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Replacement Reserve Cost Benefit Analysis in GB Draft Report

National Grid ESO

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Contents

Overview of project

	Overview
The project	– GB may no longer fully participate in Project TERRE, having been excluded from the EU internal market for energy. – National Grid Electricity System Operator (NG ESO) has appointed AFRY Management Consulting to conduct a Cost-Benefit Analysis (CBA) on the implementation of a Great Britain (GB) only Replacement Reserve (RR) product, and a further consideration of a cross-border RR arrangement with France. – Our work will provide an update to the 2016 ENTSO-E CBA, which identified a benefit for Great Britain of ~€17 million per annum (2013 money base) as a result of access to lower priced reserve from France over the interconnector. This analysis also identified limited benefits from a GB only product.
This document	– This document provides key results from the CBA for a number of scenarios. – We have presented the CBA over four key sections: 1. Methodology of modelling and description of scenarios; 2. Quantitative market assessment of the benefits of implementing RR product; 3. Cost of implementing RR; and 4. Qualitative discussion of issues flagged by GB TERRE Implementation Group. – This document should be considered a continuation of an earlier document titled 'NG ESO: Review of Replacement Reserve Product and ENTSO-E CBA', shared here in August 2021.

INTRODUCTION

Executive summary

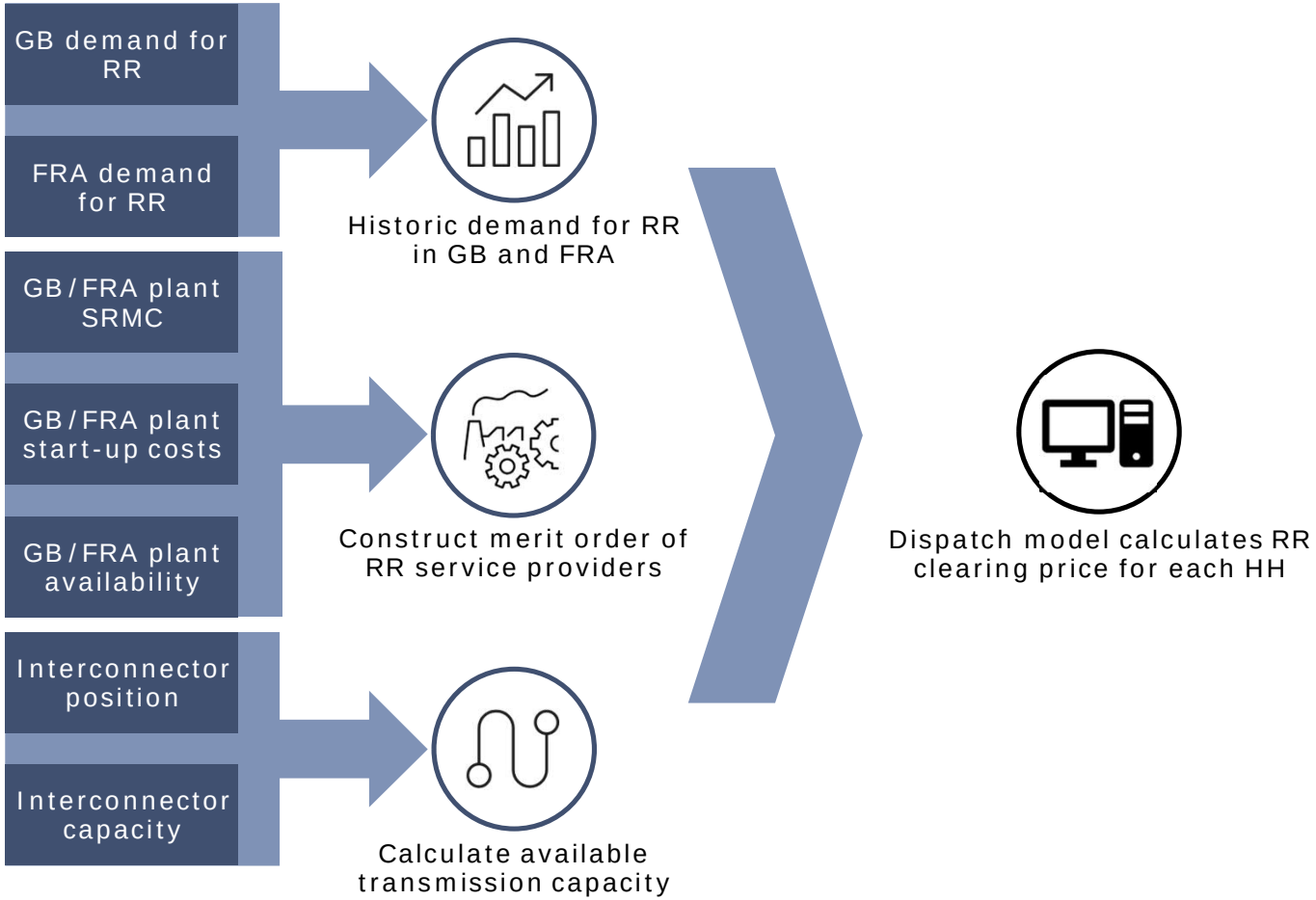
- To understand the impact of introducing a RR product, we have created a model to assess the market benefits in GB if there had been a RR product over the period 2019-2021.
  - The analysis is thus backward-looking, and all monetary figures are in money of the day.
- We have created a number of scenarios to explore the impact of bidding behaviour as this can be expected to change with a new product.
- Data provided by NG ESO shows historic GB costs for counterfactual balancing actions that could have been met by the proposed RR product equated to £127.4M in 2019, £110.5M in 2020, and £367.4M in 2021*.
- 2021 is an outlier due to unusual market conditions (extended outages, commodity price highs) and thus excluded from presented averages.
- Modelled results indicate that:
  - The average annual benefit of a GB only product depends heavily on bidding behaviour, ranging from £4.8m if margin bidding maintained to £26m if variable cost bidding becomes common.
  - The additional benefit of including France is £4.3m with IFA1 capacity with a marginal further benefit if IFA2 was considered.
- The indicative costs of implementing RR in GB are estimated at £13-20m CAPEX and £4m per year OPEX. This does not include industry costs incurred by BSPs and Interconnectors.

* - Note 2021 has been calculated from Jan-July and extrapolated pro-rata

Contents

METHODOLOGY

We have used a dispatch model to calculate the clearing price of RR in each HH period from 2019-2021



*SRMC: Short-run marginal costs

High level methodology

- The demand for RR in each half-hour (HH) in GB and France has been sourced from NG ESO and ENTSOe.
- A merit order of RR providers has been constructed for each half hour (HH) by determining the plants' variable costs and average availabilities for different technologies on a monthly basis.
  - BSPs' bidding takes into consideration plant-specific availability, SRMC* and start-up costs.
  - The bidding behaviour of the BSPs with regard to the inclusion of non-variable cost (e.g. profit margin or return on investment) varies across the scenarios.
  - In order to assess the provision of cross-border RR, some scenarios are limited to a GB only merit order, while for others, we model a common merit order for GB and France.
- The available transmission capacity for IFA1 is calculated in each HH period using historic positional and capacity data. An additional restriction has been made to limit potential cross-border contribution in times when prices suggest the IC should have been fully importing into GB (to discard current actions taken by NG ESO to manage RoCoF)
- The aforementioned inputs are then run in a dispatch model to calculate a RR clearing price for each HH period from 2019-2021.

METHODOLOGY

We have developed two scenarios for the implementation of a GB-only RR product and will compare this against actual historic costs

	Scenario description
Scenario 0	**Scenario 0: Status Quo** – The total historic costs in GB were calculated by using the accepted offer volumes and prices which were classified as RR-like actions, as provided by NG ESO. The cost consists of contributions from the BM and also from non-BM STOR. – For 2021 the cost and cost savings have been extrapolated pro rata to extend to a whole year, based on the assumption that current market conditions (January-July inclusive) remain.
Scenario 1	**Scenario 1: GB RR - Variable cost bidding** – In this scenario, we assume strict variable cost bidding in response to the Pay-as-Clear (PaC) design (SRMC + start-up cost + BSUOS + scarcity rent). – Despite this being a logical bidding strategy under PaC, this may result in an overly optimistic reduction in pricing. This is because service providers have the choice of participating either in the BM or RR. If there is a systematic bias that one market has higher prices than the other, we would expect either capacity to be offered predominantly in the higher priced market (BM), or for some opportunity cost pricing to come into the lower priced market (RR). – The cost savings of this scenario represents the upper bound of what could be expected in the past years on the introduction of RR.
Scenario 2	**Scenario 2: GB RR - BM opportunity cost bidding** – In this scenario, it is assumed that new entrants make use of the fact that a PaC RR market is easier to participate relative to the Pay-as-Bid (PaB) BM, enabling them to bid at their variable cost. Conversely, more established players are assumed to apply a premium to their bids calibrated by historic margins achieved in the BM. – The logic of this approach is that established players have the choice of participating either in the BM or RR, thus demanding the same value in RR that they receive in the BM. However new entrants options are considered restricted by their relative lack of market data/resources, thus we assume they would prefer to bid at variable cost given the PaC pricing approach. – The cost implications of this scenario likely represent a more realistic outcome to the introduction of RR relative to Scenario 1.

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METHODOLOGY

In addition to this, we have developed two further variants of Scenario 2 which examine the benefits of cross-border RR provision with France

	Scenario description

Scenario 2+	Scenario 2+: GB plus FR RR - BM opportunity cost bidding + IFA1
	– Same bidding as Scenario 2.
	– In this scenario, the merit order of RR service providers is shared across GB and France. A French merit order was created in a similar way to the GB model inputs, and RR requirements can be met through use of the interconnector.
	– The cross-border RR volume that can be utilised is constrained by 2 factors: (1) The historic Available Transmission Capacity (ATC) on IFA1 and (2) the physical notification of the interconnector.
	  – For example, where GB is fully exporting to FR, this creates a maximum of 4GW of RR "flows" across the interconnector, and the limiting factor become the relative costs of RR provision in the two markets. However, it should be noted that the RR requirement is less than 1GW in 99% of periods.
	  – An additional restriction has been made to limit potential cross-border contribution in times when prices in the two countries suggest the IC should have been fully importing into GB. This restriction is made to discard actions taken by NG ESO to manage RoCoF as these are not expected to be required once RoCoF issues resolved.

Scenario 2++	Scenario 2++: GB plus FR RR - BM opportunity cost bidding + IFA1 + IFA2 – Same bidding as Scenario 2 and 2+ with the merit order of RR service providers shared across GB and France and ATC of IFA1 and theoretical IFA2 assuming it was operational from 2019-2021. – The theoretical ATC on IFA2 is assumed to use the same availability profile as IFA1, as IFA2 was assumed to operate identically to IFA1 from a wholesale market perspective. (Note that this simplifying assumption may under-state the capacity availability, but may over-state the price differentials between the two markets.)

Scenario commentary

– Scenario 2, and its variants, likely represents the benefits of introducing RR in the short- to medium-term (GB or GB-France, respectively).

– However Scenario 1 should not be discounted. As more flexible technologies (flexible generation, energy storage, demand response, etc.) enter the system and gain wider access to the BM, margins in these markets may be eroded. Ultimately, the trend will be towards service providers bidding on RR closer to variable costs, except in times of significant scarcity.

– Following this logic, Scenario 1 may be more representative of the costs and cost savings longer term.

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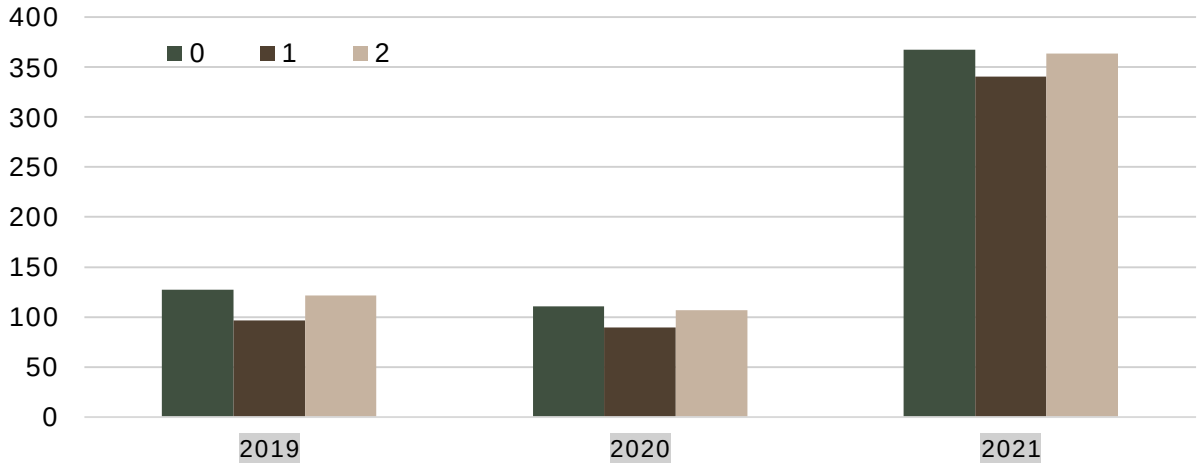
Contents

The benefit of a GB only product depends heavily on bidding behaviour

Upward balancing cost (£m)

	2019	2020	2021
Scenario 0	127.4	110.5	367.4
Scenario 1	96.5	89.5	340.3
Scenario 2	121.8	106.5	363.6
Delta from 0 to 1	*-30.9*	*-21.0*	*-27.1*
Delta from 0 to 2	*-5.6*	*-4.0*	*-3.8*



Note: 2021 totals are extrapolated pro rata from Jan-July to represent a full year

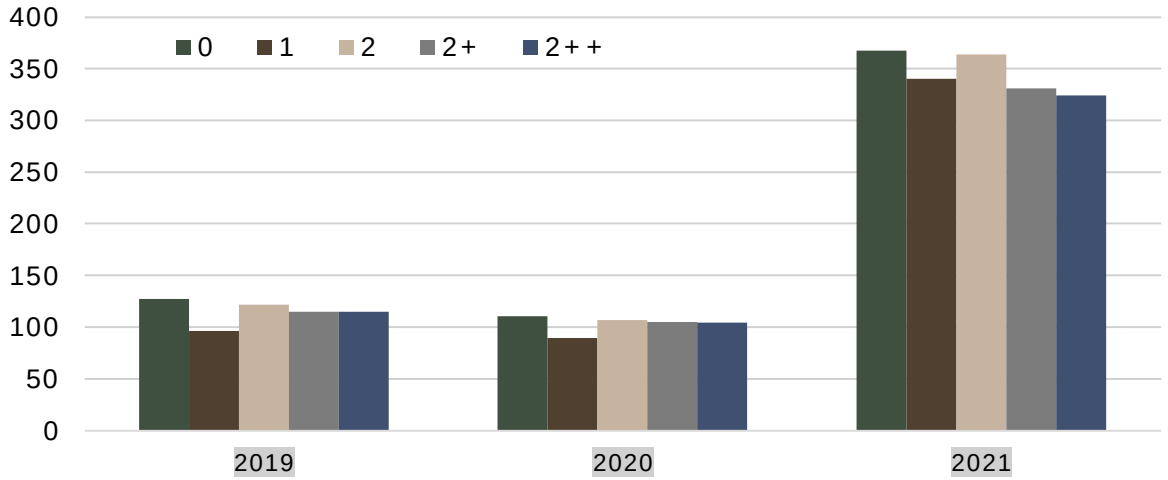
Commentary

- All years show benefits (negative deltas) for a GB only RR product, the levels of which depend heavily on the assumption on bidding behaviour.
- Across the three years, the benefits fall in a similar range.
- Using variable cost bidding (scenario 1) leads to a benefit of £21m-31m depending on the year.
- Allowing some established players to maintain higher margins(scenario 2) leads to a lower benefit of £3.8m-5.6m depending on the year.

The benefit of including France is more variable across the years, showing greatest benefit in 2021

Upward balancing cost (£m)

	2019	2020	2021
Scenario 2	121.8	106.5	363.6
Scenario 2+	115.1	104.7	330.7
Scenario 2++	114.5	104.5	324.3
Delta from 2 to 2+	*-6.7*	*-1.8*	*-32.9*
Delta from 2 to 2++	*-7.3*	*-2.0*	*-39.3*



Note: 2021 totals are extrapolated pro rata from Jan-July to represent a full year

Commentary

- We see additional benefit when we consider French plants within the analysis.
- In 2019, with opportunity cost bidding, we see a delta of £6.7m from the connection to French reserve. In 2020, the delta is only £1.8m.
- Scenario 2++ (assuming 1GW of extra interconnection) enhances these benefits only marginally.
- Results for 2021 show greater benefits than 2019 and 2020.
  - Higher benefits are caused by a difference in scarcity rent in the two markets in 2021 and it is plausible that in reality the markets – if better integrated – would react to each others price level and therefore the delta would be smaller.
- Note that we have only had access to French data from January 2021 and have used this to estimate availability and costs in 2019 and 2020 (in combination with GB data).

The average cost savings per scenario show the importance of capturing changing bidding behaviour

Costs per scenario (£m)					
		2019	2020	2021	Average of 2019 and 2020
Scenario 0	Status Quo	127.4	110.5	367.4	
Scenario 1	GB RR - Variable cost bidding	96.5	89.5	340.3	
Scenario 2	GB RR - BM opportunity cost bidding	121.8	106.5	363.6	
Scenario 2+	GB plus FR RR - BM opportunity cost bidding + IFA1	115.1	104.7	330.7	
Scenario 2++	GB plus FR RR - BM opportunity cost bidding + IFA1 + IFA2	114.5	104.5	324.3	
Delta from 0 to 1	*Status quo to GB variable cost bidding*	*-30.9*	*-21.0*	*-27.1*	*-26.0*
Delta from 0 to 2	*Status quo to GB opportunity cost bidding*	*-5.6*	*-4.0*	*-3.8*	*-4.8*
Delta from 2 to 2+	*GB only to GB plus France (IFA1)*	*-6.7*	*-1.8*	*-32.9*	*-4.3*
Delta from 2 to 2++	*GB only to GB plus France (IFA1 and IFA2)*	*-7.3*	*-2.0*	*-39.3*	*-4.6*

Note: 2021 totals are extrapolated pro rata from Jan-July to represent a full year

Commentary

- Average costs and cost savings (deltas) are presented for each scenario.
- In the GB only scenarios, average cost savings of £4.8m to £26m depend on bidding behaviour.
  - As noted previously, opportunity cost bidding is likely to represents the benefits of introducing RR in the short- to medium-term however variable cost bidding could represent a world with more flexible technologies, hence may be more representative longer term.
  - These cost savings represent a benefit to the consumer to the detriment of the producers overall (accepting lower margins), however there is likely some movement between producers.
- In the GB plus France scenarios, the average cost savings of £4.3m (IFA1) and £4.6m (IFA1 and IFA2) present additional benefit (above GB only case).
  - These cost savings however represent a ‘real’ benefit as cheaper plants are used to meet RR demand, i.e. there is a more efficient dispatch.
  - 2021 presents a greater benefit

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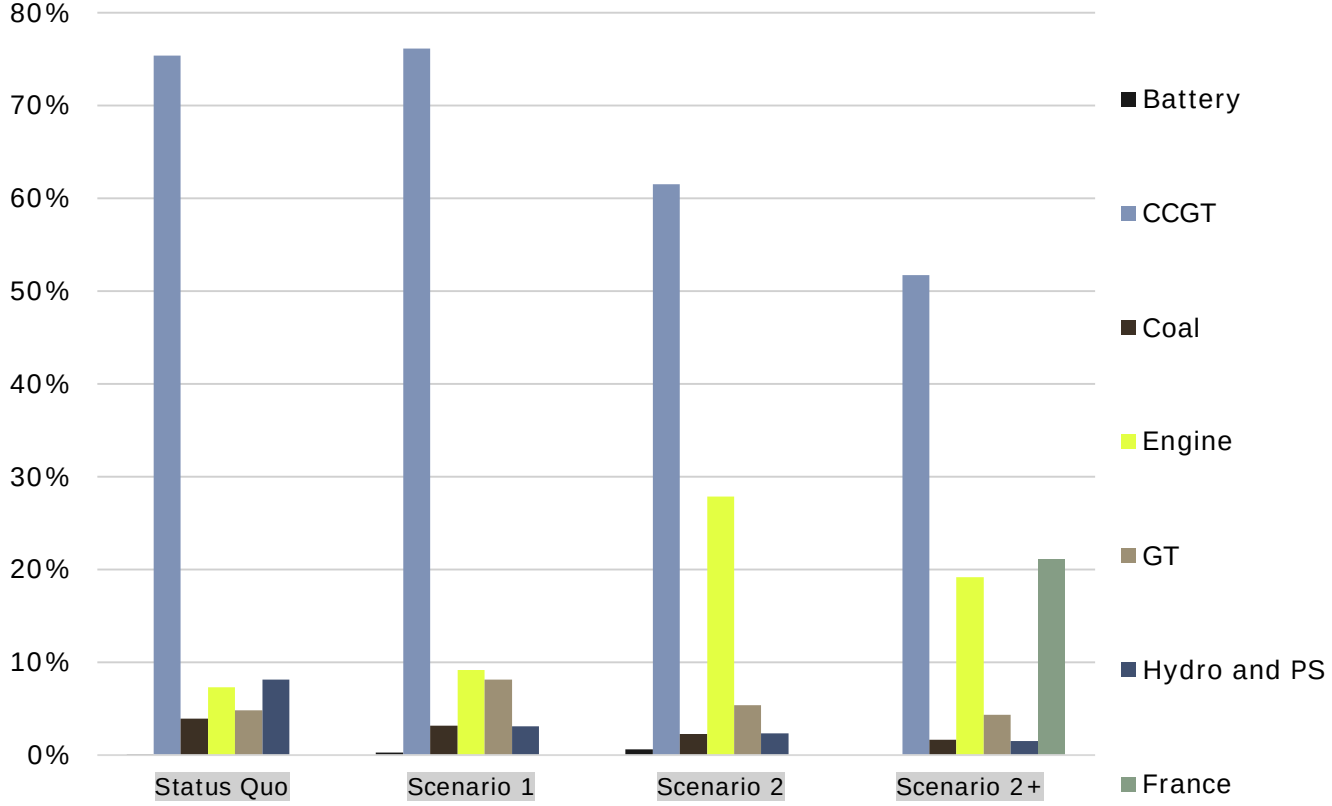
The technology split changes somewhat by scenario, with CCGTs dominating throughout

2019 volume split by technology



Commentary

- In the Status Quo, the technology providing RR-like actions is dominated by CCGTs.
- Scenario 1 with variable cost bidding sees a very similar technology split.
- Scenario 2 sees a higher contribution from engines.
  - With the established players bidding at higher prices, new entrants are 'in merit' more often.
- Scenario 2+ sees moderate levels of French plants contributing, reducing the amount of RR met by domestic CCGTs.

Note: 2021 totals are extrapolated pro rata from Jan-July to represent a full year

Contents

ESTIMATED COSTS OF IMPLEMENTING RR

The indicative costs of implementing RR in GB are considered across the scenarios; these are estimated at £13-20m CAPEX and £4m per year OPEX

Cost item	GB-only (Scenario 1 and 2)			GB plus FR (Scenario 2+ and 2++)		
	Assumptions	Costs		Assumptions	Costs	
		CAPEX	OPEX		CAPEX	OPEX
GB RR platform – CAPEX	NG ESO owns the IPR for the LIBRA platform – costs will be similar to implementation of existing TERRE.	£10m	-	GB plus FR platform would be developed to accommodate FR also participating in wider EU platform.	£15m	-
GB RR platform – OPEX	Costs similar to existing TERRE platform.	-	£2m per year	Costs similar to existing TERRE platform.	-	£2m per year
TSO costs – CAPEX	NG ESO will need to regression test with new code implemented in 2021, test with BSPs and roll-out.	£3m	-	NG ESO will need to regression test with new code implemented in 2021, test with BSPs and roll-out. Additionally, NG ESO would need to develop and test with ElecLink, IFA and IFA2.	£5m	-
TSO costs – OPEX	Increased staffing requirements (control room and post-event analysis), IT monitoring, and training.	-	£2m per year	Increased staffing requirements (control room and post-event analysis), IT monitoring, and training.	-	£2m per year
BSP costs	BSP costs unknown at this time					
Interconnector costs	Interconnector costs unknown at this time					
TOTAL	£13m CAPEX & £4m per year OPEX			£20m CAPEX & £4m per year OPEX		

Note: To date, NG ESO has invested £18m adapting internal IT systems, implementing business processes, and testing with the general industry; this should be compared against the original estimate, given as part of the Grid Code and BSC change, of £25m to £31m.

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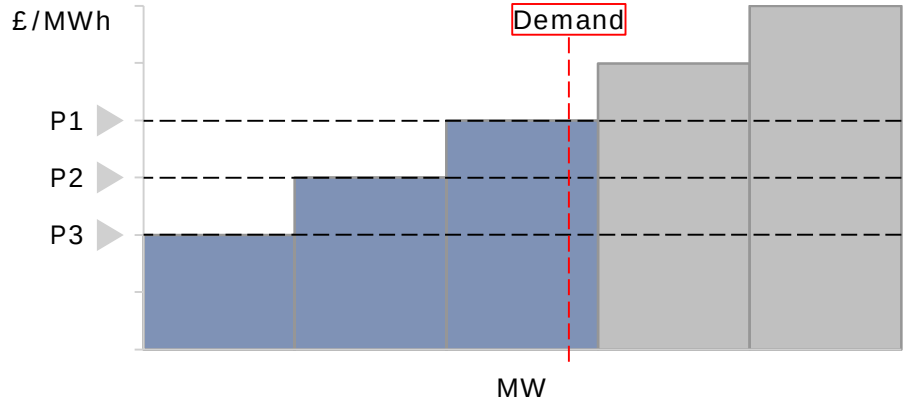
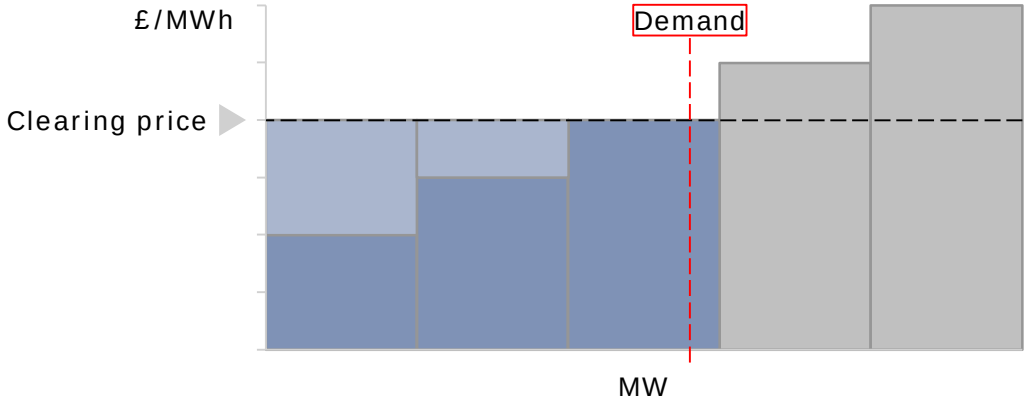
Contents

The RR product utilises a pay-as-clear pricing methodology, in contrast to pay-as-bid adopted in the BM

PAY-AS-BID: PARTICIPANTS RECEIVE BID/OFFER-SPECIFIC PRICE



PAY-AS-CLEAR: PARTICIPANTS RECEIVE SINGLE CLEARING PRICE



Commentary

- The BM remunerates participants in a pay-as-bid manner given the variable nature of bids and offers in relation to speed, duration, location, etc.
- Conversely, the relatively homogenous RR product proposed under Project TERRE allows for participants to be remunerated utilising a pay-as-clear approach.
- In theory, under fully competitive conditions with perfect information, pay-as-bid and pay-as-clear should produce similar results:
  - Pay-as-bid participants are incentivised to price mimic the marginal unit (e.g. highest cleared price offer/lowest cleared price bid).
  - Pay-as-clear participants are automatically awarded the price set by the marginal unit (e.g. highest cleared price offer/lowest bid).
- In practice, this is not always the case: Pay-as-bid may result in inefficient dispatch e.g. if uncertainty leads to difficulty establishing the marginal unit. Furthermore, pay-as-clear offers clearer price signals and wider access for smaller players without having to anticipate the behaviour of the entire market. However, providing a single clearing price in the BM or attempting to homogenise BM products creates its own inefficiencies given the range of services that are procured using the same platform.
- The impacts of contrasting remuneration methodologies does not fall within the remit of the project, however it is important to flag that this limits the insight of comparing historic counterfactual costs, against scenarios implementing RR.

Wider Reserve Reform: Comparison of Replacement Reserve to existing GB Products

Existing Products

Planned Products

	Dynamic Containment (DC)	Firm Frequency Response (FFR)	Short Term Operating Reserve (STOR)	Quick Reserve (QR)	Slow Reserve (SR)	Replacement Reserve (RR)
Overview	– Designed to operate post-fault, i.e. for deployment after a significant frequency deviation in order to meet the most immediate need for faster-acting frequency response.	– Monthly electronically tendered service though which NG ESO procures energy that can respond within 10 or 30 seconds.	– STOR is procured from generation and/or demand. Procured via 3 tenders each year.	– Quick Reserve is a fast-acting reserve product which is intended to bridge the gap between the new frequency response services and the slower reserve product(s).	– Slow Reserve is a manually activated reserve, intended to manage short notice supply demand imbalances and transition frequency recovery into BM timescales.	– RR will be procured from both BM and Non-BM participants. – No decisions have been made on procurement etc.
Minimum Size	– 1MW	– 1MW	– 3MW	– TBC	– TBC	– 1MW
Aggregation of smaller units	– TBC	– Yes	– Yes	– TBC	– TBC	– Yes (delivery based on 15MW blocks).
Response requirements	– Response in <1 second for a duration of <20 minutes.	– Response in <10 seconds sustained delivery of 20 seconds; or – Response in <30 seconds sustained delivery of 30 minutes.	– Response in <20 minutes sustained delivery of >2 hours.	– Full delivery in 30 seconds. – 1-minute extendable full output blocks, maximum of 20 minutes, stopped at any time.	– Full delivery in 15 minutes. – 1-minute extendable full output blocks, up to 240 minutes.	– Response in 30 minutes sustained delivery of 60 minutes.

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OTHER QUALITATIVE ISSUES

Wider Reserve Reform: Impact of Replacement Reserve on other existing and planned products

		Impact of Replacement Reserve
1	Impact Existing Products	– We anticipate a cross over between NGESO use of STOR (while it is still used) and the potential for Replacement Reserve. For example, in the event of a loss and subsequent instruction of STOR – NGESO may be able to stand STOR down sooner and use RR as an alternative. This has the potential to reduce the expenditure in the STOR market. – We expect no impact for the use of Dynamic Containment or Firm Frequency Response.
2	Impact on Proposed Products	– There is potential for some overlap between the use of Replacement Reserve and the current requirements for 'Slow Reserve'. There are similarities in the response requirements of providers and the broader aims of the two products. – We expect limited impact of Replacement Reserve on the use of 'Quick Reserve'.
	Conclusion	– There are similarities between the aims and requirements of the STOR product, its proposed replacement 'Slow Reserve' and 'Replacement Reserve'. – The impact may increase complexity for participation – participants will need to try and optimise across more markets. It could also reduce competition within the markets if participants choose to operate in one market over another. This could reduce the benefit presented in this analysis.

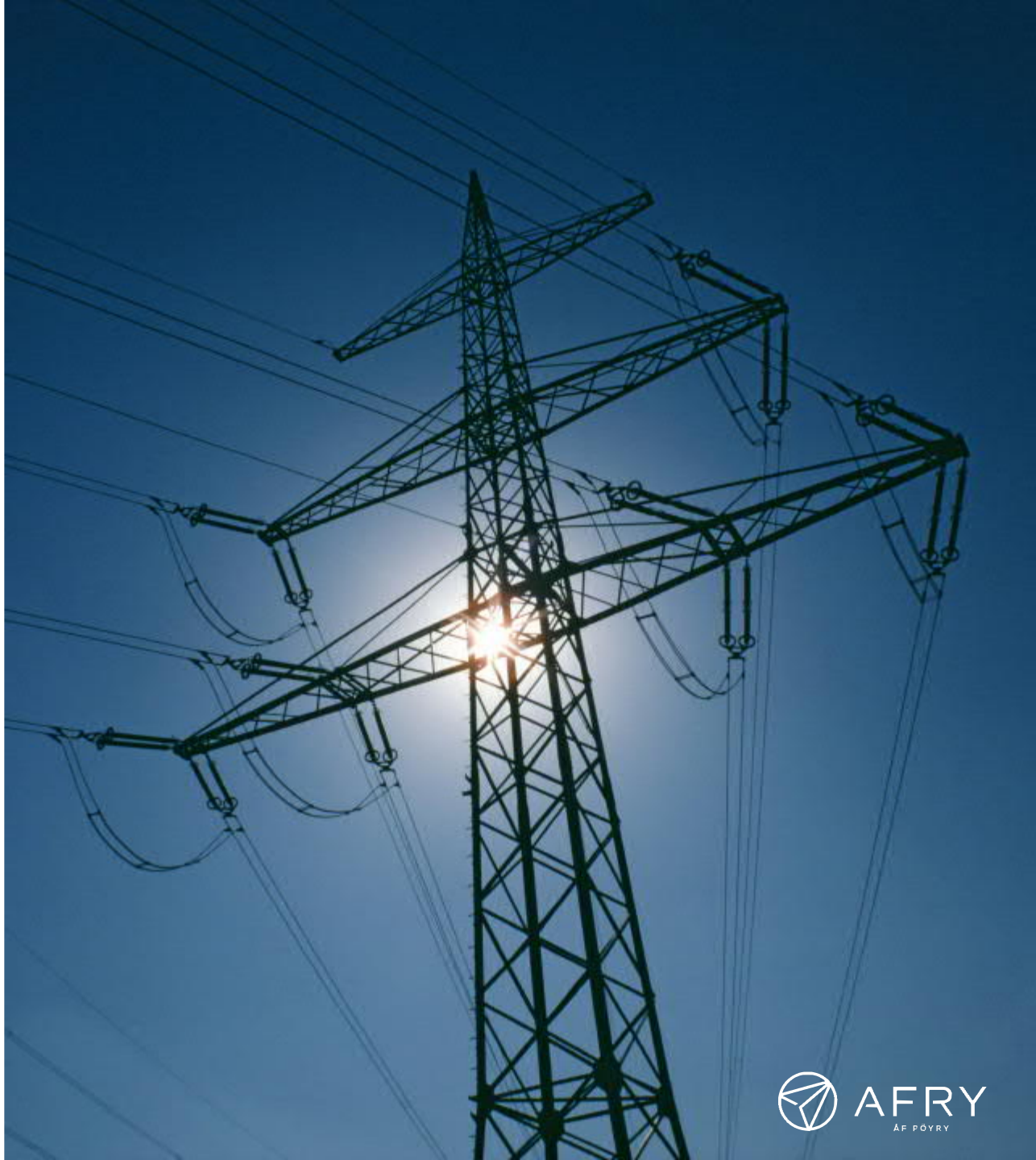
OTHER QUALITATIVE ISSUES

Hourly vs. continuous auctions

- Continuous trading of simple products gives better opportunities to adapt to changing forecasts in the context of a high-RES system, but it does require pay-as-bid pricing.

- Conversely, delays in trading until the next auction round could mean that restorative actions are more costly (generally, the availability of flexibility reduces closer to delivery).

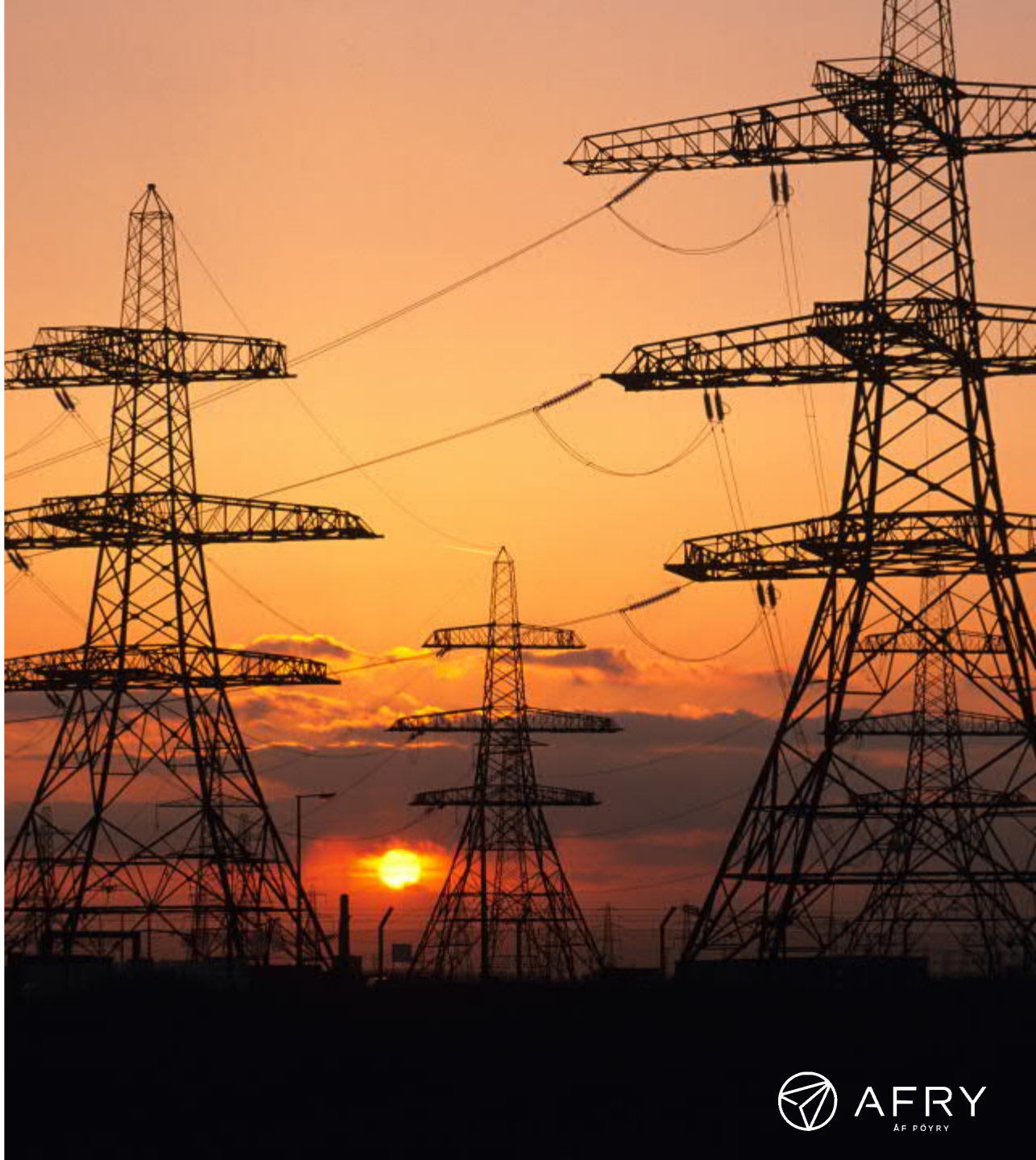
- This could be mitigated with frequent auctions, but this effectively also requires pay-as-bid pricing behaviour, as there will be limited liquidity in any of the individual markets.



OTHER QUALITATIVE ISSUES

Non-delivery

- Non-delivery of Balancing Service Providers:
  - Non-delivery of accepted offers/bids is dealt with within the BM: effectively for non-delivered offers, participants are charged the higher of the relevant imbalance charge or the accepted offer price (and the equivalent for non-delivered bids).
  - For non-delivery of cross-border trades, the protocols of interconnector scheduling would need to be resolved: there is potentially an imbalance position in both price areas. If the interconnector flow is adjusted to reflect the non-delivery of the service by the BSP, the imbalance would be isolated to a single area. Care is needed to ensure there are no perverse incentives.
- Non-delivery of Interconnector:
  - Will result in RR imbalance in both regions – potentially very costly.
  - Interconnectors may want to limited liability in certain instances.



Contents

ANNEX

We have identified some limitations to the analysis performed

Limitation	Description
Historic years	Backward looking analysis may not be fully reflective of rapidly evolving electricity systems (physically and legislatively).
Wider implications	Not looking at wider impacts that RR would have on total system (wholesale, BM, CM, ancillary, network reinforcement, etc.).
Bid-offer calculations	Variable cost calculations uses technology tranches – less accurate than plant level calculations taking into consideration locational costs/limitations.
Remuneration impacts	Pay-as-clear vs. pay-as-bid – implications of contrasting pricing methodologies are noted and we have aimed to present a range of potential behaviour changes.
Limited RR offer data for France	Only received 2021 YTD data for RR and bidding volumes and prices – assumptions made on 2019 and 2020.
Gaming of bids by TSOs	Not considering perverse bidding behaviours by TSOs – there may be opportunities for gaming LIBRA system such as holding back cheap reserve for domestic use.
HVDC losses	Transmission losses over interconnectors and consideration of who will be financially responsible are not considered in this analysis. This will result in disparity of allocated RR across borders and, assuming metering at the interconnector infeed, likely force the exporting area to compensate without being financially remunerated.
Scarcity rent	Scarcity rent is being included in GB but not in France, i.e. we are not considering a change in French bidding behaviour in response to tightness in GB. This is specifically relevant for scenario 2+ in 2021.
IFA2 availability	In scenario 2++, the availability is assumed to be as per IFA1 which likely under-states the capacity availability, but may over-state the price differentials between the two markets.
RR requirement	The requirement for RR has not been changed within the analysis.

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