
AFRY
Making Future

Reactive power market design – Market design

Report to National Grid ESO

MARCH 2022

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Agenda

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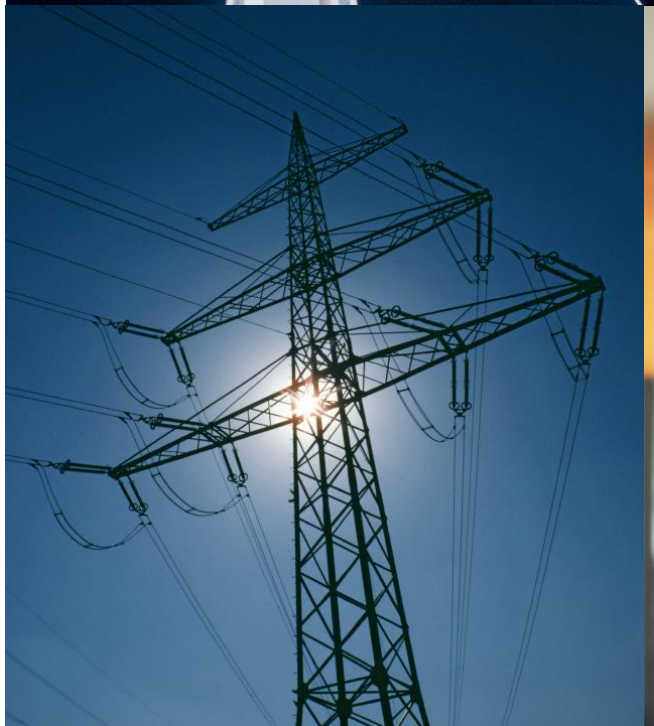

Preface

- This project was initiated by National Grid ESO as a part of their strategy towards a zero-carbon system that will take GB to net zero by 2035
- It is one of NGESO's innovation projects funded by the Network Innovation Allowance (NIA)
- The project presents recommendations for a high-level design for a reactive power market, as well as providing new analysis tools for the assessment of reactive power needs and solutions
- This report details the core market design process, including options considered and recommendations
- The project does not present a final decision: further assessment; regulatory and detailed design considerations; and consultation with industry will be needed to crystalise the way forward
- AFRY has undertaken this project in conjunction with Energynautics, DotEcon, Ignis Markets and a dedicated ESO team with input from ESO subject matter experts
- The project started in September 2021 and finished in March 2022

SUMMARY

Key messages

There is a critical **trade-off** in the market arrangements between **complexity and efficiency;** ultimately arrangements that are too complex may present barriers to deployment for ESO and barriers to entry for providers.

Single timeframe market approaches fall short, as they do **not adequately facilitate crucial decisions** that must be taken by providers (investment, operational, closure)

Long-term timeframes mean that ESO is able to ensure **system security** by giving participants a higher degree of certainty in making investment decisions – the assessment of TO counterfactual solutions at this stage ensures **value for consumers.** We are also proposing a T-1 to finesse procurement volumes

Including a **short-term** market ensures there is an appropriate route to market for a broad range of potential participants, facilitating providers that may be exposed to volatile opportunity costs, high variable costs, and/or low availability visibility – ultimately increasing competition & resources available and promoting **value for consumers** and contributing to **system security**

Systematic and recurring long-term market obliges ESO to forecast requirements regularly. This acts to ensure a **higher degree of transparency** for market providers who are able to plan and build project pipelines accordingly

Procurement strategy of **opportunistic buying** represents value for consumers while ensuring system security. The shortfall is always bought if it cannot be met in subsequent timeframes **ensuring security**. If provider bids represent perceived value for money, ESO can procure additional capability from eligible providers in advance in the interest of **value for consumers**

'Package' bids within a **combinatorial auction** allow providers to **offer synergies** where they exist. The advantages of a **pay-as-clear** market are significantly **diluted** in the context of a reactive power market – **pay-as-clear** market designs are **difficult** to apply practically and effectively on a nodal basis, as **multiple clearing prices** (for products and nodes) must be determined. Each point may only have a small number of effective bidders and market power is better controlled with **pay-as-bid pricing**

SUMMARY

Key recommendations

The preferred market design should build on **existing arrangements** and **learnings** from the Pathfinder process to ensure complexity can be managed

We have recommended a market design that is run over **two timeframes**

- **Long-term** annual markets operating in **investment timeframes** which offer multi-year contracts to underpin investment in assets, complemented by annual **year-ahead** contract rounds to finesse procurement
- **Short-term** market which operates at the **day-ahead** stage to enable participation of assets which are unable to make long-term commitments
- This is complemented by the continued use of the Balancing Mechanism as a back-stop

In both market timeframes, we are proposing an opportunistic procurement strategy

- ESO must buy at least the **shortfall** against the requirement where it exists
- ESO reserves the right to **purchase more** than the minimum quantities required, **if economic** (if prices offered are lower than expected alternative costs at subsequent timeframes)

We recommend **different remuneration** mechanisms in **different timeframes**:

- In the long-term market, we are proposing an **availability payment only**, reflecting the cost structure of appropriate asset types
- In the short-term market, we are proposing a combination of an **availability payment** and a **utilisation payment** at prevailing ORPS rates (for ease of metering settlement, with a potential to move to user defined utilisation in the future)

We are recommending a **pay-as-bid** approach in both timeframes due to the nodal nature of the market, and multiple products being procured simultaneously – pay-as-clear was deemed an impractical approach due to the need to construct multiple clearing prices to accurately reflect value of locational services and pay-as-bid may help to control any local market power

All commercial providers are ultimately eligible to participate (though this is subject to different criteria in long/short term timeframes), though will only be selected if they bring a **benefit to the system** in terms of **incremental capability** ('additionality') and/or **cost efficiency**

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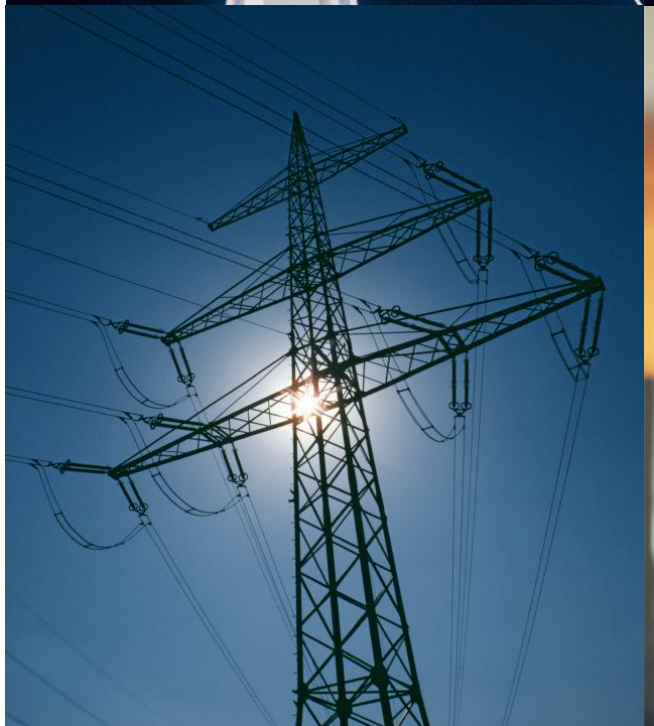
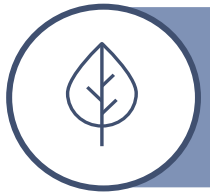


This document presents a recommendation for a GB reactive power market design including the process and assessment leading to the proposals

CONTEXT



Net-zero

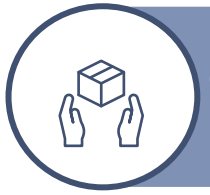
NGESO's role in facilitating the energy transition will be crucial. System security is one of the primary challenges in the transition towards a decarbonised power system – ensuring continuity of supply in an evolving energy mix.

System security

The local nature of reactive power issues and the changing locations in which assets are choosing to connect to the system, as well as the technological shift away from large thermal power stations, presents a challenge for NGESO in keeping the system secure and reliable.

Cost

Spend on voltage services has increased and is likely to grow as system need for reactive power increases, hence there is need to procure reactive power services in a more economic and competitive way.



Opportun-ities

New technical solutions could offer a benefit to NGESO, consumers and market participants. To realise these projects and facilitate the right assets in the right places, a framework to competitively reward effective providers is needed.

KEY MARKET DESIGN ACTIVITIES

- Initially, we identified critical design choices that can materially impact on both providers and ESO in the market arrangements and grouped these choices (and associated options) into 'building blocks'.
- These were developed into internally consistent (strawman) options that could be compared and assessed, resulting in an initial listing of four options.
- Each option is constructed in terms of the underlying design philosophy, sufficiently broad to assess the merits and drawbacks of various design choices when scrutinised.
- An appraisal was undertaken to understand to identify design choices that best facilitated our objectives. We also ruled out design choices that performed poorly against objectives or presented an unacceptable level of risk for unintended consequences to manifest.
- We made an evidence-based recommendation of a preferred option against the objectives. The selection and refinement of the options have been determined by the AFRY and ESO team.
- Consideration of the options was informed by industry in public webinars and surveys, and by the core AFRY & ESO team, leading expert workshops, case studies and modelling work.
- The project team has contributed its knowledge and experience in considering the options and identified areas that require further analysis and development.

The Commercial Market Design is one of five workstreams within the 'Reactive power market design innovation project' – The recommended design has heavily relied on input from all workstreams

1 Scene setting

Outlining current arrangements, shortcomings and future challenges

Defining market objectives

2 Market analysis

Heat-map of current and potential future providers

Technology **case studies**

DER blockers and routes to market

3a Defining demand

Modelling 2025 requirements based on FES scenarios

3b Requirement methodology

Develop a repeatable **methodology** for creating market signals of demand, considering; volumes; effectiveness; and location

4 Market design

Design strawmen, qualitatively assess and provide recommendation on end-to-end market design for reactive power

5 Economic modelling

Give a view on cost, volumes, changes in carbon emissions and shape of requirements.

Test market design elements of the strawmen

Recommendation and way forward

Process to develop and select high level market design

1a. Scene setting

1

Establish 'givens' and make **assumptions** on all relevant topics

Assumption	Implication
xxx	yyy
xxx	yyy
xxx	yyy

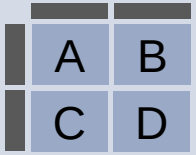
1a. Scenario definition

2

Identify **key uncertainties** in physical world and define **scenarios (FES)**

Uncertainties

- Need for new technologies
- Need for locational prices



1b. Objectives and criteria

3

Establish **design principles** (objectives and priorities)

Primary principles	Cost	Sustainability	...
Sub principles	Stability	Investability	...
Constraints	100% RES	Carbon negative	...

2a. Building blocks and options

4

Define **building blocks**, and the **options** for each building block. This defines the scope of the market design.

Building blocks	Options		
Approach to cap. adequacy	Scarcity pricing	Capacity mechanism	...
Approach to regulation	Prescriptive	Open	...
...	...	...	...

2b. Strawmen design options

5

Create '**strawmen**' (high-level designs) that explore alternative **philosophies**; and have the **scenarios** in mind

Building blocks	Strawman 1	Strawman 2	Strawman ...
Approach to cap. adequacy	Scarcity pricing	Capacity mechanism	...
Approach to regulation	Prescriptive	Open	...
...	...	...	...

2c. design options assessment

6

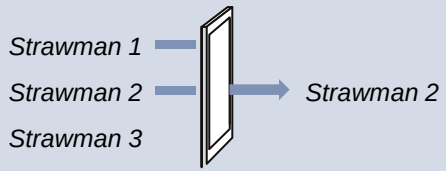
Assess each **strawman** against **design principles** in the context of all **scenarios**

	Cost	Sustainability	...
Strawman 1	○	◔	●
Strawman 2	◔	●	●
Strawman 3	○	○	◔

3b. Final end to end solution

7

Select the **end-state strawman** that performs best across the **scenarios**



3c. Final recommendation

8

Develop a **roadmap** to transition to **end-state strawman** from today

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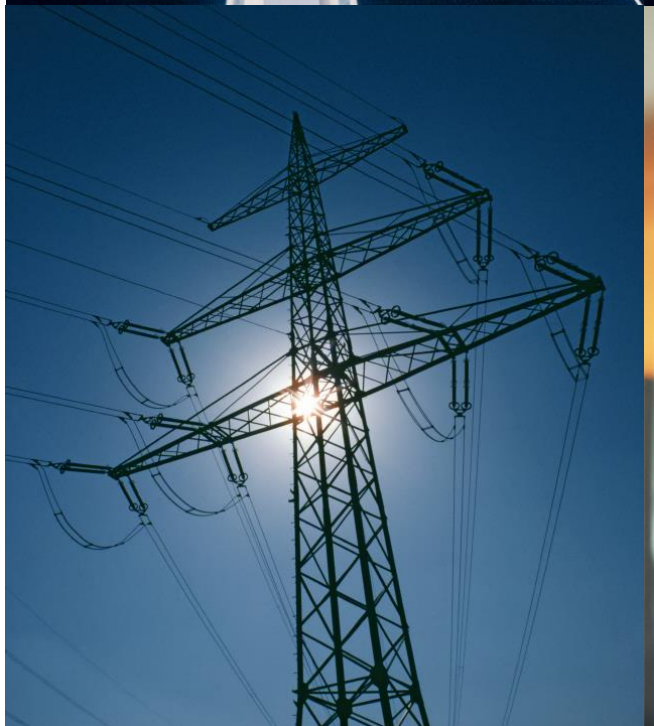

Market objectives create a framework for evaluation of market design performance based on desired outcomes

Primary objectives

Ensuring **cost efficient provision** of reactive power to **maintain system voltage security** in the context of a **zero-carbon system**

Secondary objectives

Practical
- Ease of implementation
- Ease of ongoing operation

Investable
- Respecting existing investments
- Supporting efficient future investments

Transparent
- Visibility of service values
- Clear procurement decisions

Enduring (stable)
- Suitable/adaptable to future challenges
- Well understood governance for changes

Consumer value
- Promoting competition between providers
- Minimising cost burden on customer

Freedom of choice
- Technology agnostic
- Avoiding lock-ins

Constraints

No capability only solutions

Central buyer (NGESO) vs. decentralised obligations (supplier)

No modification of existing ORPS/obligations

Why do we need objectives?

- The market design process should be focused on desirable outcomes – what do we want the market to actually do?
- Objectives allow us to make our intentions for the market mechanism clear.

How do we choose objectives?

- Primary objectives outline the overall desired end-state ignoring difficult questions on the physical realities.
- Secondary objectives allow us to set the context, the key questions are:
  - What do we believe the market will need to achieve primary objectives?
  - Is there anything that does not define ultimate success, but is important enough to be considered in the process?

What are the implications for preferred solutions?

- Objectives give us a framework to evaluate performance of proposed options, adding structure to an inherently nebulous process.
  - *Evaluating key choices against an established framework allows us to identify and capture areas of uncertainty where they exist.*
- We can move to identify our desired solution, generally a solution that best meets the objectives – however the relative weighting of importance is subjective.

MARKET OBJECTIVES

The primary objectives of the market design set a framework to determine success

Primary objective	Explanation & rationale
Cost efficient provision	– Cost efficiency refers to the overall economic efficiency of the system[1] in this context, reducing the spend required to meet reactive power constraints on the network relative to the baseline. – In recent years, costs for managing voltages on the network have increased substantially and this is one of the key drivers for exploring reform options today. – Any future arrangements need to establish the framework to deliver a benefit with respect to current voltage management practices.
Maintain voltage security	– NGESO is intending to procure services to comply with licence obligations to ensure a safe and reliable supply of electricity throughout the network. – This is the ultimate purpose of the market and will be delivered through procuring a suite of reactive power products, which will give NGESO the tools needed to manage the system voltage. – Whilst this is the ultimate goal, ignoring other key objectives does not constitute 'success', as solutions delivered may not provide enduring security in an evolving energy landscape.
Zero carbon compatible	– NGESO has committed to be able to run the system with net-zero carbon emissions in any given period should the market deliver that solution (by 2025). – With the evolving system, it would be a fallacy to design market arrangements which cannot accommodate technologies capable of delivering against this commitment. – In the context of reactive power, this means ensuring arrangements are able to cater for scalable zero-carbon solutions for providing reactive power services.

Notes: [1]It does not explicitly address which parties reap the benefits of reduced cost (i.e. the impact on producer and consumer surplus), however in the context of electricity supply it is often implied that reduced costs lead to greater consumer benefits, we have added a secondary objective to make this point explicit.

Secondary objectives help to enable primary objectives and address other key themes that do not preclude market success

Secondary objective	Explanation & rationale
Consumer value	– Whilst economic efficiency should be the ultimate goal of a market mechanism the distribution of value that a market is able to realise through increased efficiency is an important consideration. – The solution should promote competition between all providers (and their preferred solutions) to ensure economic potential is realised and ultimately deliver value for money for consumers.
Transparent	– Transparency is needed for a market to function effectively and, the absence of sufficient information on which to make commercial decisions could lead to inefficient outcomes. – In the context of a reactive power market with a single buyer, there is a need to communicate needs in a way that allows market participants to understand their costs of service provision to the greatest degree possible. – Without sufficient transparency, additional risk is placed on the sellers, which will feed through into their bidding behaviour.
Investable	– The market should give investors sufficient clarity for them to recognise and manage their risks. – Risks should be borne by the party most suitably equipped to bear them and undue unknowns should not be placed on providers unless there is sufficient reward to justify these risks. – Incentives should not just target investment as a whole, but focus on rewarding the right investments to improve overall system efficiency.

Secondary objectives help to enable primary objectives and address other key themes that do not preclude market success

Secondary objective	Explanation & rationale
Practical	– Any market arrangements must be practical from both buyer and seller perspectives, sharing the burden of responsibility for dealing with unknowns (allocation of risk and corresponding rewards). – The solution itself must be deliverable from the ESO perspective, as unnecessary complexity can lead to additional administrative cost burdens, which can offset some benefits of implementation.
Enduring (stable)	– The market design should be sufficiently stable for market participants to avoid unnecessary administrative burden and associated costs. – Give providers confidence in the new market arrangements that participation is meaningful and sufficiently valuable to incentivise ongoing participation (ultimately helping to promote liquidity).
Freedom of choice	– Freedom of choice for providers in terms of the technologies they wish to employ to participate in the market. – Freedom of choice for providers to make commercial decisions and trade-off between different value streams in response to price signals. – Freedom for the ESO to change arrangements should the market fail to deliver in line with other objectives and needs (e.g. tightening rules to prevent anti-competitive behaviour).

Constraints on the solution allow us to manage certain degrees of freedom within the design process

Key constraints	Explanation & rationale
Existing arrangements	– The ESO needs to retain a 'backstop' level of security to the system. Existing arrangements, whilst not necessarily economically optimal, have demonstrated that this security can be achieved. – Any future changes to remove existing arrangements could only be considered once the replacement solution has demonstrated it is able to deliver.
Central buyer	– Alternative models to a central buyer exist, such as decentralised obligations on suppliers (e.g. the Renewables Obligation). – The ESO is procuring services to meet its own obligations and wishes to retain a level of control to meet their statutory obligations – a change to these obligations would be required for other models to make sense.
No capability only options	– Capability payments remunerate participants simply for the existence of capacity to provide services/products. – Without a corresponding obligation to be available and/or utilised, it is not possible for the ESO to provide value for consumers or guarantee they can meet security requirements. – In an immature market (with no price history), it is difficult for long-term providers to price short-term revenue into their offers.

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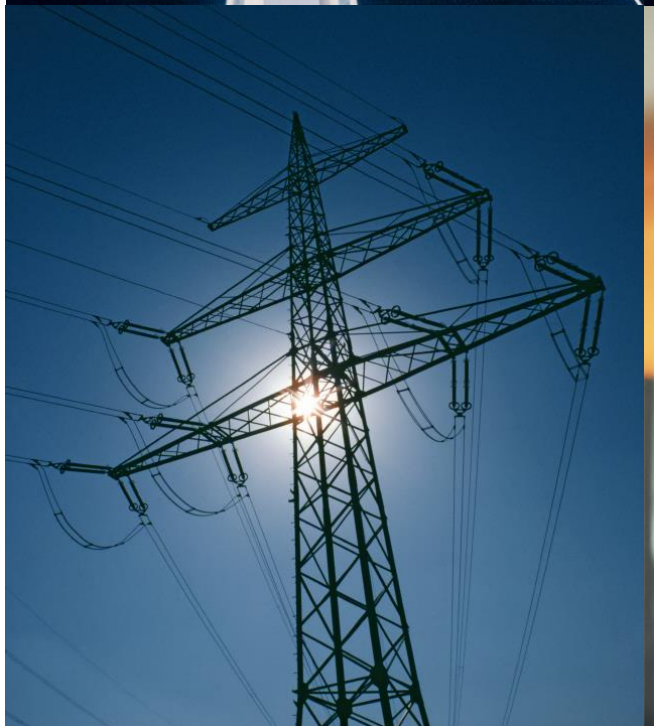

BUILDING BLOCKS AND OPTIONS

We have defined 10 building blocks, each with different options. These were later collated into four strawmen design options

Timeframe

Short term vs. long term market

Contract types

Contract alternatives with different delivery obligations

Eligibility

Classifies participants eligible for payment

Pricing mechanism

How services are remunerated

Product Linking

Cover potential linking between products

Frequency of procurement

Defines how frequent the market is run

Locational requirement

Method for defining locational requirements

Provider effectiveness

Defines how effectiveness factors are assessed

Availability requirement

Minimum availability requirement during the contract period

Regulatory back-stop

Principles for how to apply price caps

Timeframe

Contract types

Eligibility

Pricing mechanism

Product Linking

Background & Motivation

A market should support system security and efficiency in both the short and the long run. The timeframe is essential because it determines the market's ability to drive long term investments, ensuring adequate capability is in place to meet forecasted stability requirements; while at the same time supporting short-term planning and efficient dispatch. ESO is the sole buyer for reactive power, meaning that all timeframes need to be considered.

Supporting efficient future investments (long-term)

New reactive power providers will need to emerge to ensure voltage stability in the future. A long-term market, at least 1+ year ahead, should facilitate economically efficient alternatives to building new TO owned grid assets.

Rout to market for existing capability (short-term)

A market should provide routes to access for existing MVAr capability not already utilised within the existing arrangements that NGESO access. A short-term market, typically day-ahead, will allow already commissioned units to bid in their (additional) capability. It will also allow for more trading options in combination with LT contracts.

Options

A Long-Term (LT) market only (firm or non-firm)

- Focuses on long-term procurement, with both firm and non-firm contracts.
- Close to real time activity is needed to accept notifications of availability from non-firm providers and to organise how the procured capability is dispatched, using a remuneration mechanism which is determined within the LT contracts.

B LT market + ST market

- Long-term procurement is present but is more limited as it is not intended to meet all the reactive power needs. The short-term market complements the long-term market as a top-up solution and as a backup to meet the residual needs.

C Short Term (ST) market only

- All reactive power is procured in ST market (or existing mechanisms, e.g. Balancing Mechanism), and any long term investments are driven by the price and volume expectations in the ST market.

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Background & Motivation

The contract determines what is being procured, i.e. the period, duration, availability requirements within this period and variables such as 'firm' or 'non-firm' availability. Firm contracts have high availability commitments. Non-firm contracts accommodate providers which may be available close to delivery but which are unable to offer firm LT commitments.

Contract duration

Contract duration impacts investment decisions for potential providers, and cost correlates with amortisation life of new build assets. Longer contracts allow for lower cost per year as the capital cost is spread further.

Shorter contracts gives better forecast accuracy as ESO has a better view of its requirements, the alternative providers and their costs.

Shapes

Reactive power needs vary significantly during the season and during the day. A market should seek to minimise over-procurement. Offering shaped contracts could enable the SO to procure MVAr capability more accurately, if the profile of needs can be predicted. Shaped contracts can also be designed to fit different types of technologies, enabling a broader access to the market.

Options

A Complex long-term contract offering

- Multiple new LT contracts targeted at meeting different needs and technology segments
- Non-firm and conditional contracts aimed to factor in the variable providers which can be available under certain conditions (those providers that are not able to offer firm commitments on standard contract terms)
- Fixed shaped contracts and NGESO 'call-options' targeted at limiting over-procurement

B Simple long-term contract offering

- Standard long-term baseload contracts, similar to the Pathfinder contracts
- Baseload contracts are well established and minimises the complexity of the market, making it practical to implement and reduces issues around transparency

C Short-term contracts

- Short term contracts for a daily market time window, with a granularity allowing to procure daily shape, typically on a granularity of 30min or 4hour (EFA block)
- Duration of contracts must meet SO operational requirements, while at the same time enable providers to make economic decisions in correlation with their production plans

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We have defined six alternative contract types, targeted at different requirements and provider segments

			Description	Objective	Targeted segment
Long-term	Base	**Firm baseload**	– Provider commits to firm availability with a high expectation of reliability throughout the contract period – Product duration e.g. 15 year baseload	– Meet baseload need that *can* be forecast	– Firm capacity with lowest cost of providing availability
Long-term	Shaped	**Firm fixed shape products**	– Provider commits to firm availability with a high expectation of reliability throughout the contract period – Product duration e.g. seasonal or daily-peak	– Meet shaped (peak) needs that **can** be forecast	– Firm capacity with medium (variable) cost of providing availability, available at **predicted** times of need
Long-term	Shaped	**Conditional products**	– Committed under certain predefined conditions – E.g. when wind is blowing	– Meet needs that correlates with types of variable production	– Firm capacity with significant (variable) cost of providing availability, which NGESO would prefer not to use baseload
Long-term	Shaped	**NGESO 'call options'**	– Provider commits to availability on demand by NGESO throughout the product duration, at contracted quantity and price – Provider paid only when ESO calls for availability	– Meet peak needs that **cannot** be forecast	– Firm capacity with high (variable) cost of providing availability, which NGESO would prefer to call only when needed
Long-term	Shaped	**Non-firm provider 'put option'**	– Non-firm contract for availability. Provider has an option to sell its availability [day-ahead] at contracted quantity and price – Provider paid only when announcing availability – *Requires a short-term mechanism that guarantees a payment for the volumes which the provider can (and wishes to) make available through a non-firm contract*	– Incentivise incremental capability increasing overall capacity for which availability **cannot** be forecast	– Variable RES providers able to evaluate incremental investment
Short-term	Base	**Short term (firm)**	– Firm contracts with short procurement lead time [day-ahead] – Product duration at low granularity [e.g. 30min]	– Meet short term needs, accurately, in any direction	– Firm capacity – Route to market for variable RES providers and/or providers with high variable/opportunity costs

Background & Motivation

Eligibility rules in ST and LT arrangements should:

- Support efficient decisions in all timeframes
- Avoid windfall gains at the expense of consumers
- Ensure no perverse incentives (gaming)

Contribution from existing plant schedule

- Considerations to remunerate providers based on plant schedule. Spinning synchronous generation has natural capability to provide reactive power

Technology neutrality

- Ensuring that participation is encouraged from all relevant providers, and that new technologies are not implicitly excluded from this future market.

Capability beyond existing arrangements

- Assets already providing services under existing agreements (e.g. ORPS) should be able to participate if they have capability beyond current obligations.
- Existing ORPS providers might have the ability to offer availability below ORPS price, yielding better value for money for consumers.

Options

A Incremental (investment or capability)

- Incremental Investment // Eligible: Capability which doesn't already exist and requires material investment to be accessible, i.e. additionality criteria (beyond ORPS)
- Incremental Capability // Eligible: Incremental capability, including; ORPS providers outside of MSA ranges; existing providers with no MSA in place; and closing assets
- Excluded: TO assets & LT contract holders; and new/existing ORPS providers within ORPS ranges

B Global selective

- Eligible: In general, all providers. However, NGESO discretion for awarding contracts. ESO buys (expected) shortfall plus the economically desirable – incl. ORPS if it is cheaper than alternatives
- Excluded: TO assets and LT contract holders; and uneconomic ORPS providers more expensive than BM alternatives; ST-market alternatives; or ORPS utilisation price

C Global (Gross)

- Eligible: In general, all providers are eligible. Limited NGESO discretion for awarding contracts. This means it also includes ORPS providers within ORPS ranges; ORPS providers outside of ORPS ranges; non-ORPS/uncontracted providers
- Excluded: TO assets and LT contract holders

Background & Motivation

- The approach on structuring the payment comes down to the risk management practices and deciding where the risk lies in each option (payment structure) and who takes the risks. Trade-off with complex payment structures and simplicity/transparency
- Pricing mechanisms should also consider factors such as investment incentives; alternative costs/revenues; and wear and tear on equipment

Availability and utilisation pricing

- Utilisation is defined as the delivery of reactive power (absorption/injection) to the grid in line with dispatch instructions by the ESO
- Availability is defined as the availability to deliver reactive power at some point in the future
- Utilisation price can be included as part of the availability contract or priced separately, and can be defined by provider; fixed based on an index; or otherwise (incl. zero)
- A market might have multiple payments within different timeframes and contractual arrangements, where prices are set differently
- For non-firm or non-contracted providers, the availability or utilisation pricing must be adequate to get effective dispatch

Options

A Availability price only

- Payment for availability, and no payment for utilisation
- Provider bundles utilisation costs into their availability price

B Availability + utilisation price

- Payment for availability and utilisation separately

C Utilisation only

- Providers are only paid for utilised reactive power (MVArh)

X Other related topics to be defined

- Pay-as-bid vs pay-as-clear
- (Utilisation) payment via the ORPS default payment mechanism; a technology-specific fee; or offered fee as part of availability offer.
- Regulatory back-stop / price-cap

Background & Motivation

- There are multiple products being procured, i.e. **absorption** and **injection, pre-fault** and **post-fault**
- Products are split to meet different system needs
- Linking products allows providers to optimise combinations of different products, enabling them to offer better prices than if offered separately
- Forcing providers to offer products separately would open for market access to technologies without capability to offer availability on all products

Product definitions

- **Pre-fault absorption,** utilised primarily when power system flows are low
- **Pre-fault injection**, utilised primarily when power system flows are high
- **Post-fault absorption,** utilised primarily when parts of the network from where pre-fault absorption providers were dispatching become isolated or if high gain circuits are switched in
- **Post-fault injection,** utilised only when a step change occurs either after a fault/unplanned outage or after operational switching to support voltage levels

Options

A Linking enabled between all products

- Participants are allowed to submit orders with different pre/post-fault absorption and injection quantity
- Different order types could include all-or-nothing or mutually exclusive bids
- Linking is optional

B All products must be procured separately

- The different products are procured separately, each with separate price associated with them
- Linking between products not enabled

Background & Motivation

- Frequency of procurement determines when and how often a market is run
- Should consider practicality, transparency and economic efficiency
- Investment decisions are tightly linked with other market arrangements and aligning with their schedules should be considered

Frequent procurement

- Frequent procurement gives predictability and would enable providers to participate with multiple projects over time, build supply chains, etc. (take advantage of technology learnings)
- Requires automated and standardised processes to allow for efficient provision for all parties and to avoid high operational costs

Infrequent procurement

- Procuring reactive power on an ad-hoc basis does not require recurring and systematic assessments
- May not capture all voltage compliance issues
- Infrequent procurement means there are limited opportunities for participation, and some suitable cost-efficient solutions may miss out (e.g. from not having opportunities to build a project pipeline)

Options

A Annual (LT) and daily (ST) procurement

- LT: Systematic and recurring assessment of the entire GB done annually for a given contract period with a defined lead-time[1]
- ST: Daily requirement assessment and procurement for the next day (day-ahead)

B Infrequent procurement based on need

- Following the same pattern as current Pathfinders
- Assessment of reactive power requirements are done on an irregular basis and market is opened for procurement if and when needed

Background & Motivation

- Reactive power cannot travel great distances in the grid and is constrained by distance over cables, voltage levels, transformer equipment and potential outages
- Needs are nodal by nature, and the effectiveness of providing reactive power from one node to another varies depending on the abovementioned factors

National vs. regional markets

- In practice, GB is physically divided in more or less separate regions due to effectiveness constraints. The option is to treat each region separately or to do a combinatorial market
- If treated separately, question of National vs. Regional markets comes down to trade-off between simplicity & operational effectiveness vs. ability to tailor products, timings and services for each region separately

Options

A National

- One common national market. Makes the process coherent and simple for both NGESO and market participants
- Needs are defined per node, and procurement decisions accounts for providers' ability to solve requirements at any node across GB simultaneously

B Regionally separated markets

- GB is split into regions, fully decoupled from each other. Product and services can be tailored per region. Adds flexibility, but can increase operational complexity
- Needs are defined per node, and procurement decisions accounts for providers' ability to solve requirements at any node within the region simultaneously

Background & Motivation

- Providers will have different effectiveness of providing reactive power to a specific node based on physical factors such as their electrical proximity.
- A market design should factor in effectiveness of providers, and must consider the balance between economic efficiency; stability; accuracy; transparency; and practicality

Effectiveness Factor (EF)

- To allow fair assessment of all potential providers across different locations, effectiveness factors can be used. The effectiveness factor can be applied as a percentage where 100% means output = input. A factor of 50% means that the provider must absorb or insert twice as much MVAr as required to meet the needs at the receiving end.
- The true effectiveness factors are incredibly dynamic in each operational hour and cannot be accurately reflected in forward procurement
- Effectiveness factors can be determined as scalars, either applied to price or volume

Zonal or nodal (individual) effectiveness

- We are comparing two options of applying effectiveness factors. Either a nodal approach where each individual asset has a particular effectiveness factor, or Zonal approach, which is a special case of nodal approach where effectiveness factors are grouped based on their electrical proximity.

Options

A Zonal approach

- Provider nodes are grouped into zones based on their electrical proximity to the need
- Assets within a zone are given the same effectiveness factor
- Effectiveness factor determined from zones to nodes based on physical factors such as their electrical proximity towards a node with demand

B Nodal approach

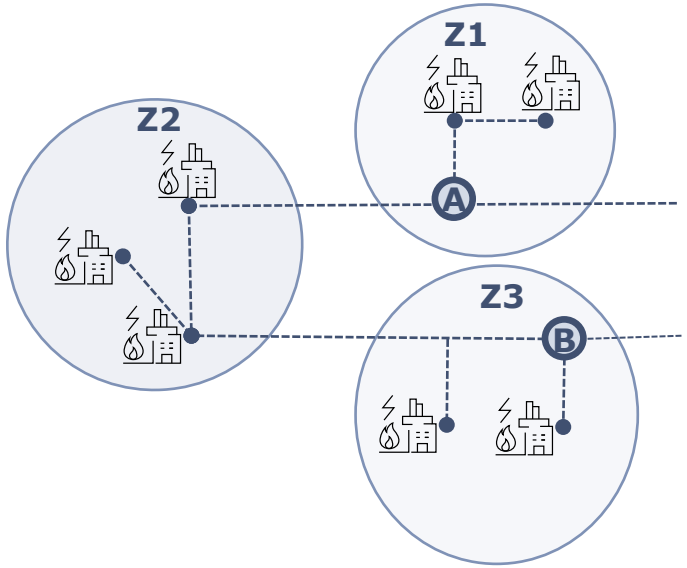
- Effectiveness factor defined individually per demand node based on physical factors such as their electrical proximity towards other nodes
- Effectiveness factors defined for all nodes in the grid, expressed by an extensive effectiveness matrix

! Other factors to be considered

- Issue with conflicting absorption/injection between two zones or nodes at any specific time; marginal or average effectiveness; weighting between time periods based on system need; and dynamic or fixed effectiveness factors

Frequency of procurement | Locational requirement | **Provider effectiveness** | Availability requirement | Regulatory back-stop

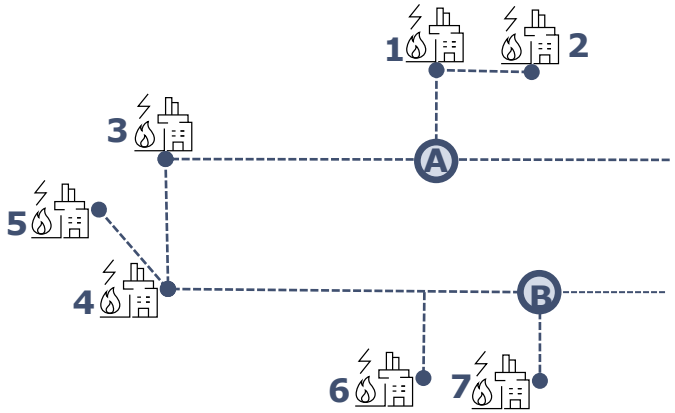
A Zonal approach, simplified example



Effectiveness matrix	
Connection	EF
Z1→A	98%
Z2→A	82%
Z3→A	30%
Z1→B	30%
Z2→B	80%
Z3→B	95%
…	…

B Nodal approach, simplified example

Demand node Provider node



Effectiveness matrix	
Connection	EF
1→A	98%
2→A	92%
3→A	87%
4→A	79%
5→A	75%
6→A	62%
7→A	58%
1→B	58%
2→B	52%
…	…

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Background & Motivation

- The ESO procures availability to deliver reactive power at some point in the future, while recognising that 100% reliability cannot be expected long-term
- It is essential for system security that providers are available to provide reactive power when instructed
- Not meeting the requirements should be penalised in a way that motivate compliance, while at the same time avoiding creating such risk for providers that it prevents them from participating in the market.

Long-term market

- Unplanned outages and planned maintenance prevents providers from being able to commit to 100% availability over a longer period
- A market design must consider the trade-off between system security, cost (related to over-procurement to mitigating unavailability risk), and avoiding creating market blockers by setting too high requirement thresholds

Short-term market

- Plans for the next day are relatively predictable and providers should be held accountable for being available 100% of the time.

Options

A High long-term availability requirement [95%]

- LT: Providers commits to 95% availability
- ST: Self-declared availability (firm) per market time unit, i.e. 100%
- Failing to be available and/or deliver when instructed results in facing non-performance process

B Medium long-term availability requirement [90%]

- LT: Providers commits to 90% availability
- ST: Self-declared availability (firm) per market time unit, i.e. 100%
- Failing to be available and/or deliver when instructed results in facing non-performance process

Background & Motivation

- A price cap should limit exposure to market power abuse thus limiting excessive cost to consumers
- It should represent a trade-off between limiting barriers to entry and preventing speculative excessive bidding
- Regulated back-stop should reflect the alternative cost of solving the system security issue by other means available to the SO

Long-term market

- A back-stop (price cap) should be defined by the cost of an alternative TO investment that represents a valid alternative to fall back on
- If procuring beyond the forecasted capacity gap ('must buy'), the price cap should reflect the willingness to pay weighted against the alternative cost of procuring it later (in ST-market, via BM or other)

Short-term market

- At 'point of no return' (PONR), TO alternative assets are no longer a valid reference for a price cap as it is too late to begin constructing them to meet the demand. Therefore, the ESO should already have secured enough reactive power to cover the forecasted capacity gap.
- ST price cap should reflect a valid alternative cost of solving the constraints closer to the delivery of the service

Options

A Alternative cost TO assets (LT) & BM alternative cost (ST)

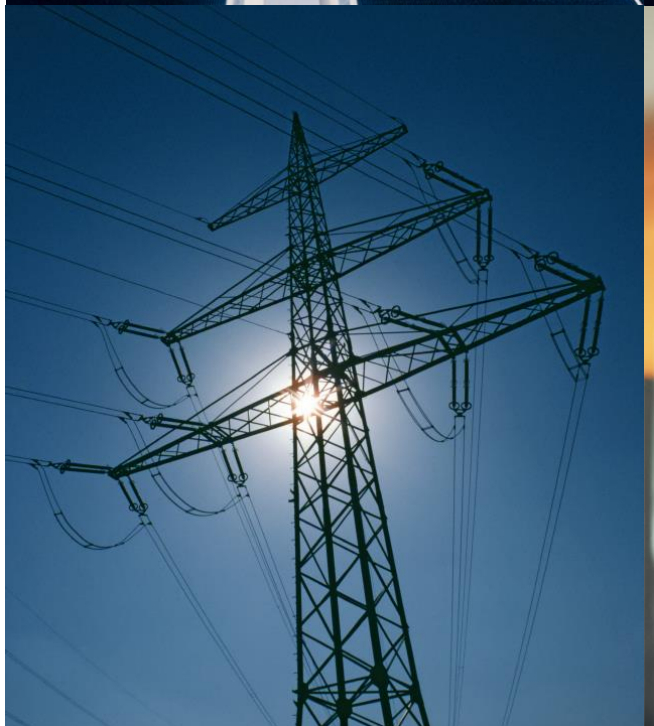
- LT: Price cap is set at the cost of building new TO asset(s) depreciated over the contract period, as TO assets presents a valid alternative to fall back on
- ST: Balancing mechanism costs will function as a back-stop. If no resources are available on the short-term market (or too expensive), NGESO can procure resources on the BM.

B Alternative cost TO assets + ST alternative (LT) & BM alternative cost (ST)

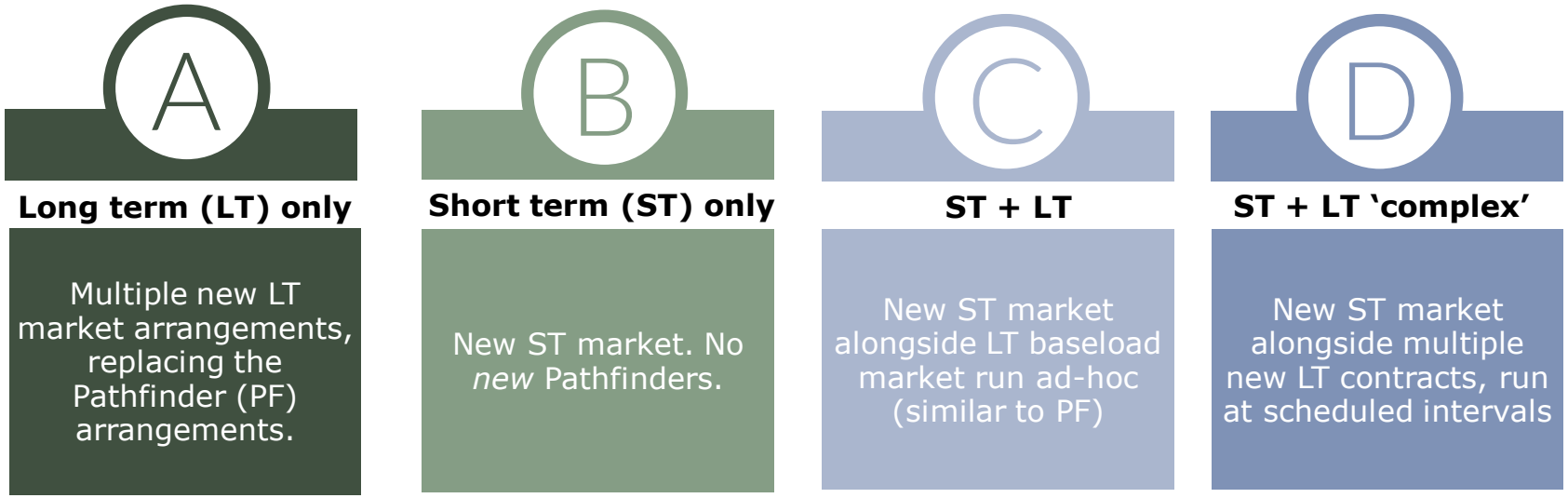
- LT: Price cap is set at the cost of building new TO asset(s) depreciated over the contract period, as TO assets presents a valid alternative to fall back on.
- LT opportunistic buy: Alternative cost in short-term market. The price on the long-term market shouldn't exceed the forecast cost of meeting the requirements on the short-term market (once capacity constraints are satisfied).
- ST: Balancing mechanism costs will function as a back-stop. If no resources are available on the short-term market (or too expensive), NGESO can procure resources on the BM

X Option of having no back-stop is not considered as a valid option

Agenda



Four design options (strawmen) were created for evaluation based on combinations of the 10 building blocks



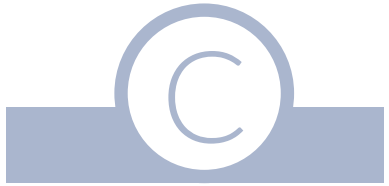
Note: Adjustment to ORPS arrangements are not within the scope of this project, however their interaction with potential products has been considered

STRAWMAN DESIGN OPTIONS

The combinations of timeframe and contract types outlined below. All options accommodate existing Pathfinders with Balancing Mechanism as backstop

Long term only (LT)

Short term only (ST)

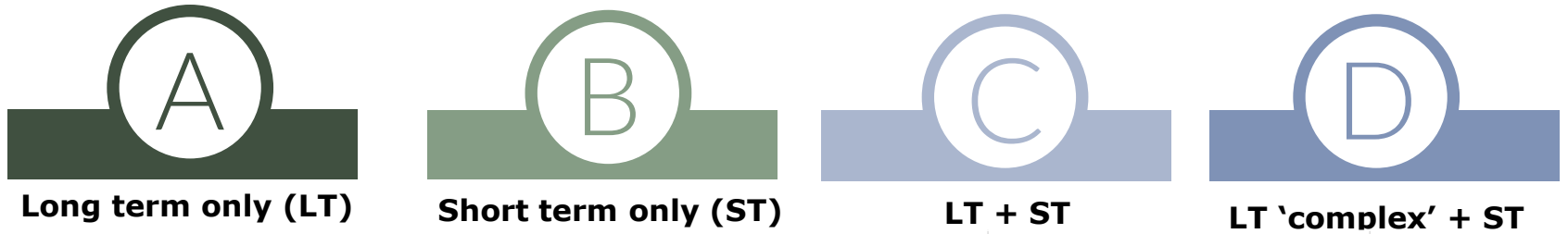


ST + LT

ST + LT 'complex'

Long-term (timeframe)	**Existing PF** 1,2,3	✓	✓	✓	✓
	Future advanced PF (ad hoc) Firm Baseload	✗	✗	✓	✗
	Firm baseload	✓	✗	✗	✓
	Firm shape products (Fixed shape products, conditional & 'Call options')	✓	✗	✗	✓
	Non-firm provider 'Put options'	✓	✗	✗	✗
Short-term (timeframe)	**ST day-ahead market**	✗	✓	✓	✓
	ST market requirement	✗	Gross* (net of existing PF contracts)	Shortfall	Shortfall
	BM and other ad hoc balancing services	(✓)	(✓)	(✓)	(✓)

The options have different conditions which providers need to be eligible for participation



Eligibility	Long term only (LT)	Short term only (ST)	LT + ST		LT 'complex' + ST	
			LT	ST	LT	ST
Incremental	✓	✗	✓	✗	✗	✗
Global selective	✗	✗	✗	✓	✓	✓
Global	✗	✓	✗	✗	✗	✗

	Incremental (investment/capability)	Global selective	Global (Gross)
Eligible	– **Incremental Investment:** Capability which doesn't already exist and requires material investment to be accessible, i.e. additionality criteria (beyond ORPS) – **Incremental Capability:** including; ORPS providers outside of MSA ranges; existing providers with no MSA in place; and closing assets	– In general, all providers are eligible. However, NGESO discretion for awarding contracts – ESO buys (expected) shortfall plus the economically desirable – incl. ORPS if it is cheaper than alternatives[1]	– In general, all providers are eligible. Limited NGESO discretion for awarding contracts – This means it also includes ORPS providers within ORPS ranges ; ORPS providers outside of ORPS ranges; non-ORPS/uncontracted providers
Excluded	– TO assets and LT contract holders – New and existing ORPS providers within ORPS ranges	– TO assets and LT contract holders – Uneconomic ORPS providers more expensive than BM alternatives or ORPS utilisation price	– TO assets and LT contract holders

1: Only works for a two-part bid | 2: Three variants: DSO Plays facilitator (no DSO assets: this is the status quo) vs. DSO plays aggregator (DSO assets included) vs. no DER participation

STRAWMAN DESIGN OPTIONS

Replace pathfinders and provides multiple options for procuring reactive power long term, also providing a route to market for variable RES

Long term only (LT)

Contract types

- Firm baseload
- Firm fixed shape contracts
- Conditional contracts
  NGESO 'Call option'
- Non-firm 'Put option'
- 'Put option' remuneration

Short term only (ST)

- ST contracts

ST + LT

- ST contracts
- Firm baseload

ST + LT 'complex'

- ST contracts
- Firm baseload
- NGESO 'Call option'

- Minimise transaction cost
- Firm contracts provide enhanced LT security of supply and also price hedging for NGESO
- 'Put options' give a route to market for variable RES, potentially creating investment incentives in added capability

- LT forecasting difficult and unprecise, both in terms of qty and directions (leading/lagging)
- Put options gives ESO a commitment to pay for an undefined qty. If high price - very unattractive
- Over procurement more likely than with a ST market

STRAWMAN DESIGN OPTIONS

‘Short term only’ depends on a strong confidence in future volumes and prices to incentivise new investments in the long term

Contract types	A	B	C	D
	Long term only (LT)	**Short term only (ST)**	ST + LT	ST + LT ‘complex’
	Firm baseload	ST contracts	ST contracts	ST contracts
	Firm fixed shape contracts		Firm baseload	Firm baseload
	Conditional contracts			NGESO ‘Call option’
	NGESO ‘Call option’			
	Non-firm ‘Put option’			
	‘Put option’ remuneration			

- Effective at meeting short term needs accurately in any direction
- Route to market for variable RES and uncontracted capacity
- Increased dispatch efficiency compared with LT commitments

- Inefficient at creating LT investment incentives
- Past point of no return for building new incremental assets to fill capacity gap
- High set-up and transaction cost

This option combines a new ST market with an ad-hoc LT market (similar to PF), bringing more focus on short term needs than today

	A	B	C	D
	Long term only (LT)	Short term only (ST)	**ST + LT**	ST + LT 'complex'
Contract types	Firm baseload	ST contracts	ST contracts	ST contracts
	Firm fixed shape contracts		Firm baseload (PF)	Firm baseload
	Conditional contracts			NGESO 'Call option'
	NGESO 'Call option'			
	Non-firm 'Put option'			
	'Put option' remuneration			

- Firm contracts provide enhanced LT security of supply and also price hedging for ESO
- ST as route to market for variable RES and uncontracted capacity
- Balance between LT market providing baseload and ST market meeting peak requirements – decreasing tendency for over procurement
- Somewhat increased dispatch efficiency compared with (only) LT commitments

- High set-up and transaction cost

Introduces multiple annual LT procurement opportunities, in addition to a ST market

Contract types	A	B	C	D
	Long term only (LT)	Short term only (ST)	ST + LT	**ST + LT 'complex'**
	Firm baseload	ST contracts	ST contracts	ST contracts
	Firm fixed shape contracts		Firm baseload	Firm baseload
	Conditional contracts			Firm fixed shape contracts
	NGESO 'Call option'			NGESO 'Call option'
	Non-firm 'Put option'			
	'Put option' remuneration			

- Same as 'ST+LT' option
- Call contracts and fixed shape products provide enhanced LT security of supply and also price hedging for ESO
- Somewhat increased dispatch efficiency compared with (only) LT commitments

- High set-up and transaction cost
- More complex than ST+ LT baseload only

Next slides summarise all building blocks for each of the four strawman options considered

Long term only (LT)

Pricing mechanism

Availability
- General: Pay-as-bid
- General: Payment £/MVAr/SP
- 'Call options':
  - Additional option premium
  - Paid only when ESO calls for availability
- Non-firm: Paid only when provider announces availability [e.g. day-ahead]

Utilisation (TBD)
Variant 1: No utilisation
Variant 2: Utilisation (self-bid, Pay as Bid)
Variant 3: Utilisation (ORPS or regulated)

Contracts types

Firm Baseload
- *Penalties: Non-payment, becoming more 'penal' below availability requirement*

Firm fixed shape products
- *Penalties: Non-payment, becoming more 'penal' below availability requirement*

Conditional products
- *Penalties: Non-payment, becoming more 'penal' below availability requirement*

NGESO 'Call option'
- *Penalties: Sharp 'penalty' price as this is a 'peak' requirement*

Non-firm provider 'Put-option'
- *Penalties: Non-payment*

General penalty principles: Contract termination for sustained non-performance

Timeframe

- Long-term
  - [5 year +] contract duration
  - [1-5 year] lead times

Locational requirement

Nodal market, where reactive power requirements are identified and stated per node, and effectiveness factors are also calculated per node

Product linking

Linking between all products enabled

Provider location

- Effectiveness factor defined individually per asset
- Effectiveness factor adjusted to represent least cost solution
- Effectiveness factor fixed at point of contracting for the whole product duration

Frequency of procurement

National annually procurement

Regulatory back-stop

TO owned asset solution depreciated over the contract period [e.g. 15y horizon]

Availability requirement

Firm products: High [95%]

Non-firm 'Put option': No commitment, just incentive based, until provider has declared availability. Then high [95%]

Short term only (ST)

Contract types

- **4h EFA blocks**
- *Firm penalty for non-delivery of declared availability (beyond non-payment [strong fixed penalty agreed price * X or agreed price + X]).*

Timeframe

- Short-term
  - Day-ahead
  - 4h contract duration

Locational requirement

Nodal market, where reactive power requirements are identified and stated per node, and effectiveness factors are also calculated per node

Pricing mechanism

£/MVAr/SP availability payment
£/MVAr/SP utilisation payment

- Availability and utilisation (two-part bid, pay as bid)

Product linking

Linking between all products enabled

Provider location

- Effectiveness factor defined individually per asset
- Effectiveness factor adjusted to represent least cost solution
- Dynamic effectiveness – changing frequently, to reflect changes towards reference node

Frequency of procurement

National daily procurement for next day

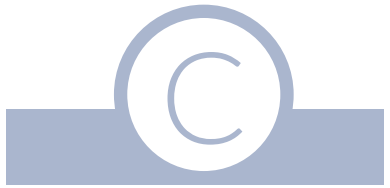
Regulatory back-stop

Balancing mechanism, i.e. alternative BM cost

Availability requirement

- Self-declared availability (firm) per market time unit
- Failing to deliver declared availability/utilisation results in facing non-performance process

STRAWMAN DESIGN OPTIONS



ST + LT

Pricing mechanism

LT:

- Availability only, with *no* utilisation payment
- Pay as bid
- £/MVAr/SP availability payment

ST:

£/MVAr/SP availability payment
£/MVAr/SP utilisation payment

- Availability and utilisation (pay-as-bid)

Contract types

LT:

- **Firm Baseload**
- Penalties: Non-payment, becoming more 'penal' below availability requirement.
- Contract termination for sustained non-performance

ST:

- **4h EFA blocks**
- Penalties: Firm penalty for non-delivery of declared availability (beyond non-payment [strong fixed penalty agreed price * X or agreed price + X])

Timeframe

- Long term
  - [15 year] contract duration
  - 4 year lead times
- Short-term
  - Day-ahead
  - 4h contract duration

Locational requirement

Nodal market, where reactive power requirements are identified and stated per node, and effectiveness factors are also calculated per node

Product linking

Linking between all products enabled

Provider location

- Effectiveness factor defined individually per asset
- Effectiveness factor adjusted to represent least cost solution
- **LT:** Effectiveness factor fixed at point of contracting for the whole product duration
- **ST:** Dynamic effectiveness – changing frequently, to reflect changes towards reference node

Frequency of procurement

LT: Regional procurement, ad-hoc
ST: National daily procurement for next day

Regulatory back-stop

- **LT:** TO owned asset solution depreciated over the contract period [e.g. 15y horizon]
- **ST:** Balancing mechanism, i.e. alternative BM cost

Availability requirement

- **LT:** High [e.g. 95%]
- **ST:** Self-declared availability (firm) per market time unit

Failing to deliver (declared) availability/utilisation results in facing non-performance process

ST + LT 'complex'

Pricing mechanism

LT:

- Availability only, with no utilisation payment
- Pay as bid
- £/MVAr/SP availability payment
- 'Call options':
  - Additional option premium
  - Paid only when ESO calls for availability

ST:

£/MVAr/SP availability payment
£/MVAr/SP utilisation payment

- Availability and utilisation (pay-as-bid)

Contract types

LT Firm Baseload
- *Penalties: Non-payment, becoming more 'penal' below availability requirement*

LT fixed shape
- *Penalties: Non-payment, becoming more 'penal' below availability requirement*

LT NGESO 'call options'
- *Penalties: Sharp 'penalty' price as this is a 'peak' requirement*

ST
- **4h EFA blocks**
- Penalties: Firm 'penalty' for non-delivery of declared availability (beyond non-payment [strong fixed penalty agreed price * X or agreed price + X])

General penalty principles: Contract termination for sustained non-performance

Timeframe

- Long term
  - [15 year] contract duration
  - 1-4 year lead times
- Short-term
  - Day-ahead
  - 4h contract duration

Locational requirement

Nodal market, where reactive power requirements are identified and stated per node, and effectiveness factors are also calculated per node

Product linking

Linking between all products enabled

Provider location

- Effectiveness factor defined individually per asset
- Effectiveness factor adjusted to represent least cost solution
- **LT:** Effectiveness factor fixed at point of contracting for the whole product duration
- **ST:** Dynamic effectiveness – changing frequently, to reflect changes towards reference node

Frequency of procurement

LT: National annual procurement
ST: National daily procurement for next day

Regulatory back-stop

- **LT:** TO owned asset solution depreciated over the contract period [e.g. 15y horizon]
- **ST:** Balancing mechanism, i.e. alternative BM cost

Availability requirement

- **LT:** High [e.g. 95%]
- **ST:** Self-declared availability (firm) per market time unit

Failing to deliver (declared) availability/utilisation results in facing non-performance process

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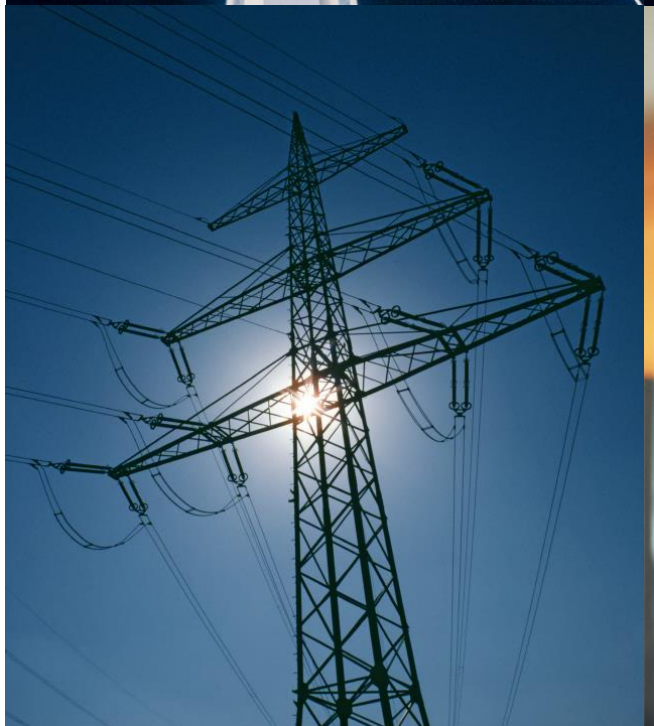
Agenda



STRAWMAN ASSESSMENT

The strawmen have been evaluated against each of the objectives, highlighting strengths and shortfalls, then leading to a desired option

BASIS FOR ASSESSMENT

Objectives
Form the criteria by which the strawmen were assessed

Stakeholder engagement
Inputs from surveys, 1-2-1 sessions and industry workshop fed directly into the design and assessment process, helping to understand the market perspective

ESO experts
Internal dialogues with ESO experts, testing assumptions and the different options against system operational requirements

Fundamentals
Fundamental economic principles and experience from similar and relevant market arrangements

OUTCOME

Desirability
The outcomes give indications for which of the strawmen is expected to give most desirable results, based on their high level design principles

Capture input
Evaluating multiple choices against an established framework allows us to test ideas with stakeholders and to identify and capture areas of uncertainty where they exist

Narrowing the design
Moving from four design options to one helps to eliminate non-viable options and to focus on the more material details of an end-to-end market design

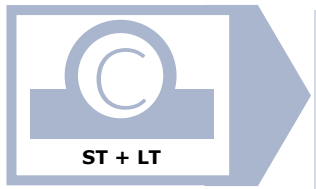
Further work
The appraisal forms a basis for the final end-to-end market design and should serve as a guidance for further work in the final implementation of the market

STRAWMAN ASSESSMENT

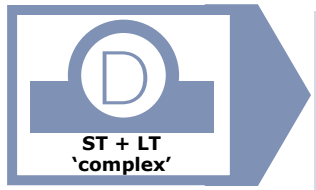
The assessment concludes that a hybrid of C and D is the most pragmatic way forward whilst maximising benefits against the objectives

Not preferred option because of unpredictability of demand.
- × Leads to over-procurement to maintain adequate system security, raising cost
- × All risks needs to be mitigated by NGESO in the long-term when degree of predictability is low
- × High barriers of entry for some technologies

Not a viable option (initially) because:
- × Exposing ESO to system security risk (operates beyond investment timeframes)
- × Limited incentives for new investment – exposes providers to changeable needs with single buyer risk



- ✓ Combination of long-term and short-term market gives the best balance between system security and cost efficiency, while increasing consumer value by promoting competition from a wider range of technologies
- × Ad-hoc nature of information sharing and procurement difficult for providers to build pipelines and offer most effective solutions



- ✓ Adding peak contracts allows reducing over-procurement compared to baseload only, thus can reduce cost while also increasing freedom of choice
- × Introducing overly-complex contracts makes the market less practical and value less transparent

STRAWMAN ASSESSMENT

LT-only market exposed to forecast errors. ST-only leaves NGESO with risk of insufficient available capability in real-time

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Maintain voltage security	A **LT only**	– LT market ensures adequate capability is in place to meet forecasted reactive power requirements. Operating in investment timeframes provides enough lead time for investment decisions. – Wide product suite enables flexibility to meet variable system conditions. – Diverse product suite enables a wider range of technologies to offer reactive power capability.	– LT-only procurement exposes market to variable requirements and forecast errors. LT-only procurement means there are limited backstop solutions closer to real-time if conditions change (reliance on ORPS and BM as backstop). – Product-suite and multiple contract structures provide some options to manage these risks, but are not a perfect solution. – Over-procurement. larger share of procurement from non-firm products, translates in (a) larger requirements in real time, (b) larger risk premia in real-time.
	B **ST only**	– Recurring & systematic requirements determination enable ESO to have a measure of potential risks ahead of time.	– While the ST arrangement may enable better forecasting from providers & ESO, it does not ensure capability required will be in place. There may be instances where there is insufficient capability, even in the BM.

STRAWMAN ASSESSMENT

A combination of LT and ST market allows appropriate balance between securing future shortfalls and managing system closer to real-time

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Maintain voltage security 	 **ST + LT**	– Ensure adequate capability is in place to meet forecasted stability requirements. Pathfinder arrangements (or a version of this) operate in investment timeframes (LT). ST market provides a backstop solution in case conditions change. – Global eligibility incentivises providers needed to meet requirements to remain open. The ST arrangement provides a degree of revenue and volume certainty to existing providers to remain open.	– Infrequent, non-systematic nature of procurement similar to PF does not oblige ESO to make regular forecasting and requirement determinations. It increases the years relying on infrequent forecasts and requirement determinations – This can increase exposure to forecast errors and variability in requirements. Irregular procurement does not require recurring and systematic assessments and may not capture all voltage compliance issues. Situations of shortage can arise.
	 **ST + LT 'complex'**	– Hybrid market timeframe mitigates issues of under and over-procurement. LT market ensures capability is in place to meet forecasted requirements. ST market provides a stop-gap solution in case conditions change (close to real-time, accurate forecasting, minimise role of BM in managing stability). – All providers are eventually eligible for participation and remuneration under LT & ST arrangement. – Year-ahead procurement provides revenue/volume signalling to existing providers (who may otherwise decide to decommission) to remain open. – Systematic and recurring LT market obliges SO to make forecasting, requirement determinations. This acts to ensure a higher degree of certainty for market providers and forecasting in requirements. Mitigates exposure to forecasting errors.	– Not securing *all* needs in advance leaves some uncertainty.

STRAWMAN ASSESSMENT

An immature short term market gives inadequate voltage security on its own

Objective	Model	Score	Justification
Maintain voltage security 	 **LT only**		✓ Provides range of LT contracts to ensure adequate capability to meet voltage security requirements (though over-procurement may be a problem) × Limited short term-route to market options even if providers technically capable – reliance on ORPS and BM as backstop
	 **ST only**		× Risk of inadequate investment in necessary capacity due to limited suppliers, particularly while market is new. Uncertain whether market will have developed sufficiently once current security backup (CCGTs via BM) has become less viable
	 **ST + LT**		✓ Able to flex volume procured in LT baseload to limit dependence on ST market (at least until it has developed) × Ad-hoc process may not capture all voltage compliance issues
	 **ST + LT 'complex'**		✓ Provides range of LT contracts, in addition to ST contracts, to ensure adequate capability to meet voltage security requirements ✓ Systematic process should capture all long term voltage compliance issues

STRAWMAN ASSESSMENT

ST-only and LT-only arrangements are exposed to issues of over and under-procurement

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective

Cost efficient provision 	 **LT only**	– Shortfall market requirement – demonstrates value for money by only remunerating for provision not already present.
		– Wide product-suite gives ESO choice in determining preferred ratio to meet requirements at least-cost. Choice of products give flexibility to ESO. Hence, they can determine most cost-efficient procurement mix. Range of contract structures can help to mitigate and manage risks.
			– LT-only procurement exposes market to forecast error. Can lock ESO into cost-inefficient outcomes of over-procurement and scarcity/extreme pricing with under-procurement.
			– Product-suite and multiple contract structures provide some options to manage these risks, but are not a perfect solution:
			  – Over-procurement: if too much non-firm provision shows up in real time.
			  – Under-procurement: may require ESO to over-rely on expensive call option contracts.
			– Difficult to forecast operational costs in LT timeframe – may translate into additional risk premia and costs.

	 **ST only**	– Close to real-time procurement is more accurate, mitigating over/under-procurement, particularly if requirements are variable and volatile. – Close to real-time procurement removes some of the availability risk that weather-dependent providers may face. It incentivises wider participation and competition from potentially lower-cost solutions. – Gross market requirement - acts to provide incentive for existing provision (that is needed to meet requirements) to stay open. This can minimise reliance on new, incremental capability, which is expected to be more expensive than procuring existing providers.	– ST-only procurement exposes ESO to under procurement which can lead to scarcity and extreme pricing. There are no explicit arrangements to guarantee that capability is in place. It may lead to expensive stop-gap actions (BM or other last resort actions). – Participants may attach risk premium to a new ST-only market - the volume & price uncertainty can lead to more expensive offers. This may only apply in initial stages of market launch, as impact diminishes over time with market maturing. – Gross market requirement - procuring for the whole requirement stack and remunerating providers that are there as part of an existing market schedule is more expensive than procuring only for the shortfall.

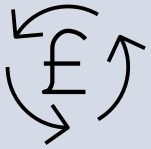
STRAWMAN ASSESSMENT

Operating in both LT and ST market timeframes promotes cost-efficient outcomes by managing volume risk whilst broadening competition

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Cost efficient provision 	 **ST + LT**	– Hybrid timeframe - close to real-time procurement under the ST market is accurate, mitigating over/under-procurement, particularly if requirements are variable and volatile. The Pathfinders operate in investment timeframes, seeking new capability if needed to meet requirements. – Pathfinders procure for new capability and so it is a top-up approach only procuring for required capability to meet shortfalls, providing value for money.	– The infrequent, ad-hoc nature of Pathfinders may impact bid costs and participation of potential providers. – Frequent procurement would enable providers to participate with multiple projects over time, build supply chains, etc. (take advantage of technology learnings). – Infrequent procurement also means there are limited opportunities for participation, with the risk that some suitable, cost-efficient solutions may miss out. – Being unable to procure shape at a more granular level means that ESO must procure availability for an entire year (Baseload), even though the forecasted shortfall only occurs during e.g. cold winter seasons. This is likely to increase the chance of over-procurement, i.e. procuring more than needed.
	 **ST + LT 'complex'**	– Opportunistic eligibility & hybrid timeframe incentivise wider participation and competition. The ST arrangements reduce availability risk compared to a LT procurement for intermittent providers. LT procurement in investment timeframes enables provision of new capability, if needed. – Mitigates scarcity & extreme pricing close to real-time. – Hybrid timeframe and wide product-suite & contract structure provide flexibility for ESO in meeting requirements at least-cost. ST & LT procurement work to balance over & under-procurement. ESO is flexible to procure its desired volume from the LT & ST market timeframes. – Choice of products gives flexibility to ESO to determine the most cost-efficient procurement mix. Range of contract structures can mitigate and manage risks.	– ST market may be marginalised and fail to provide an efficient route for procuring availability.

STRAWMAN ASSESSMENT

A combination of short and long term markets can reduce the potential for over-procurement

Objective	Model	Score	Justification
Cost efficient provision 	 **LT only**		✓ Shaped products can reduce over-procurement compared to baseload contracts only ✓ New contract options (non-firm and shaped contracts) allow for more parties to be able to participate and, therefore, increase participation and competition. × Lack of a short term market may result in missed opportunity to procure cheap reactive power and also will inevitably lead to some over-procurement that could otherwise be captured by a short term market × Long lead time increases risk of forecast errors, increasing risk of over/under-procurement
	 **ST only**		✓ A well functioning short-term market will limit over-procurement ✓ Once established, a short-term market can provide signals for incremental investment in capability, and possibly larger, higher capex investments too × Risk of high prices and costly provision in periods and areas with high demand. This should, in theory, be reduced over time as high prices triggers new investment opportunities and thus more supply in regions where needed × May be too risky for new investment and limit range of suppliers and competition × This model proposes to pay everyone for the service regardless of pre-existing obligations which may lead to additional spend
	 **ST + LT**		✓ New baseload contract form could allow for more parties to participate and therefore increase participation and competition (e.g. over sized converters) ✓ Short-term market can top-up long term market, reducing risk of over-procurement versus use of LT contracts only ✓ Short-term market can provide route to market for uncontracted, potentially cheap resources with volatile availability – e.g. wind ✓ Once established, short-term market can provide signals for incremental investment in capability, and possibly larger, higher capex investments too
	 **ST + LT 'complex'**		✓ Shaped products can reduce over-procurement compared to baseload contracts only ✓ New contract options (non-firm and shaped contracts) allow for more parties to participate and therefore increase participation and competition. ✓ Short-term market can top-up long term market, further reducing risk of over-procurement × ST market may be marginalised and fail to provide an efficient route for procuring availability

STRAWMAN ASSESSMENT

LT-only solution may lock ESO in sub-optimal carbon-intensive provision and rely on carbon-emitting stop-gap solution through the BM

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Zero carbon compatible	**LT only**	– Accelerated decarbonisation can arise as a result of the other objectives of this market such as cost-efficiency and system security. A market can help reduce reliance on expensive and carbon-intensive stop-gap solutions via the BM. – Wide contract suite lowers barriers to entry for clean generation. Procurement via non-firm products offers a route-to-market for providers (RES, weather dependent) subject to availability risk.	– LT procurement and long contract duration can lock-in ESO with sub-optimal carbon emitting providers. – Procurement of call options can risk striking contracts with sub-optimal carbon-emitting providers (typically for providers who can commit in advance but have high short-run marginal costs, such as thermal generators). – No option to rely on ST procurement. Relying entirely on LT procurement may lead ESO to miss out on more efficient and carbon-friendly providers. – Product definitions (incl. call options) may risk striking long-term contracts with carbon emitting plant for which these contracts would be appropriate. – No obligation to provide zero-carbon solutions, albeit they are theoretically compatible.
	ST only	– Accelerated decarbonisation can arise as a result of the other objectives of this market such as cost-efficiency and system security. A market can help reduce reliance on expensive and carbon-intensive stop-gap solutions via the BM. – Lowers barriers to entry for clean providers. ST procurement offsets the majority of the availability risk for weather-dependent (RES) providers. – ST-procurement and limited duration contracts avoid lock-in with sub-optimal carbon-emitting providers. Recurring procurement helps ESO to procure most modern, clean technology.	– Scarcity and limited options close to real-time, may force ESO to take sub-optimal stop-gap actions (e.g. through the BM or what is available on the day), which may be carbon intensive. – No obligation to provide zero-carbon solutions, albeit solution theoretically compatible.

STRAWMAN ASSESSMENT

LT markets reduce reliance on carbon-intensive stop-gap solutions, and ST enables ESO to contract technologies that may not be there in the LT

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Zero carbon compatible	 **ST + LT**	– ST market lowers barriers to entry for clean generation. The short lead time of procurement offsets the majority of the availability risk for weather-dependent (RES) providers. – Accelerated decarbonisation can arise as a result of the other objectives of this market such as cost-efficiency and system security. A market can help reduce reliance on expensive and carbon-intensive stop-gap solutions via the BM. – Hybrid timeframe provides choice, limiting potential lock-in of suboptimal carbon emitting providers in LT timeframes and mitigating ST shortage/reliance on sub-optimal carbon alternatives in real-time (e.g. through the BM).	– No obligation to provide zero-carbon solutions, albeit solution theoretically compatible.
	 **ST + LT 'complex'**	– ST market lowers barriers to entry for clean generation. The short lead time of procurement offsets the majority of the availability risk for weather-dependent (RES) providers. – Hybrid timeframe provides choice, limiting potential lock-in of sub-optimal carbon-emitting providers in LT timeframes and mitigating ST shortage/reliance on sub-optimal carbon alternatives in real time (e.g. through the BM). – Potentially provides range of LT contracts suited to zero-carbon sources (details of complex LT contracts needs further consideration). – Multi-year agreements tied to provider's characteristics, including emissions limit criteria.	– No obligation to provide zero-carbon solutions, albeit solution theoretically compatible.

STRAWMAN ASSESSMENT

All strawmen are zero carbon compatible, while a short-term market is highlighted as key to capture new zero-carbon compatible technologies

Objective	Model	Score	Justification
Zero carbon compatible 	 **LT only**		✓ Potentially provides range of LT contracts suited to zero-carbon sources (details of complex LT contracts needs further consideration) × Product definitions (incl. call options) may risk striking long-term contracts with carbon emitting plant for which these contracts would be appropriate
	 **ST only**		✓ Provides ST contracts suited to zero-carbon sources ✓ Option performs well as it avoids lock-in of sub-optimal carbon provision and the ST, close to real-time procurement maximises chances of procuring the most modern, zero-carbon compatible technologies (of the future). × No obligation to provide zero-carbon solutions, albeit they are theoretically compatible × Can incur sub-optimal carbon actions if shortages occur
	 **ST + LT**		✓ ST arrangement maximises the chances of procuring the most efficient, zero-carbon compatible technologies close to real-time (which may otherwise not be available in the LT market) ✓ Provides LT baseload contracts suitable for zero-carbon sources (either all of capacity or only part) × No obligation to provide zero-carbon solutions, albeit they are theoretically compatible
	 **ST + LT 'complex'**		✓ Potentially provides range of LT contracts suited to zero-carbon sources (details of complex LT contracts needs further consideration) ✓ ST arrangement maximises the chances of procuring the most efficient, zero-carbon compatible technologies close to real-time (which may otherwise not be available in the LT market) × No obligation to provide zero-carbon solutions, albeit they are theoretically compatible

LT-only exclude providers with variable availability (e.g. variable RES) while ST-only is exposed to high price risk due to 'point of no return'

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Consumer value 	 **LT only**	– Provides route to market for new sources of reactive power, increasing competition and access to potentially cheaper providers. – The different LT contracts are designed to capture a wide variety of technologies, increasing competition.	– Lack of competition in some localities may result in high prices (or need for mitigation of market power). – Incremental eligibility (new and existing ORPS providers within ORPS ranges are excluded) may leave out resources that otherwise would have been cheaper. – Little use made of providers with availability profiles that do not fit long-term contracts.
	 **ST only**	– Provides route to market for new sources of reactive power, increasing competition and access to potentially cheaper providers.	– Lack of competition in some localities may result in high prices (or need for mitigation of market power). – Procurement takes place beyond 'point of no return', thus high price risk.

STRAWMAN ASSESSMENT

Complex LT contracts, designed to capture a wide variety of technologies, increasing competition

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Consumer value 	 **ST + LT**	– Provides routes to market for new sources of reactive power, increasing competition and access to potentially cheaper providers.	– Lack of competition in some localities may result in high prices (or need for mitigation of market power). – Absence of shaped contracts may lead to long term over-procurement.
	 **ST + LT 'complex'**	– Provides broadest routes to market for various new sources of reactive power, increasing competition and access to potentially cheaper providers. – More complex LT contracts, designed to capture a wide variety of technologies, increasing competition.	– Lack of competition in some localities may result in high prices (or need for mitigation of market power).

STRAWMAN ASSESSMENT

Risk of market power in all designs is present and may manifest in high prices, especially in the short-term market

Objective	Model	Score	Justification
Consumer value 	 **LT only**		✓ Provides route to market for new sources of reactive power, increasing competition and access to potentially cheaper providers × Lack of competition in some localities may result in high prices (or need for mitigation of market power) × Incremental eligibility (new and existing ORPS providers *within* ORPS ranges are excluded) may leave out resources that otherwise would have been cheaper × Little use made of providers with availability profiles that do not fit long-term contracts
	 **ST only**		✓ Provides route to market for new sources of reactive power, increasing competition and access to potentially cheaper providers × Lack of competition in some localities may result in high prices (or need for mitigation of market power) × Procurement takes place beyond 'point of no return', thus high price risk
	 **ST + LT**		✓ Provides routes to market for new sources of reactive power, increasing competition and access to potentially cheaper providers ✓ ST supply can provide an alternative to LT contracts, constraining LT market power to some degree × Lack of competition in some localities may result in high prices (or need for mitigation of market power) × Absence of shaped contracts may lead to long term over-procurement
	 **ST + LT 'complex'**		✓ Provides broadest routes to market for various new sources of reactive power, increasing competition and access to potentially cheaper providers ✓ ST supply can provide an alternative to LT contracts, constraining LT market power to some degree × Lack of competition in some localities may result in high prices (or need for mitigation of market power)

STRAWMAN ASSESSMENT

Complexity of contracts for 'LT only' option makes it less transparent

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Transparent 	 **LT only**	– LT product standardisation and frequent market events facilitate transparency in the long run.	– Forecasting, requirement determinations and procurement conducted in LT timeframes with long lead times can make participation less transparent. As providers face more uncertainties and have less visibility further away from real-time. – Complex suite of products can make processes (such as assessment) less transparent. – Geographically fragmented and multiple complex products on pay-as-bid basis makes requirements and pricing difficult to communicate. – Likely existence of localised market power may constrain transparency.
	 **ST only**	– Close to real-time procurement enables better visibility for participants. – Individual bids and individual prices results in high transparency. – ST product standardisation facilitates transparency.	– Likely existence of localised market power constrains transparency – Limited visibility of long term requirements for participants

STRAWMAN ASSESSMENT

Lack of consistent process makes option C less transparent

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Transparent 	 **ST + LT**	– Infrequent LT market events provide opportunity for comprehensive communication. – LT baseload and ST product standardisation facilitates transparency.	– Geographic fragmentation and pay-as-bid basis makes requirements and pricing difficult to communicate. – Likely existence of localised market power constrains transparency. – Lack of consistent process (ad-hoc long term procurement).
	 **ST + LT 'complex'**	– LT product standardisation facilitates transparency in the long run. – Recurring/systematic procurement can inherently make the arrangements more transparent (requirement determinations, results sharing etc.).	– Geographically fragmented and multiple complex products on pay-as-bid basis makes requirements and pricing difficult to communicate (but ST market, albeit small, facilitates transparency). – Likely existence of localised market power constrains transparency. – Forecasting, requirement determinations and procurement conducted in LT timeframes with long lead times can make participation less transparent, as providers face more uncertainties and have less visibility further away from real-time.

STRAWMAN ASSESSMENT

A diverse mix of contracts, geographic fragmentation and pay-as-bid solution leaves potential transparency challenges

Objective	Model	Score	Justification
Transparent 	 **LT only**		✓ LT product standardisation and frequent market events facilitate transparency in the long run × Geographically fragmented and multiple complex products on pay-as-bid basis makes requirements and pricing difficult to communicate × Likely existence of localised market power may constrain transparency
	 **ST only**		✓ ST product standardisation facilitates transparency × Likely existence of localised market power may constrain transparency (e.g. need to delay publication)
	 **ST + LT**		✓ Infrequent LT market events provide opportunity for comprehensive communication ✓ LT baseload and ST product standardisation facilitates transparency × Geographic fragmentation and pay-as-bid basis makes requirements and pricing difficult to communicate × Likely existence of localised market power constrains transparency × Lack of consistent process (ad-hoc long term procurement)
	 **ST + LT 'complex'**		✓ LT product standardisation and frequent market events facilitates transparency in the long run × Geographically fragmented and multiple complex products on pay-as-bid basis makes requirements and pricing difficult to communicate (but ST market, albeit small, facilitates transparency) × Likely existence of localised market power constrains transparency

STRAWMAN ASSESSMENT

Short-term only markets may fail to incentivise investment as a standalone solution

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective

Investability 	 **LT only**	– Incentivise investment for providers who can commit in advance and require revenue certainty (e.g. high capex) with LT firm procurement. Forward market for availability reduces price and volume risk. Longer contracts could significantly reduce risk for merchants.
		– Availability uncertainty for variable RES providers (e.g. wind farms) means a ST mechanism is needed to some extent, which leads to the idea of a firm / non-firm LT market.
		  – Firm**:** Incentivise investment for providers who can commit in advance and require revenue certainty (e.g. high capex).
		  – Non-firm: Incentivise investment for providers who cannot commit in advance but require "some" revenue certainty to recover "some" incremental invest.
			– LT-only arrangements may not be compatible for providers lacking confidence to participate in a new market, and locking themselves into LT contracts (High exit barriers)
			– It may be difficult to reflect characteristics of different resource types e.g. challenge to account for energy costs at years-ahead timeframes, thus causing entry barriers for certain resources

	 **ST only**	– Granular and continuous price signals in a ST market can incentivise generators to invest in flexible assets. – An enduring, transparent ST market (providing a LT vision) can incentivise some (but not all) incremental investment.	– Providers are exposed to large volume risks as ESO is free to buy as much or as little as required. Volume requirements are subject to changes over time and location. A short-term only market fully exposes providers to changeable counterparty needs with no option to sell products to a third party. – Principles state that the party most able to bear a given risk should carry its exposure. Deviation from these principles is common but can result in significant levels of risk premia for providers. ESO has greater visibility of future needs (albeit imperfect). If the perceived risk of uncertainty to investors is too great, reward offered by the market will be unattractive to investors. With a ST-only market, providers face the risk of stranded assets if needs change. – Unintended consequences of global eligibility such as limited incentives for existing participants to innovate / improve their assets through additional investment.

STRAWMAN ASSESSMENT

LT markets reduce price and volume risks, while long duration contracts further reduce providers' risk

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Investability 	 **ST + LT**	– Baseload contracts (PF) can provide investment for providers who can commit in advance and require revenue certainty (e.g. high capex) with remuneration for firm availability. – Pathfinders are building a track-record, continuing this may enable positive signals against which to mitigate uncertainty for providers (concluded procurement of Pathfinder 1 and currently running Pathfinders 2 & 3). – ST market incentivises investment for providers who cannot commit in advance but require "some" revenue certainty.	– Pathfinders are not a formal market (or enduring LT solution) and risk being seen as a "fix" to operability needs. Pathfinder frequency & volume uncertainty (no LT visibility provided but earlier signalling could facilitate efficient investment). – Long term investment has a route to market in this arrangement. However, barriers exist for smaller investments for non-firm providers (such as grid-forming intermittent assets) that cannot meet current availability criteria without substantial additional investment (e.g. storage). – Nodal prices are potentially volatile. This risk is heightened under these arrangements where the Pathfinder (as the potential LT mitigant) is only run at the discretion of ESO, large emphasis on the ST market.
	 **ST + LT 'complex'**	– Incentivises investment by providers who can commit in advance and require revenue certainty (e.g. high capex) with LT firm procurement. Forward market for availability reduces price and volume risk. Longer contracts could significantly reduce risk for merchants. – Greater freedom in the form of long-term contracts (subject to market being liquid enough) lowers barriers to entry. – ST market incentivises investment for providers who cannot commit in advance (by removing the availability risks present in forward procurement) but require "some" revenue certainty.	– Investors face tough choices as to whether participation in a market will yield returns sufficient to cover investment costs and provide an adequate rate of return to meet cost of capital thresholds (hurdle rates). – Immature/new market with no track-record. It may be difficult to give enough confidence to investors to participate in these arrangements initially.

STRAWMAN ASSESSMENT

Long term firm contracts and long lead time provide some price and volume risk mitigation. Contract diversity reduces entry barriers.

Objective	Model	Score	Justification
Investability 	A **LT only**		✓ Freedom in form of long-term contract (firm, non-firm, baseload, shape) provides some risk mitigation for participants ✓ Multi year contracts with long lead time provide investment signals for providers who can commit in advance and require revenue certainty (e.g. high capex) with remuneration for firm availability × High exit barriers: LT-only contracts present lock-in risks for providers who may be lacking confidence to participate in a new market × Entry barriers: LT-only procurement presents risks & difficulties to accurately reflect characteristics of different resource types e.g. challenge to account for energy costs at years-ahead timeframes
	B **ST only**		✓ Granular and continuous price signals in a ST market can incentivise generators to invest in flexible assets × Short-term markets may fail to deliver efficient investment signals as a standalone solution, particularly when new × A short-term only market fully exposes providers to changeable monopsonist counterparty with no option to sell products to a third party × Providers have little visibility over future needs. With a short-term only market, providers (sellers) face the risk of stranded assets if needs change, a risk they are not optimally positioned to bear
	C **ST + LT**		✓ Pathfinders multi-year contracts & lead time provide investment signals for providers who can commit in advance and require revenue certainty (e.g. high capex) with remuneration for firm availability ✓ Established nature of Pathfinder arrangements and track-record, delivers continuity that can help to mitigate uncertainty for providers. However, fundamental LT volume uncertainty remains as Pathfinders are not a formal market (or enduring LT solution) and risks being seen as a "fix" to operability needs ✓ ST market incentivises investment for providers who cannot commit in advance (by removing the availability risks present in forward procurement) but require "some" revenue certainty
	D **ST + LT 'complex'**		✓ Long contracts & lead time incentivise investment for providers who can commit in advance and require revenue certainty (e.g. high capex) with LT firm procurement. Forward market for availability reduces price and volume risk. Longer contracts could significantly reduce risk for merchants ✓ Greater freedom in form of long-term contract (subject to market being liquid enough) lowers barriers to entry ✓ ST market incentivises investment for providers who cannot commit in advance (by removing the availability risks present in forward procurement) but require "some" revenue certainty

STRAWMAN ASSESSMENT

LT-only option is less resource-intensive, as it only runs annually, and can benefit from synergies with today's PF arrangements. ST market is complex to implement but automated processes are more compatible

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Practical 	 **LT only**	– No need to set up new ST market. – Annual procurement is predictable. – Allows for re-use of tools and services.	– Complexity of requirement determinations - more resource-intensive for procurement to cover multiple years, with more uncertainties. – Wide product-suite with complex products can add to operational difficulties. For example, processes such as making assessments, requirement determinations, forecasts as well as contract management and monitoring can be more challenging under a range of different contracts.
	 **ST only**	– A short-term market running daily is more suitable for automation than LT market. It needs to cover shorter timeframes, and can act to offset the complex nature of processes such as requirement determinations. – Low forecast error at close to real time, and many steps easy to automate.	– Complex nature of requirement determination means a ST market can be potentially difficult to operate. This is subject to how variable requirements are on a day-to-day basis. – Requires new arrangements to be implemented. Current practices for requirement determinations are time-consuming, resource-intensive and would not be practical for a daily ST market. – Requires participants to run daily operations.

STRAWMAN ASSESSMENT

Hybrid market timeframe arrangements are a larger deviation from today, expected to require complex implementation and operation

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Practical 	 **ST + LT**	– Continued arrangements under Pathfinder approach. Today's requirement determinations processes are compatible and can be carried over under this arrangement. – Simplified LT baseload contract easier to manage. – Procurement through single ST platform facilitating optimisation.	– Pathfinder arrangements are complex and time consuming to run. – Facilitating and managing multiple market timeframes is more resource-intensive than ST-only and LT-only. – Short-term market requires participants to run daily operations.
	 **ST + LT 'complex'**	– Most flexible contracting options, therefore, least likely to require intervention in the face of uncertainty.	– Facilitating and managing multiple market timeframes is more resource-intensive than ST-only and LT-only. – Number of parallel LT products will require sophisticated modelling to enable optimisation of accepted offers. – Requires new arrangements for both ST and LT market. This is time-consuming, resource-intensive and costly. – Short-term market requires participants to run daily operations.

STRAWMAN ASSESSMENT

Setup of complex markets will require new sophisticated modelling and systems. Short term market requires participants to run daily operations

Objective	Model	Score	Justification
Practical 	A **LT only**		✓ No need to set up new ST market ✓ Annual procurement is predictable × Number of parallel LT products creates requirement for sophisticated modelling to enable optimization of accepted offers
	B **ST only**		✓ Procurement through single ST platform facilitating optimisation ✓ Low forecast error at close to real time, many steps easy to automate × ST market will require new systems and processes, meaning more effort is required than under one-off LT markets for ESO (mitigated by potential to align with new ESO planning/scheduling process) and providers (mitigated if already an active ST trader)
	C **ST + LT**		✓ Simplified LT baseload contract easier to manage and optimise ✓ Procurement through single ST platform facilitating optimisation × ST market will require new systems and processes, meaning more effort is required than under one-off LT markets for ESO (mitigated by potential to align with new ESO planning/scheduling process) and providers (mitigated if already an active ST trader) × Ad-hoc long term market is less predictable
	D **ST + LT 'complex'**		✓ Procurement through single ST platform facilitating optimisation × Number of parallel LT products will require sophisticated modelling to enable optimization of accepted offers × ST market will require new systems and processes, meaning more effort is required than under one-off LT markets for ESO (mitigated by potential to align with new ESO planning/scheduling process) and providers (mitigated if already an active ST trader)

STRAWMAN ASSESSMENT

LT markets only is less flexible and may fail to adapt if conditions change

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Enduring (stable)	 **LT only**	– Regular, systematic procurement of stability services provides a LT vision for participants. – Wide product suite and contract types accommodate participation from a range of providers with different technology characteristics. Future proofing for novel technologies, and changing system conditions.	– A LT-only arrangement is less compatible with highly unpredictable requirements. The lack of alternative stop-gap solutions and reliance on BM near real-time makes it a less enduring arrangement. – It is less adaptable if conditions change, and future system challenges evolve. LT-only and long contract durations give rise to problems of lock-in.
	 **ST only**	– Compatible with the ever-greater levels of renewables expected in the future. The ST market removes some of the availability risks faced by weather-dependent technologies. – Global eligibility and procuring for the gross market requirement give volume certainty, particularly to existing, in-merit providers who may be incentivised to remain open to offer stability services through this route.	– Only likely to be perceived as a stable solution after a period of time – until then a gaming risk exists: do I invest on the basis of expected returns in the ST market, or hold off thinking ESO may then have to offer LT contracts; and if they do this could undermine the expected returns on the ST market. – History has shown that investment cycles and associated investment confidence can lead to the introduction and removal of longer-term markets to ensure security (e.g. multiple GB capacity remuneration mechanisms have existing historically). – Unintended consequences of global eligibility such as limited incentives for existing participants to innovate / improve their assets through additional investment.

STRAWMAN ASSESSMENT

Choice in market timeframe and contracts enable flexibility in the arrangements to adapt to future challenges

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Enduring (stable) 	 **ST + LT**	– Hybrid market procurement timeframes accommodate varied technologies and their characteristics. For example, the ST market is an arrangement more compatible with the ever-greater levels of renewables expected in the future.	– Ad-hoc market events may limit incentives for providers to participate with multiple projects over time and to build project pipelines.
	 **ST + LT 'complex'**	– Combination of LT & ST market accommodates varied technologies with different characteristics, in particular ST market accommodating for the ever-greater levels of renewables expected in the future. – Range of contract types are more compatible for covering variable and less predictable requirements, while giving ESO flexibility to meet requirements under evolving system conditions. – Recurring procurement nature of LT + ST markets provides an enduring LT vision for market participants (a LT vision compatible with typical lifetime of assets). This provides a degree of price and volume certainty for potential participants.	– Potential uncertainty regarding the split between LT and ST procurement.

STRAWMAN ASSESSMENT

Option D performs well as it provides most choice to ESO and technologies to adapt and meet evolving requirements in the future

Objective	Model	Score	Justification
Enduring (stable) 	 **LT only**		✓ Participants have assurance during the term of their LT contracts × Design of complex products likely to involve continual refinement/modification × Future technologies may not be suitable for existing contract suite and require new contract types to be launched
	 **ST only**		✓ Compatible with the ever-greater levels of renewables expected in the future. The ST market removes some of the availability risks faced by weather-dependent technologies × Only likely to be perceived as a stable solution after a period of time – until then a gaming risk exists: do I invest on the basis of expected returns in the ST market, or hold off thinking ESO may then have to offer LT contracts; and if they do this could undermine the expected returns on the ST market × History has shown that investment cycles and associated investment confidence can lead to the introduction and removal of longer-term markets to ensure security (e.g. multiple GB capacity remuneration mechanisms have existing historically)
	 **ST + LT**		✓ Combination of LT & ST market accommodates varied technologies with different characteristics ✓ Likely to be perceived as a stable design concept ✓ Participants have assurance during the term of their LT contracts × Potential uncertainty regarding the split between LT and ST procurement
	 **ST + LT 'complex'**		✓ Combination of LT & ST market accommodates varied technologies with different characteristics ✓ Likely to be perceived as a stable design concept ✓ Participants have assurance during the term of their LT contracts ✓ Offers the greatest degree of flexibility in contracting options from the outset × Potential uncertainty regarding the split between LT and ST procurement

STRAWMAN ASSESSMENT

LT-only & ST-only options can result in limited choices for ESO

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Freedom of choice 	 **LT only**	– Wide suite of contract options gives choice and flexibility to ESO to aid it in making most efficient decisions. – Mix of Firm & Non-firm products accommodate participation from a range of technologies with different characteristics. The ST market removes some of the availability risks faced by weather-dependent technologies, it maximise participation and choice for ESO.	– Limited stop-gap solutions in case system is exposed to changes in requirements in ST timescales. ESO must make use of today's ST tools to manage changes in requirements. – Annual (and multi-year) contracts can lock ESO into inefficient contracts – Reliance on LT contracts may inhibit commercial flexibility and freedom to optimize business revenue for providers. – Reliance on LT contracts may inhibit technical flexibility and freedom to optimize sourcing for ESO. – Incremental eligibility, excluding competition from ORPS providers within ORPD ranges when economically desirable
	 **ST only**	– Global eligibility widens participation and choice for ESO. – ST contracts neutral to technology, facilitating freedom of choice for providers and the introduction of new technologies. – Avoid locked in LT obligations, facilitating commercial flexibility and freedom to optimize business revenue for providers. – Avoid locked in LT commitments, facilitating technical flexibility and freedom to optimize sourcing for ESO.	– Daily procurement limits ESO's flexibility on how far in advance it wishes to secure provision for anticipated requirements. – Reliance on BM remains in period from DA and towards real-time if conditions change.

STRAWMAN ASSESSMENT

Combination of LT & ST markets enable wider participation, increasing the choice of provision. Multiple contract types further increase choices

Objective	Model	Strengths in facilitating objective	Shortfalls in facilitating objective
Freedom of choice 	 **ST + LT**	– Short-duration contracts in ST market avoid lock-in of inefficient contracts. – Ad-hoc market events gives ESO flexibility to choose when to procure for stability services as needs arise. – Hybrid market procurement timeframes accommodate participation from a range of technologies and their characteristics, in particular accommodating for the ever-greater levels of renewables expected in the future. Enables wider participation and pool of choice for ESO. – Existence of long-term contracts helps to mitigate single-buyer risk, making market suitable for long-term dedicated investments. – ST contracts are neutral to technology, facilitating freedom of choice for providers and the introduction of new technologies.	– Ad-hoc market events can limit ESO's choice of providers –suitable assets may miss out if timeline not compatible with ad-hoc procurement. – Reliance on BM remains in period from DA and towards real-time if conditions change.
	 **ST + LT 'complex'**	– Hybrid market procurement timeframes accommodate participation from a range of different technologies and their characteristics, in particular accommodating for the ever-greater levels of renewables expected in the future. Enables wider participation and pool of choice for ESO. – ST procurement provides a stop-gap solution in case the system is exposed to changes in requirements in ST timescales. – Wide product suite and contract types give ESO choice in meeting variable requirements at least-cost. Products also give providers' flexibility to participate, widening participation and choice for ESO.	– Annual (and multi-year) contracts can lock ESO into inefficient contracts. – Reliance on BM remains in period from DA and towards real-time if conditions change.

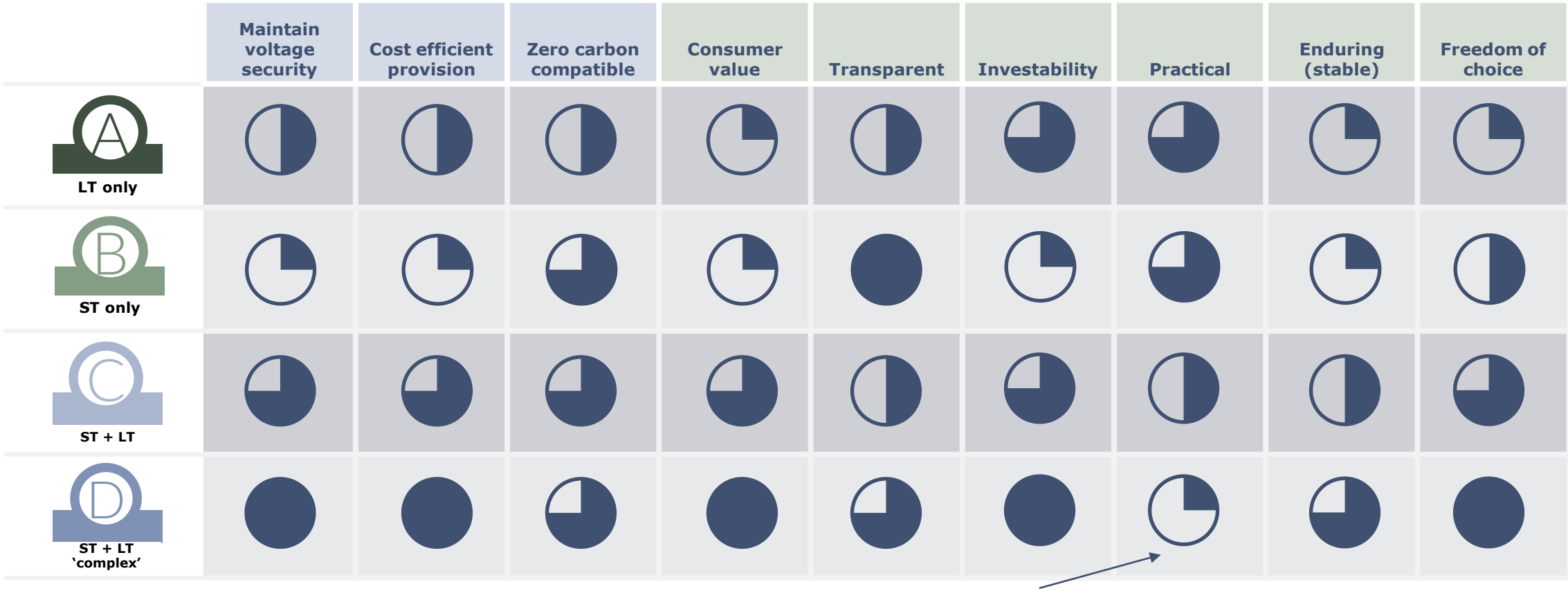
STRAWMAN ASSESSMENT

Option C and D provide ESO with a strong degree of flexibility and ongoing choice

Objective	Model	Score	Justification
Freedom of choice 	A **LT only**		✓ Opportunities for new technologies increased by range of new complex products offered × Reliance on LT contracts may inhibit commercial flexibility and freedom to optimize business revenue for providers × Reliance on LT contracts may inhibit technical flexibility and freedom to optimize sourcing for ESO × Incremental eligibility, excluding competition from ORPS providers within ORPD ranges when economically desirable
	B **ST only**		✓ ST contracts neutral to technology, facilitating freedom of choice for providers and the introduction of new technologies ✓ Avoid locked in LT obligations, facilitating commercial flexibility and freedom to optimize business revenue for providers ✓ Avoid locked in LT commitments, facilitating technical flexibility and freedom to optimize sourcing for ESO ✓ Global eligibility widens participation and choice for ESO × Not suitable for high-capex/fixed opex low marginal cost technologies (e.g. reactors) due to single buyer risk
	C **ST + LT**		✓ Existence of long-term contracts helps to mitigate single-buyer risk, making market suitable for long-term dedicated investments ✓ ST contracts neutral to technology, facilitating freedom of choice for providers and the introduction of new technologies
	D **ST + LT 'complex'**		✓ Existence of long-term contracts helps to mitigate single-buyer risk, making market suitable for long-term dedicated investments ✓ ST contracts neutral to technology, facilitating freedom of choice for providers and the introduction of new technologies ✓ Opportunities for new technologies should be enhanced with a greater range of products, though there may be complexity issues

STRAWMAN ASSESSMENT

Overall, strawman D scores highest. Reducing some of the complexity (including elements of option C) will make it more practical



Option D scores the highest but lacks practicality for both ESO and providers – conclusion is to go with a simplified version of D/more complex version of C

Stakeholder feedback

STAKEHOLDER FEEDBACK

Summary of industry engagement in key numbers

OF WEBINARS

- Webinar 1, 2 & 3: Introduction to the project; project updates; and market analysis workshop
- Webinar 4: Building blocks and design options, seeking feedback on wider design topics, followed by questionnaire
- Webinar 5: Project recap and recommendations on the market design, seeking feedback on specific design features

OF PARTICIPANTS

- Webinar 1-3: ~20
- Webinar 4: ~25
- Webinar 5: ~30

OF PARTICIPANTS VOTING

- Webinar 4: ~8
- Webinar 5: ~12
- Questionnaire: 6

OF QUESTIONS ANSWERED

- Webinar 1 Q&A: 15
- Webinar 2 Q&A: 18
- Questionnaire: 6

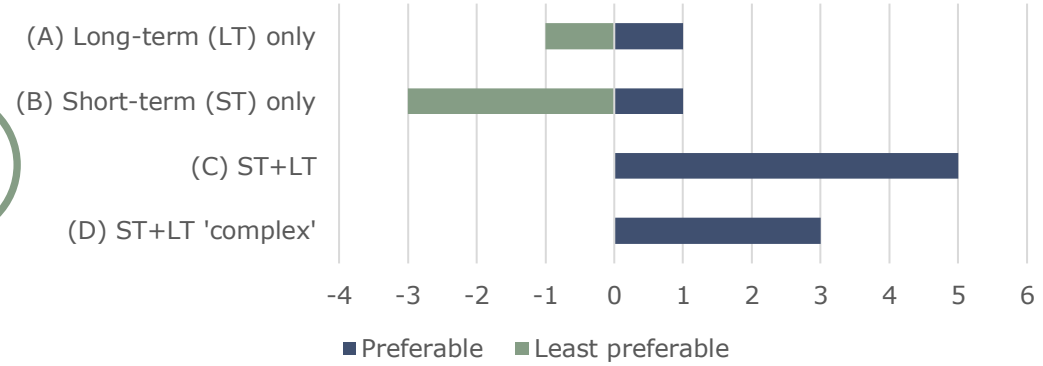
KEY BACKGROUND OF INDUSTRY PARTICIPANTS

- Energy company
- Engineering
- Network
- Energy trading
- Energy advisory
- Investment
- Software & ISVs

STAKEHOLDER FEEDBACK

Initial feedback from stakeholders indicates that a combination of short and long term market is desired. Importance of short-term market was stressed, while also being the least desirable option as a standalone solution

Q: Most and least preferable strawman option



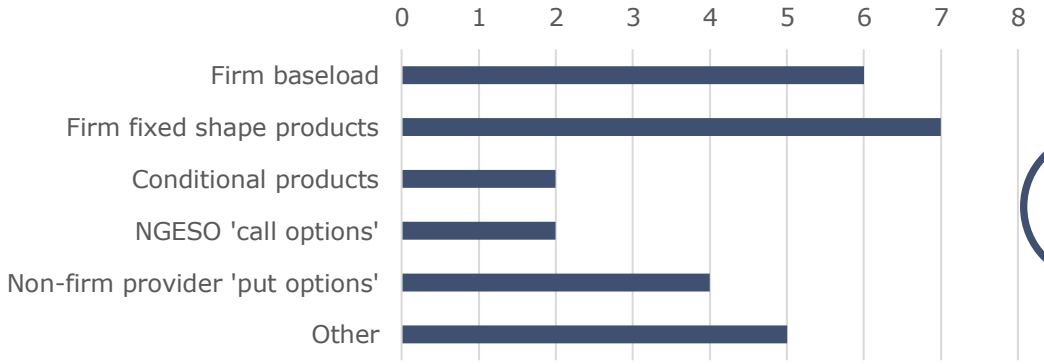
Feedback from questionnaire:
"Long-term markets have a track record of locking out emerging technologies and causing investment in technologies which don't actually perform well in the long term (they only "perform well" on market day). Continuous, short-term procurement creates the advantages of a long-term market (investment signals) without getting caught in technology traps."

Feedback from questionnaire:
"The complex market sounds like it might be too complex. But that depends on [the] details"

Feedback from questionnaire:
"Firm options provide certainty of revenues for providers and certainty of price and capability for the ESO. Other options do not provide this so might as well just fall back on short term markets …"

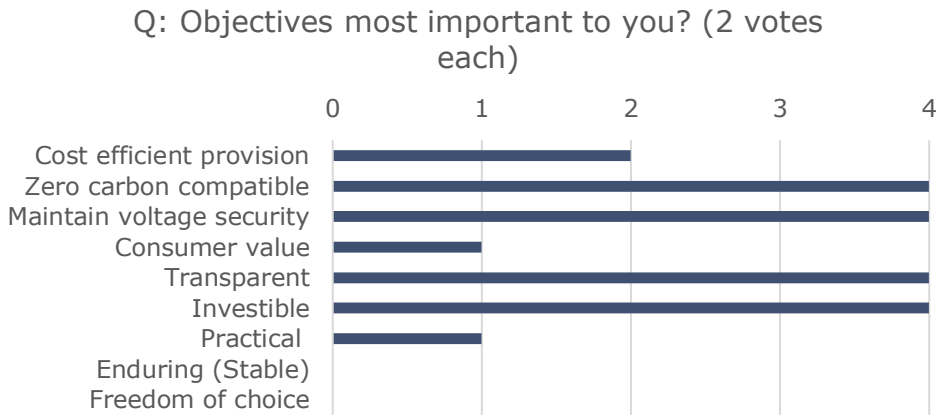
- Results indicates that Firm baseload and shaped (peak) contracts are most popular amongst participants
- Some positive feedback was receive on alternative contracts, but by some conceived as too complex and lacking firmness

Q: Most suitable contract type for long-term market?



Results from voting session during market webinar #4 on 8th December 2021 and the questionnaire sent out following the webinar

People providing feedback generally aligning with the market objectives and the contracts & timeframes for the short-term market

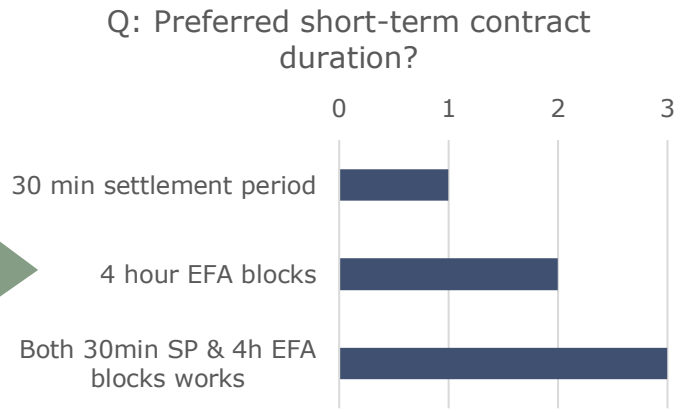


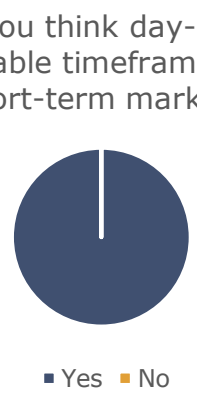
Feedback from webinar:
"Market primary objective is wrong. You aim for "cost-efficient reactive power...",but should be aiming for the most cost-efficient total system. Aiming for reactive power only tackles a symptom which leads to an unmanageable and unaffordable hotch-potch of solutions across the system; it's only by addressing the system as a whole, that the system becomes affordable, reliable, resilient and manageable."

- Webinar voting session and answers from questionnaires indicates a general consensus on the market objectives
- Comments also emphasised on "fostering new technologies" & importance of considering the system "as a whole"

4 hour EFA block is generally conceived as a viable contract for the short-term market

Feedback from questionnaire:
"Synchronous condensers need time to start up and stop - might not be practical to do every 30mins for e.g."



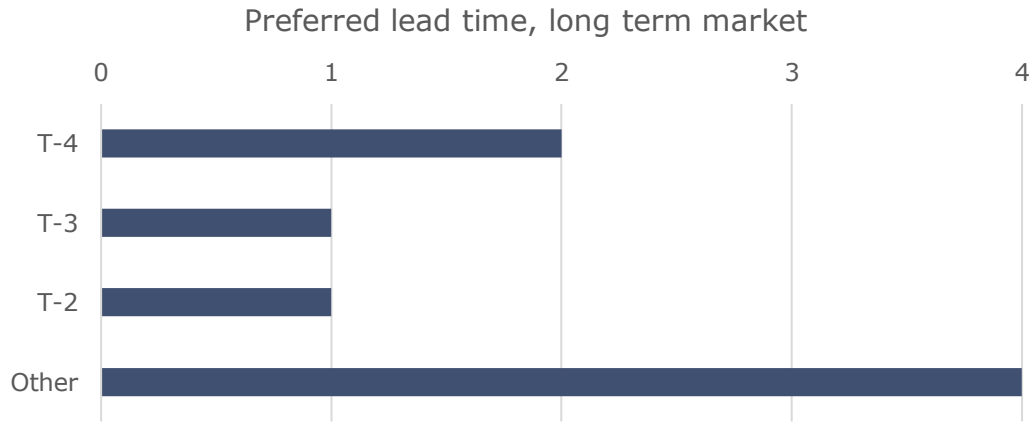


No feedback received so far indicates that day-ahead timeframe would discourage trading. As one commented: "*Most providers should be actively trading in these time-frames anyway*"

Results from voting session during market webinar #4 on 8th December 2021 and the questionnaire sent out following the webinar

STAKEHOLDER FEEDBACK

Initial feedback indicates a preference towards long lead times with contract duration of 10yrs or longer for the long-term market



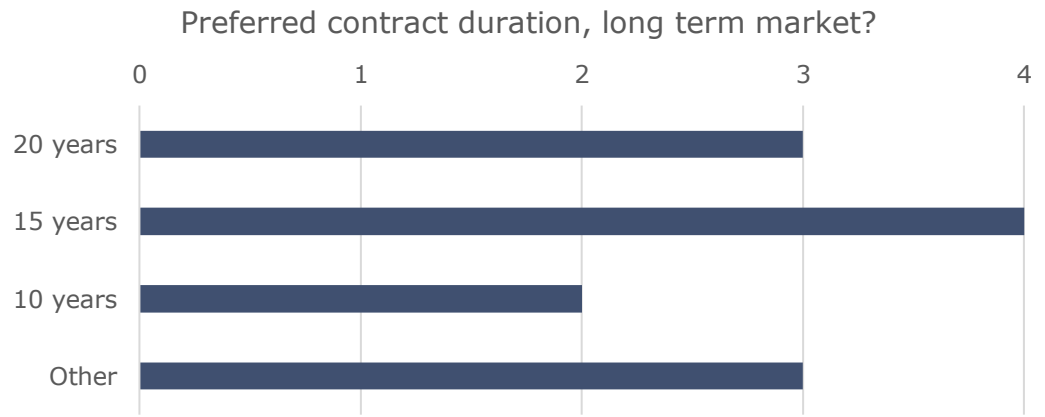
Feedback from webinar:
"Other, because many plants have longer construction and grid connection lead times"

Feedback from webinar:
"How about T-1 *and* T-4?

- Among the eight that participated in the voting, most preferred longer lead time, or a combination of long and short lead time (i.e. multiple long-term auctions)

- 15-20 year contracts most popular among the voters
- Among those selecting "other", some proposed a combination of long and shorter (e.g. 1yr) contract durations

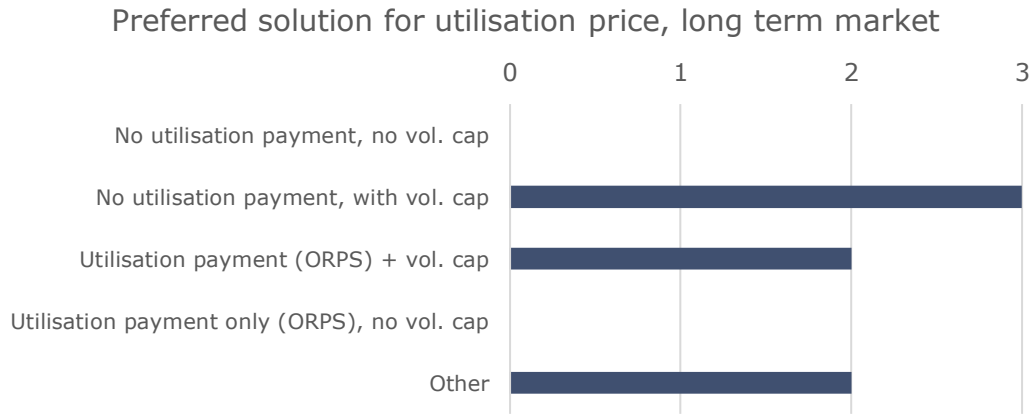
Feedback from webinar:
"Long-duration contracts for new build plants only. Contract duration correlates with amortisation life, so the longer the duration, the lower the cost of the services - with lead time to delivery of the services as long as is necessary to build and connect to the grid. Medium duration for major refurbs or new build. Short duration for anyone to bid - at short lead time to delivery of the service.



Results from voting session during market webinar #5 on 17th February 2022 and the questionnaire sent out following the webinar #4. Results have been summarised where questions were the same

STAKEHOLDER FEEDBACK

There was little consensus on utilisation payment other than it should contain a volume cap. Most thought availability requirement should be 90% or lower.



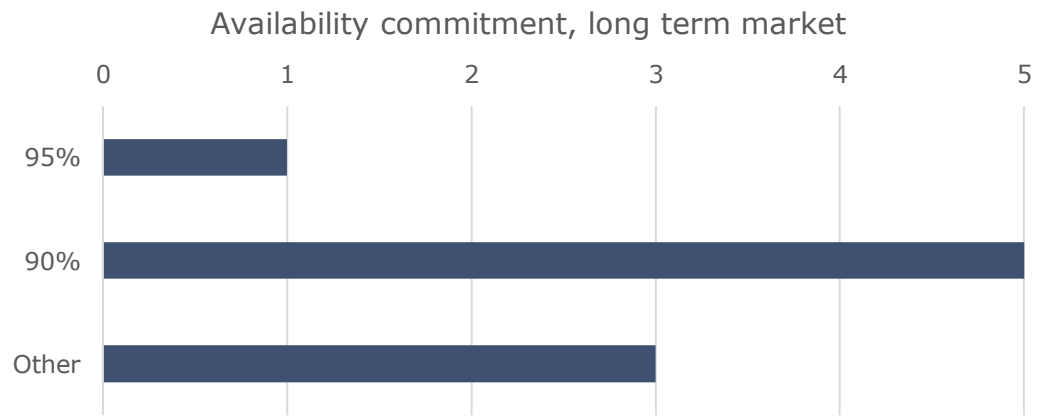
- Voting results gave little steer on preferred utilisation payment mechanism, other than indicating that a volume cap is preferred
- Some form of remuneration of utilisation is needed (as commented by one participant), but alternatively this cost can be factored into the availability price

Feedback from webinar:
"Utilisation payment is needed because flexing the amount delivered will require costs. Availability needed because of reservation, and capex"

Feedback from webinar:
"I think it's impossible to give such a high % commitment this far out

Feedback from webinar:
"Should have a lower threshold but use the availability that each technology quotes as one of the judgement criteria for awarding the contract"

- Indications that participants prefer lower availability requirements for long-term contracts



Results from voting session during market webinar #5 on 17th February 2022 and the questionnaire sent out following the webinar #4

Agenda

RECOMMENDED MARKET DESIGN

A combination of option C & D has been identified as the desired solution

- The assessment work and continued dialogue with ESO experts and other stakeholders has delivered a recommended market framework designed to meet the challenges faced by both the ESO and providers
- The recommended 'Option E' builds further on design strawmen options C and D
- Some design features has been changed in the process, and the recommendation includes an extended overview with additional design elements
- In addition to describing the end-to-end market design, this chapter provides further explanation of the rationale behind some of the key design choices

Preferred option

E

RECOMMENDED MARKET DESIGN

	Long-term market	Year-ahead	Short-term market	Description / rationale
Products	– Pre-fault injection – Pre-fault absorption – Post-fault injection – Post-fault absorption			4 products in both markets : – Pre and post fault – Absorption and injection
Product linking	Option to submit mutually exclusive bids or bundled bids for a combination of products[1]			Participants can link products and make their offers mutually exclusive. Applicable for technologies capable of providing both injection and absorption, pre and post fault.
Contract type	Baseload availability [+ Potential for Fixed shape/peak window products][1]	Same as Long-term market	4 hour EFA blocks	Fixed shape/peak considered in the future. ESO preference for short-term market is EFA blocks initially, in line with initial provider feedback.
Locational Requirement	Nodal			Requirements are calculated and communicated per node.
Procurement strategy	Shortfall + Opportunistic			ESO buys (expected) shortfall plus additional capability if economically efficient
Provider Eligibility	Incremental *investment* only (additionality criteria, e.g. new build assets, existing assets making material investments to unlock additional MVAr)[1]	Incremental *capability* only[1]	Global selective: All providers are eligible. However, NGESO discretion for awarding contracts	**Incremental investment:** Capability which doesn't already exist and requires material investment to be accessible **Incremental capability:** e.g. ORPS providers outside of MSA ranges, existing non-ORPS providers, closing assets **Global selective:** NGESO procure if economically efficient to do so. All providers are eligible incl. existing ORPS providers in MSA ranges

[1]Further investigation merited

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RECOMMENDED MARKET DESIGN

Preferred option E

	Long-term market	Year-ahead	Short-term market	Description / rationale
Frequency of procurement	National annual procurement	National annual procurement	National daily procurement for next day (D-1)	Annual basis for long term, buying the shortfall and/or opportunistic buying (if no shortfall, opportunistic buying can still occur). ST market has the same logic but broader eligibility.
Lead Time	T-4[1]	T-1[1]	D-1 (post-exchange)	Sufficient lead time for asset deployment, closure decisions, and operational decisions across the three time frames.
Product duration	15 year[1]	1 year	4 hour EFA blocks	Aligns with other long-term contracts (CM, CfD) for the long-term market. EFA blocks sufficient granularity based on ESO experience & in line with provider feedback
Payment structure	**Availability** £/MVAr/SP availability payment	**Availability** £/MVAr/SP availability payment	**Availability + utilisation** – £/MVAr/SP availability payment – £/MVAr/SP utilisation via ORPS payment mechanism	**Long term** market mainly targeting high-capex & low variable cost. **Short term** market targeting high availability & variable cost or low availability & variable cost providers.
Clearing principles	Pay-as-bid			Due to nodal nature of requirement and bundled products (multi-clearing price impractical)
Price control	– TO owned asset solution depreciated over [15y] horizon for new build[1] – Forecasted short term cost for opportunistic procurement	Forecasted cost of meeting need in subsequent timeframes for opportunistic procurement, [price cap TBC][2]	Real-time alternative cost forecast (cost of meeting demand in balancing timeframes)	One tool to mitigate potential manifestation of market power given nature of reactive needs

[1] Further investigation merited
[2]Existing procurement routes remain open to ESO to solve specific challenges outside of reactive specific market arrangements if necessary

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Preferred option E

	Long-term market	Year-ahead	Short-term market	Description / rationale
Availability requirement	High [95%][1]	High [95%][1]	100%	Failing to deliver (declared) availability/utilisation results in facing non-performance process
Non-performance process	Penalties: Non-payment, becoming more 'penal' below availability requirement (similar to current pathfinder approach)		Firm 'penalty' for non-delivery of declared availability (beyond non-payment [strong fixed penalty agreed price * X or agreed price + X])[1]	Strong incentives to 'show up' due to criticality of need. Simple to start with. Desirable end state may be to expose participants to replacement costs (akin to imbalance), depending on time frame.
Effectiveness factor	– Effectiveness factor defined individually per node for each demand node – Fixed at point of contracting for the whole contract duration		– Effectiveness factor defined individually per node for each point of need – Dynamic, i.e. changing frequently, to reflect changes towards reference node	Effectiveness determined for both pre- and post-fault products. Effectiveness factors subject to change with changing network topology. Effectiveness factor in any market timeframe is the blended effectiveness factor over the periods in relevant contract duration.

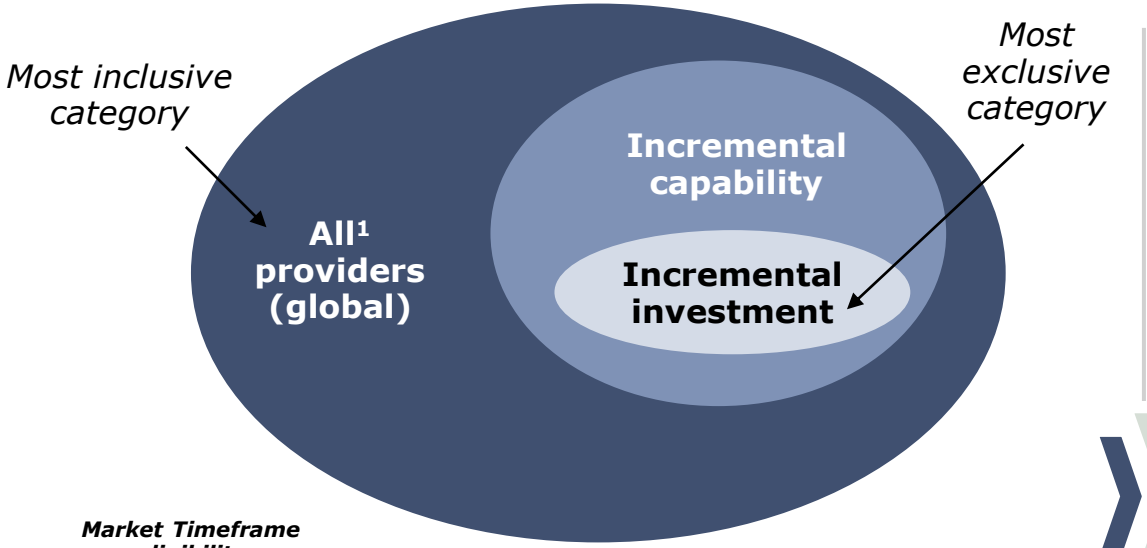
[1]Further investigation merited

RECOMMENDED MARKET DESIGN

Rationale behind eligibility, market timeframes and contract types

Preferred option E

Due to the nature of arrangements (pay-as-bid, locational, overlapping obligations) we propose 3 categories of eligibility for our preferred option



Market Timeframe eligibility

Long term T-4	Incremental *investment* only (similar to CM, investment threshold test)
Year ahead T-1	Incremental *capability*, including ORPS providers outside of MSA ranges, existing providers with no MSA in place, closing assets
Short term	All[1] providers including ORPS providers in Mandatory Service Agreement (MSA) ranges

Justification of eligibility exclusions

Long term T-4	– This process is for long term contracts, supporting *incremental investment* in new assets – Opportunistic procurement is possible, if a new investment would be cheaper than the alternative – Inclusion of existing assets would complicate the process and cloud transparency
Year ahead T-1	– This process is closer to delivery than the T-4 round, and NGESO's views of capabilities and needs will be more refined – This is an opportunity for providers with firm availability to monetise *incremental capability* from existing assets, including capability not available under the grid code and also assets which would otherwise be expected to close.
Short term	– This is a final procurement round after the D-1 energy market and interconnector nominations, which allows otherwise uncontracted providers to offer availability to NGESO. – Bids will be accepted if they are needed to meet any remaining shortfall and if they are cheaper than the alternative (including the possibility of activation in the BM).

Notes: [1]All categories exclude providers that already have long term *firm* commitments/contracts to prevent double payment (e.g. Pathfinder contract holders, TO assets in RAB)

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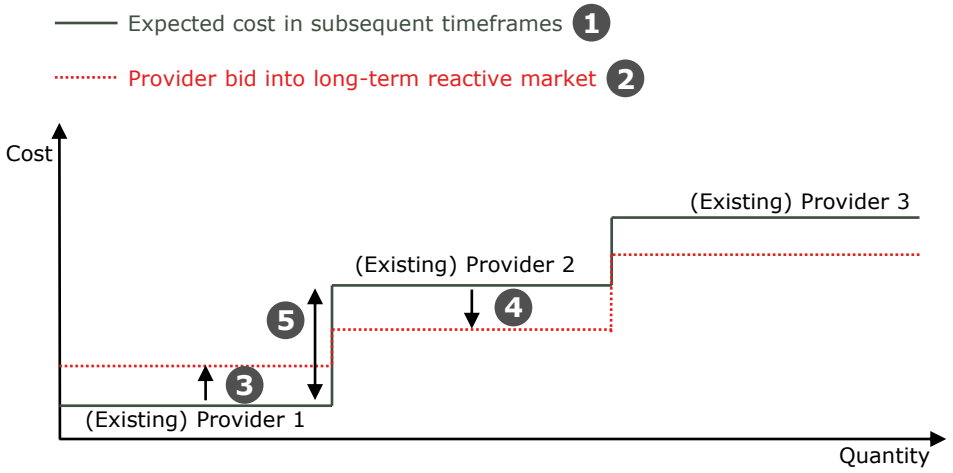
Preferred option E

Including existing providers in LT (T-4) would lead to unacceptable balance of risk for consumers, and process would be non-transparent for providers

Stylised example – if global eligibility were permitted in long term market (with opportunistic buying for pay-as-bid market)



1. Cost of procuring in subsequent timeframes must be established **for each provider** over 15 year period
2. Provider bids into long term market with guaranteed availability price (forgoes ORPS payments)
3. Provider 1 offers less competitive price than expected – consequently reject bid
4. Provider 2 offers more competitive price than expected costs – consequently accept bid
5. Relativity of providers bids irrelevant, willingness to pay based on **individual unit long-term forecasts**

Conclusion: Long term (15y) cost (& dispatch) forecast uncertainty too high on an *individual unit level*, balance of risk unacceptable for consumers and process would be non-transparent for providers – include existing asset closer to real time (T-1 for incremental, ST market for all)

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Preferred option E

Our proposed solution has selective eligibility across timeframes due to issues with forecast error, transparency, and practicality

Eligible **Ineligible**

	Long term (T-4)	**Long term (T-1)**	**Short term (day-ahead)**
Incremental investment	Can be easily identified as providing additionality to ensure security. Buy curve can be established for opportunistic approach based on marginal unit cost displacement	Assets that can deploy quickly should not be excluded from the arrangement	Unlikely to pursue this approach, but providers should be allowed to access short-term market if they don't wish to make long term commitments
Incremental capability	Unclear how to define closing plants with a high level of accuracy, opportunities for other incremental providers in later timeframes	Offers an opportunity for closing providers, or providers who may not be available in subsequent timeframes. Buy curve can be established for opportunistic approach based on marginal unit cost displacement	Providers with a high opportunity cost, variable cost, or low availability certainty for access to additional capability given a route to market when MW positions and costs are more certain
All	Appetite to pay on individual unit basis in pay-as-bid, multi-timeframe market. Impossible to establish universal buy curve for existing providers. High level of forecast uncertainty for units available in subsequent timeframes	Appetite to pay on individual unit basis in pay-as-bid, multi-timeframe market. Impossible to establish universal buy curve for existing providers. High level of forecast uncertainty for units available in subsequent timeframes	Higher degree of certainty on individual unit level costs, precedent exists for procuring existing providers if discount to real time solution in the interest of consumers

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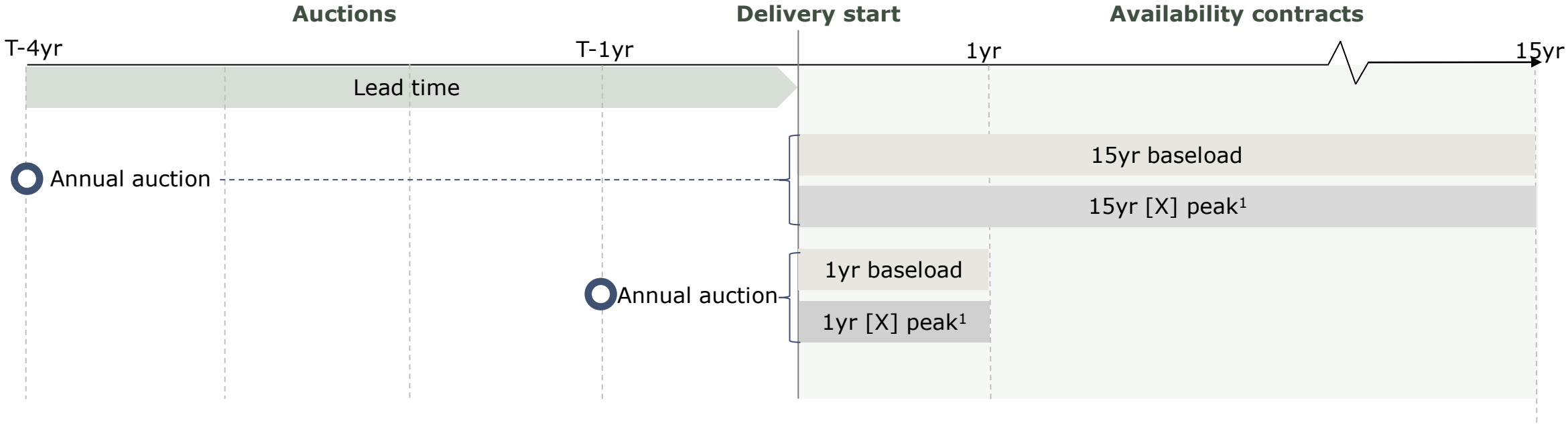
Preferred option E

Lead time and contract duration for LT market depends on several aspects, such as lead time for building new assets and forecast accuracy

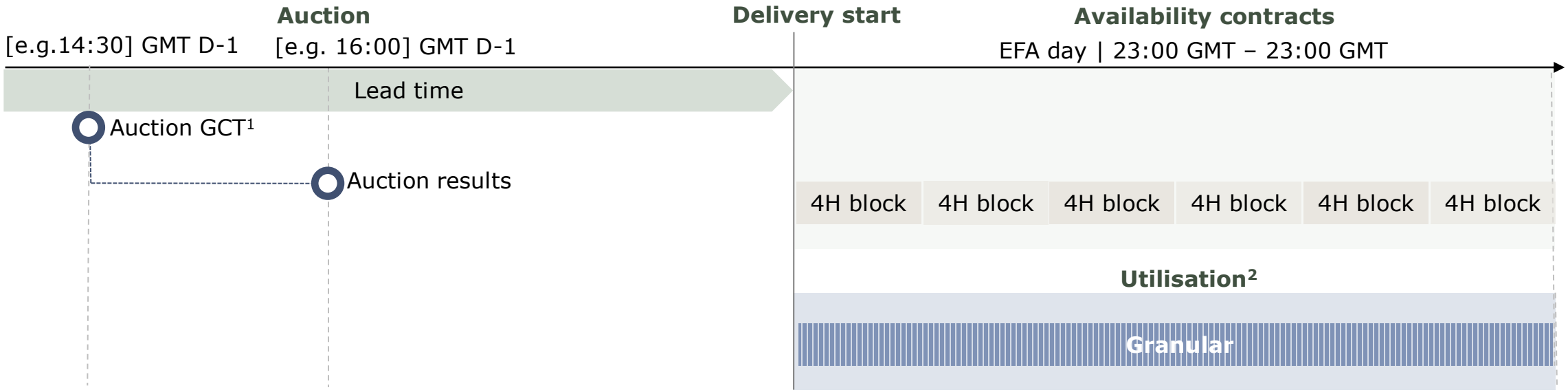


Lead time	– To minimise forecast errors, the ideal time of an auction is as close to delivery as possible – However, to allow potential new build assets to offer availability, market lead time must reflect lead time of building new assets (3yr or more) – As a compromise, it is an option to have a second auction closer to delivery. The intention is to remove barriers to entry for technologies that relies on business decisions being made closer to delivery such as closure decisions.
Contract duration	– Contract duration impacts investment decisions for potential providers, and cost correlates with amortisation life of new build assets. Longer contracts allow for lower cost per year as the capital cost is spread further. – Shorter contract period can create blockers to market for new builds as total amortisation is spread over too short time period – Shorter contracts gives better forecast accuracy as ESO has a better view of its requirements, the alternative providers and their costs

[1]Fixed shape/peak contracts initially excluded but recommended as an option to be considered in the future.

Preferred option E

Short-term auction should be run daily, with contracts that sufficiently meet the need for procuring day-shapes without making market overly complex



Lead time	– To minimise forecast errors, the ideal time of a ST auction is as close to delivery as possible, while avoiding operating out of office hours – Availability should be procured prior to the intraday timeframe to allow NGESO to plan ahead of the BM timeframe – To allow providers to bid according to their power plans, auction should run after GB DA power auction and IC results have been published
Contract duration	– 4h block contracts allows NGESO to reduce over-procurement, compared to day-base contracts, as they can limit the procurement to only cover periods with a forecasted need – In theory, the market should seek to offer as short contracts as possible, to limit over-procurement and allow greater degree of flexibility for weather-dependent variable RES. However, shorter contracts than 4h EFA blocks are deemed impractical by ESO control room – 30min contract periods impractical for technologies with slow ramp rate, giving insufficient time to ramp up/down

[1]Gate Closing Time (GCT) is the deadline for submitting orders. | [2]Dispatch instructions should not be constrained by timeframe and are defined in the product technical specification, metering requirements and compliance will need to in line with technical obligation

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Preferred option

We have recommended two contract types, with an additional option for future development. Other presented alternatives were discarded to limit market complexity

		Availability	Description	Objective	Targeted segments
Long-term	**Year baseload**	24/7, 365 days of the year	– Provider commits to firm availability with a high expectation of reliability throughout the contract period – Product duration e.g. 15 year baseload	– Meet additional baseload need that *can* be forecast	– Firm capacity with lowest cost of providing availability
	Fixed shape*	24/7, all days of the contract period	– Provider commits to firm availability with a high expectation of reliability throughout the contract period – Product duration e.g. seasonal or daily-peak	– Meet shaped (peak) needs that *can* be forecast	– Firm capacity with medium cost of providing availability
Short term	**4H EFA block**	4 hours	– Firm contracts with short procurement lead time [day-ahead] – 4-hour EFA blocks allows NGESO to shape their demand, without the complexity of the 30min contracts. More economic and practical for providers. – An EFA day runs from 23:00 GMT – 23:00 GMT.	– Meet short term needs, accurately, in any direction – Procure daily shape that can be forecast day-ahead	– Firm capacity with lowest cost of providing availability – Rout to market for variable RES providers – Technologies where switching on/off on a 30min basis is uneconomic

*** Fixed shape (peak contracts**) are recommended as an option to be considered in the future, but to minimise complexity in the implementation phase we recommend to defer, and re-appraise once market has matured.

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RECOMMENDED MARKET DESIGN

Appraisal of design option E against market objectives

APPRAISAL OPTION E

LT timeframe facilitates incremental capacity filling gap between capacity and future requirement, while ST enables optimising existing capability – ensuring sufficient reactive power availability in the operating window

Primary objective	Strengths in facilitating objective	Shortfalls in facilitating objective
Maintain voltage security 	– Long-term timeframes means that ESO is able to ensure system security by giving participants a higher degree of certainty in making investment decisions. In effect, it ensures capacity is in place to meet forecasted requirements – ST market provides a stop-gap solution in case conditions change – All providers are eligible for participation and remuneration under both LT & ST arrangement – Provides revenue/volume signalling to existing providers (who may otherwise decide to decommission) to remain open – Systematic and recurring LT market obliges ESO to make forecasting, requirement determinations. This acts to ensure a higher degree of certainty for market providers and forecasting in requirements. – ST and year-ahead market mitigates exposure to forecasting errors – Incremental eligibility in the long-term market ensures new capability is made available to the ESO	Not securing all needs in advance leaves some uncertainty

APPRAISAL OPTION E

Proposed market aims to limit over-procurement while mitigating extreme pricing close to real-time. ST market provides route to market for providers unable to make LT firm commitments

Primary objective	Strengths in facilitating objective	Shortfalls in facilitating objective
Cost efficient provision 	– The combination of ST & LT procurement work to balance over & under-procurement. ESO is flexible to procure its desired opportunistic volume from the LT & ST market timeframes – Year-ahead market offers an opportunity to procure capability from providers with 'incremental capability', e.g. assets considering closure – Close to real-time procurement under the ST market is accurate, mitigating over/under-procurement particularly if requirements are variable and volatile – LT+ST market mitigate scarcity & extreme pricing close to real-time	– Choice between a complex or simple contract suite is a trade-off between cost efficiency and simplicity. The recommended baseload (LT) and 4h EFA block (ST) is simple and transparent but provide less flexibility for ESO in meeting requirements at least-cost.
Zero carbon compatible 	– ST market lowers barriers to entry for clean generation. The short lead time of the procurement offsets the majority of the availability risk for weather-dependent (RES) providers – Hybrid timeframe enables choice, limiting potential lock-in with sub-optimal carbon-emitting providers in LT timeframes and mitigating ST shortage/reliance on sub-optimal carbon alternatives in real time (e.g. through the BM) – Multi-year agreements tied to provider's characteristics, including emissions limit criteria	– No obligation to provide zero-carbon solutions, albeit solution theoretically compatible

APPRAISAL OPTION E

Three timeframes incentivise wider participation and competition, where LT market ensure investability. Simplified, recurring auctions give transparency

Primary objective	Strengths in facilitating objective	Shortfalls in facilitating objective
Consumer value 	– A mix of Incremental & Global selective eligibility over three timeframes incentivise wider participation and competition. LT procurement operates in investment timeframes and enables new capability, if required. The ST arrangements reduce availability risk compared to a LT procurement for intermittent providers.	– Lack of competition in some localities may result in high prices (or need for mitigation of market power)
Transparent 	– Using one methodology signalling needs and nodal effectiveness in a consistent way allows market participants to understand their costs of service provision to the greatest degree possible – Recurring and systematic procurement makes services predictable and can inherently make the market arrangement more transparent for market providers which are able to plan and build project pipelines accordingly – Limiting number of contract types simplifies services and helps facilitating transparency	– Geographic fragmentation and pay-as-bid basis can make requirements and pricing difficult to communicate – Likely existence of localised market power constrains transparency
Investible 	– Long contracts & lead time incentivise investment for providers who can commit in advance and require revenue certainty (e.g. high capex) with LT firm procurement. Forward market for availability reduces price and volume risk. Longer contracts could significantly reduce risk for merchant investors. – ST market incentivises investment for providers who cannot commit in advance (by removing the availability risks present in forward procurement) but require "some" revenue certainty	– Investors face tough choices as to whether participation in a market will yield returns sufficient to cover investment costs and provide an adequate rate of return to meet cost of capital thresholds (hurdle rates). – Immature/new market with no track-record. It may be difficult to give enough confidence to investors to participate in these arrangements initially.

APPRAISAL OPTION E

Option E provides a framework that ensures consistency, supporting a practical and enduring solution over time

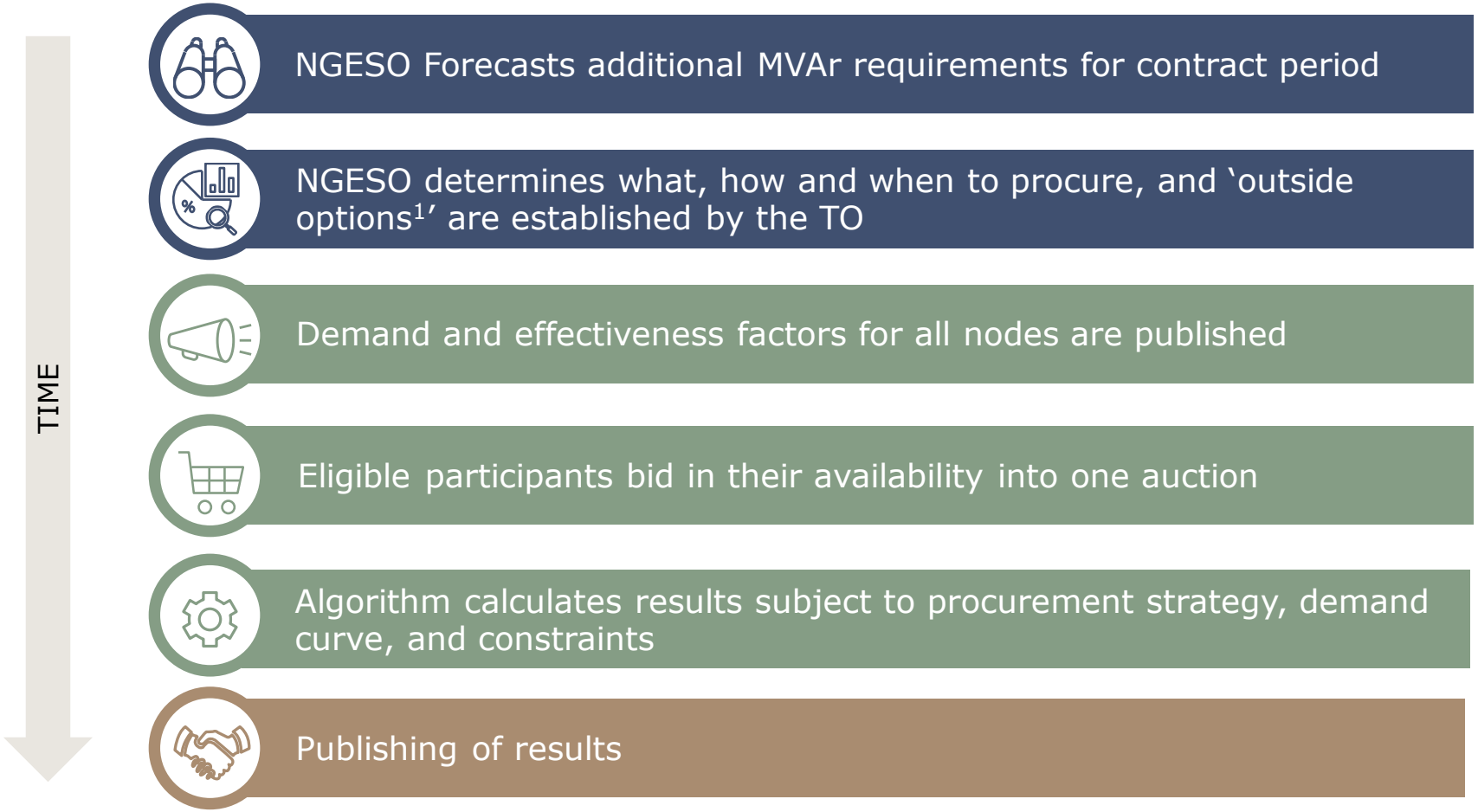
Primary objective	Strengths in facilitating objective	Shortfalls in facilitating objective
Practical 	– Recurring and consistent LT and ST markets allows for optimising and automating processes, eventually making arrangements more practical in the long run – Simplified LT baseload contract easier to manage compared with option D – Procurement through single platform across the UK facilitating optimisation – Building on existing arrangements and learnings from the Pathfinder process to ensure complexity can be managed	– Facilitating and managing multiple market timeframes is more resource-intensive than ST-only and LT-only – Short-term market requires participants to run daily operations – There is an interaction between reactive power products and other products (e.g. inertia and response) and co-optimisation of these products could make the solution more practical for participants
Enduring (stable) 	– Combination of LT & ST market accommodate technologies with different characteristics, in particular ST market accommodating the ever-greater levels of renewables expected in the future – Recurring procurement nature of LT + ST market provide an enduring LT vision for market participants (a LT vision compatible with typical lifetime of assets). Offers a degree of price and volume certainty for potential participants	– Potential uncertainty regarding the split between LT and ST procurement
Freedom of choice 	– Hybrid market procurement timeframes accommodate different technologies and their characteristics, in particular accommodating technologies unable to make LT commitments. Enables wider participation and pool of choice for ESO – ST contracts neutral to technology, facilitating freedom of choice for providers and the introduction of new technologies	– Opportunities for new technologies could be enhanced with a greater range of contracts, though there may be complexity issues related to introducing more contract types

RECOMMENDED MARKET DESIGN

High-level overview of the market processes

MARKET PROCESS

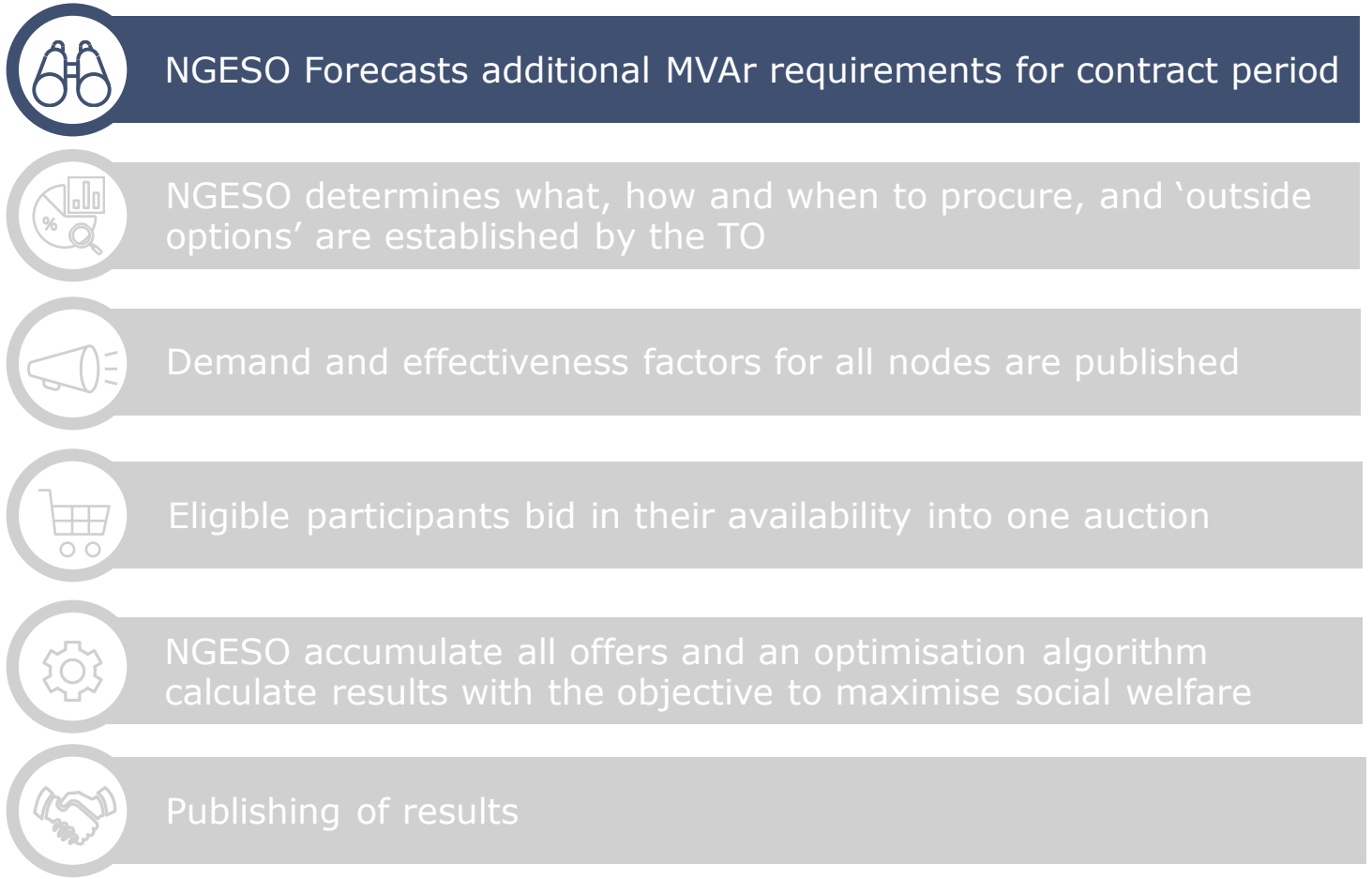
The proposed market process consists of 6 main stages for both long- and short-term markets, each run for GB as a whole



[1]Outside options refers to alternative TO assets which can replace providers if more economic to do so

MARKET PROCESS

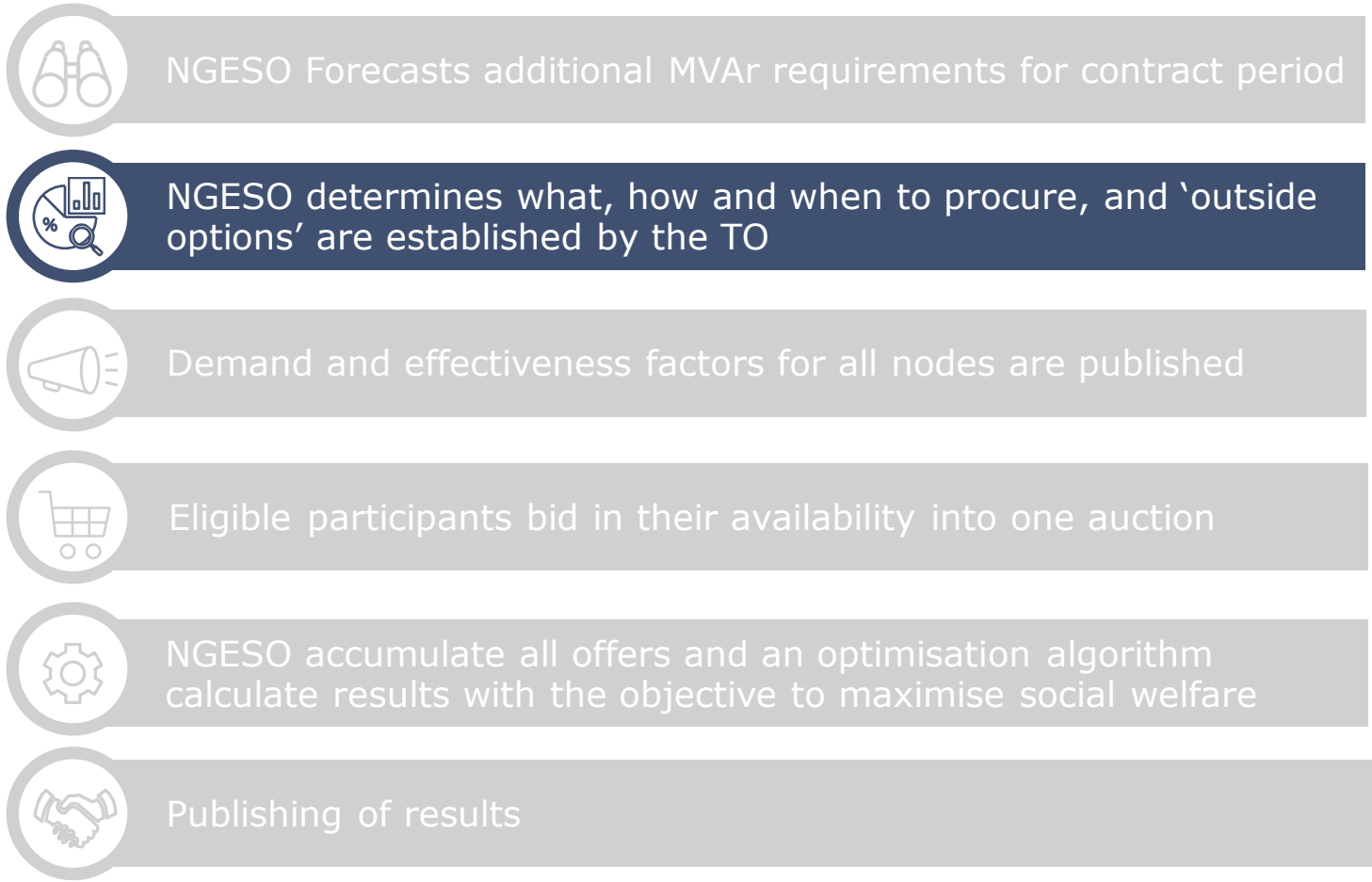
Long term market process



- Economic dispatch and load flow analysis are run together to forecast demand for additional reactive power
- The methodology defines nodal MVAr availability requirements; node-to-node effectiveness; and specific provider-to-node effectiveness for all four products
- For the long-term markets, the assessment of the forecast demand for additional reactive power availability will be run annual, potentially leading to no new need, and therefore no new long-term procurement
- The methodology enables a consistent way to identify and meet needs in a cost-efficient way, and enables a repeatable way to produce market signals

MARKET PROCESS

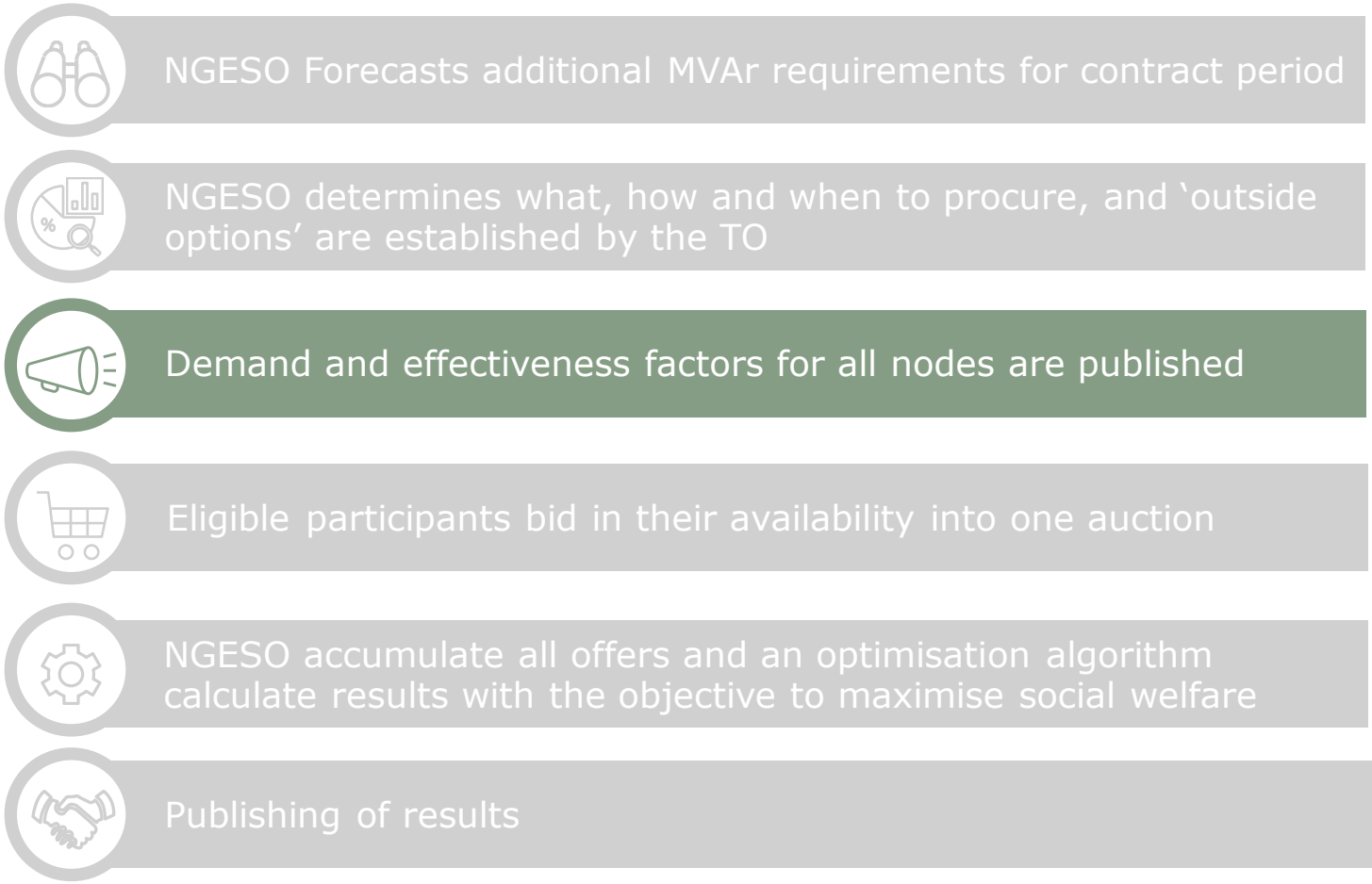
Long term market process



- NGESO is ultimately hedging price and volume risk, and procurement decisions should be based on a predefined **procurement strategy**[1]
- The long-term market must ensure there is sufficient (available) capacity as operational timeframes approach
- Priority is to procure shortfall (gap between existing and additional future capability), i.e. 'must buy'
- Once shortfall has been met, ESO may wish to procure additional volumes in the long-term markets if it expects a discount relative to procuring it closer to delivery, i.e. 'opportunistic buy'
- If multiple contracts (e.g. baseload & peak) for same delivery timeframe is used, a minimum volume to be procured by each must be established

[1]Procurement strategy is covered in details in the following chapter

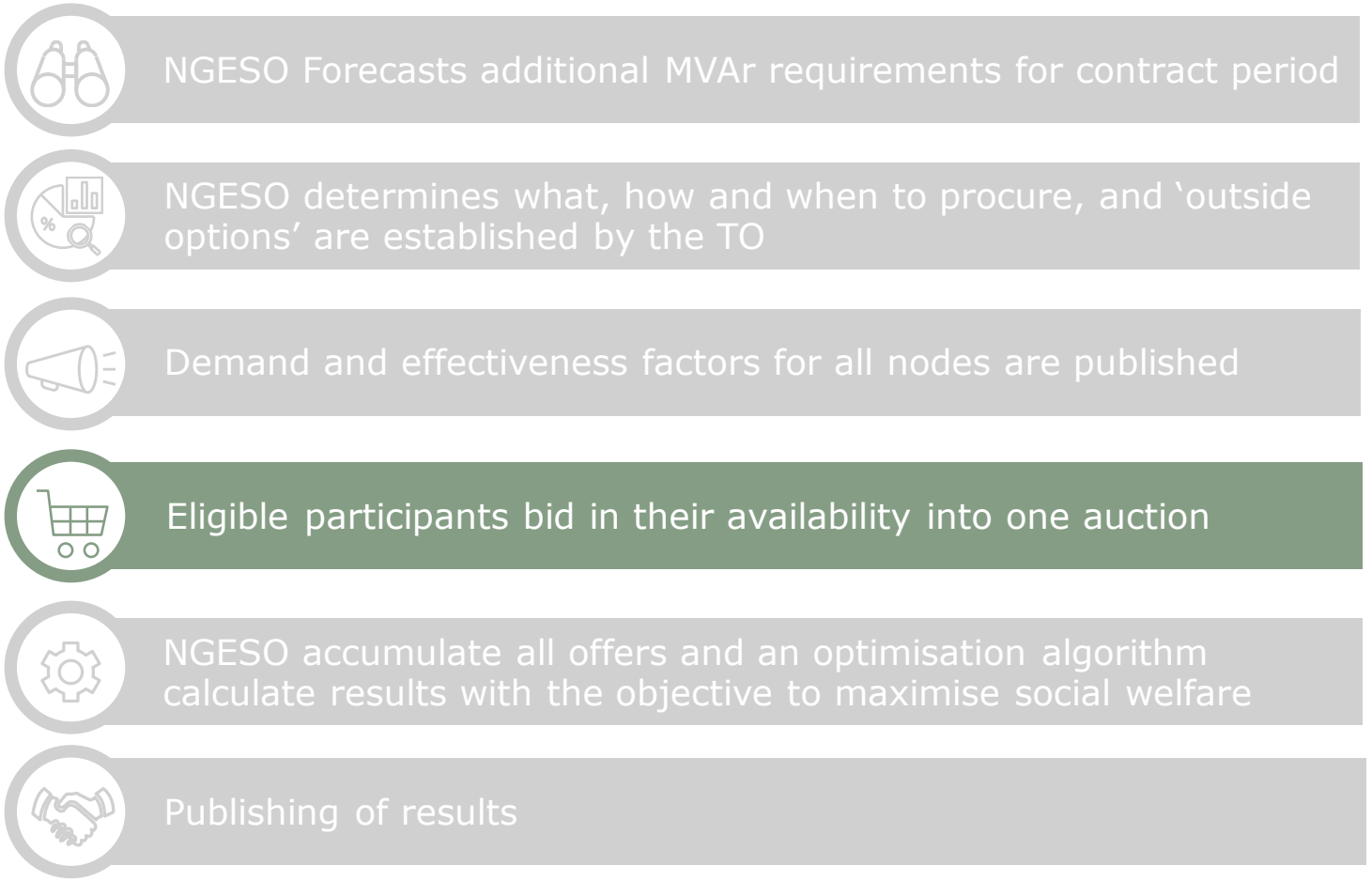
Long term market process



- The above two steps will produce a list of demand nodes with MVAr requirements, including a node-to-node effectiveness matrix covering every supply node with a reasonable effectiveness factor towards any of the demand nodes
- The data should give sufficient basis for making investment decisions
- Market needs should be signalled in a consistent and repeatable way, giving participants predictability
- The information should be presented in a meaningful way that gives potential market participants the ability to access all information in a simple way, and to drill down into key data of interest

[1]Procurement strategy is covered in details in the following chapter

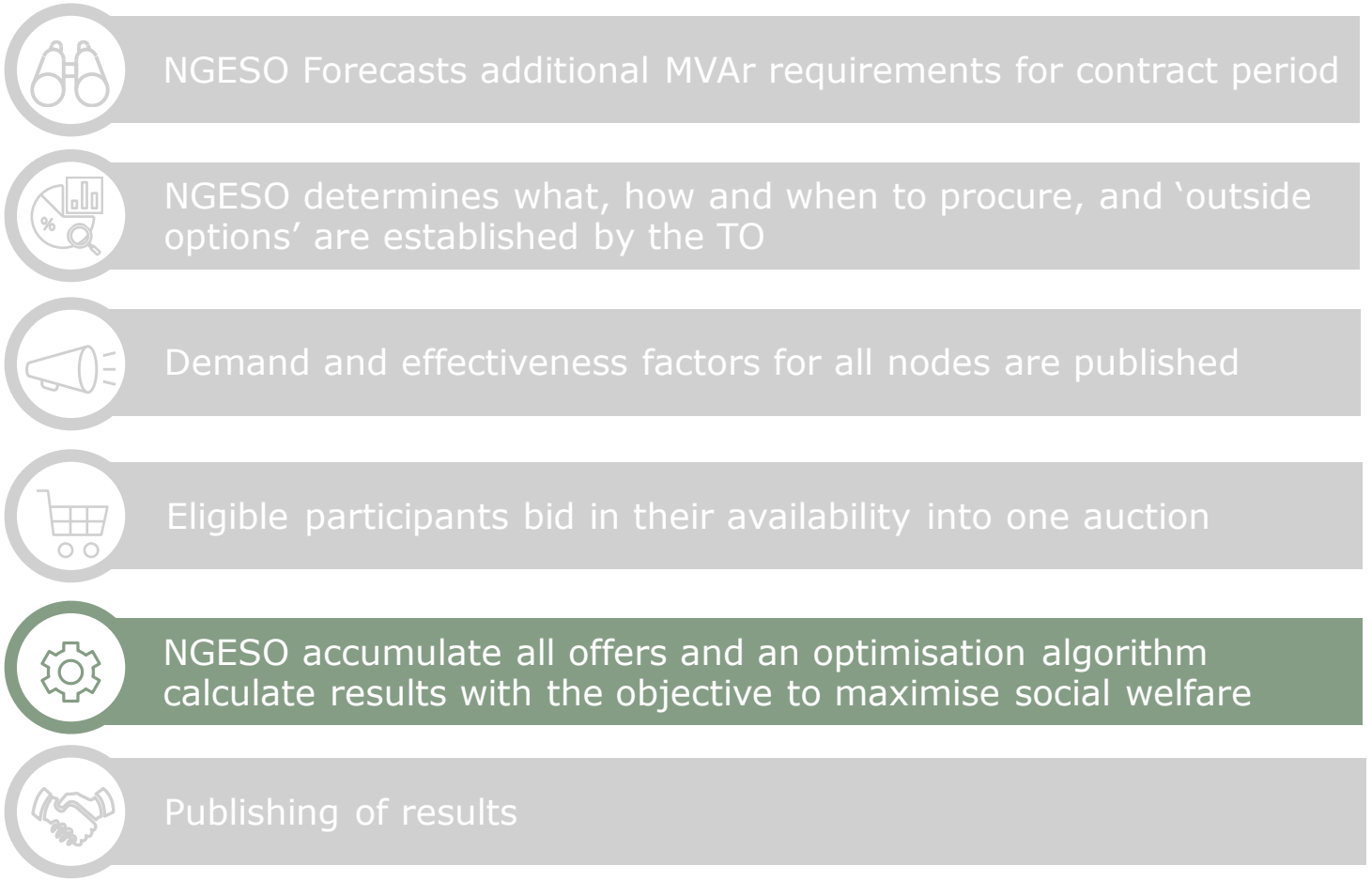
Long term market process



- We focus on a simple one-shot auction, where bidders submit bids just once
- Bids are made at the unit level and have a defined location. Each bid is defined by a quantity and a bid amount (£/MVAr/SP of availability). Each plant can make multiple, mutually exclusive bids at different quantities
- Pay-as-bid rule poses a challenge to bidders, who will need to determine what bid amount to choose in a way that maximises their expected surplus trading off the probability of winning against the price paid. Therefore, bidders will need to form expectations of the extent of competition they face in order to decide how to bid
- Outstanding item: Auction time schedule – to be decided in the next phase

[1]Procurement strategy is covered in details in the following chapter

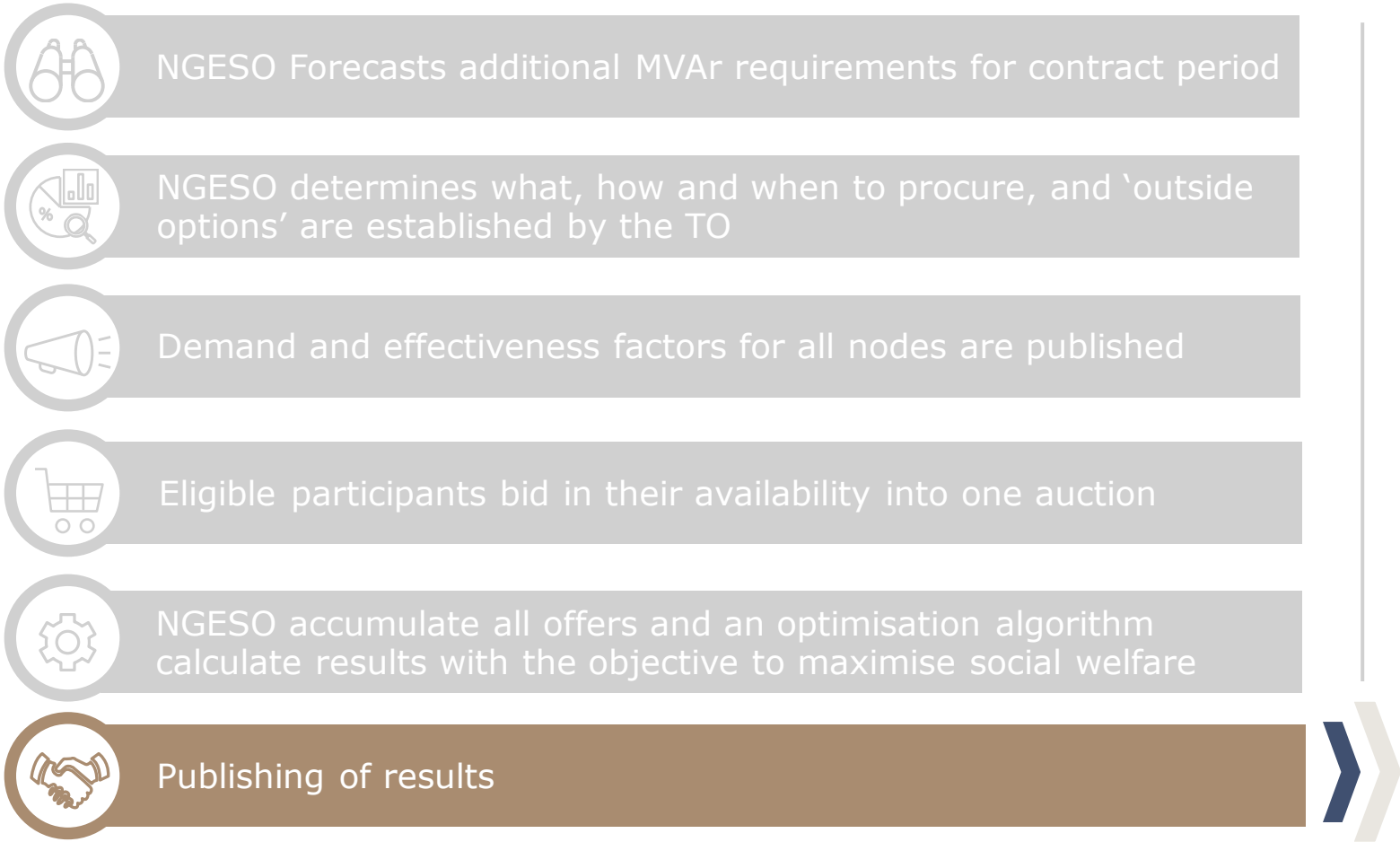
Long term market process



- The main objective of the clearing algorithm is to maximise overall social welfare. In practice, this reduces to a cost minimisation problem subject to constraints. However, cost minimisation is not 'narrow' but needs to include any flexibility in requirements and 'outside options' available to the SO if bids are not accepted
- Bids are processed to determine winning bids and payments to winners
- Under the 'pay-as-bid' rule, winning bidders are paid the amount of their winning bids (subject to delivering the contracted availability). Bid amounts determine the price that bidders are paid for supplying the quantity in their bid. The higher the bid amount, the higher the price the bidder gets *if it wins*
- Bids are tested against the 'outside option', i.e. TO alternative, and are rejected if costs are higher than the alternative

[1]Procurement strategy is covered in details in the following chapter

Long term market process



The clearing algorithm should return the following results for all contracts:

- matched bid including procured volume
- prices for all successful bids (pay-as-bid currently envisaged)
- Procurement at each node

Some derived data may need to be calculated and made available to enhance transparency, for example indicators of market value of the service at different location.

[1]Procurement strategy is covered in details in the following chapter

Communicating market needs in a sensible way requires simplification and should focus on what participants are interested in seeing

	Long term:	Short term:	Comment
What is minimum required information?	For every node with demand: • Selected desired contract types and contract period • Minimum required need for each contract type for every product expressed as MVAr/h • Effectiveness factors (EF) for nodes with EF beyond [20%][1] towards demand node • Physical constraints on relevant nodes[2] such as max technical capacity	For every node with demand: • Minimum required need for every 4h EFA block for each product for next day expressed as MVAr/h • Effectiveness factors (EF) for nodes with EF beyond [20%][1] towards demand node • Physical constraints on relevant nodes[2] such as max technical capacity	The information should be publicly available in a standardised format.
What are participants interested in seeing?	• Minimum requirements for nodes in areas where they want to conduct business • Effectiveness factors for nodes where they have or potentially will build new MVAr capacity	• Minimum requirements and constraints for nodes where they have capacity to deliver MVAr • Effectiveness factors for nodes where they have MVAr capacity • Focus will mostly remain the same from one day to another	Participants will have different needs depending on where they operate and where they intend to operate in the future.
How can requirements and constraints be shared to improve practicality?	• The information should be presented in a meaningful way that gives the potential provider ability to access all information in a simple way, and to drill down into the key data of interest. • To support visibility it is practical to allow visualisation of the data using some form of a geographical map of the nodes. Using colouring to highlight constraints etc. can be an effective tool to make it user-friendly. Piclo is a good example of how to visualise using maps.	• The data should be presented in a way that only provide the critical information needed to make daily decisions. • Participants should be able to have a user-defined view they can save for next day. • The data should come in a downloadable format to allow integration with in-house IT systems. • Data should be offered via APIs to allow automation and integration towards in-house IT systems	Participants should be able to get a filtered view on the market, to focus on what is relevant for them. In the ST day-ahead market it is important to allow participants to automate processes.

[1]The minimum effectiveness factor should be set at a level that is practical. TBD | [2] Any node within distance of a node with demand that could impact the MVAr availability

RECOMMENDED MARKET DESIGN

Procurement approach

PROCUREMENT APPROACH

Two of ESO's primary objectives across timeframes are to ensure voltage security and efficient costs

Risk faced by ESO

- Risks to the ESO manifest as a function of licence obligations (compliance risk) and balancing cost incentives (financial risk). Both of these risks can also be deemed as reputational risks.
- Obligations to keep voltages within defined (SQSS) limits are imposed on the ESO through licence obligations, however ESO cannot own and operate voltage compensation equipment throughout the network.
- In the context of ESO's remuneration framework under RIIO, performance on system operation costs can have a direct financial impact on ESO's business.

Manging risk

Managing voltage security risk

- As ESO is unable to own and operate its own assets, services must be procured from third parties.
- Securing the system voltages means ensuring sufficient reactive power capacity will be available when needed.
- Due to lead times on new assets, there is a need to procure ahead of time where a gap between capacity and requirement exists.

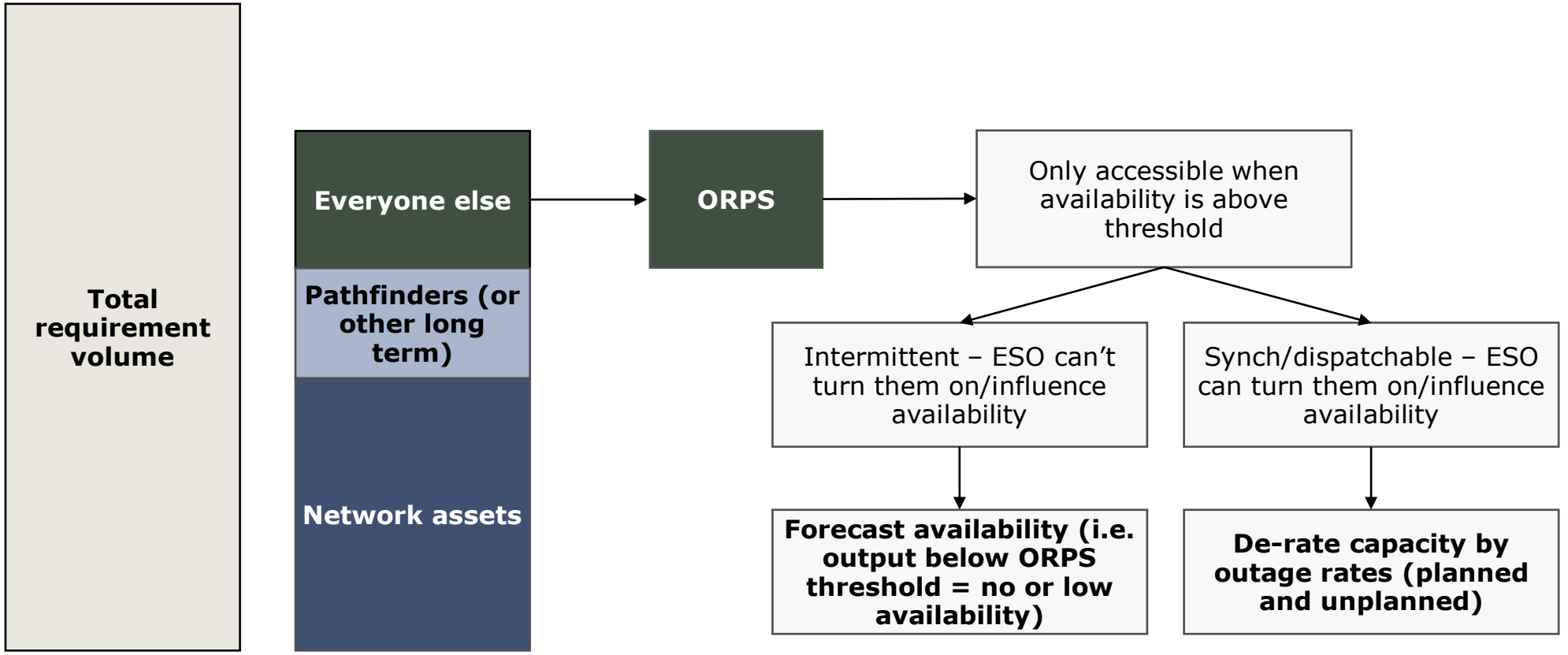
Managing voltage cost risk

- As ESO is obliged to contract with third parties to secure services, it does not have direct control over costs.
- An indirect approach must therefore be taken through the introduction of efficient procurement mechanisms.
- Procurement mechanism and contracting processes design is critical to ensuring efficient outcomes.

Long-term markets | Short-term market

PROCUREMENT APPROACH

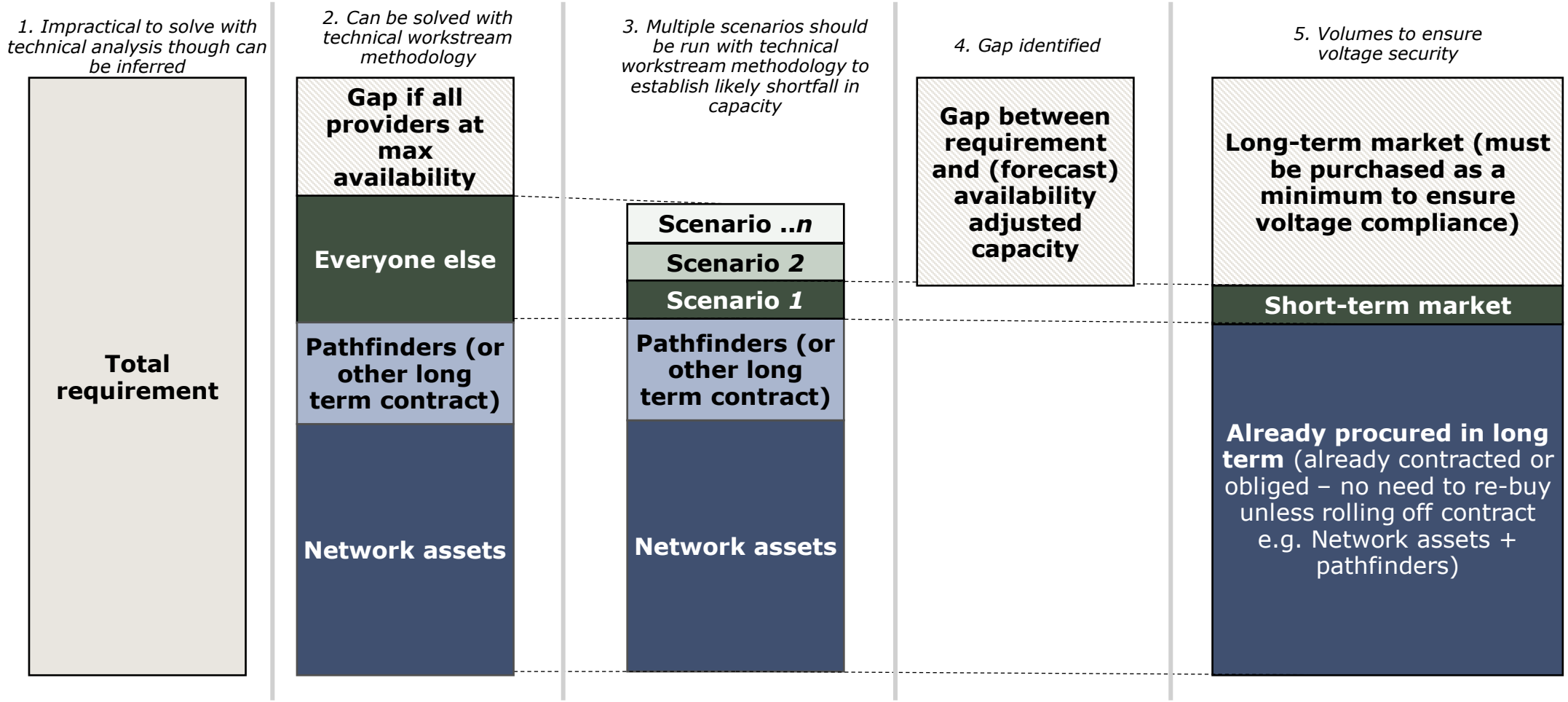
The long term market must ensure there is sufficient (available) capacity as operational timeframes approach



Long-term markets | **Short-term market**

PROCUREMENT APPROACH

Multiple scenarios can be run to understand the worst case plausible availability and secure sufficient providers to ensure SQSS compliance

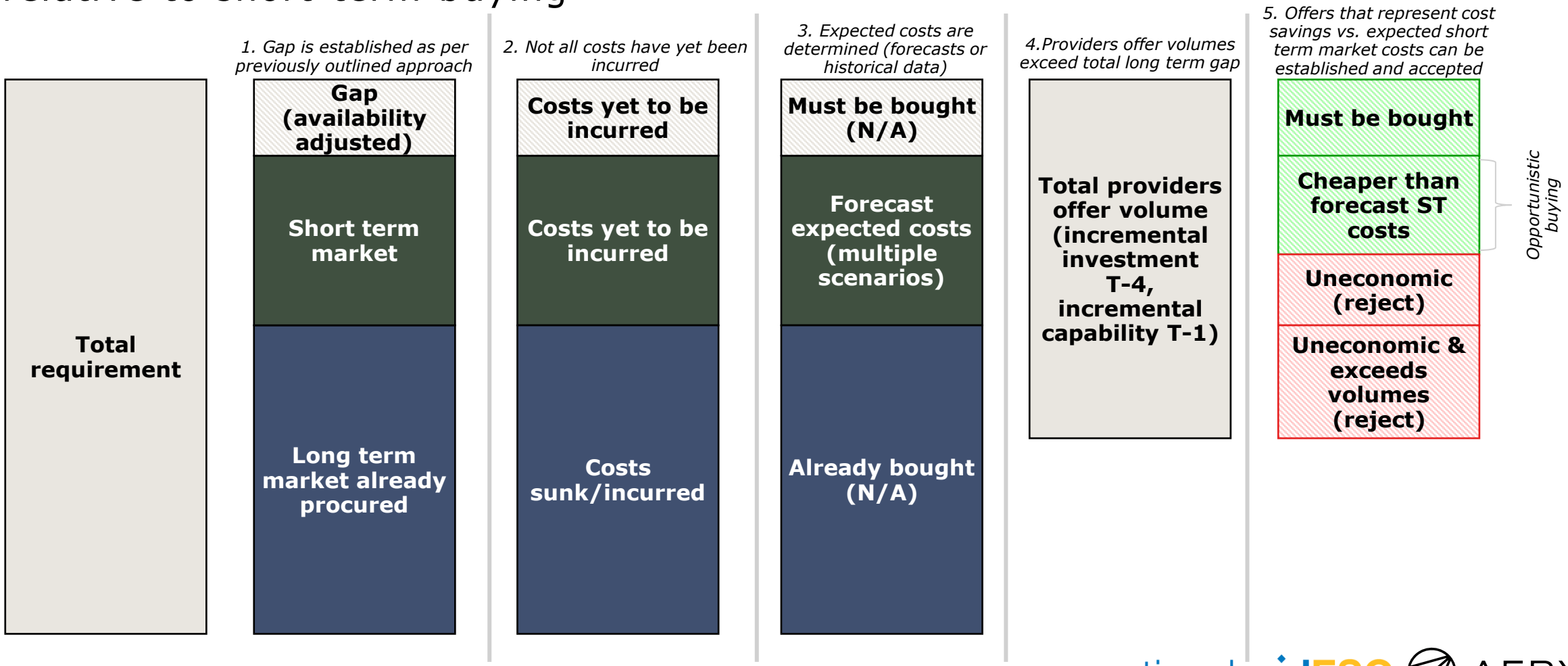


Notes: simplified example, in reality a buy curve should be established or least worst regret scenario methodology selection should be employed to determine exact volume that should be procured based on economic trade-offs

Long-term markets | **Short-term market**

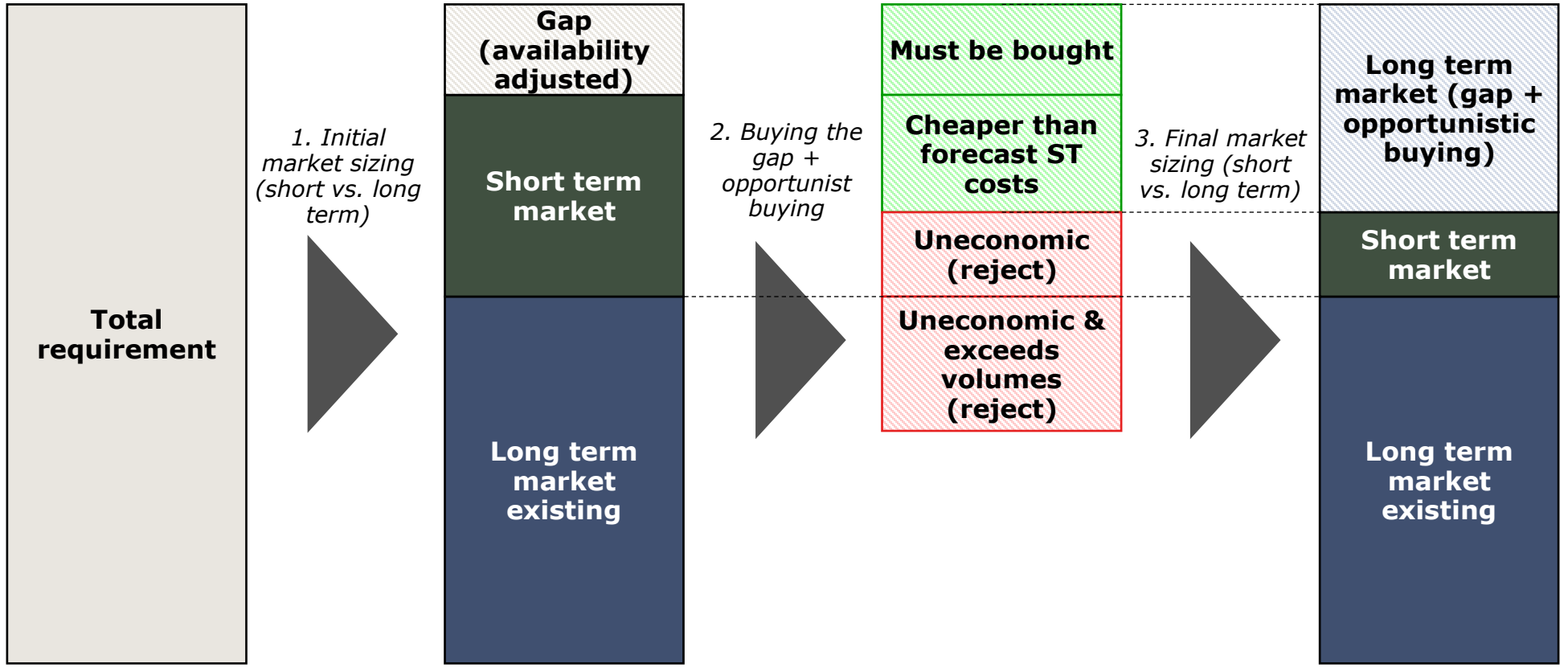
PROCUREMENT APPROACH

Opportunistic buying – Once the shortfall has been met, ESO may wish to procure additional volumes in the long-term market if it expects a discount relative to short-term buying



PROCUREMENT APPROACH

Opportunistic buying – Once the shortfall has been met, ESO may wish to procure additional volumes in the long-term market if it expects a discount relative to short-term buying

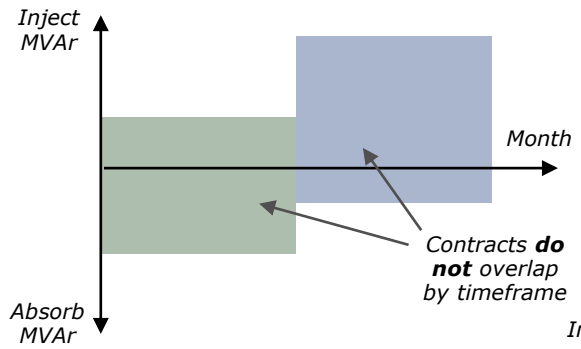


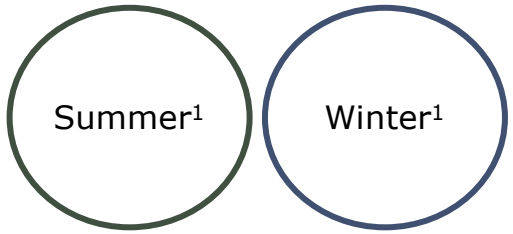
Long-term markets | **Short-term market**

PROCUREMENT APPROACH

If multiple long-term contract types are considered in the future, a minimum volume to be procured by each must be established

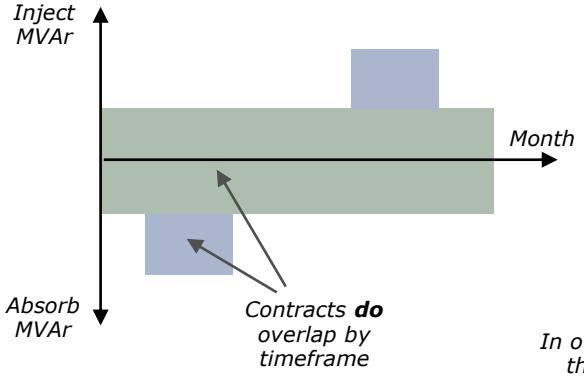
1. Determine whether or not contracts are mutually exclusive

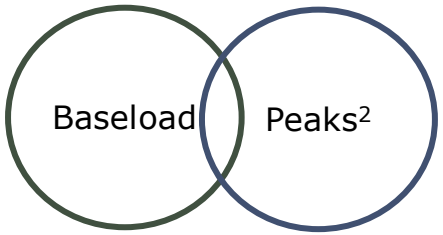




Mutually exclusive

In our current models, we are not proposing to use this contract type (pending results of technical analysis)





Not mutually exclusive (dependent contracts)

In our current these windows will be time-bound (i.e. they only apply for a certain portion of the year)

2. Run long term analysis to determine the needs

If mutually exclusive, **evaluate independently** (based on methodology from previous slides)

1. Evaluate exclusive contract parts of the contract first to determine baseload (where contracts do not overlap)
2. Secondly, evaluate dependent parts of the contract to determine peak windows (where contracts overlap)

Notes: [1]Both contracts can be considered as time-bound baseload contracts. [2]In the example the 'peak' contracts represent a time limited baseload contract, e.g. similar to the difference between a baseload annual and a baseload quarterly product in wholesale market trading. Cian McLeavey-Reville

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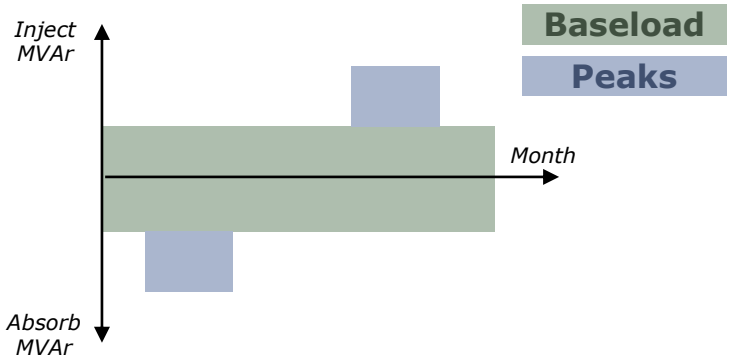
Long-term markets | **Short-term market**

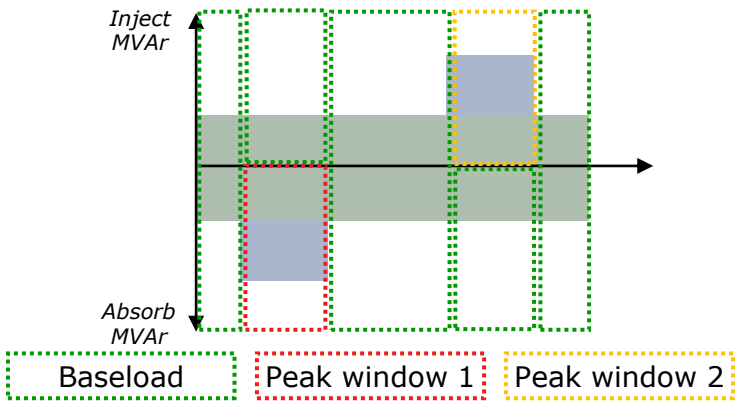
PROCUREMENT APPROACH

Step-by-step – determining needs for dependent contracts

1. Select desired contract types[1]



2. Split year into overlapping/independent periods for analysis



3. Run analysis to establish availability adjusted gap for each of these periods

Baseload (run first)

First establish the baseload minimum need by **only**[3] evaluating mutually exclusive time windows.

Peak window 1

Peak window 2

Secondly, evaluate the peak windows – taking into account (*subtracting from the need*) what you **already intend to procure** (as a minimum) from your baseload need.

4. Communicate needs to market for minimum requirement for each product

Baseload

Peak window 1

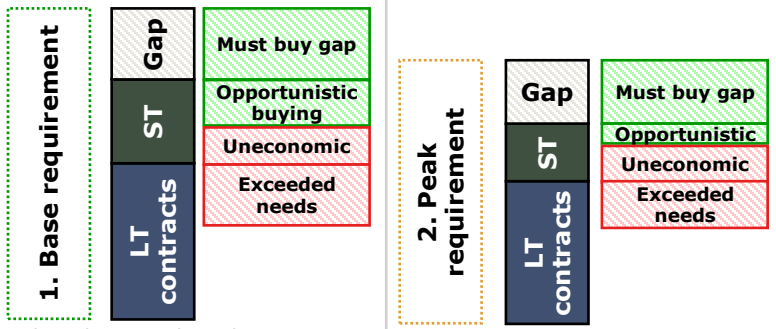
Peak window 2

Pre-fault inject min MVAr	Pre-fault absorb min MVAr
Post-fault inject min MVAr	Post-fault absorb min MVAr

5. Receive offers for each product and contract type

Offer 1	Baseload	50MVAr pre-fault injection	£150/h
Offer 2	Baseload	20MVAr pre-fault absorption	£60/h
Offer 3	Peak window 1	30MVAr pre-fault injection	£90/h
⋮			
Offer n	Peak window 2	15MVAr post-fault injection	£30/h

6. Buy shortfall and opportunistically to minimise costs to consumers[2]



Notes: [1]Afry will make recommendations based on output of technical workstream. [2]Whilst this is fundamentally complex, it will be dealt with in the market clearing algorithm, provided constraints are defined appropriately – ESO needs to calculate key parameters rather than manually assessing bids. [3]If peak products are single directional, as in the example, ESO will need to ensure they purchase enough in the baseload to cover the peak windows in the opposite direction to the peak product

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PROCUREMENT APPROACH

Sophistication of long term contracts offers both risks and opportunities

Shape

- When selecting contract types (e.g. baseload, peaks, seasons) the objective should be to try and match the contracted volumes with the shape of the requirement.
- More accurate representation of shape can offer better value in terms of contracting by reducing over-procurement.
- The more accurate the shape, the clearer the signal to the market in terms of ESO's actual needs.

Complexity

- The greater degrees of freedom in contract types, the more choices that need to be made when procuring.
- The more complex the suite of contracts, the more reliant on accurate understanding of shape and by extension, a greater reliance on future modelling.
- Greater complexity in the contract suite can make it hard for market participants to understand the successful solutions; which may impede competition.

Optionality

- Minimum thresholds for each contract type must be met, but ultimately the most economic solution should be selected.
- ESO is free to select the cheapest option, even if that means buying a baseload contract to meet a peak need.

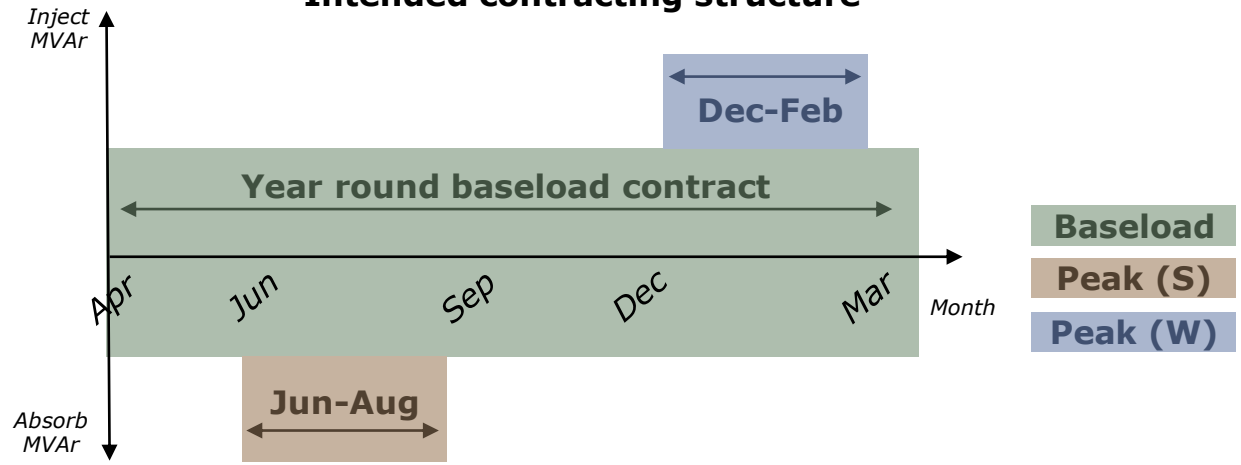
PROCUREMENT APPROACH

Worked example (1/3) – long term contracts with multiple contract types

1. Select desired contract types

- For this example we will assume annual baseload and selected period peak contracts are desirable.
- We will assume a Summer (S) Peak contract running from June-August (inclusive) for extra absorption
- We will assume a Winter (W) Peak product running from December-February (inclusive)

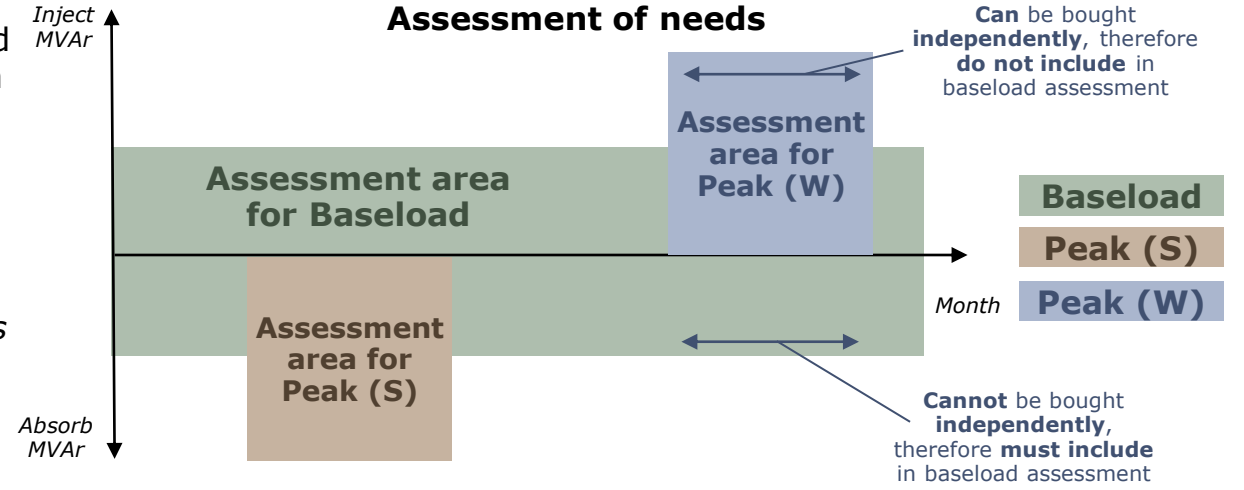
Intended contracting structure



2. Split year into overlapping & independent periods for analysis

- Identify where contracts overlap and where they do not (this should align with your 'opportunity to purchase')
- *Note in the example we have an upwards and downwards peak contracts and upwards peak contracts for S/W – we can ignore these in the baseload assessment as we have an opportunity to purchase independently.*

Assessment of needs



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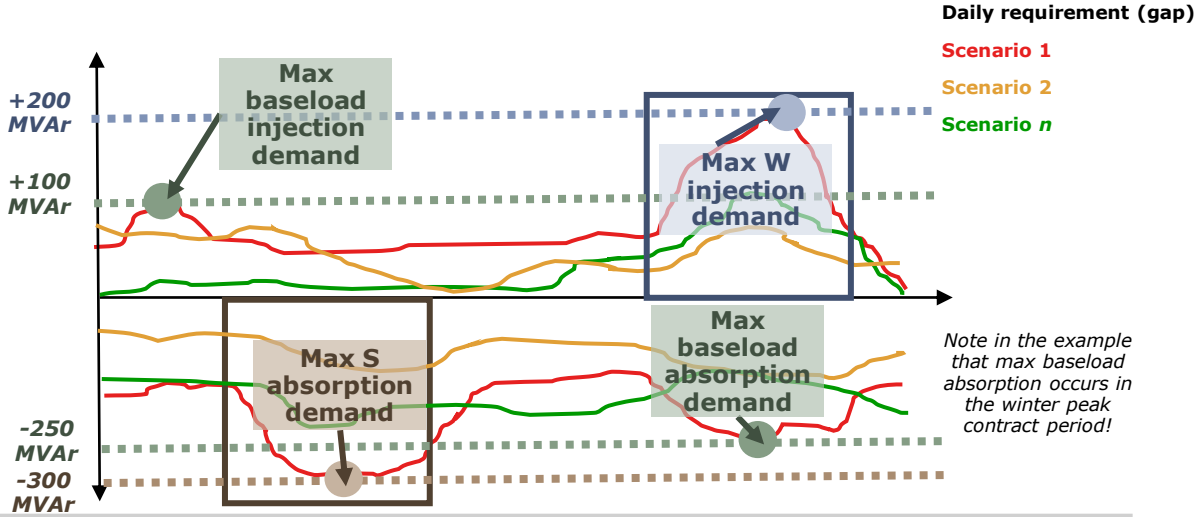
PROCUREMENT APPROACH

Worked example (2/3) – long term contracts with multiple contract types

3. Run analysis to establish availability adjusted gap for each of these periods

- Multiple (credible) scenarios should be run to understand potential requirements.
- In this example we ascribe equal probability to all scenarios and secure for the 'worst credible case'.
- This can be run pre-or post contingency.
- Max demand for each product in each contract window identified.



4. Communicate needs to market for minimum requirement for each product

- Calculate the volume required on a baseload basis from the previous step, this is the minimum volume to be procured to meet the 'gap'.
- Calculate the difference between what will be contracted baseload, and needs for peak products to determine the shortfall for peak products.

Baseload injection	+100 MVAr	Winter Peak (injection only)	+200 MVAr - + 100MVAr = +100 MVAr
Baseload absorption	-250 MVAr	Summer Peak (absorption only)	-300 MVAr - - 250MVAr = -50 MVAr

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PROCUREMENT APPROACH

Worked example (3/3) – long term contracts with multiple contract types

5. Receive offers for each product and contract type

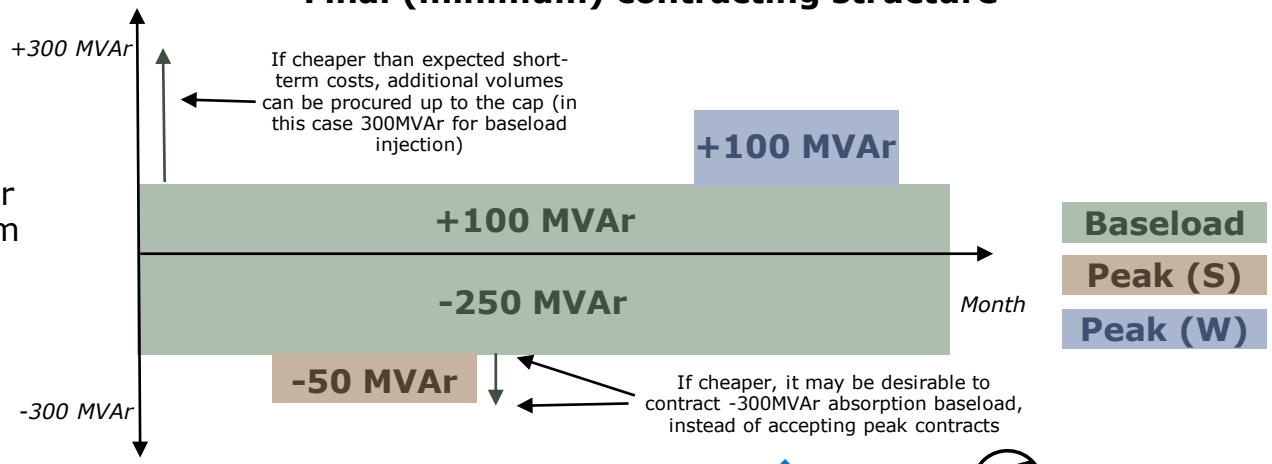
- Receive offers from market participants for each of the offered products.
- Establish 'willingness to buy' (for additional volumes from ESO perspective:
  - Establish maximum procurement volume from long-term market.
  - Establish expected cost in the short-term market.

Baseload injection	Min volume: +100 MVAr Max volume: +300MVAr Expected cost: £20/MVAr/h	**Winter Peak (injection only)**	Min volume[1]: +100 MVAr Max volume +350MVAr Expected cost: £30/MVAr/h
Baseload absorption	Min volume: -250 MVAr Max volume: -500MVAr Expected cost: £15/MVAr/h	**Summer Peak (absorption only)**	Min volume: -50 MVAr Max volume: -350MVAr Expected costs: £20/MVAr/h

6. Buy shortfall and opportunistically to minimise costs to consumers

- Buy at least the minimum volume for each product (in this case must be secured by new build).
- Buy providers whose costs are lower than that expected in the short-term market (subject to cap, can be met by any providers if economic).

Final (minimum) contracting structure



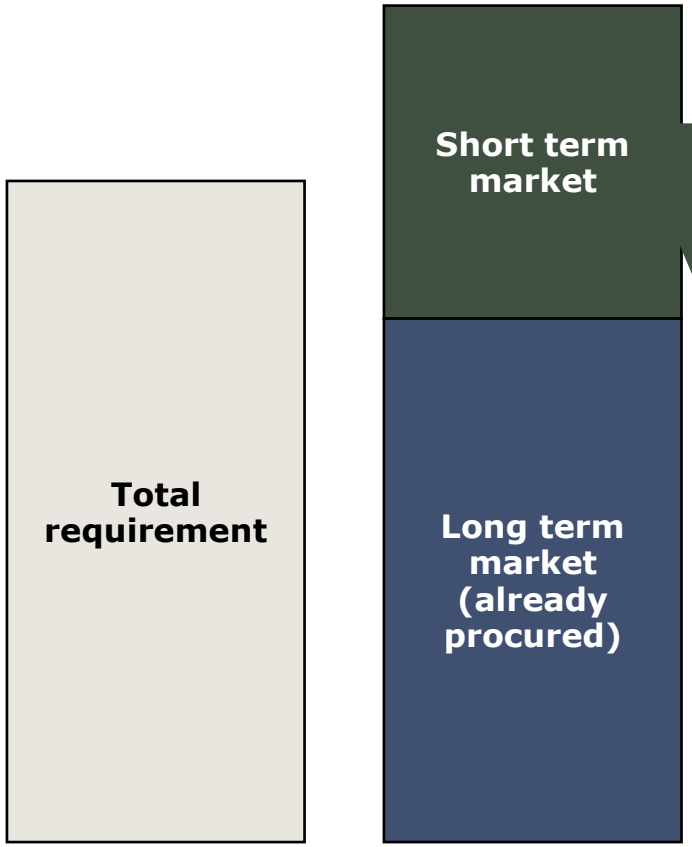
Notes: [1]Can be met by baseload contracts if more economic to do so

Long-term markets | Short-term market

PROCUREMENT APPROACH

Once operational timeframes approach, the volume to be procured from the short-term market must be assessed

1. Once operational timeframes approach there should always be an excess of potential capability over the total requirement



2. There are three core types of providers that can be procured close to real time

ORPS providers within MSA ranges (accessible in the BM, can be instructed for MVAr[1])

ORPS providers outside of MSA ranges (not accessible in the BM, no route to instruct MVAr)

Other providers (not accessible in the BM, no route to instruct MVAr)

3. Core provider examples

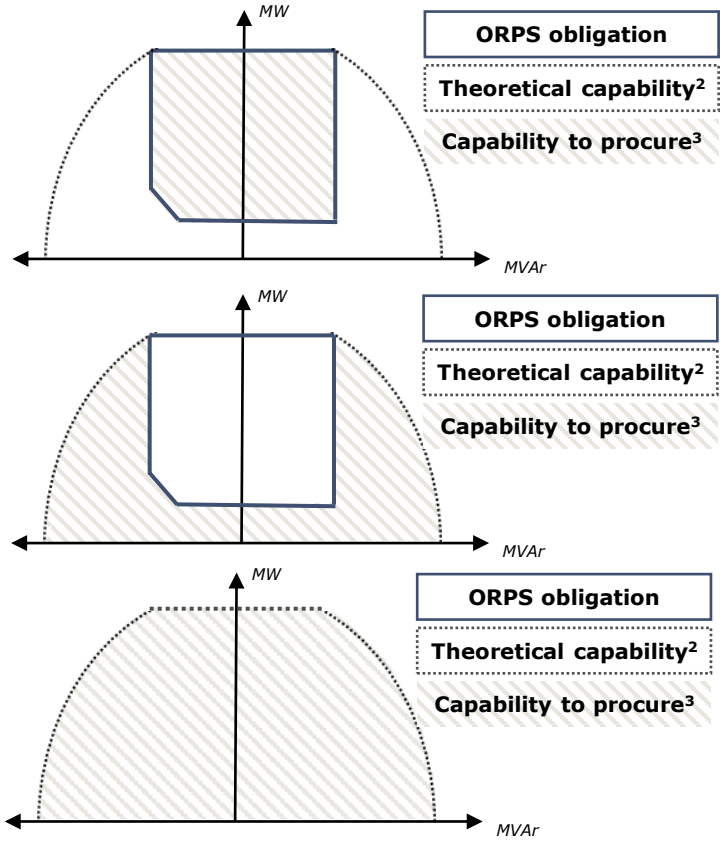
Dispatchable: CCGTs, biomass, batteries (depending on State of Charge), interconnectors etc.

Non dispatchable: wind, solar etc.

All technologies technically capable and bound by ORPS (e.g. batteries at low power output)

All technologies technically capable not bound by ORPS (e.g. embedded providers without a Mandatory Service Agreement)

4. Stylised example procurement target vs. reactive performance chart



Notes: [1]This depends primarily on whether or not providers are dispatchable or variable as ORPS obligation only becomes binding above availability threshold (MSG for synchronous and 20%< for non-synchronous). [2]Varies substantially by technical configuration and type of asset, MVA rating of equipment may also limit MVAr output at high MVAr output, substantial economical trade-offs may exist to access any of this capability. [3]May only procure parts of shaded area (participants not obliged to offer all)

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Long-term markets | Short-term market

PROCUREMENT APPROACH

ESO may want to procure different provider types for different reasons

Non-incremental

ORPS providers within MSA ranges (accessible in the BM, can be instructed for MVAr[1])

- Both synchronous and non-synchronous generators have an obligation to provide ORPS, critically this only above a certain MVAr dispatch threshold (20% for non-synch, SEL for synch).
- Actions can be taken by dispatchable generation to influence their availability (e.g. for synchronous CCGTs can turn on, for non-synchronous batteries can alter output)
- It may be desirable to pay providers for availability **where payments will influence their behaviour.** Critically it is unlikely to be beneficial to pay providers who have no control to increase their active MVAr output (such as intermittent providers) in this category[1].

Incremental

ORPS providers outside of MSA ranges (not accessible in the BM, no route to instruct MVAr)

- Some providers have oversized converters (or other reactive comp. equipment) able to export additional reactive power beyond what is required by the grid code. Notably from the Market Analysis workstream under this project, grid code requirements are more strict under ENTSO-E (wider MVAr range required for non-synch providers), additional capability may therefore be more broadly accessible (as some providers have indicated under the Market Analysis workstream).
- For some providers (in particular battery storage), there may be a MVAr trade-off with energy production, meaning there could be a large range of variable costs for these provider types that depends on the opportunity cost of injecting and withdrawing active power from the grid at the time of delivery.

Incremental

Other providers (not accessible in the BM, no route to instruct MVAr)

- The Market Analysis workstream has identified 10-15GVAr of potential additional resource in the system that is as yet uncontracted via ORPS.
- Much of this capacity is embedded generation, a route to facilitate these is being explored separately – regardless, any market solution should seek to procure these additional volumes if economic to do so.

Notes: [1]Does raise the possibility for gaming by market participants declaring lower than expected PNs and securing contracts in the category of ORPS providers outside ORPS ranges (where PN is <20% rated MVAr) – this can be managed through efficient monitoring and settlement practices.

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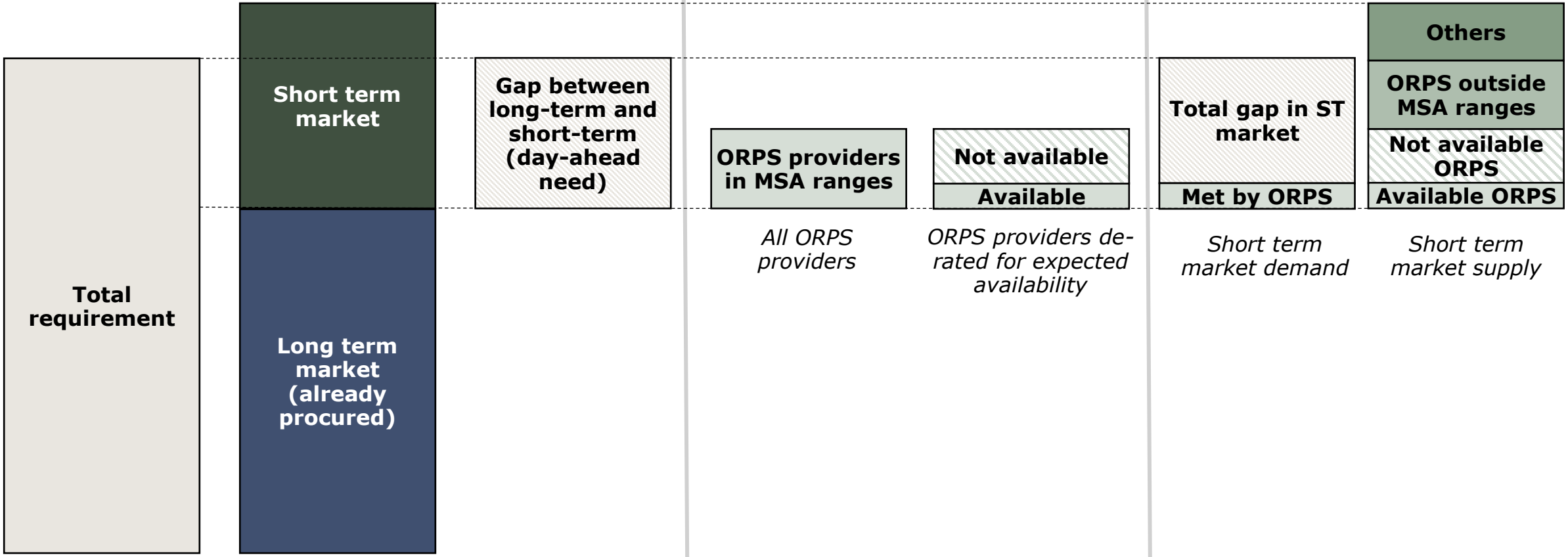
PROCUREMENT APPROACH

The gap (if any) between long-term contracts and short-term needs must be identified

1. The gap between long-term contracts and residual short-term need is established based on day-ahead forecasts of voltage issues, employing the same methodology as the long term, but focussed on a single day

2. Once total need is established, determine expected available capability[1] from ORPS

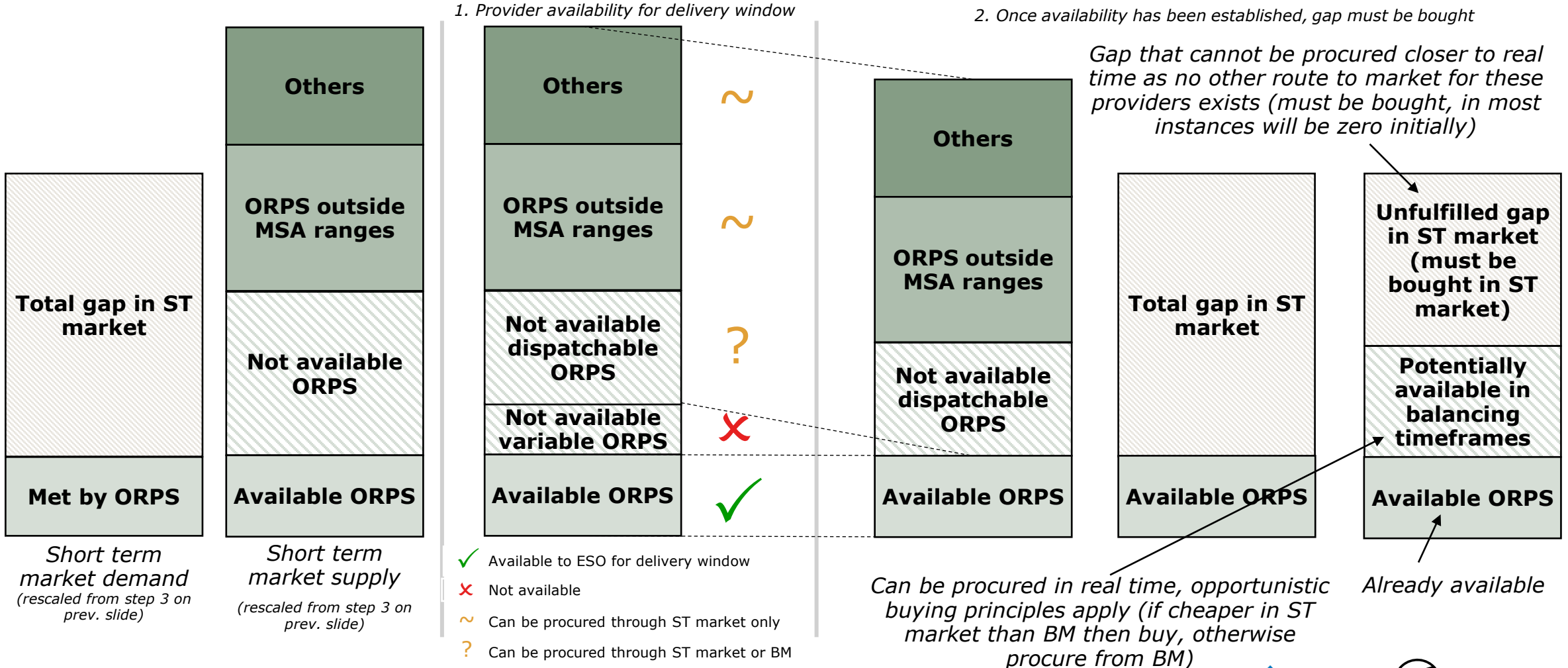
3. Establish categories for buying, there will be an expected volume of capability from ORPS, ORPS providers that are not available, and potentially a gap between these providers and the total requirement



[1]At point of assessment this can be based on PNs, note that if this is a hard-rule it may open opportunities for gaming as plants declare PN=0 when they actually intend to run to be considered for procurement at this stage. One alternative is to procure everyone who can influence their dispatch/availability.

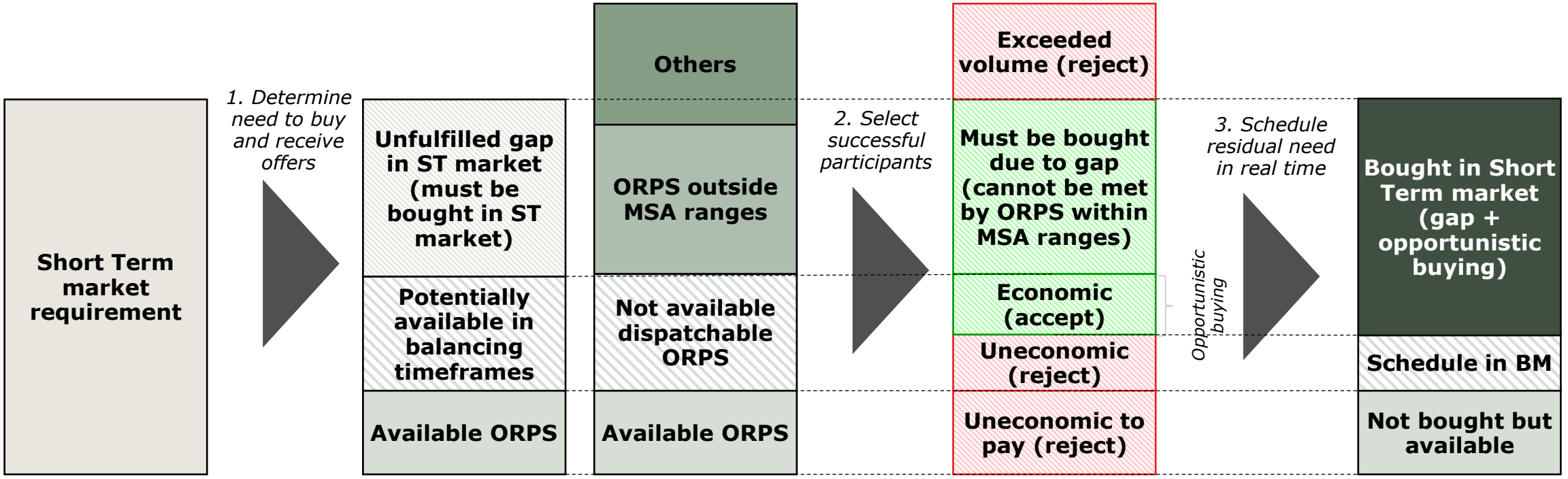
PROCUREMENT APPROACH

Deciding what to buy opportunistically at the day-ahead stage requires understanding of what is potentially available 'on-the-day'



PROCUREMENT APPROACH

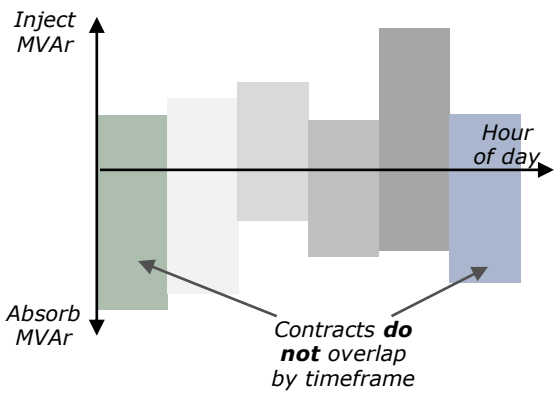
Ultimately, once real-time is reached all residual needs must be fulfilled either through the short term market or in the balancing mechanism

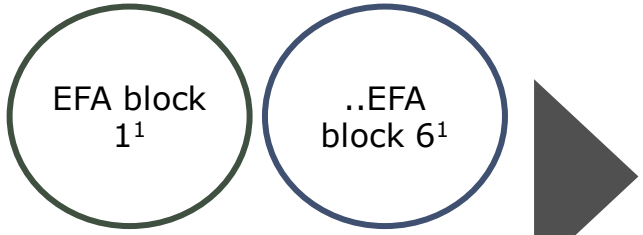


PROCUREMENT APPROACH

Volumes for each EFA block must be determined with a similar approach to how the long term market requirements setting works

1. Contracts will be mutually exclusive by time frame (based on 4h EFA blocks)





Mutually exclusive

In our current model we are proposing mutually exclusive contracts for the short term market

2. Run short term analysis to determine the needs

Evaluate max needs for each EFA block for each product to determine requirement using methodology from Technical Workstream to determine needs. Principles from long-term market forecast apply over a more limited time-frame.

Notes: [1]Both contracts can be considered as time-bound baseload contracts.

Long-term markets | **Short-term market**

PROCUREMENT APPROACH

ESO will have to determine willingness to pay at each stage for opportunistic buying

Timeframe	Long term (T-4 & T-1) opportunistic buying	Short term opportunistic buying
Type of forecast	Long term forecast of expected costs throughout contract period duration from the short term market (assuming there is no shortfall)	Forecast short term costs of procuring availability through the balancing mechanism for the following day
Price forecast approach	Long term fundamental analysis (scenario modelling) – suggested adaptation to FES scenarios to incorporate evaluation as BAU activities (similar to NOA)	Prevailing available bid/offer data from BM and expected action volumes + other costs (i.e. ORPS rates, volumes, replacement costs etc.)
Forecast accuracy and application	Forecast for longer term periods will inherently be less accurate, probabilistic approach or least worst regret decision making principles should apply	Forecast accuracy higher – buy if expected short term market costs are below alternative (balancing mechanism costs) and a capability gap remains

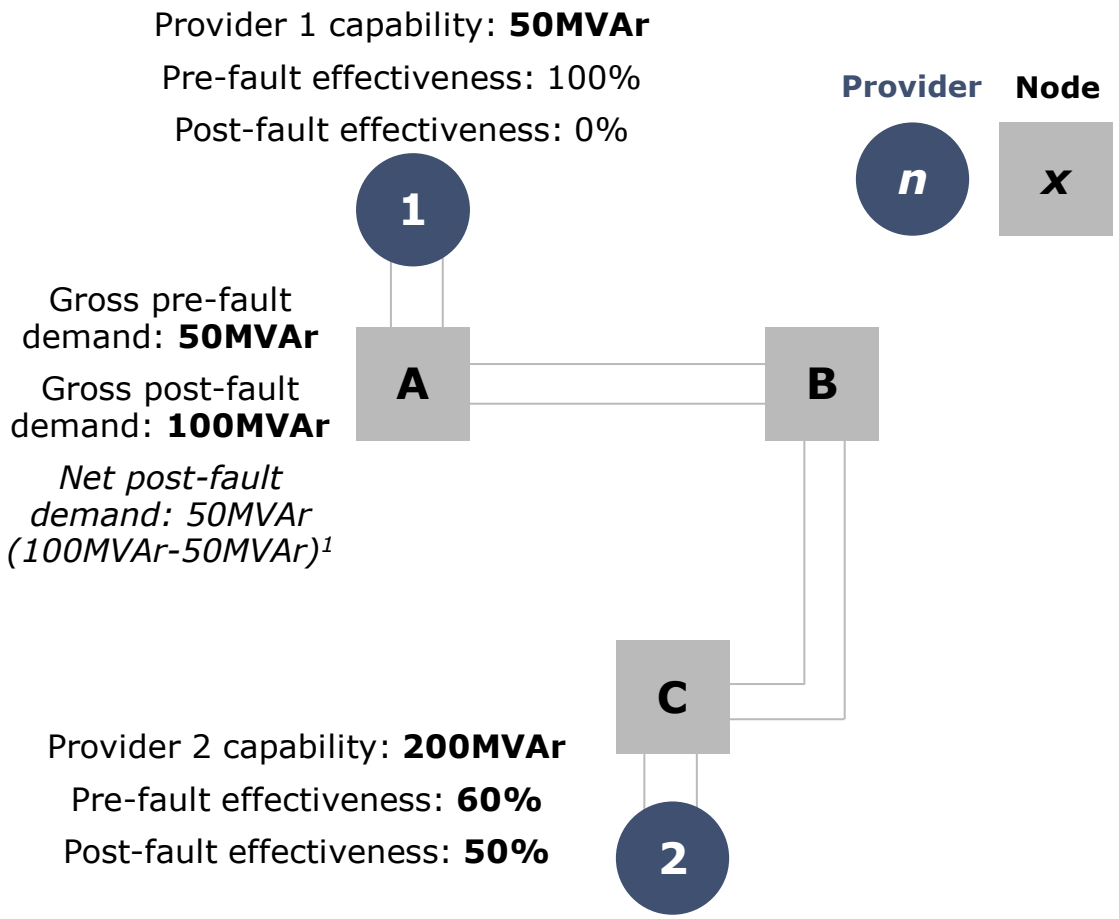
RECOMMENDED MARKET DESIGN

Rationale behind Pre- and Post-fault products

We are proposing 4 products including pre/post fault (step change) for both reactive power injection and absorption

	Pre-fault (step change)	Post-fault (step change)
Absorption 	– Allows pre-fault, steady state voltages to be maintained within SQSS limits – Utilised primarily when power system flows are low	– Allows voltages steps and steady state voltages to be maintained within SQSS limits following an event or operational switching – Utilised primarily when parts of the network from where pre-fault absorption providers were dispatching become isolated or if high gain circuits are switched in
Injection 	– Allows pre-fault, steady state voltages to be maintained within SQSS limits – Utilised primarily when power system flows are high	– Allows voltages steps and steady state voltages to be maintained within SQSS limits following an event or operational switching – Utilised only when a step change occurs either after a fault/unplanned outage or after operational switching to support voltage levels

Providers may be able to provide both services in a given direction, but this would likely be in different quantities (1/2)



- In the example, the requirement at node A is:
  - 50MVAr for pre-fault injection (total/gross requirement).
  - 100MVAr for post-fault injection (gross requirement).
- For simplicity any demand at nodes B and C are ignored.
- In the example:
  - Provider 1 can offer 50MVAr on a pre-fault basis and can satisfy the requirement.
  - Provider 1 is separated from node A in the most critical contingency case and cannot offer any capability to post fault.
  - Provider 2 is hardly affected by contingencies and can deliver 200MVAr at 60% effectiveness pre-fault (120MVAr at point of need) and 50% post-fault (100MVAr at the point of need).
  - In the example, if provider 2 is accepted, both the pre- and post-fault need is met as pre-fault provider 2 can meet the 50MVAr required (100MVAr can be delivered at the point of need, this represents overholding). In the most critical contingency the gross requirement is still met (100MVAr).
  - If provider 1 is accepted, post-fault requirements must be met by a different provider.

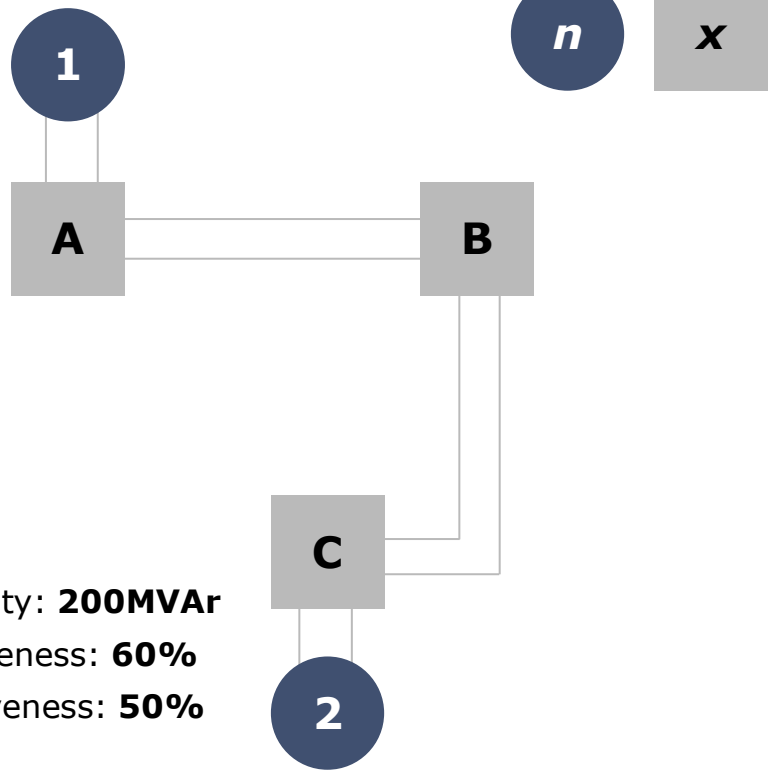
Notes: [1]For illustration purposes only

Definition of requirements is key to ensuring procurement decisions are consistent with needs (2/2)

Provider 1 capability: **50MVAr**

Pre-fault effectiveness: 100%

Post-fault effectiveness: **20%**



Gross pre-fault demand: **50MVAr**

Gross post-fault demand: **100MVAr**

Net post-fault demand: 50MVAr (100MVAr-50MVAr)[1]

Provider 2 capability: **200MVAr**

Pre-fault effectiveness: **60%**

Post-fault effectiveness: **50%**

- If provider 1's post fault effectiveness is 20% instead of 0% (i.e. can offer some capability in the critical contingency case) then it can offer some post-fault capability against the gross post-fault need.
- Provider 1 can offer 50MVAr * 20% = 10MVAr to the post-fault need.
- If provider 1 is accepted, the post fault need to be secured from other providers would be 100MVAr – 10MVAr = 90MVAr.
- Crucially this is measured against the gross need.
- If we use the net need for postfault (50MVAr) – the change in effectiveness of providers between pre-and post-fault must be accounted for separately **as it assumes 50MVAr is still being delivered from pre-fault providers which is unlikely to be true.**
- If we wished to use the net post-fault demand of 50MVAr then we would need to adjust our demand upwards to account for the change in effectiveness factor (assuming provider 1 has been accepted).
  - This is 50MVAr (net post-fault requirement) + (100% - 20%) * 50MVAr = 50MVAr + 80% * 50MVAr = 50MVAr + 40MVAr = 90MVAr
  - This 'adjusted' net-post fault need is equal to our gross post-fault need subtracting the contribution from Provider 1 using the Post-fault effectiveness.
- **The recommendation would be to use the gross-post fault demand to avoid this interim (complex) calculation.**

Notes: [1]For illustration purposes only

RATIONALE BEHIND PRE- AND POST-FAULT PRODUCTS

The definition of these products require an understanding of expected quantities of reactive power (not just capability)

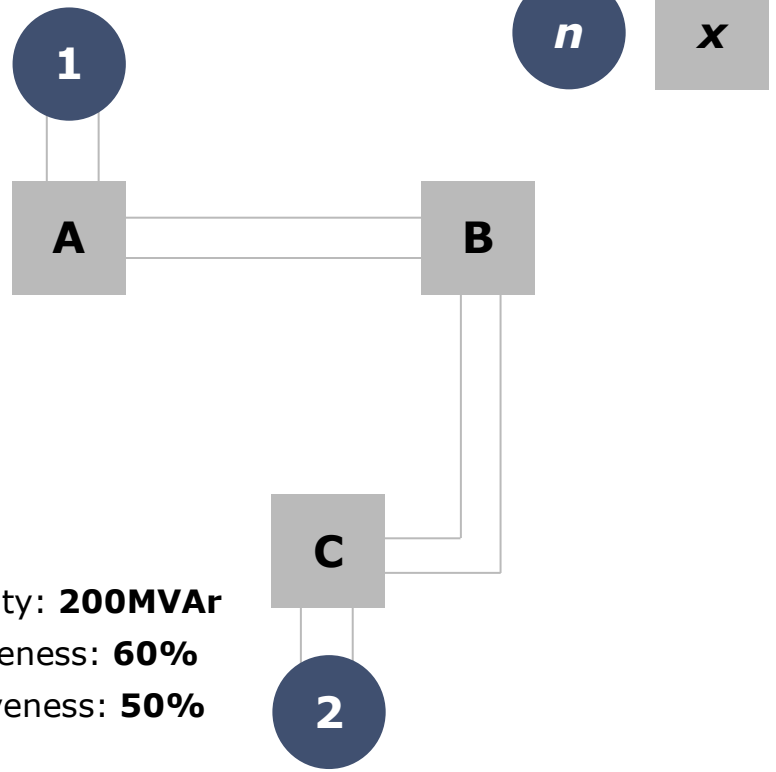
- ESO's methodology today ensures that the post-fault needs can be met. Our understanding is this is not weighed with meeting pre-fault requirements.
- We split these requirements due to the significant difference in expected dispatch volumes (MVArh) between the two products.
- The post-fault product is designed to secure for **specific uncommon events**, which are only expected to occur in a small number of periods. The MVArh (volume) output will be very low relative to pre-fault, but the MVAr (capability) needs are much higher than for pre-fault services.
- The pre-fault product is designed to be instructed much **more regularly.** The MVArh (volume) output will be be significantly higher than for our post-fault product.

Example – economic efficiency through multiple products (1/2)

Provider 1 capability: **50MVAr**

Pre-fault effectiveness: 100%

Post-fault effectiveness: 0%



Gross pre-fault demand: **50MVAr**

Gross post-fault demand: **100MVAr**

Net post-fault demand: 50MVAr (100MVAr-50MVAr)[1]

Provider 2 capability: **200MVAr**

Pre-fault effectiveness: **60%**

Post-fault effectiveness: **50%**

- Assumptions:
  - Pre-fault utilisation of 5500 hours/year (repeatedly procured through the short term market).
  - Post-fault utilisation of 100/y hours (repeatedly procured through short-term market).
  - Utilisation price of £5/MVArh for both providers
  - Availability price of £0.2/MVAr/h for both providers
- Outcome 1: Provider 1 is accepted only:
  - Post-fault need not met, option not viable.
- Outcome 2: Provider 2 is accepted only:
  - Pre-fault and Post-fault requirements met.
  - **Total solution cost for the year** = Availability price * Duration * MVAr + (MVAr need * Utilisation rate pre-fault * Utilisation price)/Pre-fault effectiveness + (Utilisation rate post-fault * Utilisation price) / Post-fault effectiveness = 0.2*8760*200 + 5500*50*5/60% + 100*100*5/50% = **£2,742,067**

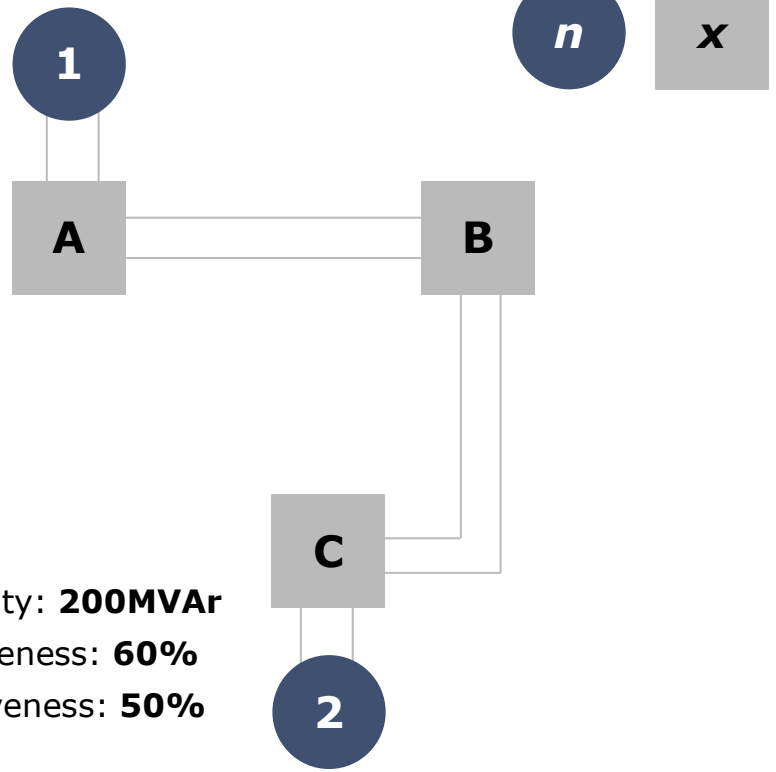
Note: Assumes pre and post fault periods do not overlap for simplicity, otherwise adjust post fault volumes down by pre fault need * utilisation price

Example – economic efficiency through multiple products (1/2)

Provider 1 capability: **50MVAr**

Pre-fault effectiveness: 100%

Post-fault effectiveness: 0%



Gross pre-fault demand: **50MVAr**

Gross post-fault demand: **100MVAr**

Net post-fault demand: 50MVAr (100MVAr-50MVAr)[1]

Provider 2 capability: **200MVAr**

Pre-fault effectiveness: **60%**

Post-fault effectiveness: **50%**

- Outcome 3: both Provider 1 and Provider 2 are selected.
  - Provider 1 is accepted for pre-fault need and is assigned as such.
  - Provider 2 is accepted for post-fault need (but can be used pre-fault if desired).
  - Utilisation payments are uniform so provider with the highest effectiveness factor takes primacy depending on the situation.
  - Total cost of the solution:
    - Provider 1 = Availability price * Duration * MVAr + (MVAr need pre-fault * Utilisation rate pre-fault * Utilisation price)/pre-fault effectiveness = 0.2*8760*50 + (50*5500*5)/100% = **£1,462,600**
    - Provider 2 = Availability price * Duration * MVAr + (MVAr need post-fault * Utilisation rate post-fault * Utilisation price)/post-fault effectiveness = 0.2*8760*200 + (100*100*5)/50% = **£450,400**
    - Provider 1 + provider 2 **= £1,913,000**
- If only provider 2 was accepted the cost would be **£2,742,067**. Accepting both providers and using the pre-fault provider with high effectiveness for pre-fault needs = **£1,913,000**
- **The total saving by accepting both providers:**

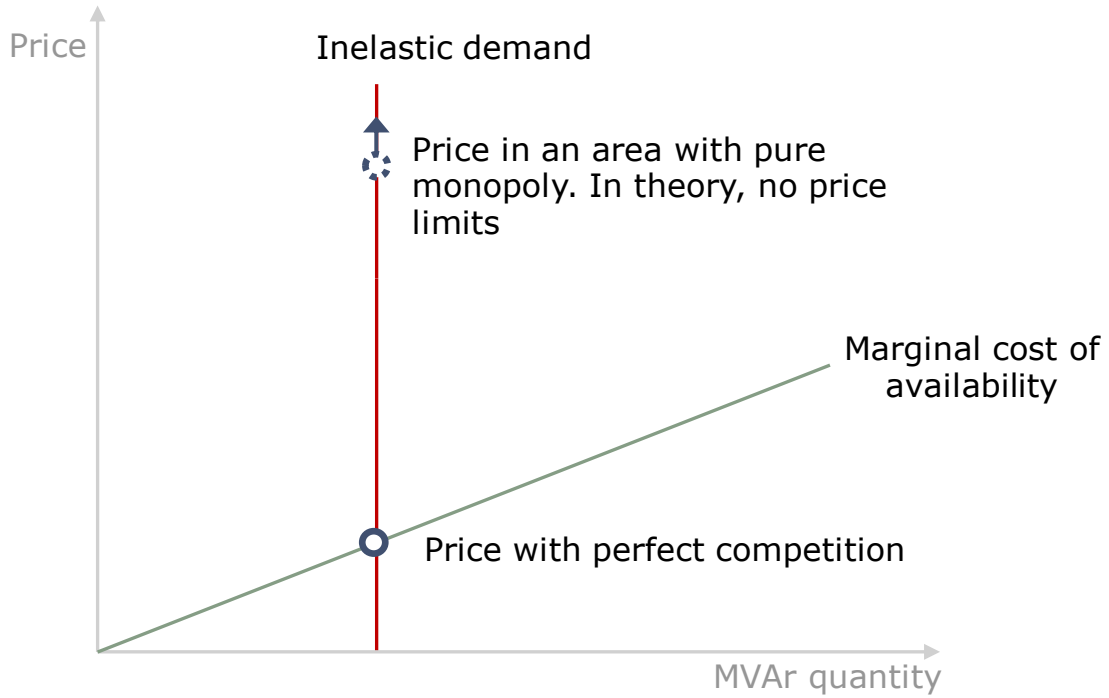
£2,742,067 - £1,913,000 = £829,067/y

Note: Assumes pre and post fault periods do not overlap for simplicity, otherwise adjust post fault volumes down by pre fault need * utilisation price

RECOMMENDED MARKET DESIGN

Market power issues

Potential for market power issues in the market for reactive power is evident, with inelastic demand and supply limited by the locational nature of reactive power and isolated areas with few providers



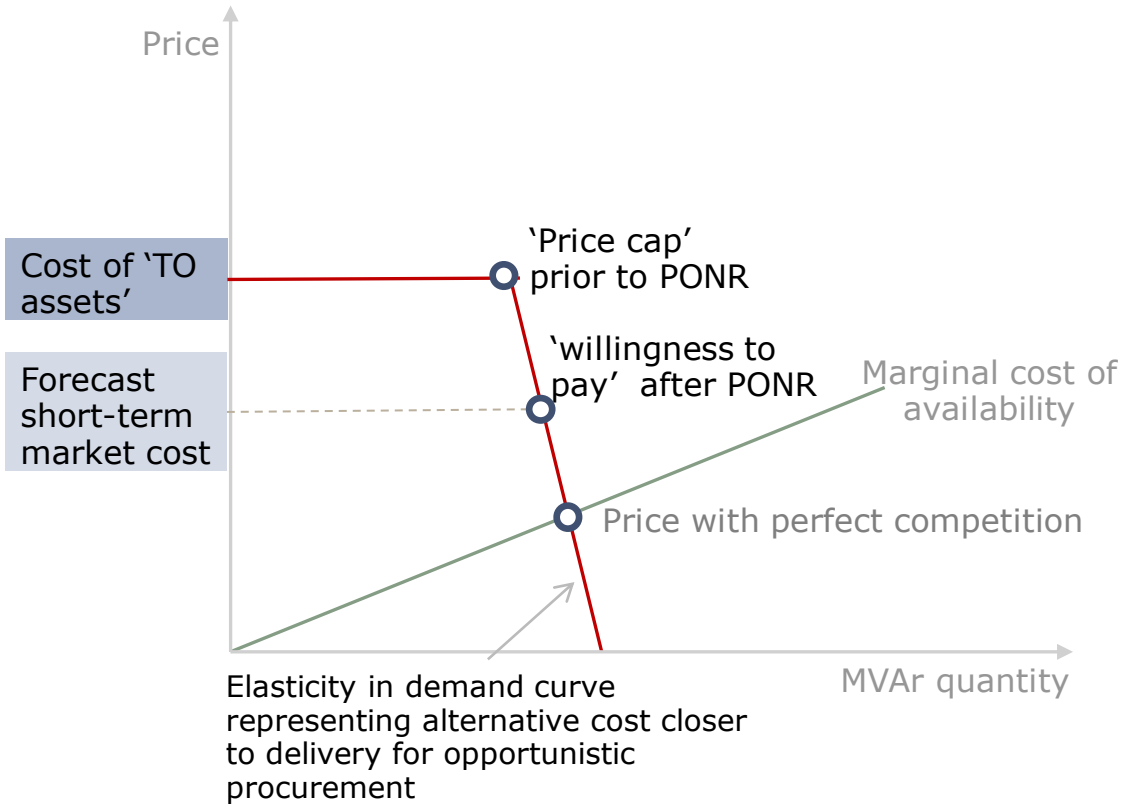
Factors limiting competition

- Providers beyond 50km of the constrained area have low effectiveness of solving the issue
- Grid constraints causing limited connection opportunities for potential new providers
- Weather conditions and outage events preventing potential providers from contributing

Inelastic demand

- Failure to meet SQSS is not an option
- Therefore, a mechanism to prevent excessive prices is desirable

One of the critical tools for mitigating market power is to have an 'outside option' to fall back on



Limit barriers to entry
Increase competition by having multiple auctions with varied lead time and support mix of contracts appropriate for different types of technologies. Avoid high thresholds (e.g. set low min. QTY) and aim for global/opportunistic eligibility. Remove barriers for DERs.

Nodal approach
Use nodal approach to create overlapping local markets, rather than zonal approach with pre-determined geographic market delineations

'Outside option' (Threat of substitution)
In this context, 'outside option' refers to alternative TO assets which can replace providers if more economical to do so. I.e., acting as 'price cap'. Only applicable for the long-term market, prior to 'point of no return' (PONR).

Alternative cost closer to operational hour
For opportunistic purchasing, the forecast of short-term market costs will form the demand curve, representing alternative cost for different levels of opportunistic procurement.

Regulation[1]
- Regulated price caps
- Licence obligations on participants e.g. to govern bid behaviour

Use 'Buyer power'
Imbalance of information. Don't communicate needs explicitly – ask for offers only. (**highly unpopular** with providers, creates a barrier to efficient investment, **practically not an option**)

[1]Note the practical difficulties of regulation of "excessive" bids. Would need an appropriate licensing framework. Potentially part of assessment of 'regulatory protection' in the 'way forward'

Market 'price cap' for the long-term market T-4 is indirectly set as cost of TO assets depreciated over an appropriate horizon

Principles

- Price cap (or back-stop) should limit exposure to market power abuse and thus limits consumer cost
- A price cap should represent a trade-off between limiting barriers to entry and preventing speculative excessive bidding
- In practice, application of a price cap does not mitigate the need to meet the SQSS (no 'value of lost load' equivalent)

Proposal for long-term market

'Outside option'

The cost of a transmission-owned asset depreciated over [15yr[1]] horizon acts as a 'price cap' for procuring shortfall in the long-term market T-4

The cost of building a new TO asset depreciated over 15y horizon is a reasonable approach, as TO assets presents a valid alternative to fall back on.

Drawbacks:

- Requires a lead time of minimum 3+ years (point of no return), and can therefore only be applied to auctions with 3+ years lead time
- TO assets cost differs depending on location and size[2]. Therefore, need to assess cost for multiple nodes and solutions that will comply with voltage obligations

Opportunistic price curve

Forecast of the short-term market costs will form the opportunistic demand curve, serving as an indirect 'price cap' for opportunistic buy in the long term market

The willingness to pay represents the price curve for any 'opportunistic buy' in the long-term market. In other words, the price on the long-term market shouldn't exceed the forecast cost of meeting the requirements on the short-term market (once capacity constraints are satisfied).

[1]Further work recommended to explore amortisation period and/or residual value of TO assets to ensure comparability with commercial providers, who have the opportunity to reflect their views on residual value implicitly through bids into the market. | [2] In the Mersey Pathfinder tenders, cost per effective MVAr for TO (NGET) assets ranged from £109k - £54k

Short-term demand curve should reflect alternative cost of procuring the required MVAr in the balancing timeframe

Principles

- After 'point of no return' (PONR), TO assets are no longer a valid reference for the price cap as it is too late to begin constructing them to meet the demand
- By PONR, NGESO should already have procured sufficient reactive power to cover the forecasted capacity gap between total system need and future expected capacity adjusted for availability. Therefore, offered MVAr should be cheaper than expected cost of existing capacity to be economic

Proposal for short-term market

Alternative cost in Balancing Mechanism forming the demand curve

To find an optimal trade-off between facilitating competition and preventing speculative excessive bidding behaviour, the market should ideally seek to find a price cap that reflects the marginal cost of the most expensive available technology. This is not straight forward as it is highly dynamic, considering the variety of technologies and conditions.

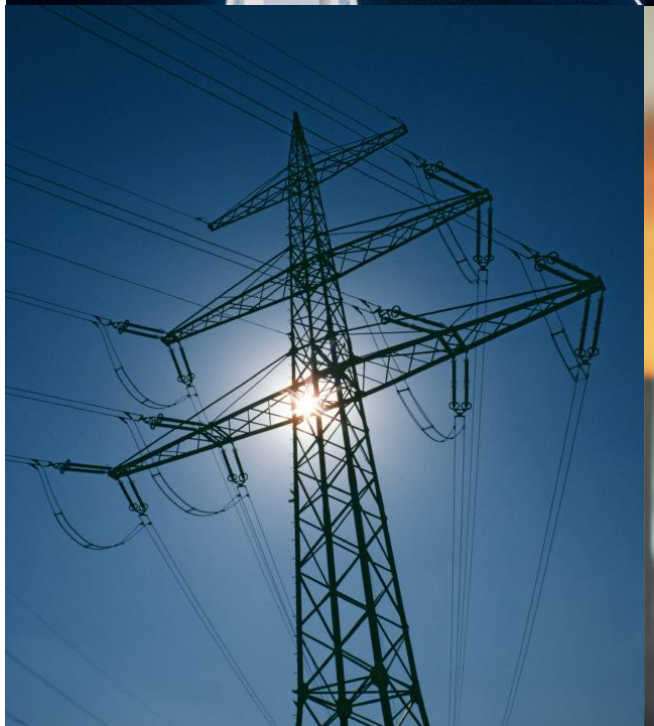
As a solution, the Balancing Mechanism is a viable alternative, as the alternative cost of solving the constraints in the BM timeframe should be visible at the day-ahead stage based on prevailing bid/offer data.

Balancing mechanism costs will function as the point of 'willingness to pay' at each step in the demand curve. If no resources are available on the short-term market (or too expensive), NGESO can procure resources on the BM.

Drawback: Can be seen as a price target, complex to forecast and open to gaming.

Alternative simple solution could be to use historical costs, however this involves risks of under-procuring.

Agenda



Key outstanding items for further consultation and analysis

Implementation readiness and cost

Gap analysis identifying ESO cost and effort to implement new systems and processes.

CBA and/or market trial

Potential for a market trial for ST market, and CBA analysis to be conducted once sufficient data gathered.

Design refinement

Considering feedback received so far in the process, we recommend further consultation with stakeholders to reach final conclusion on issues affecting practicality for participants and ESO (minded-to positions presented but confirmation needed).

There must also be further refinement of detailed design questions including 'incremental' criteria, specific penalty arrangements, settlement timing etc.

Participant readiness

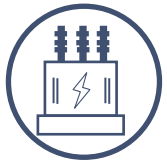
Identifying any residual barriers and feedback in practical implementation aspects, incl. time & effort needed for integrating with new systems and processes. Continued dialogue with participants.

Ofgem review of ancillary service assets

Assess impact of Ofgem regulatory review of ancillary services assets (once complete) to ensure design compatibility.

TO participation

Refine approach to how TO asset cost data are assessed and included in the LT auction as back-stop.



Residual value TO assets

Further work to explore residual value of TO assets to ensure comparability with commercial providers, who have the opportunity to reflect their views on residual value implicitly through bids into the market.

Expired RAB assets

TO assets outside of their RAB period should be considered as a potential solution if economically efficient. This issue warrants further investigation.

Stacking services

Stacking and co-procurement, exploring potential benefits of co-optimisation with other services.

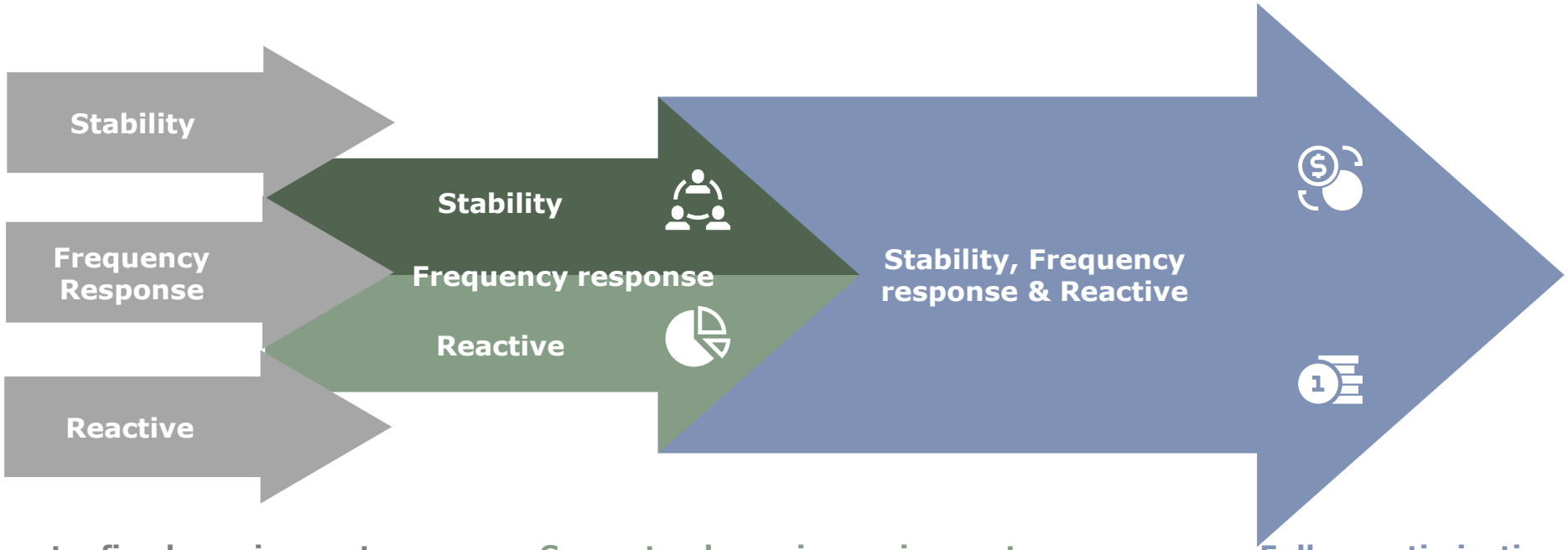
Regulatory protection

It may be desirable to investigate some form of regulatory protection from potential gaming.

DER participation

We have identified several next steps for the inclusion of DER in any enduring market arrangements. These critical next steps involve changes that will impact distribution network owners, and as such will require a coordinated approach to implementation.

Ideal market journey (LT ambition): There is an interaction between reactive power products and other products (e.g. inertia and response) and the co-optimisation of these products should be assessed



Separate, fixed requirements

- Reactive power requirements are fixed and procured separately from other services that interact with it, such as inertia and frequency response

Separate, dynamic requirements

- Reactive power requirements are set dynamically, meaning the requirement is optimised as interaction between services is accounted for
- E.g. ESO can choose to procure more inertia and less (or slower) frequency response

Full co-optimisation

- Full co-optimisation to maintain and limit frequency deviation
- The ideal end-state is a form of co-optimisation across all services that interact with each other, or for which providers can offer synergies

REACTIVE POWER MARKET DESIGN

Appendix A – Economic modelling results

SUMMARY

Key messages

Utilisation costs are expected to **increase** over time and be a primary driver of future costs for reactive power (recovered by ESO)

The system is expected to continue **reliance on synchronising CCGTs** to access reactive power in the future under current arrangements

Where large reactive power requirements exist, **investment** in new assets can **reduce costs to consumers** but only if sufficiently **robust signals** are in place for participants to site their assets effectively

Introduction of **new routes to market** for MVAr only providers (or increased MVAr from existing providers) can significantly **reduce carbon emissions** related to reactive power

Offering a **short-term** route to market where providers are able to reflect their prevailing **opportunity cost of service** provision can **increase access to high effectiveness providers**, and reduce synchronisation costs – we expect this benefit to increase as capacity from new converter connected technologies grow

ECONOMIC MODELLING

AFRY has modelled a nodal reactive power market to understand the potential impact of new market arrangements on service provision

Approach in a nutshell

2025 Leading the Way FES scenario (2021 edition, BID3)

FES scenario run with thermal constraints, demand/generation schedule, these form the inputs for the technical workstream methodology

Technical workstream (Power Factory)

Key outputs from technical workstream including nodal demand for reactive (per product), nodal effectiveness of providers (per product), and provider MVAr capability

Reactive economic modelling workstream (BID3)

*Redispatch **volumes**, **costs**, and **carbon** emissions for meeting reactive power needs*

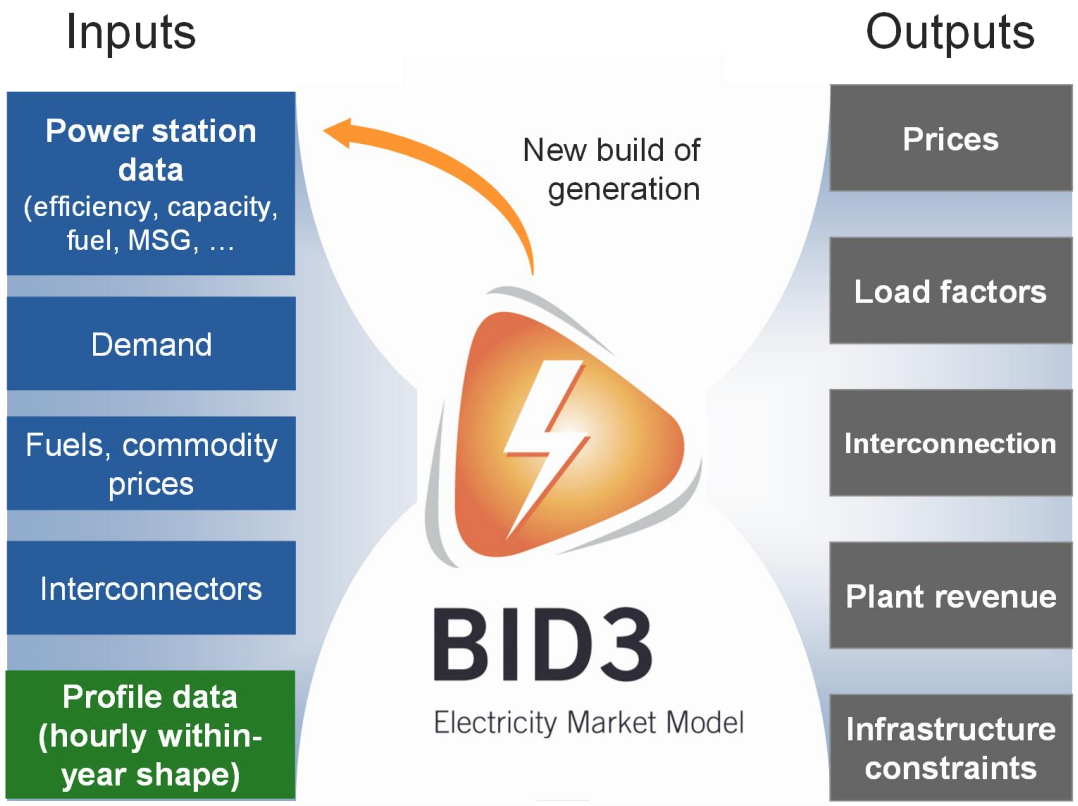
- AFRY has based analysis on ESO's **2021 edition** of the **'Leading the Way'** Future Energy Scenario. We have included a 'base case' redispatch including thermal boundary constraints so that we can later isolate the impact of voltage constraints on the modelling
- The generation/demand **schedule** has been provided to the **technical workstream** (mapping individual providers from BID3 electricity market model, to technical network model).
- The technical workstream team has undertaken analysis to determine the **MVAr need** for each product[1] at each node, and associated individual **provider effectiveness** for each product for each node.
- AFRY has **defined nodal requirements** in BID3 for each product, represented as constraints in the model.
- AFRY has also defined corresponding **provider contributions** for each of the products – de-rating MVAr capability for providers by their effectiveness factor for each product for each node.
- BID3 is then re-run to **resolve voltage constraints** – redispatched **volumes**, associated carbon **emissions**, and **costs** are calculated.

Notes: [1]injection/absorption, pre/post-fault

ECONOMIC MODELLING

BID3 projects physical operation (generator output, electricity flows, emissions) and economic behaviour (electricity prices, revenues)

Inputs and outputs of BID3



Basics of BID3

- BID3 is an optimisation model which minimises the system cost in a year subject to constraints
- It models all hours of the year and accounts for varying renewables, demand-side management, hydro and storage
- It has the following key plant dynamics
  - Start-up, Part-loading (no-load), Minimum Stable Generation
  - Minimum off times, minimum on time
  - Start-up cost and variable maintenance costs dependent on start temperature
  - Ramping
  - Reserve/response

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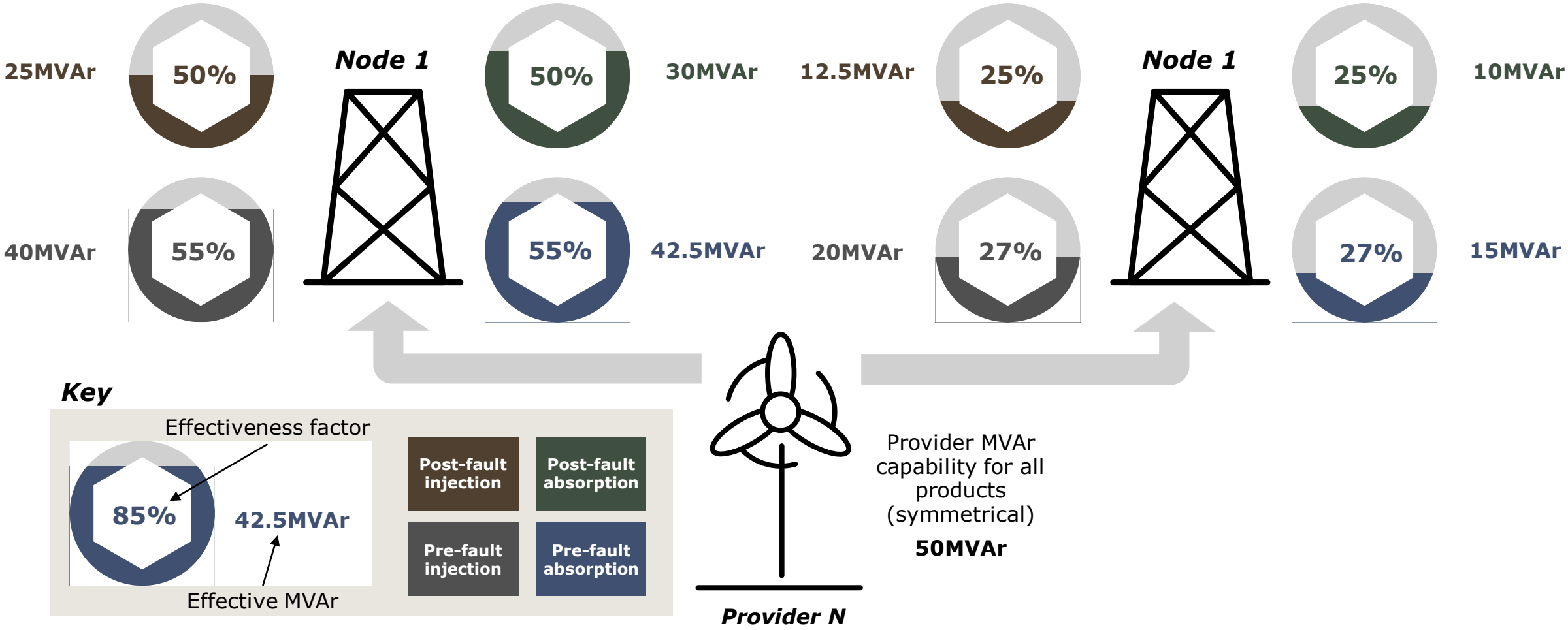
ECONOMIC MODELLING

Provider contributions for each provider, product, and node are defined in the model



Notes: Illustrative example, providers are paid based on MVArh output (rather than on effective MVArh delivered to every node) at ORPS rates based on ESO scenario prices

ECONOMIC MODELLING

We have modelled multiple cases to understand the impact of various market design assumptions

Key scenarios

Status-quo

- Only build additional assets if needed to meet requirements *(none in case assessed based on average weather patterns)*
- Actions taken in balancing mechanism to resolve constraints

Long term market

- Additional solutions economics assessed for each node depending on costs incurred to resolve constraint
- New capacity assumed to be STATCOM[1]

Short term market

- Additional capability available from existing providers (in addition to long-term)
- Additional capability available assumed to be in line with market analysis case studies
- Access to additional capability assumed to have a MW/MVAr trade-off beyond ORPS ranges (opportunity costs optimised in model)

Key outputs

Redispatch volumes

- Additional generation due to plant being synchronised to provide voltage constraints.
- Curtailment/turn-down either to 'make room' on the system for reactive providers or due to MW/MVAr trade-off (short term market)

Voltage costs

- Costs for repositioning plant to provide reactive (either through BM or market arrangements)
- Costs for new investment (annualised)
- Costs for utilisation (ORPS or market)

Redispatch emissions

- Additional emissions from:
  - repositioning plant in the BM; or
  - plant repositioning themselves when bid successful in (short term) reactive market

Notes: [1]This is conservative assumption, it may be that some needs can be met with cheaper solutions such as dedicated reactors/capacitors.

ECONOMIC MODELLING

A baseline case with only boundary constraints was run in order to isolate the redispatch costs and volumes required to meet voltage constraints in the key scenarios

Only boundary constraints

- **Only boundary constraints are resolved (without optimising the voltage constraints)**
- The results of this run are used isolate the impact of the voltage constraints in the key scenarios

Key scenarios

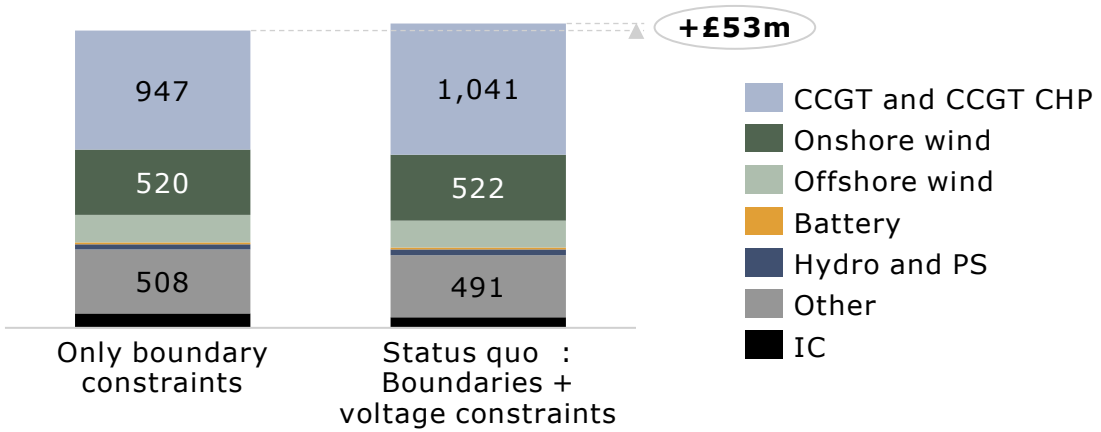
- **both boundary constraints and voltage constraints resolved**

Status-quo | **Long term market** | **Short term market**

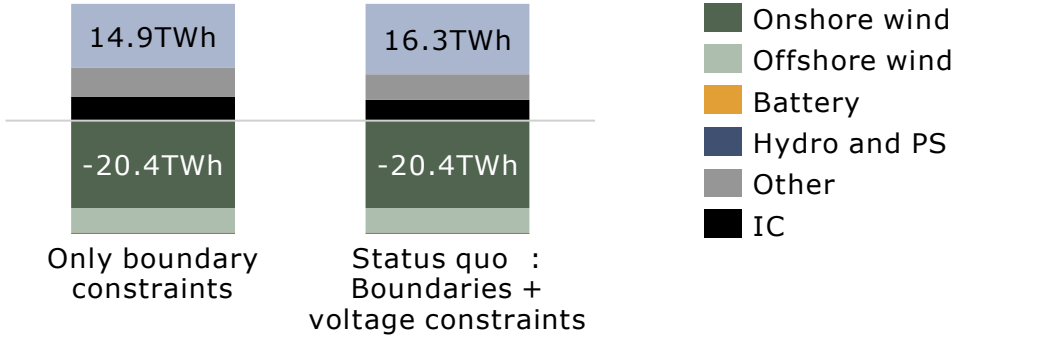
ECONOMIC MODELLING

Synchronisation costs can be estimated by considering the net increase in redispatch costs compared to 'only boundaries'

TOTAL REDISPATCH COSTS 2025, £M REAL 2020



TOTAL REDISPATCH VOLUMES 2025, TWH



- Most of the redispatch costs are due to boundary constraints (thermal constraints). The increase in redispatch costs to meet voltage constraints beyond the boundary constraints is marginal.
- Considering the difference between the total redispatch cost in the two cases allows to isolate the redispatch cost to meet voltage constraints : £53m real 2020 in this case

- Total net redispatch volumes are very similar between the only boundary constraints and boundary + voltage constraint case. Redispatch action generally lead to wind farms in congested areas to ramp down their output, being replaced with CCGTs or energy produced in other countries (via imports).
- Additional thermal plant redispatch is needed to meet to local reactive power constraints compared to 'only boundaries'

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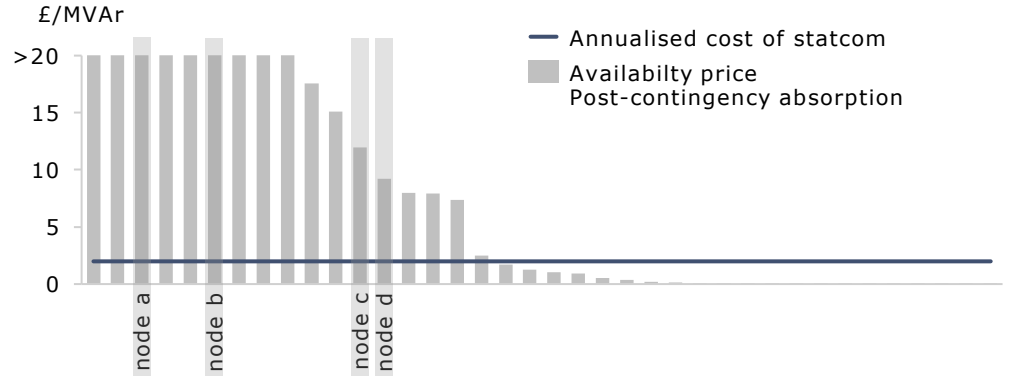
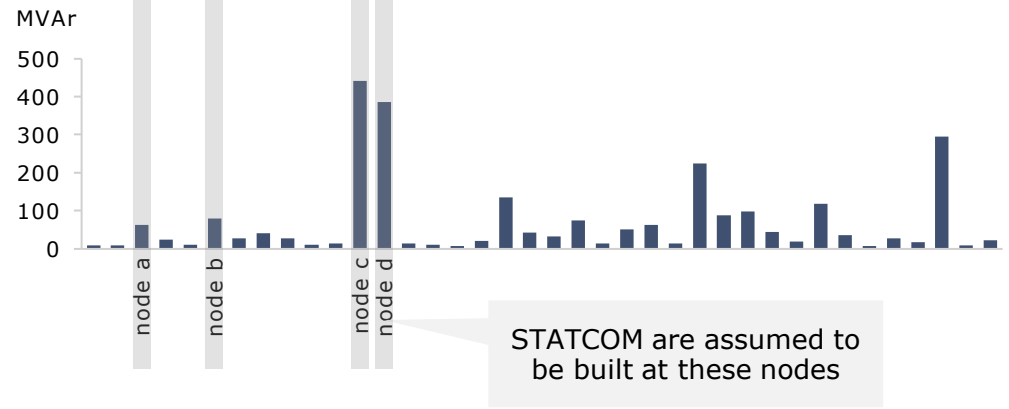
ECONOMIC MODELLING

In the long-term market scenario, new network assets are assumed to be developed in locations where it is economical, depending on costs incurred to resolve constraint

AVERAGE AVAILABILITY PRICE AT EACH NODE



AVERAGE MVAR NEED ACROSS THE YEAR



APPROACH

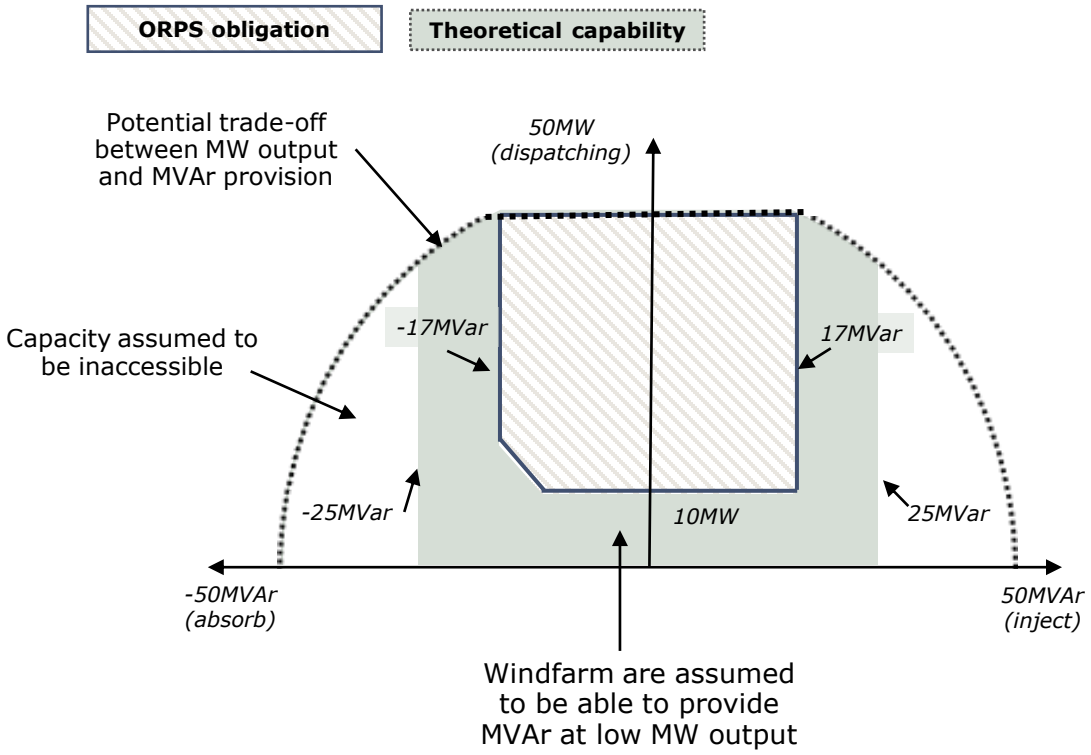
- Nodal price for the availability of reactive power at each transmission node is obtained for each of the 4 products. This represent the expected cost to meet the voltage need at this node (either through redispatch action or via the long-term market).
- The average nodal price is compared with the annualised cost of a network asset. The new capacity is assumed to be STATCOM. This is conservative assumption; it may be that some needs can be met with cheaper solutions such as dedicated reactors/capacitors.
- In nodes with significant MVAr needs (>50MVAr) and nodal price for reactive power availability above cost of network assets, STATCOM are added.

Note: Statcom costs based on ETYS 2015 Annex E

ECONOMIC MODELLING

To estimate the benefits of the short-term market, wind farms and batteries are assumed to be able fully utilise their capabilities outside ORPS ranges

THEORETICAL PQ CURVE FOR 50MW WIND FARM

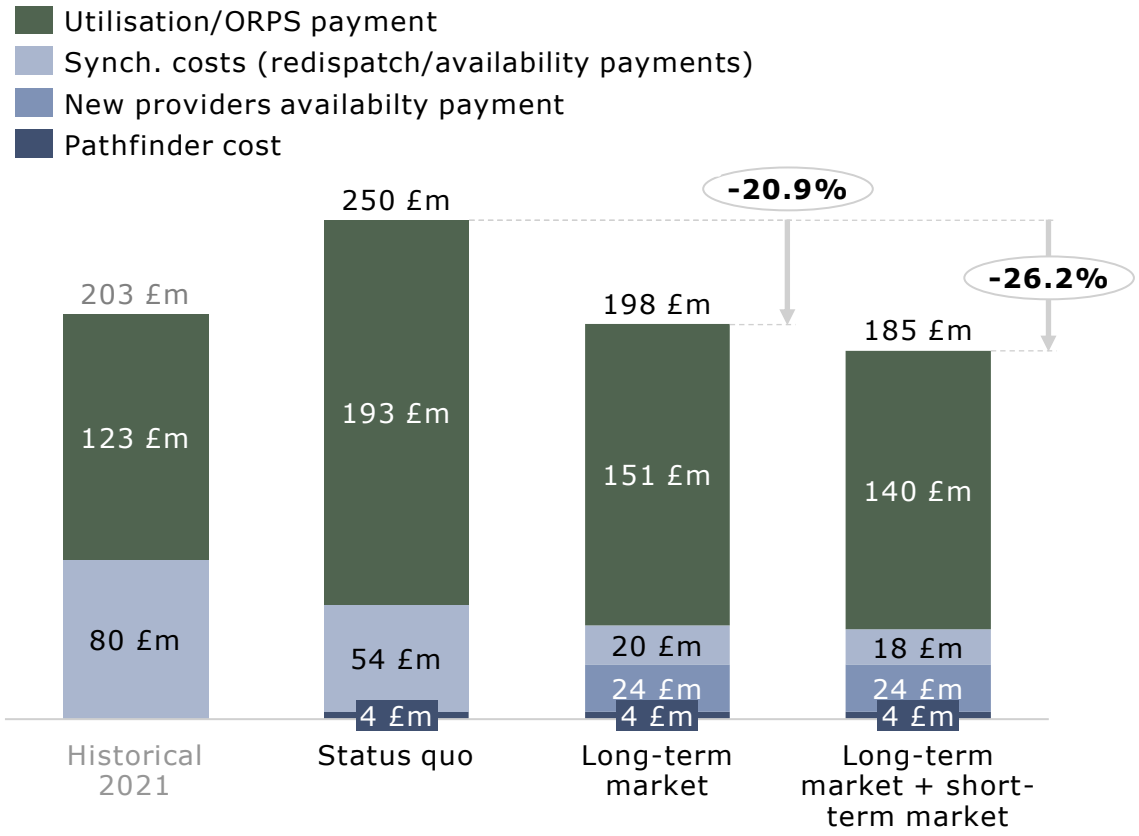


- To assess the benefits from the reactive power short-term market, additional capability available from existing providers are assumed (in addition to the long-term capabilities)
- The additional capability available assumed to be in line with market analysis case studies.
- In the case of converter connected technologies, additional capability beyond ORPS ranges are assumed to have a MW/MVAr trade-off, as illustrated in green on the left-hand chart. These opportunity costs are optimised in model.
- Overall, considering additional capabilities outside ORPS ranges could provide further capacity ranging from 2.5GVAr to 5GVAr depending on the operational patterns of potential providers.

ECONOMIC MODELLING

Significant cost benefits can be reaped through the introduction of a reactive market

ANNUAL VOLTAGE COSTS (2025 LEADING THE WAY FES SCENARIO, £M, REAL 2020)

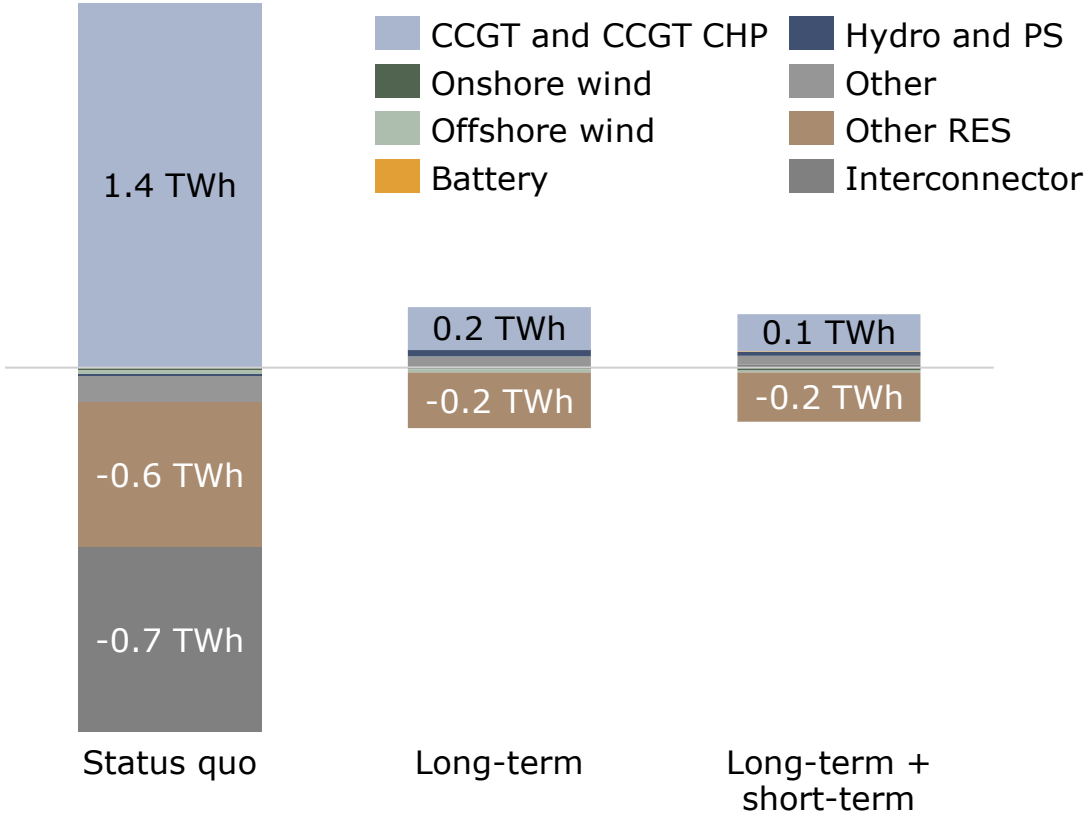


- **The voltage costs** are the sum of :
  - Costs for repositioning plant to provide reactive, either through BM or market arrangements (synchronisation cost on the chart)
  - Costs for utilisation (ORPS or market), £2.5/MVArh real 2020
  - Costs for new investment (annualised), from Pathfinders and additional STATCOMs from the long-term economic assessment
- The introduction of the long-term market for reactive power brings an economic benefit in terms of balancing and utilisation costs to meet voltage constraints. Compared to status quo, the long-term market would lower costs to meet voltage constraints by ~21%. This value is result of STATCOMs offsetting the need to pay ORPS providers for MVArhs, and partially offsetting the need to synchronise providers to ensure voltage stability
- The short-term market for reactive power brings further economic benefit beyond the long-term market. Being able to access providers extended range of MVAr capabilities reduces the need for balancing actions. It also allows for a more economically efficient dispatch (MVArh) of reactive providers, thus reducing the utilisation payments

ECONOMIC MODELLING

The introduction of competitive provision of reactive power reduces the need for balancing actions to meet voltage constraints

REDISPATCH VOLUMES FOR MEETING VOLTAGE CONSTRAINTS (TWH)



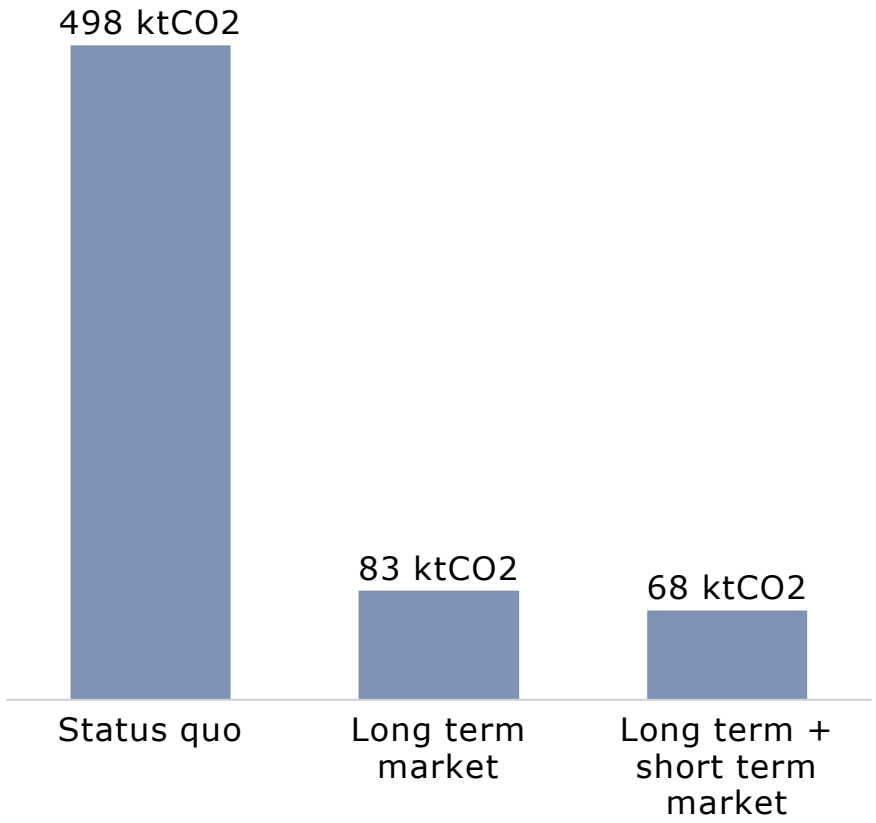
- The markets for reactive power reduce the **redispatch volumes** required
- With the introduction of the long-term market, the reduction in volumes can be attributed to offsetting the need to synchronise CCGTs to access reactive ranges
- These redispatch volumes are a significant proportion of the overall costs under the status quo, and their reduction in the long term market drives down both costs and carbon emissions
- In the scenario modelled, the reduced need to synchronise CCGTs increases the room on the system for renewable providers
- In the short term market, there is a slight reduction in overall redispatch volumes (albeit not as strong as in the long-term market), this is primarily driven by increased access to MVAr from existing providers, further reducing the number of instances in which CCGTs must be synchronised to meet reactive needs

*Difference between redispatch for 'only boundaries' and runs for both boundaries and voltage constraints

ECONOMIC MODELLING

Reduced reliance on CCGTs for resolving voltage issues results in a reduction in carbon emissions overall

NET CARBON EMISSIONS TO MEET VOLTAGE CONSTRAINTS KTCO2



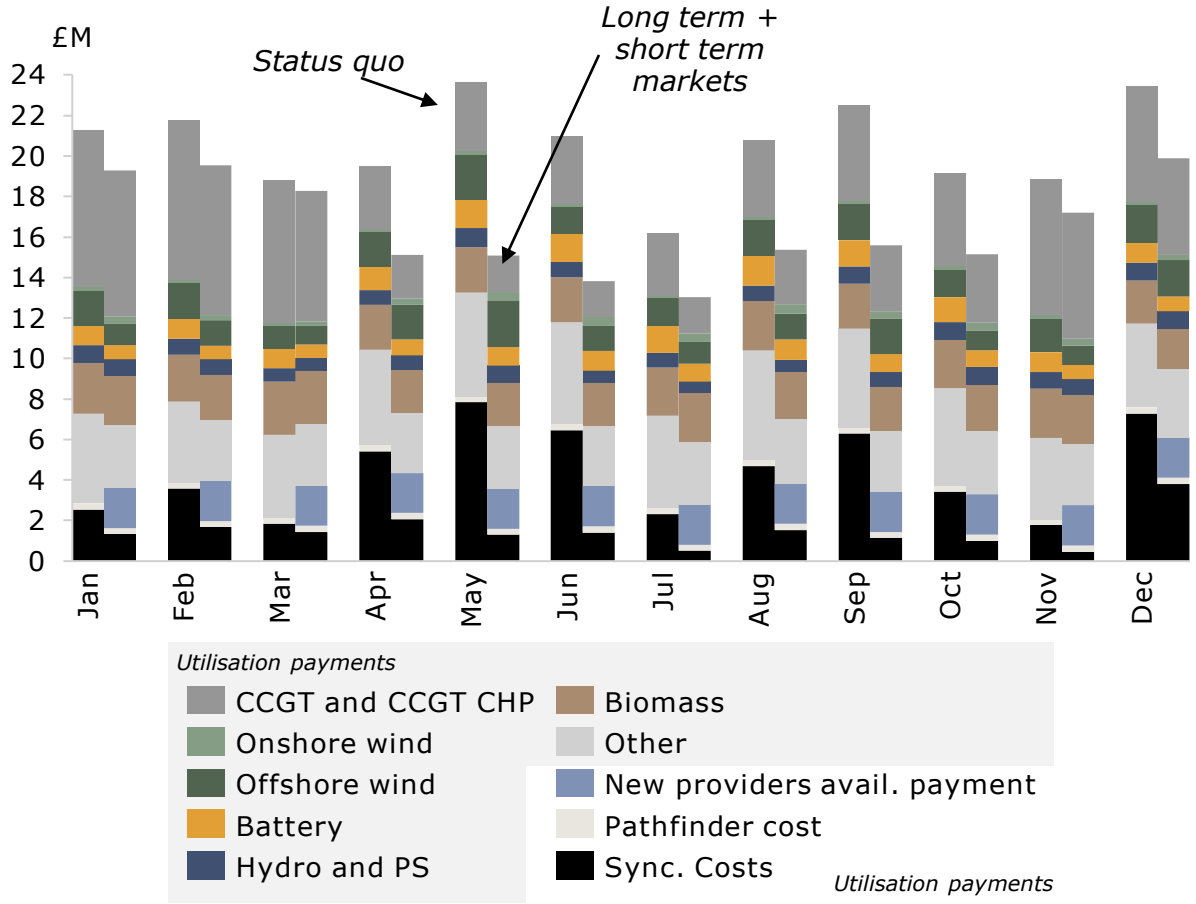
- Under the status quo arrangements, CCGTs must be synchronised to provide reactive power services relative often, resulting in a net increase in carbon emissions of ~0.5mt/y
- The introduction of a long-term market results in new build grid assets offsetting the need to synchronise CCGTs to access reactive power ranges and substantially reducing carbon emissions associated with voltage issues
- This benefit is compounded with the introduction of a short-term market as additional MVAr available from existing assets results in even fewer periods where CCGTs need to be synchronised to provide reactive power

*Difference between carbon emissions for 'only boundaries' and runs for both boundaries and voltage constraints

ECONOMIC MODELLING

Savings from a market arrangement primarily manifest in summer months

MONTHLY VOLTAGE COSTS, (2025 LEADING THE WAY FES SCENARIO, £M, REAL 2020)



- Savings from the introductions of market arrangements primarily accrue during the summer months, as fewer costs are incurred for synchronising providers to provide reactive power.
- Targeted investment at critical nodes can reduce overall spend on utilisation payments (at ORPS rates).
- In the winter, CCGTs are synchronised at the market schedule stage and so don't require payment to access MVAr capability (only utilisation).

ECONOMIC MODELLING

There are a number of potential benefits that are difficult to quantify with limited information/data on potential future behaviour & limited model horizon

Modelling horizon limitations	– We are modelling a single year in relative close proximity to today (2025 modelled year). – Longer term trends may expose a greater need for services as increasing volatility of transmission system flows over time results in higher demand for reactive power.
Additional existing capability in a short term market	– There exists significant uncertainty as to how much additional capability can be exploited by existing providers to access additional reactive power services, ultimately our assumptions have been informed by our case studies.
Locational signals influence in ST market	– Locational price signals are likely to result in increased capability where it is most required, even from existing providers, as prices rise and incentives sharpen. – In our ST scenario we have modelled uniform increased capability across locations.
Specific interactions with existing arrangements	– In the short term, if there a risk of lost revenue for ORPS providers (e.g. if they are expecting to be less heavily utilised if not accepted), providers may bid negative availability prices in the short-term market to maximise gross margins. We have not considered this behaviour in the modelling.
Plant bidding behaviour in ST market	– We have based plant bidding behaviour for availability on bids/offers for different technologies in line with mechanism behaviour (and ESO standard scenarios). – It may be the case that short term bidding behaviour diverges in the future.
TO behaviour	– Exposure of TO providers to the risk of competition means there's a risk of non-acceptance, as a result TO provider may offer more competitive (lower cost) solutions than they would under the status quo, maximising benefits for consumers.

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REACTIVE POWER MARKET DESIGN

Appendix B – Glossary & definitions

APPENDIX B

Glossary

Acronym	Term	Meaning
ESO	Electricity System Operator	National Grid ESO – the system operator in Great Britain
TO	Transmission Owner	Collective for the companies which own the transmission network in GB
DNO	Distribution Network Owner	Collective for the companies which own and operate the distribution networks in GB
OFTO	Offshore Transmission Owner	Collective for the companies which own offshore transmission infrastructure in Great Britain
GSP	Grid Supply Point	Connection Point at which the Transmission System is connected to a Distribution System
ORPS	Obligatory Reactive Power Service	Obligatory service to provide reactive power services as specified by the grid code
RIIO	Revenue=Incentives+Innovation+Output	Framework for network company remuneration in Great Britain
SP	Settlement Period	A period of 30 minutes beginning on the hour or the half-hour
SQSS	The Security and Quality of Supply Standards	Obligations on licensees to provide
STC	The System Operator-Transmission Owner Code	Defines the relationship between the transmission owners and the system operator incl. roles and responsibilities
MVAr	Mega Volt Ampere Reactive (Capacity)	Measure of capacity for reactive power (MVAr/h measure of capacity availability)
MVArh	Mega Volt Ampere Reactive hours (Volume)	Measure of volume for reactive power
DER	Distributed Energy Resources	Energy resources including generation, demand and storage connected to the distribution network

APPENDIX B

Glossary

Acronym	Term	Meaning
ESQCR	Electricity Safety Quality and Continuity Regulations	Governs the required quality of electricity supply in GB
NOA	Network Options Assessment	ESO assessment process for grid reinforcement
ETYS	Electricity Ten Year Statement	ESO view of transmission requirements for the next ten years
RAB	Regulated Asset Base	Regulated framework for cost recovery
CfD	Contracts for Difference	Low carbon support scheme in GB
CM	Capacity Market	Mechanism for renumerating capacity in GB

APPENDIX B

Definitions

Term	Example	Meaning
Contract (Delivery) Period	13:00 – 17:00 GMT 23rd May 2022 Or; Jan 2023 – Dec 2038	The contract period of delivery during which the provider shall be available to deliver the full requested change of reactive power, injection or absorption.
Product (or contract) Duration	4 hour or 5 years	Defines the duration of a standardised product.
Frequency of procurement (market schedule)	Daily or annual	Defines how often trading reoccurs.
Procurement lead time	16:00 GMT, D-1	Defines how far ahead of Delivery Period the trading happens (e.g. hours, days, months and/or years ahead). Same as Gate Closure Time, i.e. the deadline for submitting bids.
Market Time Window	24hours (00:00 – 23:59 GMT)	A fixed timeframe (ahead of time) for which products are open for trading at a given time.
Product	Pre-fault lagging	The definition of contracts/instruments available for trading. Products could differ by Contract Duration, Leading & Lagging and Static & Dynamic (depending on how we define products)
Contract (or instrument)	hh-230522-25-st-lagging	Is unique and specifies each specific contract being procured. E.g. specifying; time; direction (leading/lagging); and whether it is static or dynamic. Typically has a unique contract ID, see example which represent a half hour on 23rd May 2022, 12:00-12:30, static, lagging.
Market Time Unit (MTU)	30min	The most granular Product Duration. Also the period for which the market price is established.
Product linking		In case of multiple type of products being procured at the same time, 'linking' allows provider to offer a linked combination of products. Typically used to link leading and lagging into one offer. Typically non-mandatory.

APPENDIX B

Definitions

Term	Example	Meaning
Availability		Availability is defined as the availability to deliver reactive power at some point in the future. The utilisation price can be defined as part of the availability contract or otherwise (including zero). Commitment may be firm or non-firm (see below).
Utilisation		Utilisation is defined as the delivery of reactive power (leading/lagging) to the grid in line with dispatch instructions by the ESO
Availability requirement	95%	No assets can provide 100% availability over a long period, e.g. a year. Therefore, *firm* long-term availability markets should have a predefined availability requirement, to allow for outages.
Firm contract		Seller guarantees continuous availability (subject to contracted availability requirements) and failure to deliver would trigger a financial and/or legal liability claim. It provides the buyer (NGESO) the assurance that future voltage security is covered, but the nature of the contract prevents intermittent renewables such as solar and wind from participating in long term contracts, thus limiting the level of competition.
Non-firm contract		Contracts comes without a guarantee of continuous availability. They may be interrupted for any reason, without liability to NGESO. The provider is guaranteed a price if providing services, e.g. utilisation and/or short-term availability payment.
Outside option		In the context of this project, 'outside option' refers to the Transmission Owner solution cost counterfactual. This is considered to be an outside option because, whilst solution costs are assessed as part of the bid selection (winner determination) process, a contract is not ultimately awarded. An STC planning request is triggered and the TO is instructed to build the asset which then forms part of the relevant TO's Regulated Asset Base. This is compatible with current arrangements and has been informed by learnings from the Pathfinder projects, but may be subject to change in the future.
Shortfall/gap		The shortfall in the context of this project represents the capability that must be secured in the current timeframe to ensure voltage security in subsequent timeframes. The shortfall is contracting additional capability that would not otherwise be available in subsequent timeframes.


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