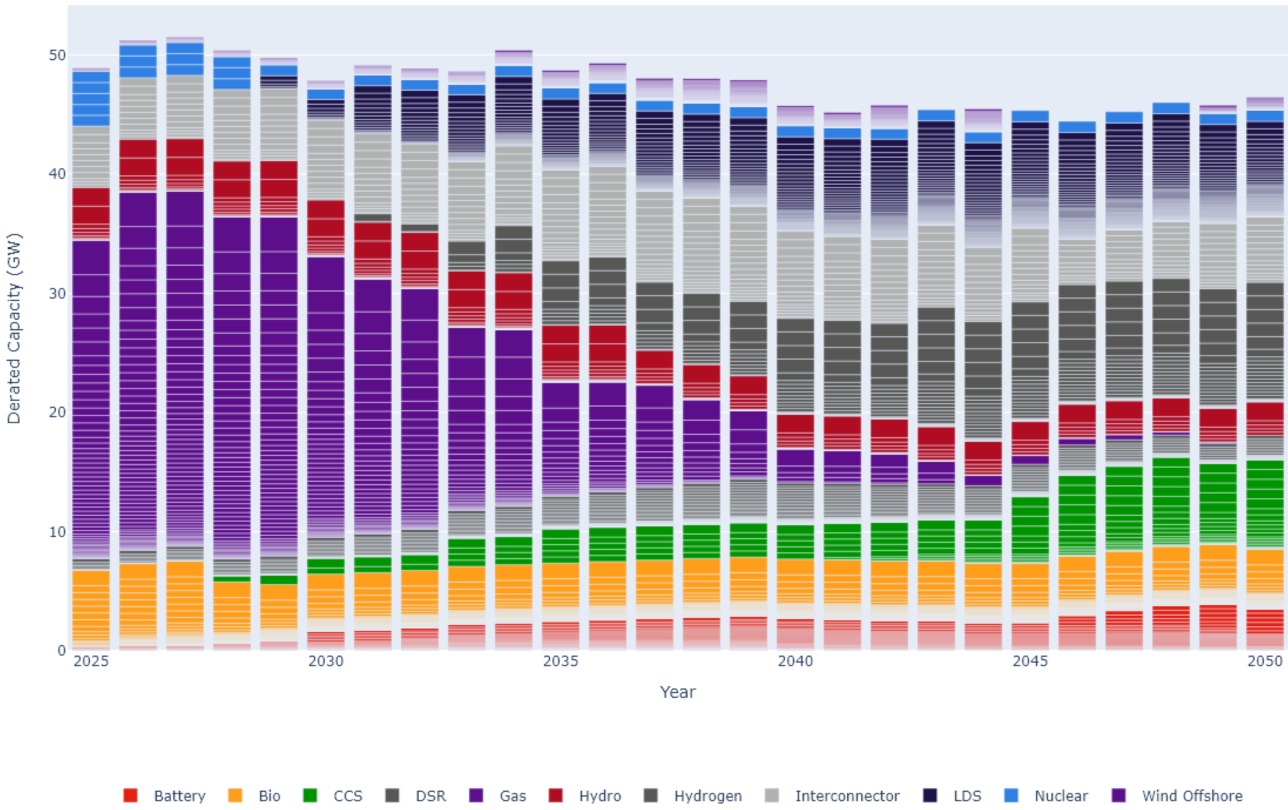
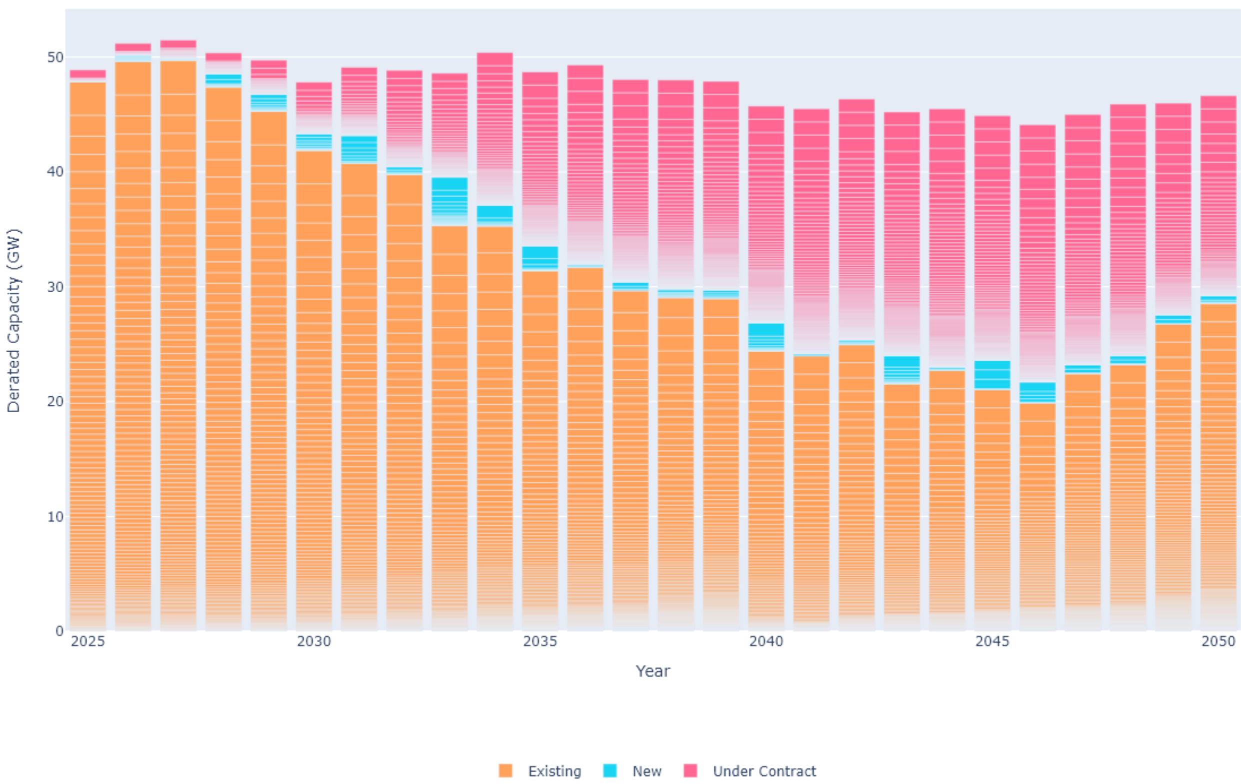


Figure 30: Capacity mix under sustained duration response split auction



As observed in the split auction for low carbon capacity, the auction design allows a step change in the amount of new-build low carbon capacity that clears in the auction (Figure 31).

Figure 31: New-build capacity under sustained duration response split auction



3. ***REMA objective: Provide the right signals for flexibility across the system.***
    a. *Providing appropriate economic signals for investment in low carbon flexibility*
    b. *Enabling participants to reap the benefits they bring for the wider energy system*

A split auction would be explicitly designed to send appropriate signals for sustained duration response. As we noted previously, it may be more difficult to design a split auction that also sends signals for response time services given the potential unintended consequences of doing so.

Our modelling demonstrates a step change in the amount of low carbon sustained duration response that would clear in the auction under the split auction compared to the status quo auction design and assuming suitable wider market conditions (Figure 32 and Figure 33).

Figure 32 Sustained Response capacity under a split auction for Low Carbon sustained response

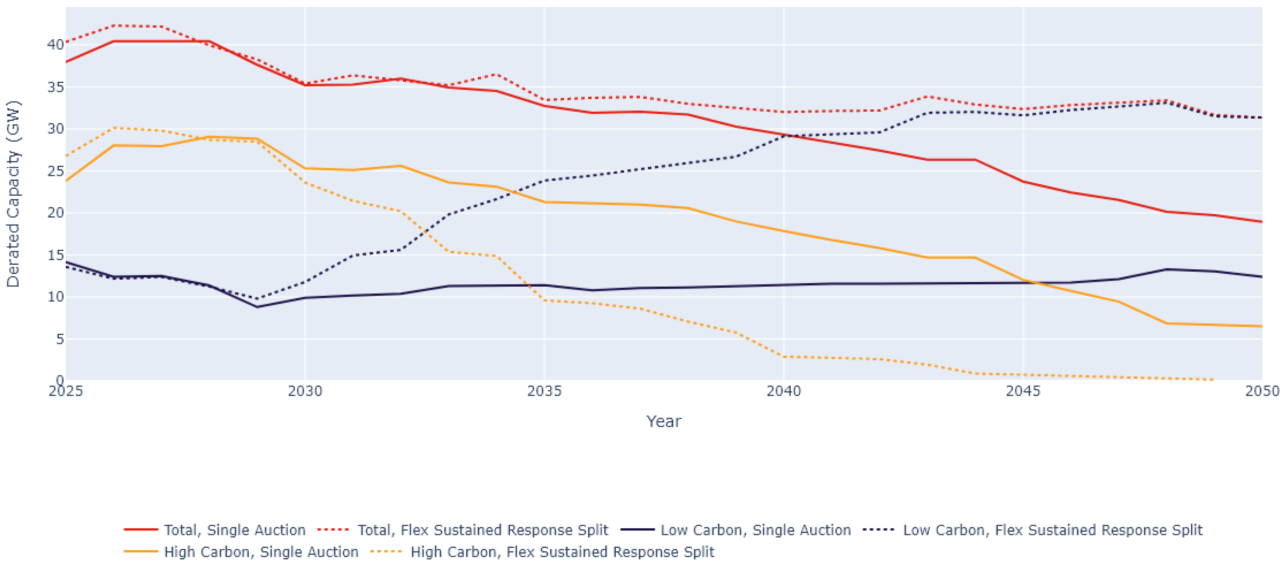
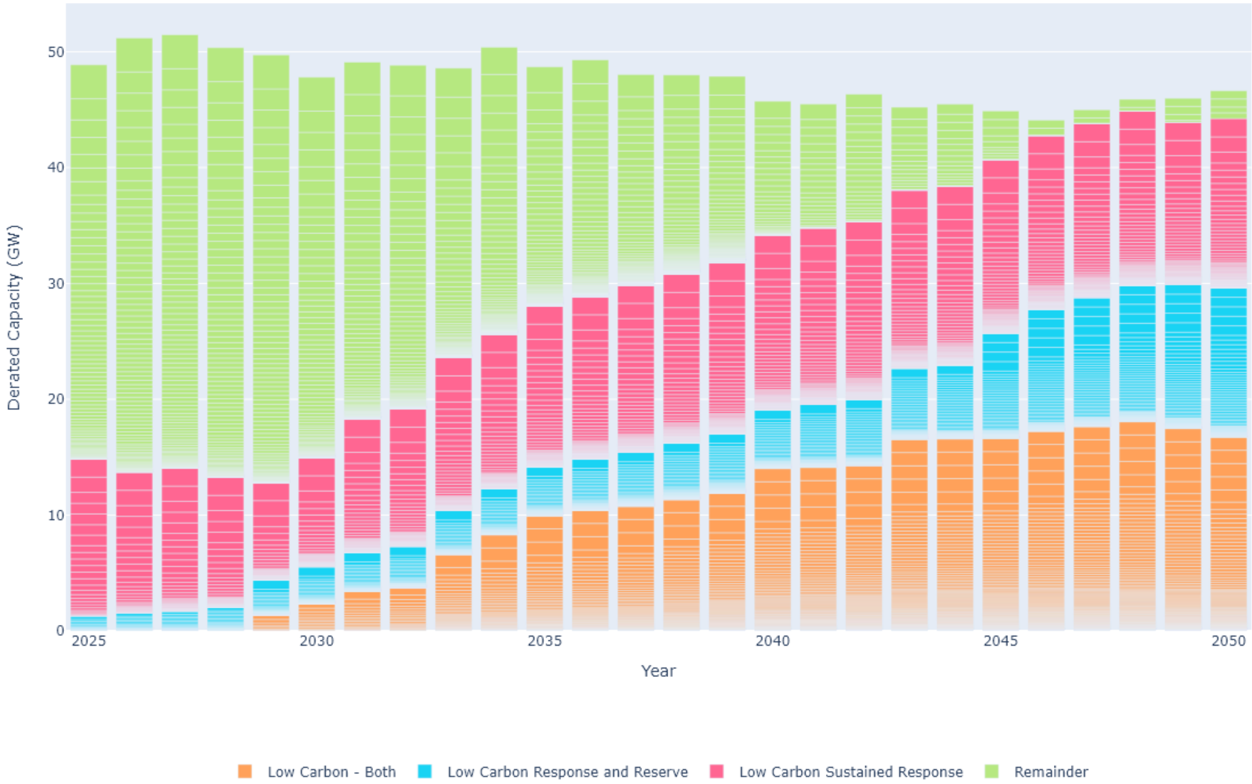


Figure 33: Sustained response and response time capability under the split auction



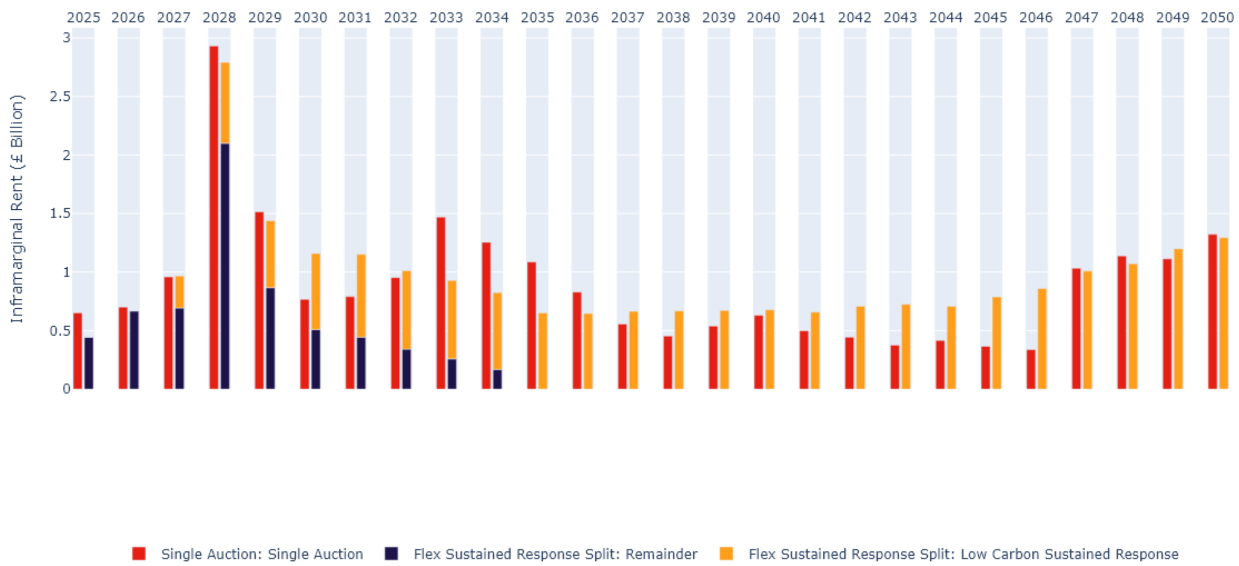
4. ***Additional objective: Cost-effective provision of energy security for consumers***
    a. *Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary*
    b. *Minimising the cost of implementing and operating the auction*
    c. *Ensuring complementarity between the CM and other mechanisms within the electricity market such as revenue cap and floor arrangements, balancing services and renewables support mechanisms.*

As with a split auction for low carbon capacity, a split auction for sustained duration response would likely increase clearing prices for eligible capacity but lower the clearing price for remaining capacity. We observe this in our modelling with the split auction for low carbon sustained duration response clearing at, or close to the auction price cap for much of the period (Figure 34).

Figure 34: Clearing prices under split auction for low carbon sustained response

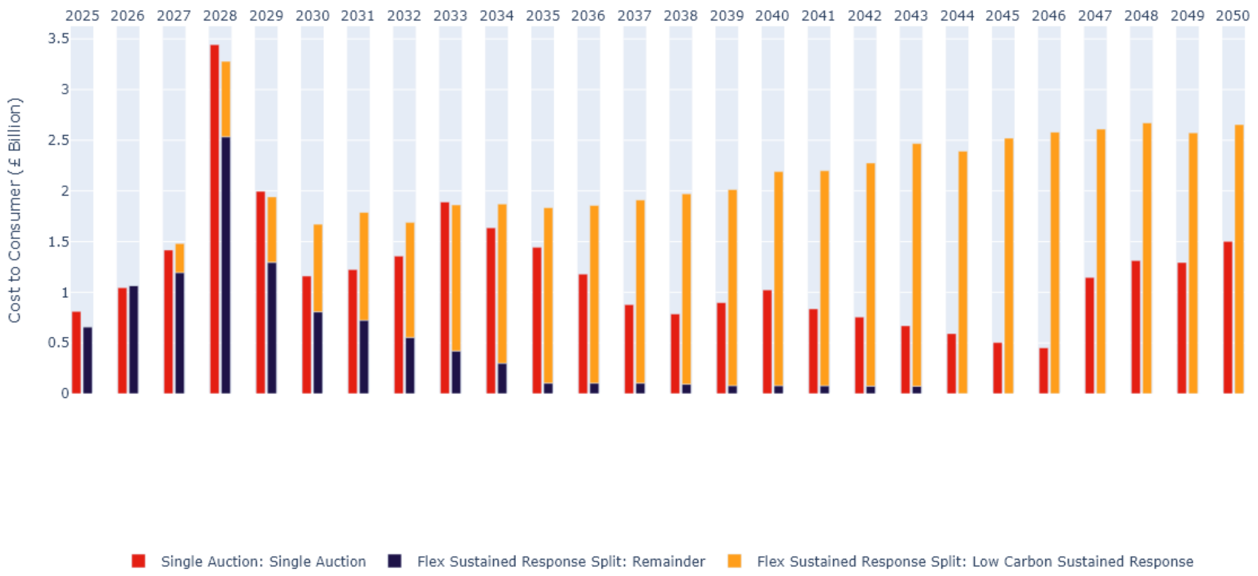
Impacts on inframarginal rent and direct auction costs would be driven by similar trade-offs to those discussed for other auction designs previously. On balance, we find that the increase in rent for some low carbon plant that can deliver sustained response services slightly outweighs the reduction in inframarginal rent for remaining capacity, increasing inframarginal rent overall under the given set of assumptions (Figure 35). Average annual inframarginal rent in the single auction is £0.89 billion whereas inframarginal rent inf the low carbon split auction is £0.69 billion and in the carbon auction is £0.25 billion resulting in total average annual rent of £0.94 billion.

Figure 35: Inframarginal rent under split auction for low carbon sustained response



The combination of effects increases the total cost of the auction from £1.2 billion to £2.08 billion, driven primarily by high priced long-term CM contracts with new build low carbon sustained response providers (Figure 36). As noted previously, this is a narrow assessment of costs limited solely to costs of the CM. This CM auction design would be intended to deliver wider benefits in other markets or in relation to security of supply given the explicit signals for flexibility. It may also deliver additional societal value attributed with the potential to increase the pace of decarbonization.

Figure 36: Capacity market costs under a split auction for sustained response



Splitting liquidity across multiple auctions could increase the risk of strategic bidding. This risk will increase the more that the auction is fragmented – e.g., into multiple auctions for different durations of response. Under the modelled split auction, we observe a higher HHI in the early years of the sustained duration response auction but falling towards the counterfactual level over time. In early years, the potential sustained response low carbon supply pool is smaller leading to more concentration in the sustained response split auction. Over time, as the volume of low carbon capacity which can provide sustained response increases, market concentration falls.

The HHI for the remaining capacity remains relatively low until late in the period when it increases to slightly higher levels (Figure 37).

Figure 37: HHI under split auction for sustained response

5. ***Additional objective: Avoiding creation of unnecessary risk and uncertainty***
    a. *Minimising unintended consequences from auction design*
    b. *Adaptability of auction design to market and technological evolution*

We previously mentioned potential challenges with security of supply and the potential reduction in auction liquidity that could introduce more scope for strategic bidding.

The target capacity for low carbon sustained duration response and response time services should be driven by need, drawing on methods summarised previously. However, in practice this introduces a challenging problem for the auctioneer who will have to manage this with imperfect information.

As we discussed for a split auction for low carbon capacity, a split auction for sustained response could have the unintended consequence of sending perverse signals to capacity if the clearing price in the sustained response auction falls below the clearing price in the remaining auction.

Finally, without broader signals for other forms of low carbon capacity, a split auction for sustained response capacity could inadvertently crowd out low carbon capacity that cannot deliver sustained response. For example, this may introduce challenges for shorter duration batteries to clear in the auction as they compete against carbon emitting plant in the main auction but with lower overall capacity targets given the target capacity set for sustained response[43]. One option to mitigate against this outcome is to hold a split auction or auction with minima for all low carbon capacity, including capacity that cannot provide sustained duration (e.g., short duration batteries). Within this split auction or auction with minima, further signals could be included for sustained duration response characteristics.

6.4 An auction with minima for low carbon flexible capacity

6.4.1 How an auction with minima would work

An auction with minima for flexibility characteristics is conceptually similar to a split auction with the same objectives. Minima would be introduced into one or more auctions to reflect an objective for capacity to provide desirable flexibility characteristics.

Minima could reflect several flexibility characteristics, e.g., a minima for capacity that can respond within a certain time horizon and another for capacity that can sustain output for a given number of hours. Multiple minima could be mapped relatively closely to the FSO’s expected requirements for operating a decarbonised power system.

If technically capable of doing so, capacity could contribute to more than one of these minimum requirements. In such a case, these assets would receive the highest clearing price of all the categories in which they participate. If multiple flexibility characteristics are introduced, the auctioneer may need to consider whether the same asset can technically contribute each of

[43] The effect will depend on the extent to which these technologies can secure higher revenues from other markets.

them simultaneously and therefore, whether they can participate in both categories at the same time.

Disaggregation and alignment with need

As with a split auction, minima could be mapped across one or more flexibility characteristics, with some similarities in outcome.

While one advantage of the use of minima is that the overall auction maintains the same level of liquidity, less competition may exist for each minimum. Indeed, the use of minima to encourage more participation of capacity with a given characteristic suggests some scarcity of capacity. Coupled with the reduction in liquidity, this could result in strategic bidding of capacity that is eligible to meet the minima which may increase the overall cost to consumers. The more minima that are introduced to reflect increasingly fragmented characteristics, the greater the risk of such outcomes.

Descending clock vs sealed bid

As with a split auction, a greater number of minima implies an increase in risk of strategic bidding. It may also increase the complexity of a descending clock auction in which the auction algorithm must cope with several parallel auction constraints to reflect the minima. A sealed bid design may become preferable if several minima are used.

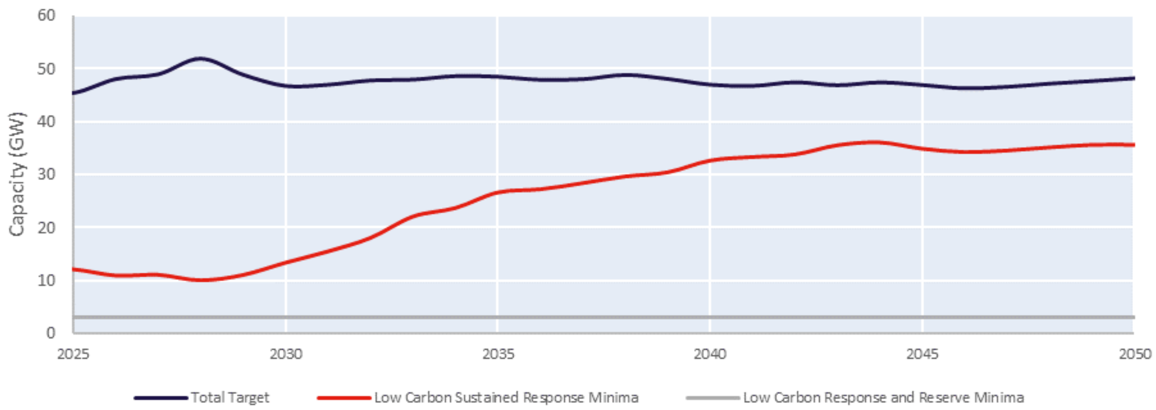
6.4.2 Evaluation of a single auction with minima for flexibility

Because capacity that participates within a minima also participates in the wider auction, a minima design allows for separate minima to be included for response time services, without the same challenges as were discussed in the case of a split auction of similar design. Even if the response time minima clears at £0/kW, eligible capacity will continue to receive the clearing price from the wider auction, thus eliminating the potential incentive to withhold response time capacity.

For modelling purposes, we maintain the same level of overall target capacity but include two minima that must clear in parallel (Figure 38):

- A minima for low carbon response time capabilities. We set this at a constant 3 GW, reflecting a rough approximation of the existing volume of response and reserve services procured by the ESO (see Table 6).
- A minima for low carbon sustained duration response. We set this in the same way as the split auction target capacity. This reflects a desire to procure an increasing requirement for capacity to cover a renewables drought and for more of this to come from low carbon sources.

Figure 38 Capacity targets for low carbon flexibility minima in the quantitative analysis



1. ***REMA objective: Ensure that the security of the system can be maintained at all times.***
    a. *Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output*
    b. *Supporting investment cases in capacity with characteristics which support security*

So long as both the minima and main auction clear, and assuming that de-rating factors and non-delivery penalties are set appropriately, an auction with minima should not directly impact on security of supply outcomes.

For flexibility services, target capacity should be driven by an estimation of need rather than simply maximising capacity with flexibility characteristics relative to the overall procurement target. In the case that a minima within the auction did not clear, this would reflect a wider security of supply risk. Given signals sent by the minima, this risk should be lower than would be observed in a single auction with no signals for flexibility.

In the case of response time services, there is an interaction with signals sent in the wider market. If the minima for response time services did not clear, this may signal that the FSO needs to procure more services closer to real time through balancing services markets if they are working in parallel to the signals in the CM.

For sustained response services, target capacity will depend on the proportion of demand which is expected to be met by variable generation in the market, therefore signaling the extent of capacity shortfall that must be met during a renewables drought. If the minima for low carbon sustained response does not clear, this implies that sustained duration capacity is unable to meet the full shortfall in renewable capacity, therefore reflecting a wider security of supply risk. Given signals sent by the minima, this risk should be lower than would be observed in a single auction with no signals for flexibility.

However, in both cases, the fact that an additional market signal is being sent to reflect the value of flexibility should not increase security of supply risk and may actively reduce it, where this signal is filling a gap in signals sent from elsewhere in the market and is sufficiently strong to encourage additional investment in flexible low carbon capacity.

When considering a minima for low carbon capacity, we found that this could undermine the provision of flexibility that would be delivered by conventional generation. Minima targeting flexibility would be explicitly designed to reduce this risk, by sending signals to ensure that a sufficient proportion of additional low carbon capacity also provided the necessary flexibility for the system.

2. ***REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB's dependence on fossil fuel generation.***

    a. *Providing appropriate economic signals for investment in low carbon capacity*

Minima which are designed to bring forward low carbon sustained duration response will likely deliver additional low carbon capacity relative to the single auction scenario. Low carbon sustained duration response will replace carbon-based alternatives allowing penetration of renewables to be balanced with low carbon back-up capacity.

While the proportion will vary depending on definition of eligibility, much of the future low carbon capacity that participates in the CM may be able to deliver a sustained response. Under the definition of at least four hours of ongoing response as defined by Aurora, it is only short duration batteries, DSR and some merchant renewables that are considered low carbon but unable to provide a sustained response in our modelling.

As a consequence, we observe a step change in uptake of low carbon capacity in the CM under this auction design (Figure 39 and Figure 42).

Figure 39: Capacity mix under low carbon flexibility minima auction

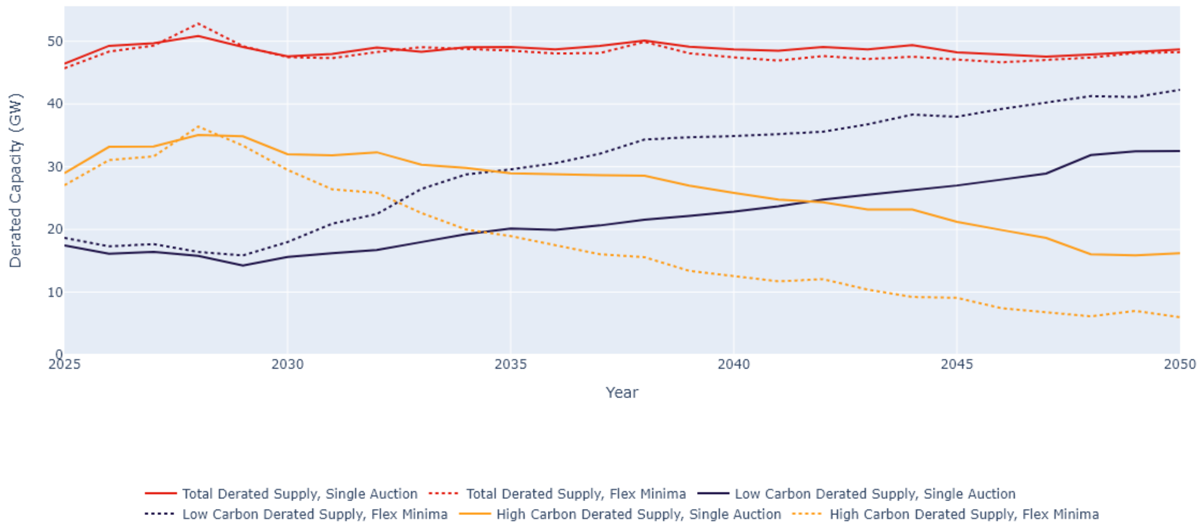
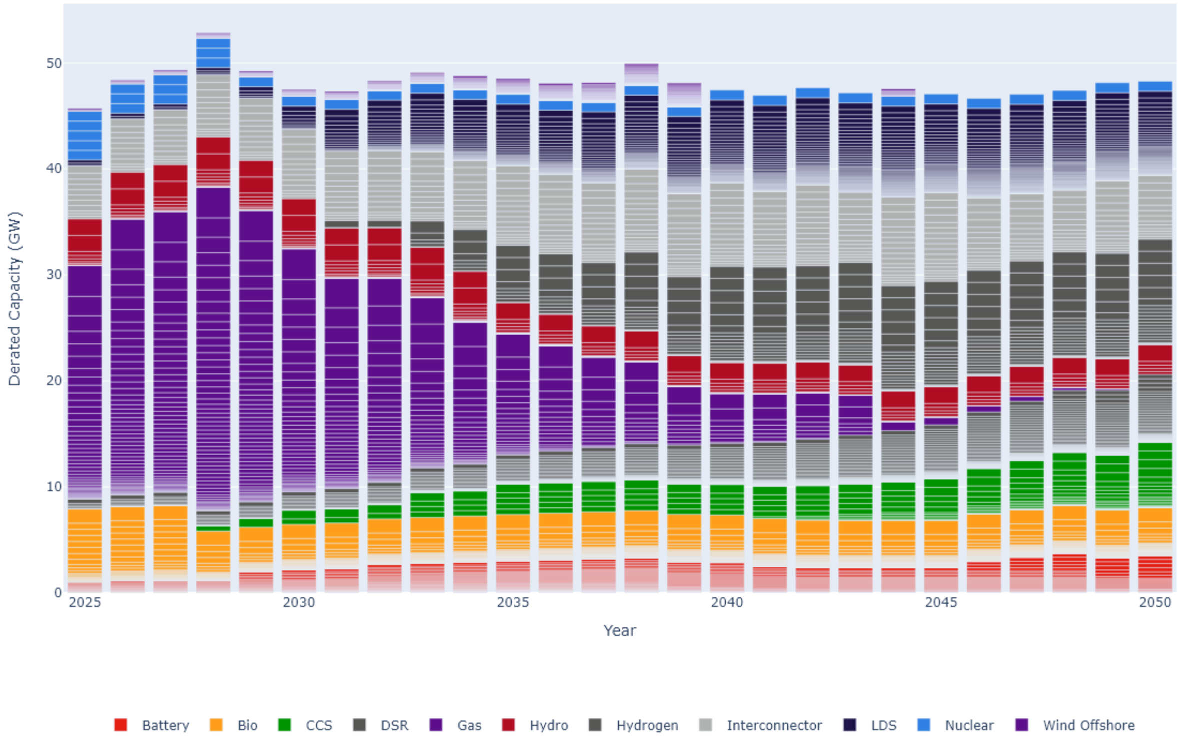
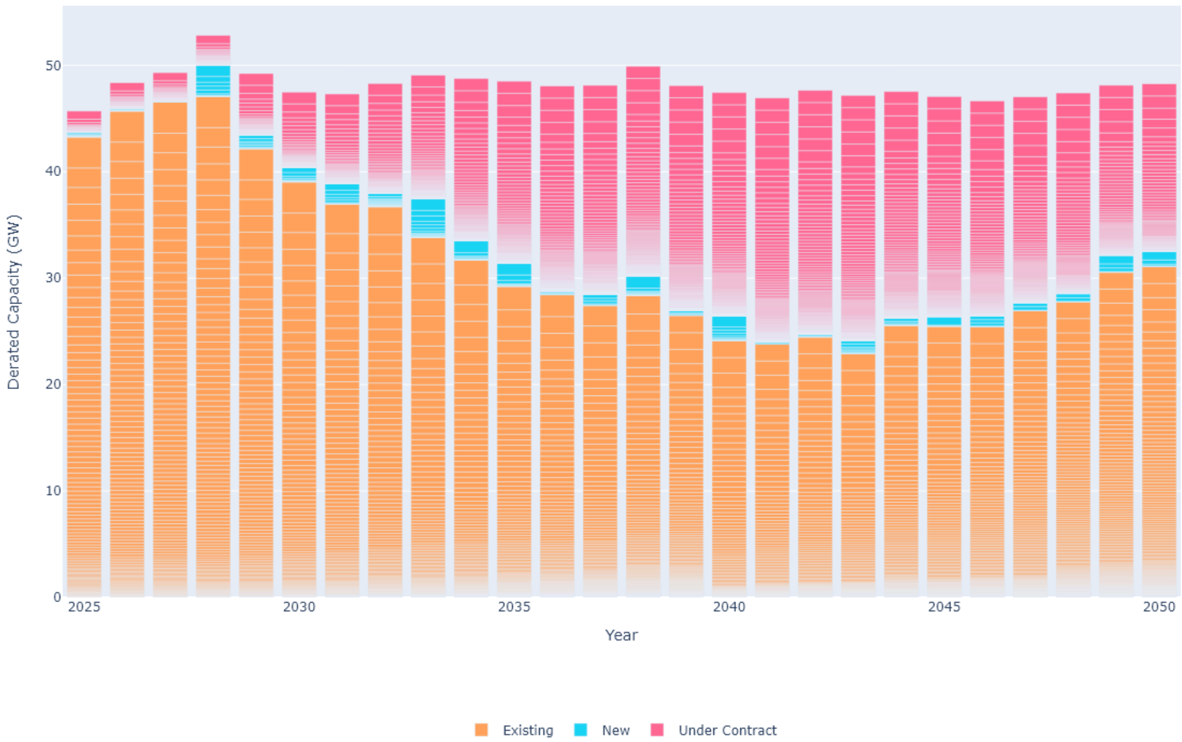


Figure 40: Capacity mix under low carbon flexibility minima auction



The auction with minima for sustained response and response time capability also delivers a step change in the amount of new-build low carbon capacity that clears in the auction (Figure 48).

Figure 41: New-build capacity under auction with minima for flexibility capability



3. ***REMA objective: Provide the right signals for flexibility across the system.***
    a. *Providing appropriate economic signals for investment in low carbon flexibility*
    b. *Enabling participants to reap the benefits they bring for the wider energy system*

While a low carbon auction with minima may deliver some flexible low carbon capacity indirectly, an auction with minima for flexibility characteristics would be explicitly designed to send appropriate signals for low carbon flexibility to meet identified sustained response and response time requirements.

Our modelling demonstrates a step change in the amount of low carbon sustained duration response that would clear in the auction under the minima target capacity that we have defined, relative to the status quo auction (Figure 42 and Figure 43). While results are relatively similar to that observed for a low carbon split auction and auction with minima, they may diverge to a greater extent under alternative auction designs, for example with a different definition of sustained response other than the four-hour duration requirement we have assumed.

Figure 42 Sustained response under auction with minima for low carbon flexibility

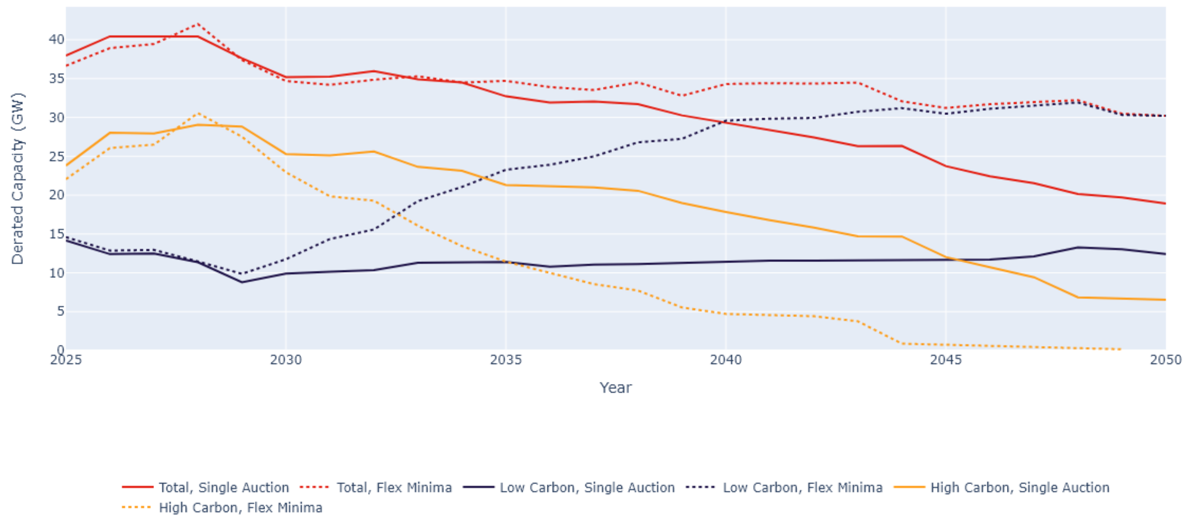
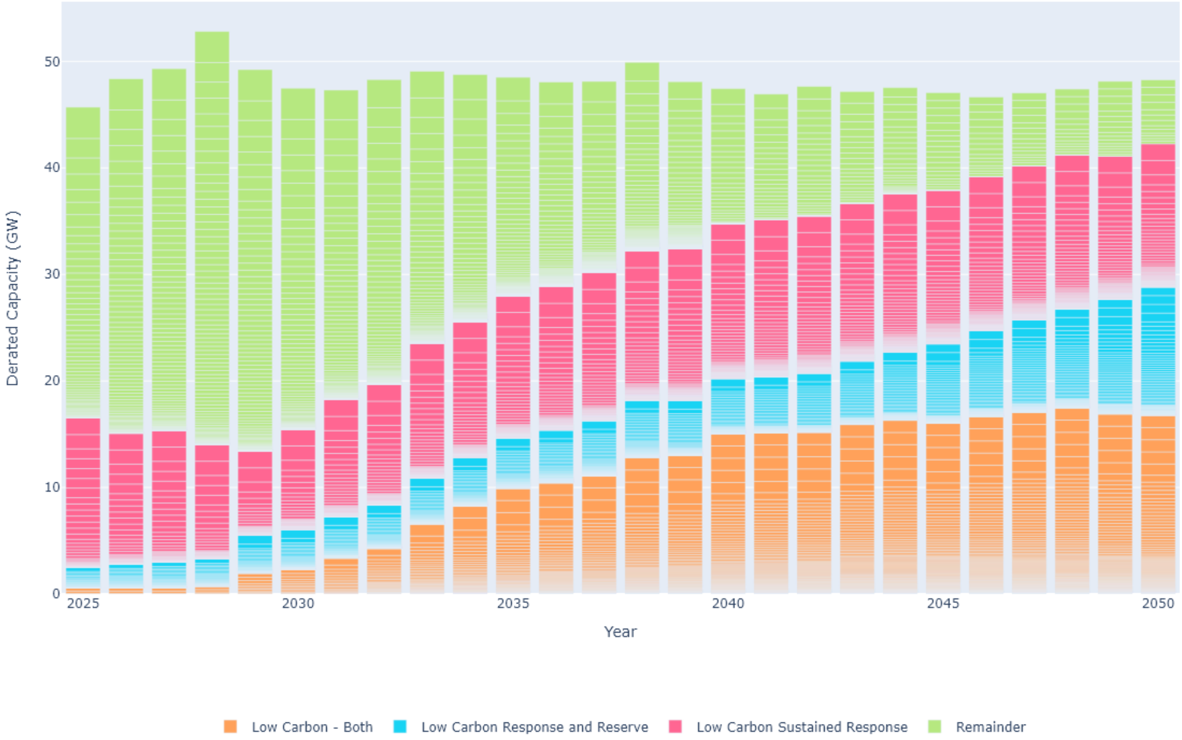


Figure 43: Flexibility under auction with minima for low carbon flexibility



Nevertheless, we discussed the importance of considering interactions with other market mechanisms which provide signals for flexibility previously. Particularly in the case of response time services, sending 'appropriate signals' for investment in low carbon flexibility requires DESNZ to consider interactions with signals that already exist elsewhere.

4. ***Additional objective: Cost-effective provision of energy security for consumers***

   a. *Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary*

   b. *Minimising the cost of implementing and operating the auction*

   c. *Ensuring complementarity between the CM and other mechanisms within the electricity market such as revenue cap and floor arrangements, balancing services and renewables support mechanisms.*

All else being equal, the impact on cost of the CM is driven by three interacting effects:

- Where a biting constraint, a minima requires more expensive flexible capacity to clear in the auction ahead of some lower priced capacity that does not contribute to the minima. This directly increases the costs of clearing the auction.
- This higher clearing price will provide some low carbon flexible capacity with increased inframarginal rent relative to the counterfactual in which it cleared in the auction but with a lower clearing price.
- On the other hand, outside of the minima, the auction will clear at a lower price as less capacity is needed from the rest of the auction. This reduces the inframarginal rent of capacity that is not eligible to participate in the minima.

Figure 44 shows the impact of the auction on the clearing prices for the minima and for the remaining capacity. This demonstrates the higher clearing price driven by CM contracts awarded to low carbon sustained duration response capacity needed to meet the minima. In our modelling, after delivering some additional low carbon response time capacity in initial years, long term response time contracts coupled with plentiful low carbon response time capacity push the clearing price of the response time minima to £0/kW (note that plant participating in this minima will continue to receive the clearing price from the main auction which is higher than the minima clearing price).

Figure 44: Clearing price under auction with minima for low carbon flexibility

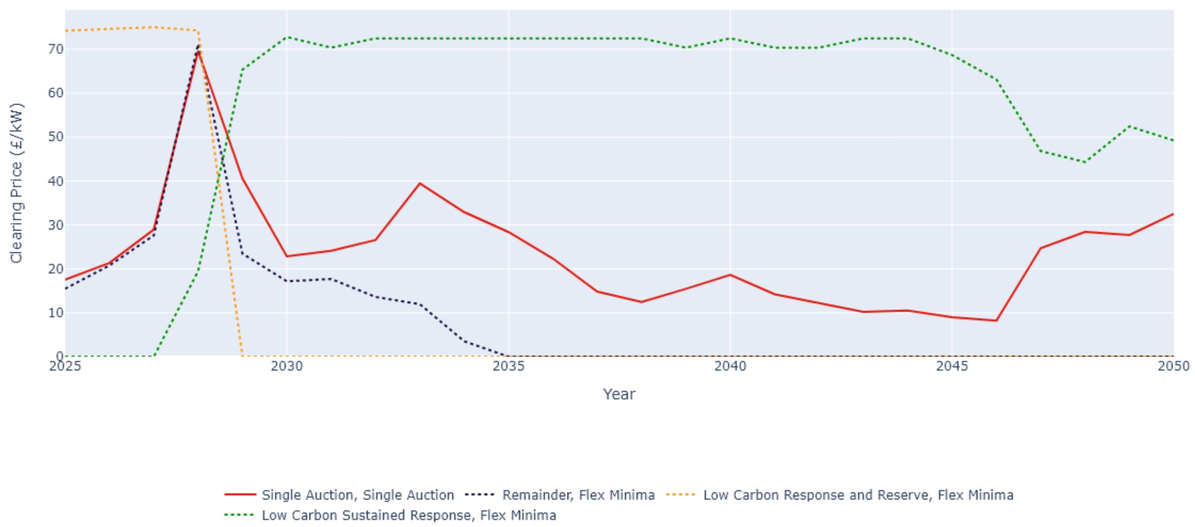
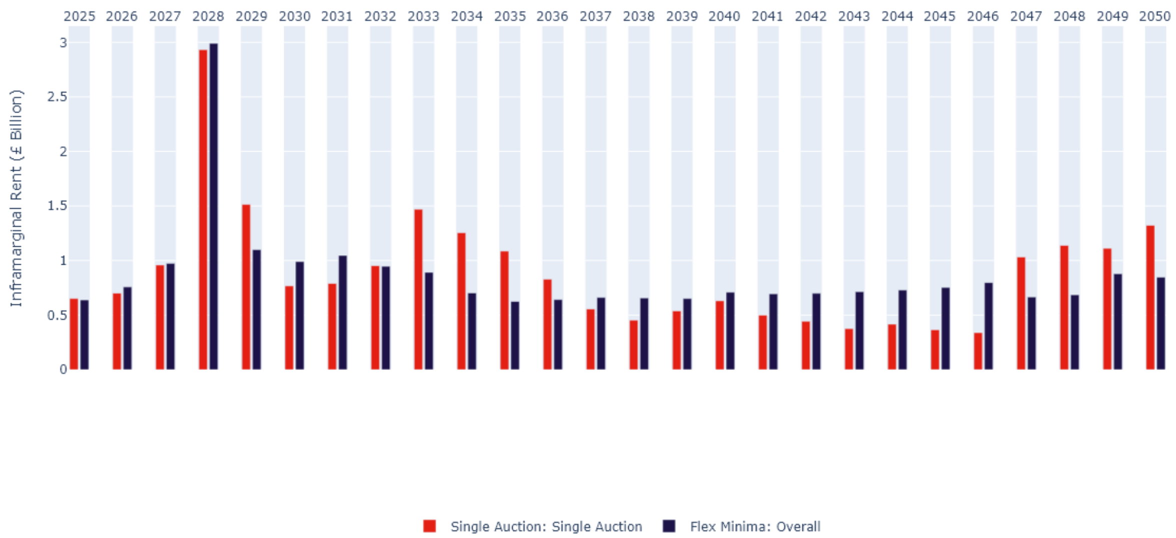


Figure 45 shows inframarginal rent observed in the minima auction we modelled. Higher inframarginal rent for some sustained duration response providers is slightly outweighed by a reduction in inframarginal rent for remaining capacity reducing average inframarginal rent from £0.89 billion to £0.86 billion.

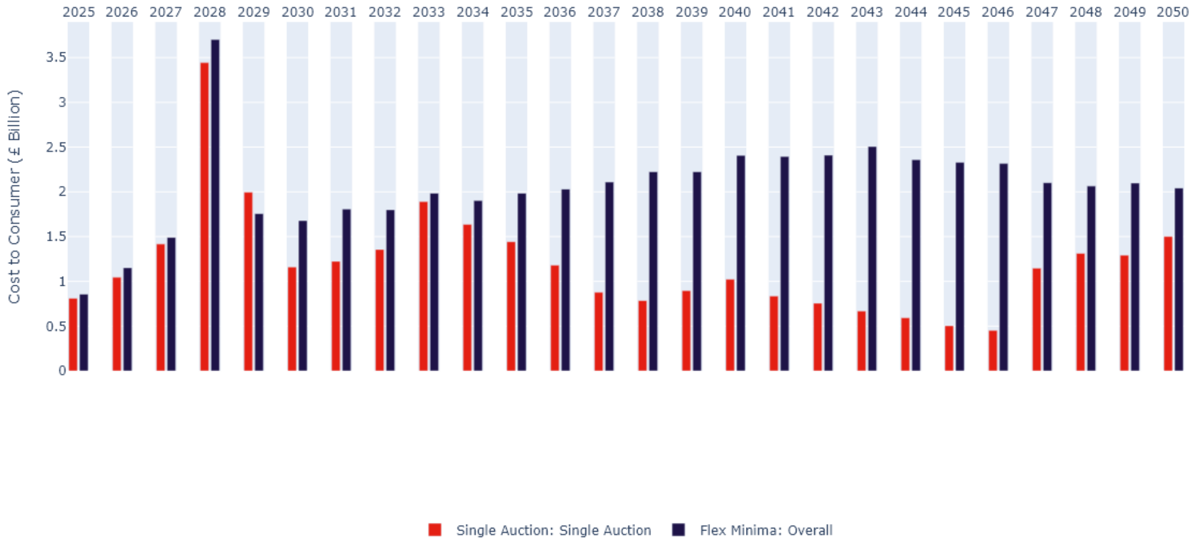
Figure 45: Inframarginal rent under auction with minima for low carbon flexibility



The overall cost of the CM would depend on the balance of factors discussed above. In our modelling, the combination of factors increases the average annual cost of the CM from £1.2

billion to £1.96 billion (Figure 46). This is primarily driven by the provision of high priced, long-term contracts to new-build low carbon sustained response providers. This is a narrow interpretation of cost focused only on the CM. As discussed previously, there are likely to be wider impacts on costs in other parts of the market and there may be wider societal benefits from accelerated decarbonization.

Figure 46: Capacity market cost under auction with minima for low carbon flexibility

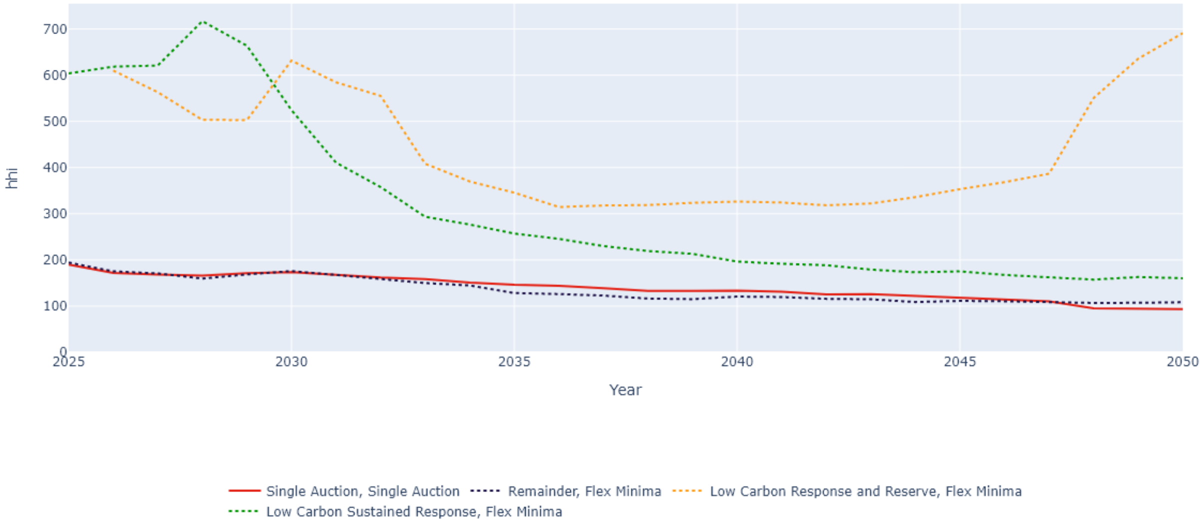


An auction with minima may also introduce strategic bidding opportunities for capacity that is eligible for the minima, especially if the minima is set at ambitious levels relative to the potential pool of eligible supply.

However, relative to the split auction, it would reduce risk surrounding strategic bidding capacity for capacity that is not eligible for the minima as this competes within a single auction against all other capacity.

We can see this trend in our HHI metric as we observe higher concentration of capacity within the response time and sustained duration response minima. The latter in particular falls over time as an increasing amount of capacity can participate within the minima (Figure 47).

Figure 47: HHI under auction with minima for low carbon flexibility



The implementation and operation of an auction with a single minima should not require significantly more resource than the existing auction design. The clearing algorithm should be relatively straightforward to develop, and we expect that a descending clock design would remain viable if preferred. The additional resource burden is most likely to result from the need to set the minima at an appropriate level which reflects the need for capacity – either driven by the need for balancing services or by the expected value delivered by capacity which can cover modelled periods of a renewables drought.

Complementarity with other market mechanisms is a key consideration for response time signals in particularly. Clarity on the role of a minima for response time characteristics relative to existing signals is an important first step to defining the role of the CM.

5. ***Additional objective: Avoiding creation of unnecessary risk and uncertainty***
    a. *Minimising unintended consequences from auction design*
    b. *Adaptability of auction design to market and technological evolution*

While reduced compared to a split auction, there remains some potential impact from reducing the broader services delivered by existing carbon emitting capacity. There is also some additional scope for strategic bidding of capacity that is eligible for the minima. Relative to the split auction, we noted reduced potential for strategic bidding for carbon emitting capacity.

The minima for low carbon sustained duration response and response time services should be driven by need, drawing on methods summarised previously. However, in practice this introduces a challenging problem for the auctioneer who will have to manage this with imperfect information.

A minima auction has one further advantage over a split auction in that it eliminates the potential unintended consequence for the low carbon auction to clear below the auction for remaining capacity. Under the minima, low carbon capacity would receive the greater of the clearing price set under the minima or the overarching clearing price. Therefore, if the marginal unit of capacity in the overall auction happens to be a carbon emitting plant, all capacity would clear at the same price avoiding the potentially distortive signals to carbon vs low carbon capacity.

6.5 An auction with multipliers for low carbon flexible capacity

6.5.1 How an auction with multipliers would work

Introducing multipliers for flexibility characteristics could be designed with the intention of reflecting the additional value that provision of these characteristics bring to the system. This could be achieved while retaining a single auction such that liquidity of the auction would be similar to that observed otherwise.

A single multiplier could be applied to any capacity which can provide one or more desirable characteristics. Alternatively, several multipliers could be introduced to reflect different flexibility characteristics. For example, a multiplier could be specified for capacity with a response time below 10 seconds, a separate multiplier for capacity with a response time between 10 seconds and 30 minutes and a further multiplier specified for capacity that can provide sustained response over a period of more than four hours.

There is a question surrounding compounding of multipliers for capacity which has multiple characteristics and so may provide additional value. For example:

- the multipliers for each characteristic could be summed;
- a separate, bespoke multiplier could be developed to reflect a combination of properties; or
- the capacity could receive the highest of the multipliers it is eligible for.

Setting multipliers

Multipliers could be set based on the FSO’s assessment of the multiplier needed to bring forward capacity with the relevant flexibility characteristic relative to other capacity against which it would be competing in the auction. This would represent a ‘cost based’ approach, replicating the strength of signal which the market has demonstrated is needed to deliver this form of flexibility.

For response time services, this assessment may be able to draw on the ESO’s procurement of balancing services which provides market-based information of the value that capacity requires within a market to provide such services.

If designed in this way, it is important to note that this will directly mirror the signals which are otherwise sent through balancing services markets. This approach may imply that signals in the CM should replace those included in balancing services markets rather than working alongside them, or at least that balancing services markets would need to be tailored to reflect signals from the CM.

An alternative is a ‘value based’ approach in which the additional benefit to consumers resulting from the capability to provide response time services is priced into the CM. This could be based on an estimate of the additional security of supply benefit which is delivered as a result of the FSO being able to access such services, e.g. by incorporating estimates of the value of lost load (VoLL). This could be based on simulation modelling to estimate loss of load expectation with and without the required volume of response time services, or based on alternative options available to the FSO such as procuring additional services from providers that do not participate in the CM.

Multipliers for sustained duration response could also be ‘cost’ or ‘value’ based. Cost based multipliers would be designed to provide a sufficient signal to low carbon sustained duration response to make it sufficiently competitive with other forms of capacity that it would clear in the auction. This could be designed based on a comparison of the CONE of a sustained duration response technology that DESNZ is seeking to bring into the market against the CONE of existing carbon emitting capacity for example.

Under a ‘value based’ design, multipliers could be designed to reflect the additional value of low carbon sustained duration response to consumers. This may combine principles for valuing low carbon as discussed previously with additional estimations of the security of supply value delivered, e.g., by incorporating estimates of VoLL.

In both cases, a value based approach would be very challenging to implement in practice given uncertainties surrounding the specific value associated with decarbonisation and security of supply benefits. A cost based approach provides a more direct mechanism for the auctioneer to influence auction outcomes towards low carbon flexible capacity.

6.5.2 Evaluation of a single auction with multipliers

One proxy ‘value based’ approach for defining multipliers for response time services is to reflect the additional value that such services receive through the ESO’s balancing services markets. Analysis of the ESO’s procurement of balancing services demonstrates a range of implied multipliers across different services. We find that the implied multipliers range between 1.5 and 3.2 when considered in the context of the 26-27 Delivery year T-4 auction results. However, this increases to a range between 2.1 and 6.3 when compared against the 5-year clearing price average. For simplicity we assume a multiplier of 3 in our modelling of a multiplier for response time characteristics.

Developing cost based or value-based approaches to establish multipliers for sustained duration response are beyond the scope of this project. For simplicity, we also model a multiplier of 3 for sustained duration response, exploring impacts on clearing and auction outcomes.

1. ***REMA objective: Ensure that the security of the system can be maintained at all times.***

    a. *Attracting sufficient capacity to maintain capacity margins at desired levels to meet both periods of peak demand and of low renewables output*

    b. *Supporting investment cases in capacity with characteristics which support security*

Assuming that de-rating factors and non-delivery penalties are set appropriately, multipliers should not impact directly on security of supply. As all capacity competes together in the same auction, there is little impact on the likelihood of clearing the auction.

2. ***REMA objective: Deliver a step change in the rate of deployment of low carbon technologies, and reduce GB's dependence on fossil fuel generation.***

    a. *Providing appropriate economic signals for investment in low carbon capacity*

Similar to our findings for low carbon capacity, we find that the impact of multipliers on the delivery of low carbon capacity is relatively muted (Figure 48, Figure 49 and Figure 50). While a multiplier of three allows low carbon capacity to bid at a third of its original intended bid price, we observe a substantial amount of capacity in the CM that is not eligible for the multiplier but bids in at a very low level or as a price taker and thus, continues to clear. As well as price takers in the auction, some of this capacity may represent existing capacity has already recouped fixed costs and covers much of its ongoing costs from wholesale market and other revenues.

Figure 48: Capacity mix under an auction with multipliers for low carbon flexibility

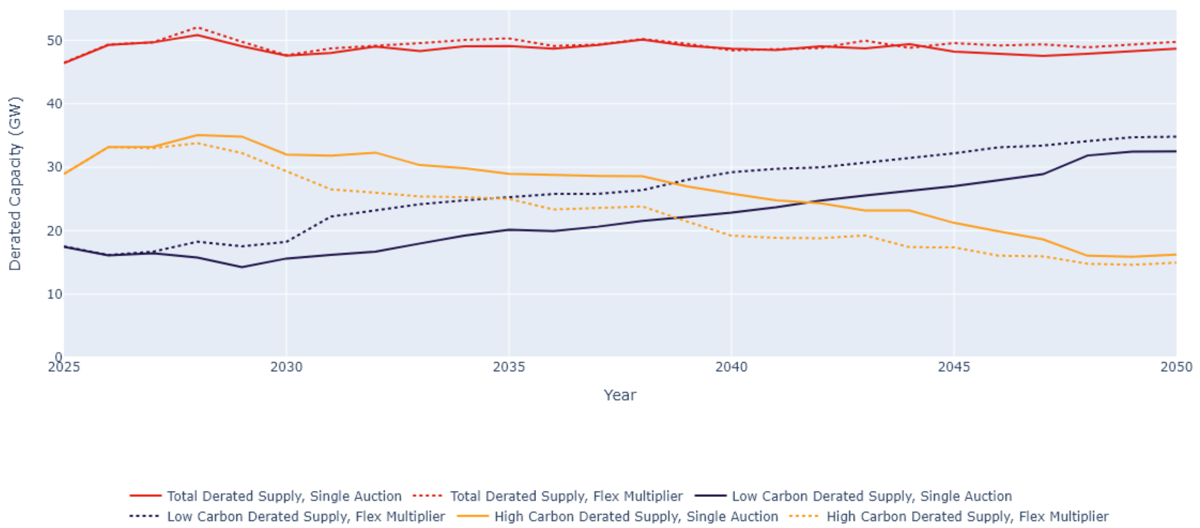


Figure 49: Capacity mix breakdown under an auction with multipliers for low carbon flexibility

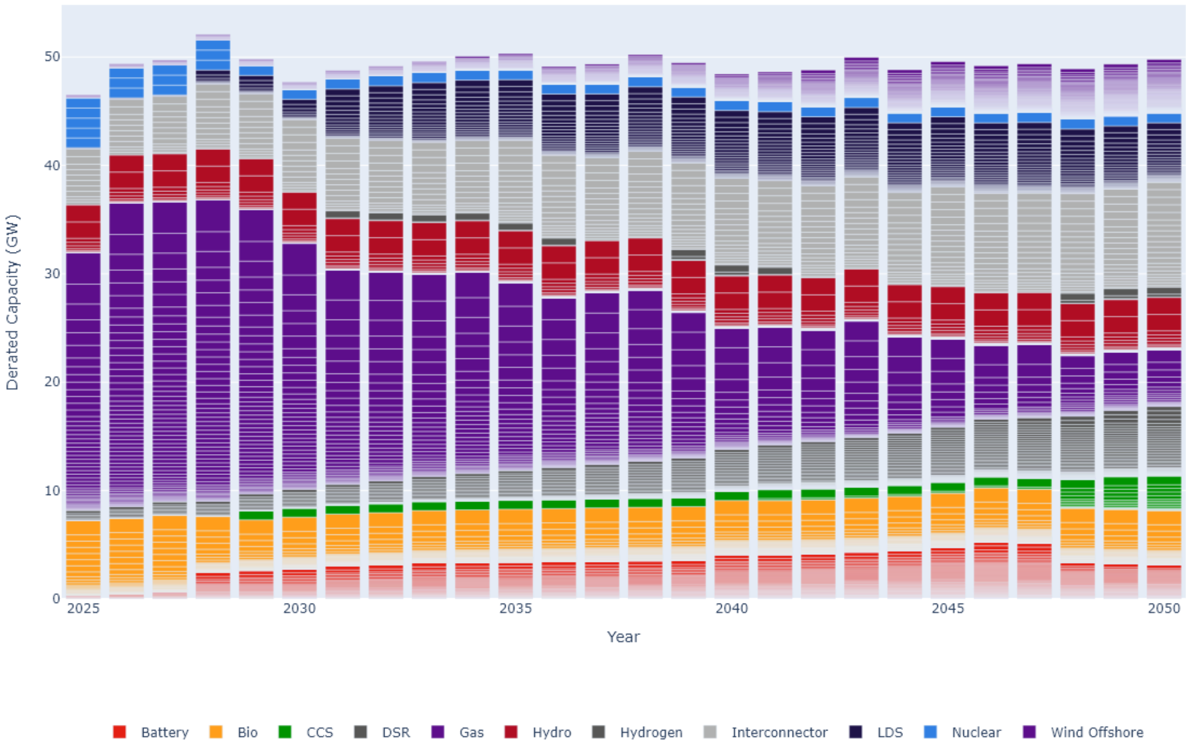
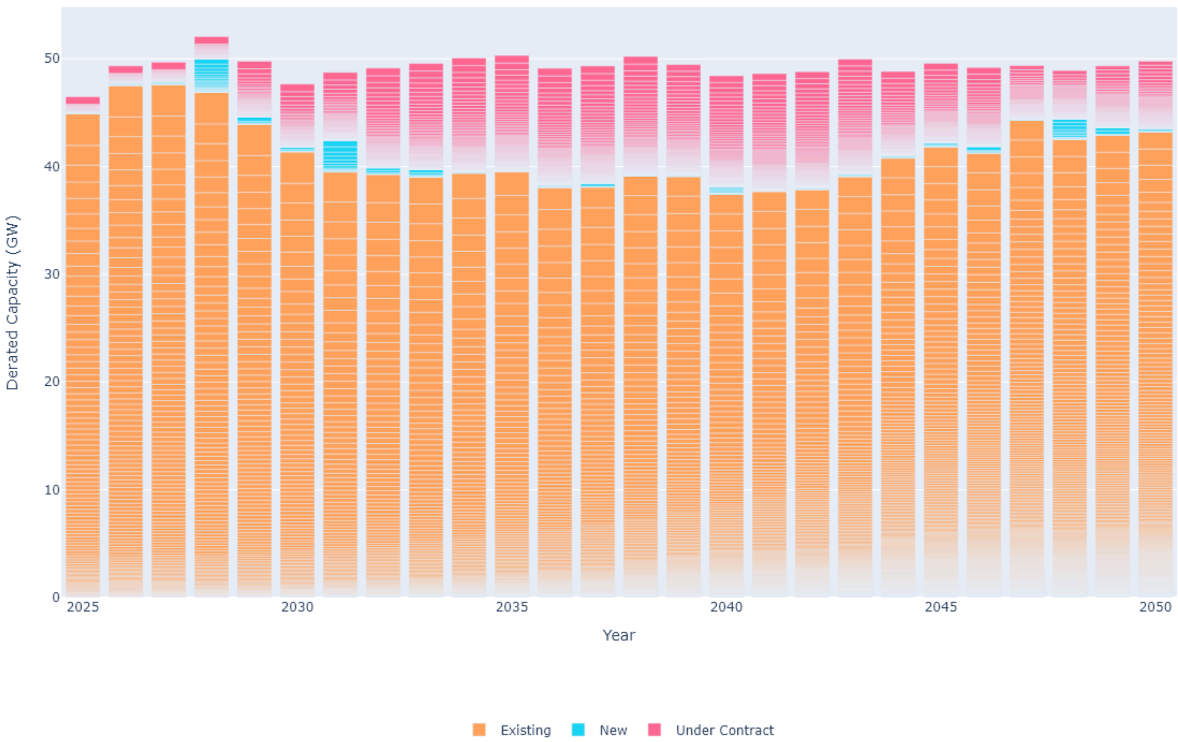


Figure 50: New-build capacity under auction with multipliers for flexibility



3. REMA objective: Provide the right signals for flexibility across the system.

a. Providing appropriate economic signals for investment in low carbon flexibility

b. Enabling participants to reap the benefits they bring for the wider energy system

Regardless of whether multipliers are value based or cost based, they are likely to leave the auctioneer with volume uncertainty.

In our modelling, given the limited impact on the supply mix in our modelling, even using a multiplier of 3 for eligible capacity has a relatively small impact on the amount of low carbon flexible capacity (Figure 51 and Figure 52).

Figure 51 Sustained response capacity under and auction with multipliers for low carbon flexibility

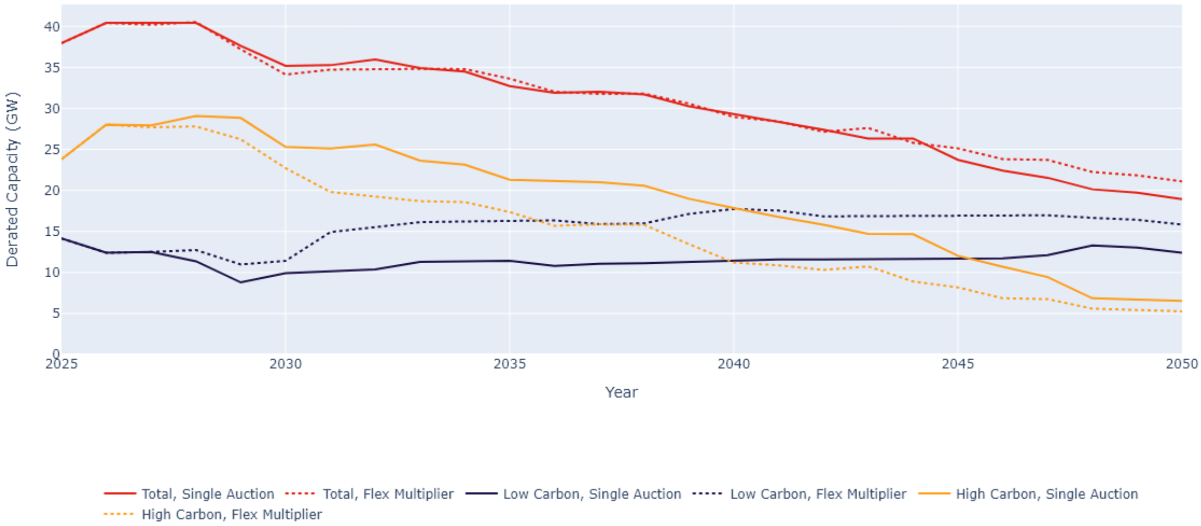
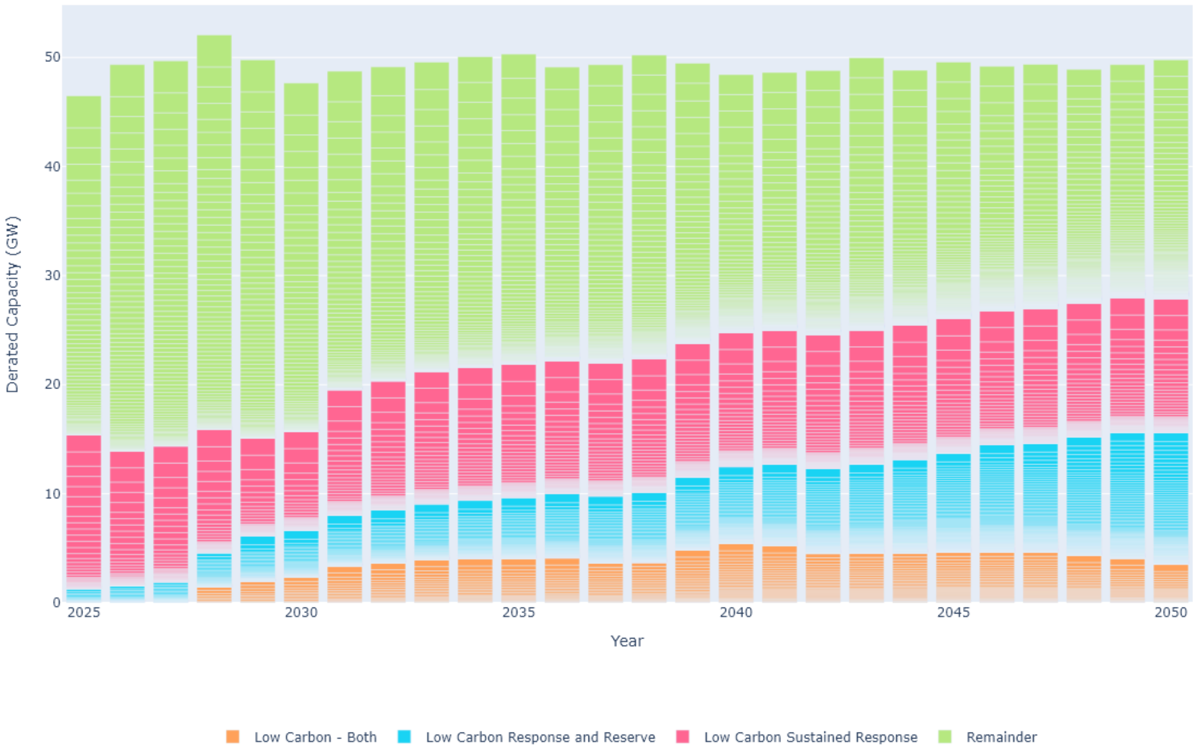


Figure 52: Flexibility provision under an auction with multipliers for low carbon flexibility



4. ***Additional objective: Cost-effective provision of energy security for consumers***

   a. *Minimising the extent to which revenues provided to companies from the capacity market are greater than necessary*

   b. *Minimising the cost of implementing and operating the auction*

   c. *Ensuring complementarity between the CM and other mechanisms within the electricity market such as revenue cap and floor arrangements, balancing services and renewables support mechanisms.*

As we observed previously, multipliers would impact on inframarginal rent of low carbon flexible capacity vs remaining capacity even if the capacity mix does not change significantly. In our modelling, the balance of effects results in a small reduction in average annual inframarginal rent (Figure 53) from £0.89 billion to £0.82 billion. It results in a small increase in average annual overall costs of the auction from £1.2 billion to £1.44 billion (Figure 54).

Figure 53: Inframarginal rent under an auction with multipliers for low carbon flexibility

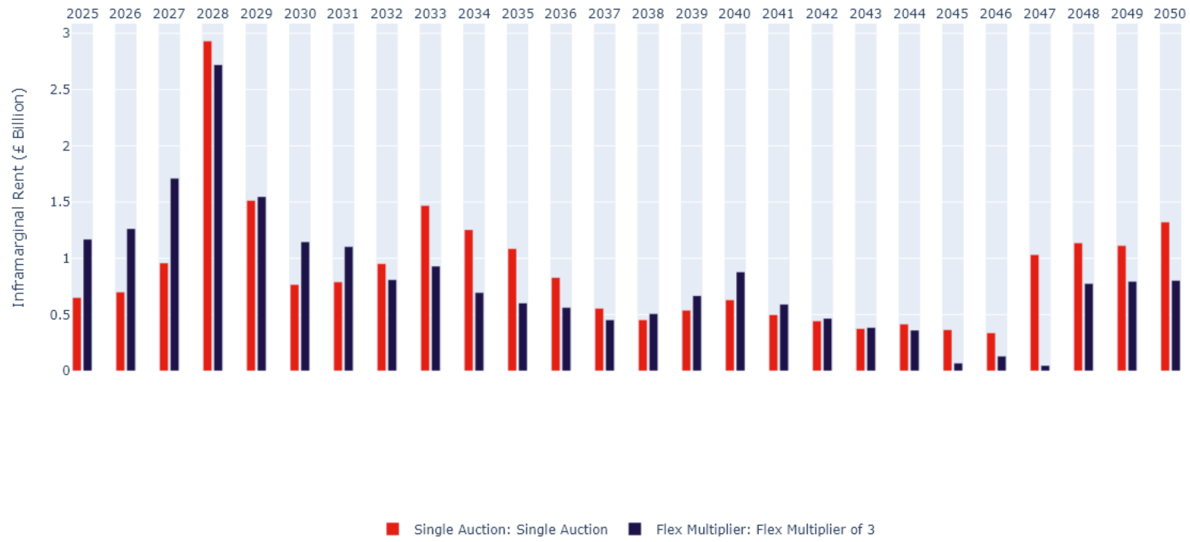
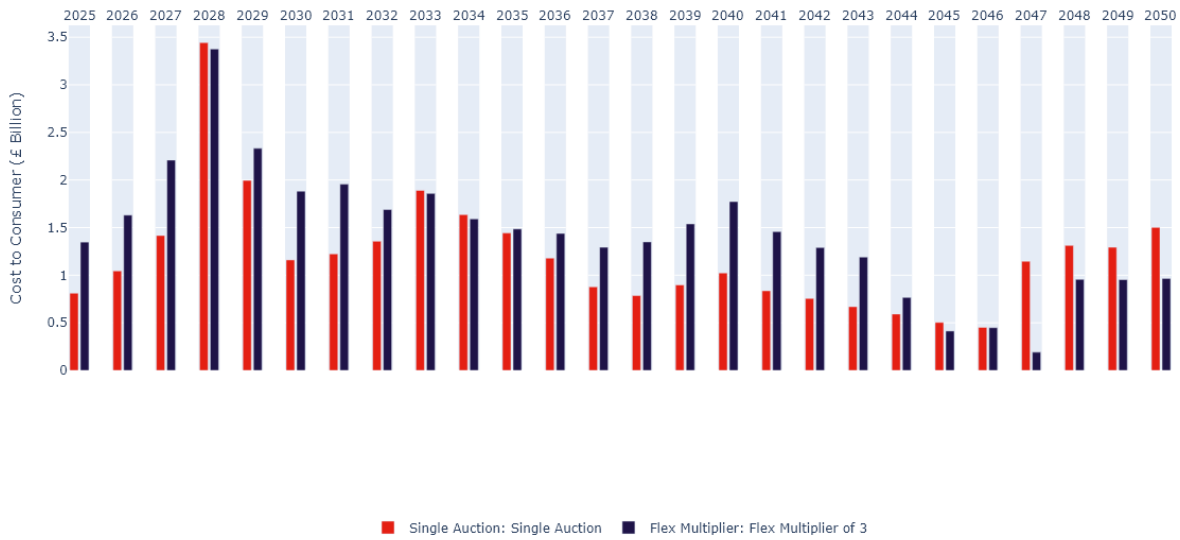
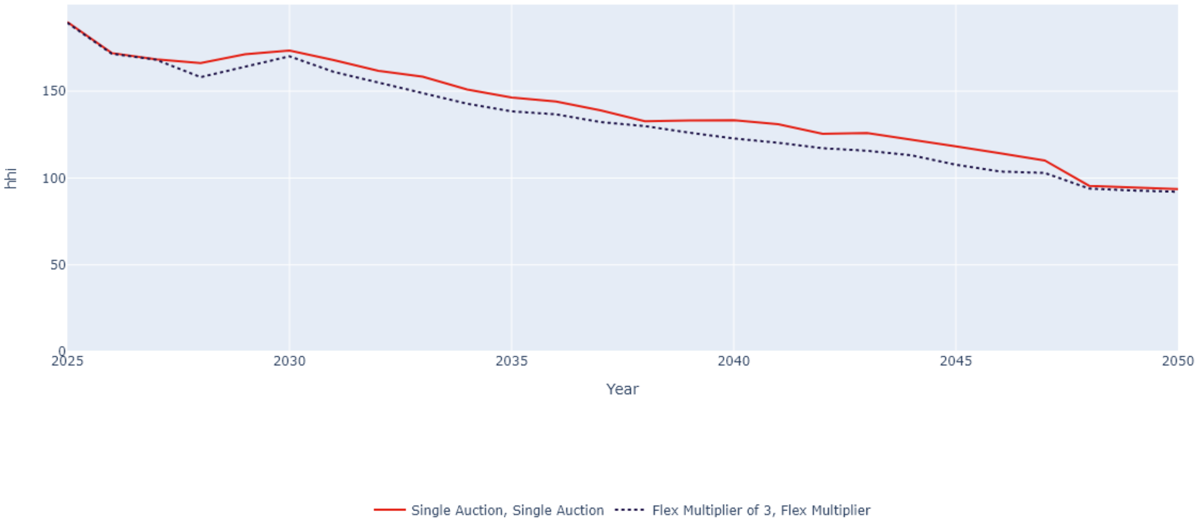


Figure 54: Capacity market cost under an auction with multipliers for low carbon flexibility



Unlike a split auction, the use of multipliers does not separate auction liquidity and so does not have a significant impact on the potential for strategic bidding (Figure 55).

Figure 55: HHI under an auction with multipliers for low carbon flexibility



5. ***Additional objective: Avoiding creation of unnecessary risk and uncertainty***
    a. *Minimising unintended consequences from auction design*
    b. *Adaptability of auction design to market and technological evolution*

For a split auction and auction with minima, we identified a challenge in setting an appropriate target capacity for low carbon flexibility, particularly given the need to do this several years in advance of delivery and for a range of capacity types. The use of multipliers reduces this challenge as the auctioneer avoids setting of a specific target capacity, instead allowing the market to determine the appropriate mix of capacity.

On the other hand, multipliers provide a much less direct mechanism for setting a desired volume of low carbon flexible capacity. As discussed elsewhere, the auctioneer faces ongoing volume uncertainty as to how much capacity will clear in the auction. The auctioneer also faces the challenge of defining multipliers. While they may be guided by the ‘cost based’ or ‘value based’ principles set out elsewhere, this is likely to be challenging to apply in practice with imperfect information.

6.6 Applicability of auction design options

The objective of incorporating signals for flexibility into the CM is subtly different to low carbon capacity. In the case of low carbon capacity, the objective is to maximise the proportion of capacity that is low carbon (subject to value for money constraints). In the case of flexibility characteristics, additional provision is subject to diminishing marginal returns, i.e., the first units of flexibility are extremely valuable but once the FSO has sufficient capability to manage the system, additional volumes only have a small amount of value (which reflects the benefits of further optionality for the FSO). The primary objective of the auction design is therefore to meet a given and relatively fixed volume of capacity of flexibility.

If the CM is designed to deliver flexibility, an auction design which delivers greater ‘volume certainty’ is likely to be preferable. This will reflect the fact that procuring too little capacity comes at a cost to consumers (from lower security of supply) as does procuring too much (which is inefficient given low marginal benefit).

An auction with multipliers does a bad job at providing volume certainty. While the auctioneer can do their best to estimate how much capacity will come forward with a given multiplier, this is highly uncertain and risks setting multipliers which attract too much or too little capacity.

Both split auctions and auctions with minima do a much better job at providing volume certainty. The auctioneer can set the desired volume of capacity directly, leaving the market to determine the price at which that level of capacity comes forward[44]. The price cap could be set based on alternatives available to the ESO and/or the estimated average cost to consumers if the desired level of flexible capacity is not achieved.

A split auction and an auction with minima are likely to result in relatively similar outcomes. Both auction types will use similar principles to set the target for the flexible capacity, in theory clearing at a similar price. However, the minima has two advantages over a split auction.

The first is practical. There does not appear to be significant benefit from running two separate auctions, whether in sequence or simultaneously. Given that the target volume of flexible capacity is relatively fixed and independent of the auction, there is little benefit from the information provided by running one auction before the other. Running a single auction with a minima can allow for some marginal savings in resource and time.

The second benefit of a minima is that all capacity competes in the same auction subject to the minima. While the use of a minima implies that a higher clearing price is expected for that part of the auction, this may not always be the case. As we observed in the case of response time characteristics, it is possible that this service element could clear at a price which is lower than the main auction if there is a high level of competition and/or existing service provision relative to the target capacity. In the case of a split auction this could introduce perverse incentives to withhold capacity from the split auction, or to intentionally become ineligible, e.g., CCS plant could be designed in such a way as to breach the emissions intensity limits for the low carbon auction if this could deliver a higher clearing price. A minima avoids this outcome by ensuring that capacity that is eligible receives the higher of the clearing price within the minima or the main auction.

[44] Note that some risk of insufficient capacity coming forward such that the target capacity does not clear is unavoidable under any auction design.

7. Recommendations for next steps

7.1 Next phases of work

In this report, we have developed an assessment of three high-level auction design options. We have considered how they may be introduced into a future CM which is intended to align more effectively with decarbonisation and potentially to send signals to providers of flexibility.

This report will form one input into DESNZ's thinking about a future CM and further work will be needed to develop the detail of any future CM design. In this section, we provide an outline of key next steps that we recommend DESNZ takes to support its further assessment.

7.1.1 Decide on the role of the CM

Before developing the design of a future CM, DESNZ must determine the role that it envisages the CM playing within the wider electricity market, including the market design that will be developed as a result of REMA. Only after identifying clear objectives for the CM and following careful consideration of interactions with other mechanisms can the design of the CM be developed to achieve such objectives.

First and foremost, DESNZ must decide whether the CM is a necessary and appropriate tool for sending investment signals to low carbon forms of capacity and to providers of various forms of flexibility. This decision should be taken with consideration of alternative existing or future features of the market that may send similar signals such as C&F and/or DPA mechanisms and the operational signals sent by balancing services markets. The coverage of these mechanisms is also relevant. For example, if a revenue certainty mechanism only covers certain technologies or projects, the CM will remain an important investment signal for those that do not receive C&F or DPA agreements.

In addition, DESNZ should also keep in mind ongoing reform to the CM which may result from its parallel consultation on shorter term CM design. For example, the potential impact from introducing tighter emissions limits on new CM contract holders from October 2034 would have to be considered alongside more fundamental reform.

Finally, DESNZ must also consider the design of the CM in the context of the changing nature of system stress events. As set out elsewhere in this report, the objectives of the CM may require fundamental reconsideration as new types of system stress events emerge which are driven by undersupply during periods of low renewables output emerge and require thinking beyond more traditional system stress driven by demand peaks. This will require careful consideration of broader parameters within the CM including the purpose and nature of de-rating factors and non-delivery penalties (and caps), and potentially the type of metrics used in defining the reliability standard. Full consideration of these issues is beyond the scope of this report but will impact directly on the objectives and design choices for a future CM.

While it is possible that similar objectives will lead to a re-design of CMs in other markets worldwide, our international review found little precedent for incorporating low carbon signals or flexibility signals into CMs.

7.1.2 Determine key design parameters

Once the objectives of a future CM have been confirmed, auction design can be tailored to achieve these objectives. This will include the determination of key high-level auction design choices, that are the focus of this report. The first fundamental choice is the form of capacity that the CM is intended to target. We have set out in this report considerations regarding appropriate high-level design choices and questions that would apply if the CM is designed to send investment signals to low carbon capacity and providers of flexibility, both response time and sustained duration response.

Beyond this, several other design choices must be made, including those set out in Table 7 below:

Table 7: Design choices and considerations

Design choice	Key considerations
Auction format – Descending Clock or Sealed Bid?	Is the potential for strategic bidding already present in the CM under a single auction? Is there any evidence that strategic bidding has taken place? Does the intended CM design lead to significant fragmentation of liquidity, therefore making strategic bidding more viable than under a single auction? To what extent is participation in the CM concentrated to a small number of companies? Building on the simple version included in this report, can a sophisticated HHI metric be estimated which also takes into account multiple unit ownership? Our international review showed that both approaches are used internationally, although a sealed bid design appears more common.
Auction format – Payment approach	What is more important to DESNZ – an auction with a cost-driven merit order which better reflects truthful bidding, or the potential to reduce total inframarginal rent? A FPPaC auction is the most common format internationally. Despite a lack of precedent, is there any merit in a SPPaC approach which may be best placed to elicit truthful bidding, at least in theory?

Eligibility of capacity	What level of emissions intensity is considered appropriate to accommodate residual emissions from CCUS plant and hydrogen blending? If response time is incorporated, how should eligibility be determined for capacity that can provide the service in some periods but not others? Should aggregated capacity that cannot meet requirements individually but that can once aggregated be eligible?
Contract length	What role does the CM play in providing revenue certainty to capital intensive new-build capacity? What contract length is needed to support new-build capacity that DESNZ would like to encourage through the CM? How much risk of sub-optimal long-term contracting is DESNZ willing to take on behalf of consumers?
Lead-time ahead of delivery	What role does the CM play in providing revenue certainty to capital intensive new-build capacity with long lead times? How much lead time is needed to support new-build capacity that DESNZ would like to encourage through the CM?
Price caps	Is DESNZ willing to increase the price cap for ‘desirable’ capacity to accommodate greater participation of low carbon/flexible capacity in the CM? What is the CONE for new-build capacity that DESNZ would like to encourage through the CM?

As an outcome from this stage, we would expect DESNZ to develop a small number of detailed auction designs for testing. This would facilitate a thorough impact assessment, supported by in depth modelling of auction outcomes. This modelling may be best placed within a whole system model that can not only model the CM but also assess the impact of auction outcomes on the wholesale market and therefore carbon emissions, system costs, etc.

Modelling can also be used to test impacts given assumptions of potential for strategic bidding and how this varies between different auction designs. ‘War gaming’ could also support this assessment by testing each CM design to breaking point, though in an artificial and simplified environment. To carry out a full impact assessment, assumptions will need to be developed regarding future target capacities and demand curves, supported by projections of project pipelines and emergence of new forms of capacity.

We would also expect detailed design development to be supported by engagement and consultation with market participants. This should inform an understanding of how low carbon and flexibility developers consider the merits of various options and how they would expect to respond to the signals sent by various designs.

As an outcome from this detailed analysis of a small number of auction design options, DESNZ would be able to select the auction design that best meets its stated objectives, undertaking a full impact assessment to support this decision.

7.1.3 Auction specific target capacity and demand curves

After a high-level auction design has been determined, several auction parameters will need to be set and updated for each auction round. As well as target capacity for the overall auction, specific target capacities and demand curves will need to be determined for separate pots/minima (or maxima) in the case of a split auction design or an auction with minima/maxima. In the case of an auction with multipliers, DESNZ would need to determine the appropriate multiplier values.

Target capacities

To develop target capacities for low carbon and/or sustained duration response forms of capacity, DESNZ will need to develop a view on the potential capacity pipeline, looking ahead to delivery timeframes. Some element of judgement is then needed to balance competing objectives. On the one hand, DESNZ will aim to maximise the amount of low carbon/sustained duration response capacity that clears in the auction. On the other hand, this must be constrained by the cost to consumers. A commitment to procure almost all such capacity will send a signal to participants that they can bid close to the price cap while remaining confident in securing a contract. Therefore, DESNZ needs to build sufficient competitive pressures into its determination of specific pot/minima target capacities. Coupling a relatively conservative target capacity with a shallow sloping demand curve can help to maximise the likelihood of 'value for money' contracts with desirable forms of capacity.

In the case of response time characteristics, the approach for setting target capacity would be different. Supported by the FSO, target capacity would be based on a view of the amount of capacity that is needed to provide response and reserve services. Again, a judgement call is needed. However, in this case, the need for judgement is to balance securing sufficient capacity to provide the required services against the provision of long-term contracts to such capacity that may lock in sub-optimal costs of service provision.

Multipliers

We have summarised two alternative 'philosophies' for the determination of multipliers. The first philosophy is 'cost based', aiming to set the multiplier at a level which makes the desirable form of capacity sufficiently competitive with conventional CM contract holders to increase the likelihood of winning a contract. In this case, the multiplier may be based on an estimate of the CONE of new-build capacity that DESNZ is seeking to secure in the auction.

The alternative philosophy

is 'value based', aiming to define multipliers based on the additional value that the desired form of capacity brings relative to conventional CM contract holders. For example, this may be based on the social cost of carbon or on the cost to consumers of a lower level of security of supply resulting from less flexible capacity than is considered optimal.

7.2 Key stakeholders

To support its further assessment and development of CM auction design, DESNZ will need to engage with a range of stakeholders. We summarise the role of some key stakeholders in Table 8.

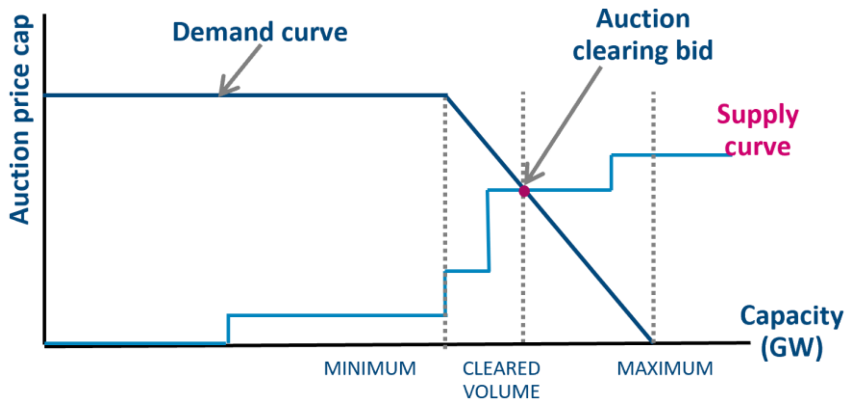
Table 8: Key stakeholders

Stakeholder	Role
Internal	Determine role of a future CM, taking into account interactions across existing market design and ongoing policy development (e.g., REMA). Inform assessment of CM design, drawing on experience of running the existing CM.
ESO/FSO	Provide views on detailed design development, in particular relating to merits of sending signals for flexibility through the CM and interactions with balancing services markets. Inform forward projections of volume requirements for response time and sustained duration response services. Support detailed development of CM rules and implementation (e.g., registration, prequalification, auction implementation, etc)
Low Carbon Contracts Company / Electricity Settlements Company	Inform need for changes to CM contracts, settlement, metering and payment arrangements.
Ofgem	Provide view on implications for energy market regulation and interactions with wider market reforms. Manage changes to CM rules and change process, as well as any implications for Disputes processes.
Market Participants	Inform design of future CM through industry consultations. Targeted engagement with certain stakeholders on specific parameters such as contract length and lead time.

Appendix A: Further detail on modelling approach

The main premise of the auction model is the calculation of the intersection point between the demand and supply curves. When the capacity market clears, participants offering their capacity at a price lower than the auction clearing price receive CM contracts. The auction is modelled as a First price Pay-as-Clear (FPPaC) in which all cleared capacity receives the price of the highest priced successful participant.

Figure 56: Illustration of auction clearing approach



The demand curve's capacity is set according to the desired reserve margin on top of expected peak demand to ensure generation adequacy. Where included in the CM modelling, we define parameters consistently with the existing CM auction design. This includes de-rating factors, contract length, the auction price cap, etc.

The supply stack is constructed from all plants that are available and eligible, placed in ascending order according to their bid price. This includes plants that already hold a long-term capacity agreement, i.e., new build plants that were successful in previous years, and any plants designated as price takers. Both effectively enter the auction with a zero-bid price to reflect their capacity contribution to the target. Plants that are price takers will then receive the clearing price of the auction, while plants already holding an agreement will continue to receive their contracted price for each year of their agreement. Based on its technology type, the capacity of each participant is de-rated to reflect the expected potential of the plant to provide capacity during times of system stress.

For all capacity, the bid price is calculated based on the difference between their expected revenues and costs. A combination of many revenues is estimated, including wholesale market revenues which are estimated from our market modelling, assumptions of balancing services revenues, etc. Ongoing costs include operation and maintenance, marginal costs of production (e.g., fuel), transmission charges, etc.

For new entrants it is assumed that their bid reflects the annuitised calculation of the 'profitability gap', including costs of investment. I.e., if the net present value (NPV) over the economic life of the plant is negative, the bid equates to the payment required for each year of the contract to increase the NPV to 0. New entrants that clear will be placed under contract for the agreement duration (set to 15 years for new build contracts), contributing their de-rated capacity to future auctions but not entering a bid. New entrants that do not clear remain in the 'potential supply pool' for following years as new entrants with an updated bid price to reflect new lifetime costs and revenues.

Existing generators, including those who have reached the end of their new build agreement, bid their profitability gap but ignoring any initial capital expenditure which is sunk – i.e., they only incorporate their ongoing costs into their bid. The maximum bid price of an existing generator is constrained by an additional price cap. Existing generators are only eligible for a one-year agreement.

Appendix B: Summary of international CM designs

ISO NE

The ISO NE Forward Capacity Market (FCM) differs from the other capacity auctions in the US in that it uses a descending clock auction format. The auction is described as a 'hybrid' descending clock auction because the auction takes place in rounds with sealed bids within each round[45]. The ISO find 'no compelling reason to expect higher or lower average Forward Capacity Auction (FCA) prices under a sealed bid auction than the hybrid descending clock auction'.

One system curve specifies a price for each capacity level for the region as a whole[46]. In the 2017 auction for the 2020–2021 capacity commitment period, zonal demand curves were introduced to reflect the additional congestion price to be paid on top of the system capacity price for specific constrained capacity zones. This creates a separate clearing price format. Capacity zones are geographic subregions of the New England Control Area that represent load zones constrained either in export or import, or contiguous (neither export nor import constrained). The systemwide and zonal demand curves are collectively referred to as marginal reliability impact (MRI) demand curves.

NYISO

The NYISO uses an auction for the 'Capability Period' which matches bids and offers and sets the market clearing price.[47] There are two Capability Periods, in the summer and in the winter. A monthly auction is used to top up capacity. Separate demand curves are used to determine:

- Total New York Control Area (NYCA) capacity obligation
- New York City (NYC) Locational component
- Long Island (LI) Locational component
- G-J Locality component

The NYC zone is the most constrained, and this constraint is reflected in the clearing prices (Table 9):

[45] Descending Clock Auction Forum (iso-ne.com)
[46] About the FCM and Its Auctions (iso-ne.com)
[47] Slide 1 (nyiso.com) Page 72

Table 9: NY ISO Demand Curve Components

	Reference point (target price) ($/kW.month)	Maximum clearing price ($/kW.month)
NYCA	9.83	16.33
G-J Locality	16.59	22.51
NYC	21.95	26.93
LI	15.96	25.11

The auction is run using a sealed bid format.

PJM

The PJM capacity market uses a single auction pot but with separate demand curves for locational delivery areas (LDA). The resource clearing price within an LDA is the sum of the marginal value of system capacity and the locational price adder (if relevant). This has the effect of some regions clearing with higher prices, for example Table 10 shows how in the 2023/25 auction the MAAX, BGE and DPL-South LDAs were constrained LDAs and had locational price adders applied.

Table 10: PJM Base Residual Auction Clearing Results in the LDAs (2023/2024)

Auction Results	RTO	MAAC	SWMAAC	PEPCO	BGE	EMAAC	DPL-SOUTH	PSEG	PS-NORTH	ATSI	ATSI-CLEVELAND	PPL	COMED	DAY	DEOK
Offered MW (UCAP)*	156,614.5	67,876.7	8,940.2	3,597.7	2,892.3	30,990.7	1,384.7	5,969.7	3,391.4	10,043.2	1,959.5	10,518.5	29,018.2	1,321.9	2,134.2
Cleared MW (UCAP)**	144,870.6	62,929.4	8,374.9	3,508.7	2,416.0	30,097.5	1,324.0	5,839.5	3,344.6	9,531.4	1,899.9	10,113.7	25,358.3	1,261.6	1,964.5
System Marginal Price	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13	$34.13
Locactional Price Adder***	$0.00	$15.36	$0.00	$0.00	$20.46	$0.00	$20.46	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
RCP for Capacity Performance Resources	$34.13	$49.49	$49.49	$49.49	$69.95	$49.49	$69.95	$49.49	$49.49	$34.13	$34.13	$49.49	$34.13	$34.13	$34.13

* Offered MW values include Annual, Summer-Period, and Winter-Period Capacity Performance sell offers
** Cleared MW values include Annual and matched Seasonal Capacity Performance sell offers within the LDA
*** Locational Price Adder is with respect to the immediate parent LDA

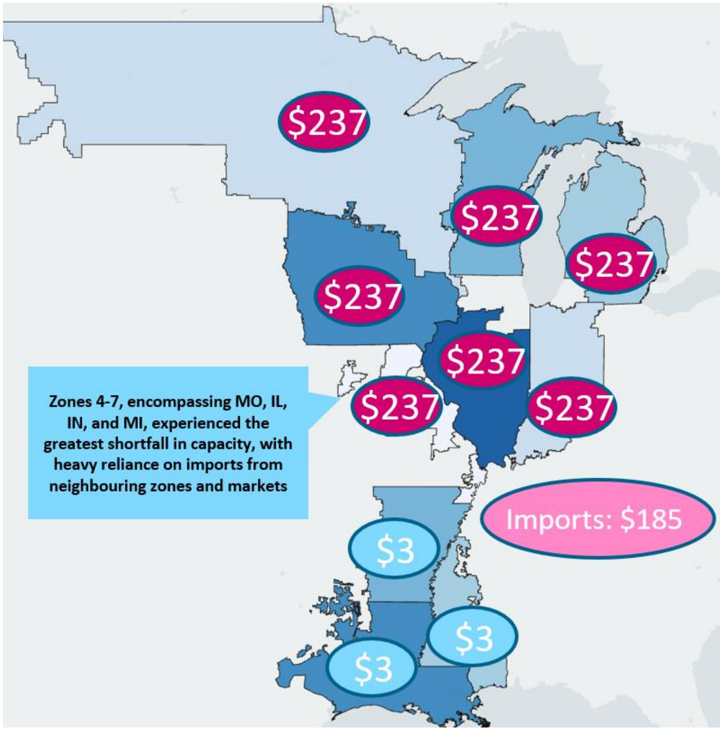
In the 2024/25 auction which closed in December 2022, a large number of planned generators did not offer into the auction in the DPL-South LDA creating issues, in part due to the locational design of the auction. Without these units, the increased reliability requirement in that region artificially inflated the clearing price. In consultation with the Independent Market Monitor, PJM considered that this potential outcome was not just and reasonable for residents in that region and the results have not been published. PJM submitted filings with the Federal Energy Regulatory Commission (FERC) proposing revisions to ensure an outcome consistent with reliability requirements of each LDA[48]. In February 2023 FERC accepted proposed revisions to the LDA reliability requirement calculation. FERC accepted changes that allow PJM to discount planned capacity resources from the reliability requirement calculation if the addition of the resources 'materially increases the reliability requirement' and the resources do not participate in the auction[49]. The move to change auction parameters after the submission of bids was widely criticised by stakeholders.

[48] item-03-2024-2025-bra-update-and-pjm-notice-of-consultation-with-the-members-committee.ashx
[49] FERC Accepts PJM Capacity Market Revisions to Locational Deliverability Area Reliability Requirement, Sparks Strong Dissent from Commissioner Danly - Lexology

MISO

On an annual basis, each load serving entity (LSE) in MISO must procure enough Unforced Capacity (UCAP) to meet their expected peak demand plus a reserve margin specified by MISO. This total value is called the Planning Reserve Margin Requirement (PRMR). LSEs have multiple options to demonstrate resource adequacy in the annual Planning Resource Auction (PRA). Importantly, as much as 90% of MISO's capacity is either self-scheduled or contracted, which means only a fraction of MISO's load clears through the PRA. In the 2022/23 auction, prices across the North and Central MISO zones rocketed, with zones 1-7 all hitting the price cap (CONE). This reflects the shortfall of firm capacity in these regions (Figure 57).[50]

Figure 57: MISO 2022/23 PRA Results



MISO is actively working to make improvements to its capacity market design. In September 2022 FERC accepted MISO's movement to establish a seasonal resource adequacy construct. This represents a move away from the current annual auction approach. This change is expected to give MISO more granular control over the auctions and to adjust capacity derating factors or zonal load requirements on a seasonal basis.

Belgian Capacity Remuneration Mechanism (CRM)

The Belgian capacity market (CRM) is a competitive bidding procedure that is market wide and technology neutral[51]. As with the GB CM, Belgium operates a T-4 and T-1 auction. The default contract length is one year, but plants requiring investment can request longer contract

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[50] Microsoft PowerPoint - 2022_PRA_Results_Posting_Final (misoenergy.org)

[51] Capacity Remuneration Mechanism (elia.be)

duration when they submit their bids. Unlike other capacity markets considered, the Belgian CRM uses sealed bids and an optimisation algorithm to select winning bids. During the bidding period, CRM candidates are invited to submit bids for which they are required to sign a binding contract if selected by the auction clearing system. After the bid submission period, all submitted bids are taken into consideration by the auction algorithm. The algorithm considers a set of predefined grid constraints that limit the selection of combinations of CMUs. It selects the combination of bids that 'maximises economic surplus' for the delivery period of the auction.

To monitor the capacity providers' ability to be ready for delivery, the assets are monitored prior to delivery (in the period between the auction and delivery year). Unavailable or missing capacity receives penalties.

I-SEM CRM

The Irish I-SEM CRM contracts capacity providers using a reliability option – i.e., an option to purchase electricity during a system stress event at a pre-determined strike price in return for a reliability premium. The CRM uses a sealed bid process with the payment price set by the highest-priced bid accepted in the merit order (1st price pay as clear).

In 2016 the SEM Committee held a consultation[52] on how locational issues should be considered in the CRM. The consultation set out four options for different auction designs:

A. Ex-ante identification of 'must-not exit' units. Option A is a non-market approach in which specific units that are known or expected to be required in order to solve locational capacity delivery constraints are contracted under mutually acceptable terms outside of the CRM auction and before it takes place.
B. Additional Capacity. This option applies a simple sealed bid approach to all, and awards Reliability Options to all bids that are in-merit in the all-island unconstrained run. Any constraint infeasibilities that result could be solved by accepting additional bids (i.e., none are removed).
C. Heuristic approach. Option C uses a two-step approach. It is based on CRM Auction Format Option 1 (simple sealed bid) but has an additional "heuristic" step to satisfy the locational and inflexibility constraints.
D. Combinatorial approach. This option only uses one run of the CRM and employs an optimisation solver to find the optimal solution.
E. Ex-post TSO system security analysis to identify must-not exit units.

The committee decided to adopt Auction Format Option B, which is based on CRM Auction Format Option 1 (simple sealed bid) with any capacity secured to meet constraints being additional to that which clears in the unconstrained auction. This additional capacity is paid on a pay-as-bid basis[53]. The reasons given for selecting this option were:

- *'The CRM Delivery Body advised that the IT solution for Option D cannot be guaranteed to be implemented in time to support the first transitional T-1 auction;*

[52] SEM-16-052 CRM 3 Supplemental Consultation Final
[53] SEM-16-081 CRM Locational Issues Decision Paper

- *Option B provides a more conservative approach to managing security of supply in a constrained system than Options C and D, and the SEM Committee is keen to ensure a managed transition between the SEM CPM and the I-SEM CRM;*
- *In a market with transmission related capacity constraints which are likely to be relaxed in the medium term due to new infrastructure, Options C and D, may send exit signals to plant which would be an efficient source of capacity once the capacity constraint has been relaxed.'*

It was also noted that Option B may deliver a lower cost solution than Options C and D while constraints persist. While consumer capacity bills were modelled to be higher under Option B, because more capacity is awarded and at a higher price, under Options C and D the energy price is lower[54]

In the longer run, the SEM Committee intends to implement Auction Format Option D, which entails a full combinatorial auction[55].

The CRM encountered some issues in early rounds with capacity that cleared the auction not being commissioned. There have been concerns raised that the T-4 timeline does not allow enough time for planning and consenting of new plants.

[54] SEM-16-081 CRM Locational Issues Decision Paper Paragraph 3.4.5
[55] SEM-16-081 CRM Locational Issues Decision Paper

Appendix C Summary of modelling sensitivities

DESNZ asked us to consider three alternative cases regarding outcomes for the CM:

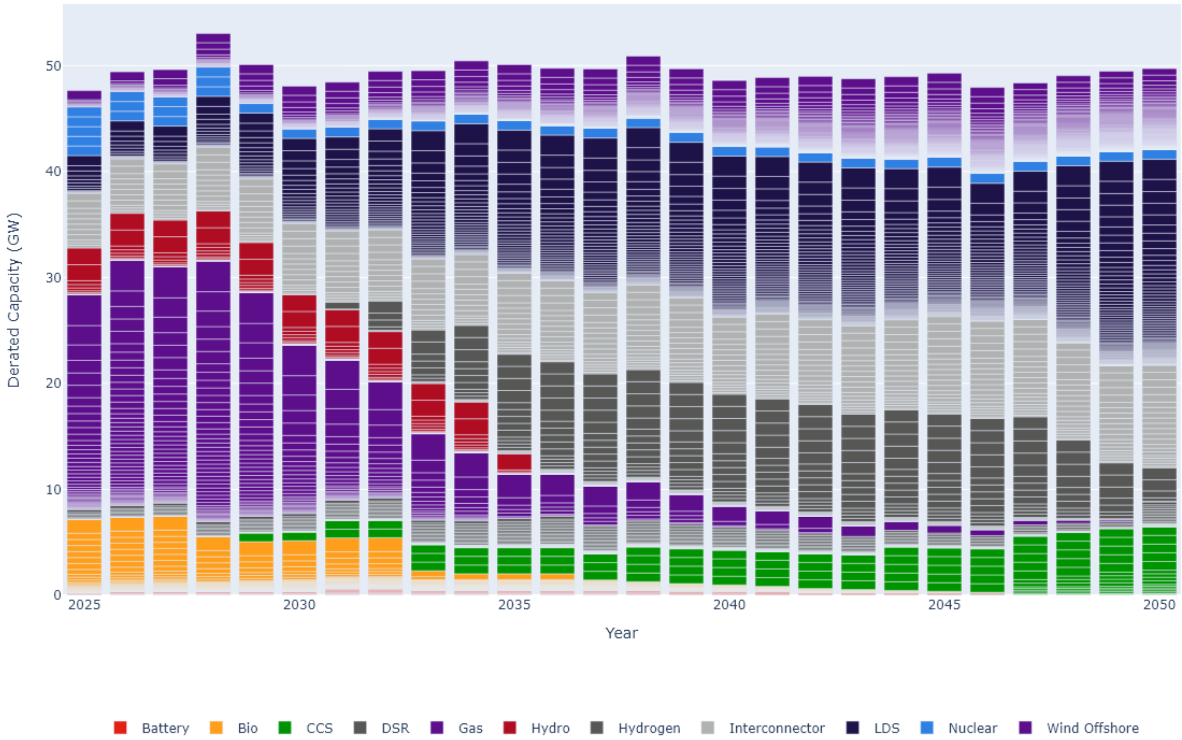
- Hydrogen to power, CCUS and LDS is supported by bespoke investment support schemes.
- A more stringent emissions intensity limit is introduced in the CM;
- The total capacity requirement is higher than assumed, reflecting a world where capacity is tight; and
- A split low carbon auction in which only new-build capacity is eligible for the split auction.

Assuming bespoke investment support schemes are in place

To explore this sensitivity, we re-ran our modelling of the counterfactual auction, allowing H2, CCUS and long duration storage technologies to take part in the CM but assuming that due to their bespoke investment support schemes, they would be willing to take any clearing price, effectively treating them as price takers.

Once we include all hydrogen, CCS and LDS capacity as price takers in the modelling, for much of the period, the majority of cleared capacity is either under contract or acting as a price taker (Figure 58). In some years, there is a remainder of capacity that is prepared to enter the CM at £0/kW due to revenue recouped from other markets, including inframarginal rent in some periods in the wholesale market when hydrogen is setting the wholesale market price.

Figure 58: Cleared supply stack under the sensitivity



By 2034, this drives the clearing price down to £0/kW in our modelling. The clearing price remains at this level for the remainder of the period (Figure 59).

Figure 59: Clearing price under sensitivity

This raises an important question about the role of the CM in a world in which much of the capacity is supported through other means. While the approach used to derive a potential supply pool may represent an ambitious scenario for deployment of mass low carbon capacity, it is likely that, once new forms of low carbon capacity start to enter the market at scale, a significant minority of capacity in the CM becomes relevant for price setting. This could lead to very low clearing prices and/or reduce competitive pressures on capacity that does set the price, introducing strategic bidding risk and potentially leading to high inframarginal rents for a large proportion of capacity.

Impacts of an emissions limit on gas

DESNZ is currently consulting on the introduction of more restrictive limits on emissions intensity to apply from October 2034. For this project, DESNZ requested that we model the CM based on existing market design, without introducing any changes which are at consultation stage. We therefore do not incorporate the proposed changes to emissions limits within our CM modelling.

If introduced the more stringent emissions intensity limit would continue to allow unabated gas capacity to participate in the CM but would restrict them to a limited number of running hours per year (c. 750 hours), designed to allow for operation as peaking plant.

Relative to our modelling, this would mean that unabated gas plant could recover less revenue from the wholesale market and would need to recover more revenue from the CM, therefore raising their bids in the auction. This may therefore have the effect of reducing the extent of unabated gas plant that clears in the auction and increasing the relative competitiveness of low carbon forms of capacity. We would also expect the clearing price to increase as a result.

This outcome would be observed under the ‘status quo’ single auction, potentially eroding some of the benefit associated with the auction design options relating to delivery of additional low carbon capacity.

A more limited potential capacity pool

DESNZ wished to understand how the merits of auction design would be affected in the case that the potential capacity supply pool is more limited – i.e., under ‘tight conditions’ within which there is less capacity that is potentially able to participate in the auction, regardless of design.

We did not carry out further modelling to explore this sensitivity. However, we assess impacts qualitatively.

The interaction between our market model and CM modelling means that the supply stack is designed to meet peak demand with a suitable margin, so we do not model the potential risk to security of supply from tight margins.

Instead, the result of tighter capacity requirements would be a more limited potential supply stack from which capacity could enter into the auction. Under such conditions, the design of the auction will have less impact on the type of capacity that clears in the auction relative to the counterfactual. Hence, the potential benefits of alternative auction designs in supporting low carbon and flexibility will be less pronounced.

Tighter conditions could also increase some of the risks associated with auction design. For example, it increases challenges associated with setting an appropriate target capacity, particularly in a split auction design.

Limiting the split low carbon auction to new-build only

DESNZ wanted to consider how results would be impacted if the split low carbon auction was limited to new-build capacity only.

We did not carry out further modelling to explore this sensitivity. However, we assess impacts qualitatively.

The main appeal of limiting the split low carbon auction to only new-build capacity is to reduce the total amount of inframarginal rent. Where both existing and new-build capacity is eligible, existing capacity will often receive substantial amounts of inframarginal rent due to the clearing price set by new-build low carbon capacity. This could deliver a similar level of low carbon capacity at a lower cost to consumers.

However, there are several potential unintended consequences to consider:

1. **Increasing auction concentration**: Limiting the split auction to new-build low carbon capacity would significantly reduce the potential supply pool within the low carbon split auction and with lumpy investment in some types of low carbon capacity, this could limit competition in the auction. In some years within our modelling of a low carbon split auction, we observed no new-build low carbon capacity clearing. In others we observed

one or a small number of units clearing. This could complicate the auctioneer’s task of setting an appropriate and sufficiently competitive target capacity. It could also increase the risk of strategic bidding and inefficient auction outcomes.

2. **Increasing inframarginal rent for carbon capacity**: There is no guarantee that limiting the low carbon auction to new build would lower overall costs of the auction. It is likely to reduce inframarginal rent of existing low carbon capacity. However, existing low carbon capacity may set the clearing price of the ‘remainder’ auction, increasing inframarginal rent for carbon capacity relative to the split auction modelled in Section 5.3.

3. **Reducing the volume of existing low carbon capacity clearing in the auction**: Where the low carbon auction is limited to new build capacity, existing low carbon capacity will need to compete with carbon capacity in the ‘remainder’ auction. Where existing low carbon capacity tends towards to be further down the merit order, this could inadvertently reduce the overall proportion of low carbon capacity which clears, possibly leading to earlier exit of low carbon capacity from the market.

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