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Replacement Reserve Cost Benefit Analysis in GB

National Grid ESO

OCTOBER 2021

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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 further consideration of a possible cross-border RR arrangement with France.
- Our work provides an update to the 2016 ENTSO-E CBA, which identified a benefit for GB of ~€17 million per annum (2013 money base) as a result of access to lower priced reserve from France over the interconnector. ENTSO-E's analysis 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 five key sections:
  1. Methodology of modelling and description of scenarios;
  2. Quantitative market assessment of the benefits of implementing an RR product;
  3. Cost of implementing RR;
  4. Net present value to assess the economic viability; and
  5. Qualitative discussion of issues flagged by GB TERRE Implementation Group including design considerations and interaction with wider Reserve Reform.
- This document should be considered a continuation of an earlier document entitled 'NG ESO: Review of Replacement Reserve Product and ENTSO-E CBA', shared here in August 2021.

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Executive summary

APPROACH

- 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, with quantitative financial benefits provided in nominal terms for that period.
- We have created a set of scenarios to explore the impact of altered types of bidding behaviour that might be expected, given the introduction of a new RR 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, high commodity prices, etc.) and thus has been excluded from presented averages.

CONCLUSIONS

- Modelled results indicate that:
  - The average annual benefit of a GB only product depends heavily on bidding behaviour, ranging from £4.8m per annum if the bidding behaviour seen in the Balancing Mechanism is maintained (BM opportunity cost bidding), to £26m per annum if variable cost bidding is adopted.
  - In AFRY's view, the scenario where participants maintain some BM opportunity cost bidding is more likely than variable cost bidding in the short-mid term, however as more flexible participants enter the system, margins could be eroded to closer to variable cost bidding in the longer term.
  - The additional benefit of including France is £4.3m with IFA1 capacity with a marginal further benefit if IFA2 was considered.
- The indicative future costs of implementing RR in GB are estimated at £13-20m CAPEX and £4m per annum OPEX. This does not include industry costs incurred by BSPs and Interconnectors.
- Using these figures, net present value (NPV) calculations show a negative NPV with BM opportunity cost bidding, but positive with variable cost bidding or the inclusion of France.
- However, exact design decisions, as well as the interaction between STOR (and Slow Reserve) and the RR product, will impact the bidding behaviour of participants potentially leading to different benefits.

* Note: GB costs in 2021 have been calculated from Jan-July and extrapolated pro-rata for the remainder of the year.

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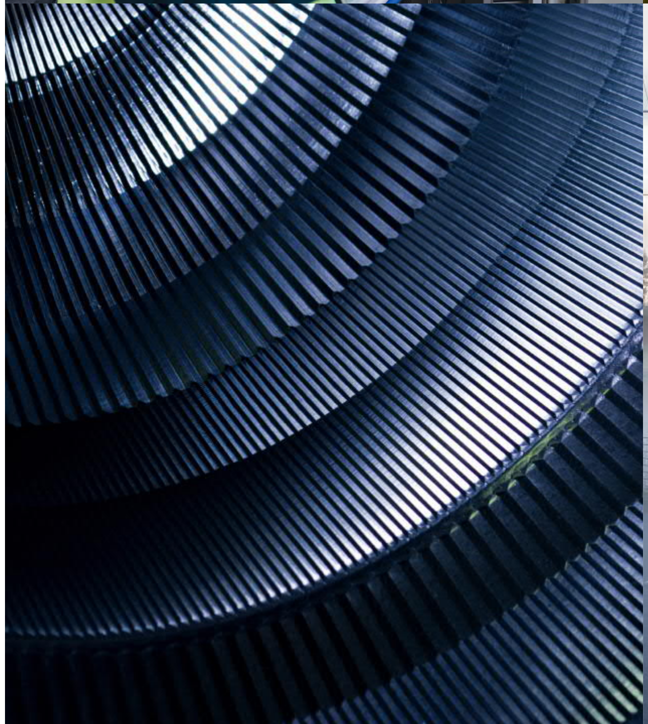

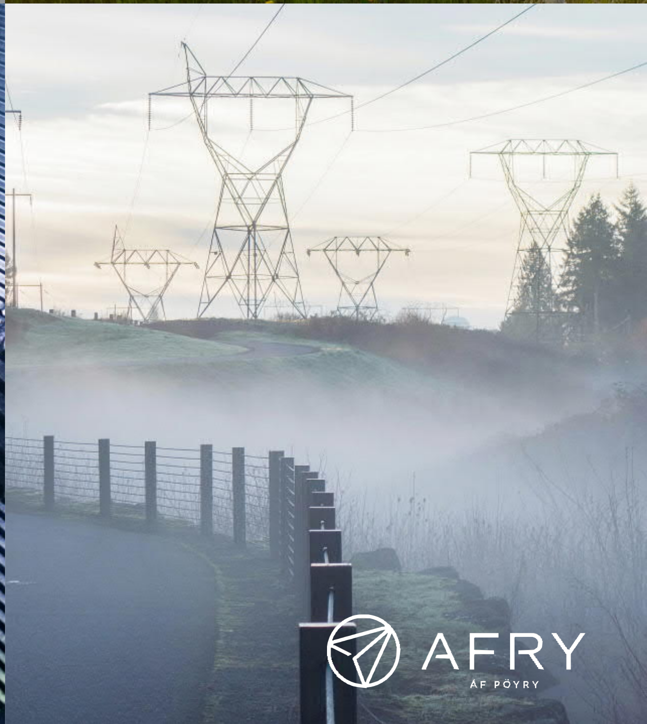

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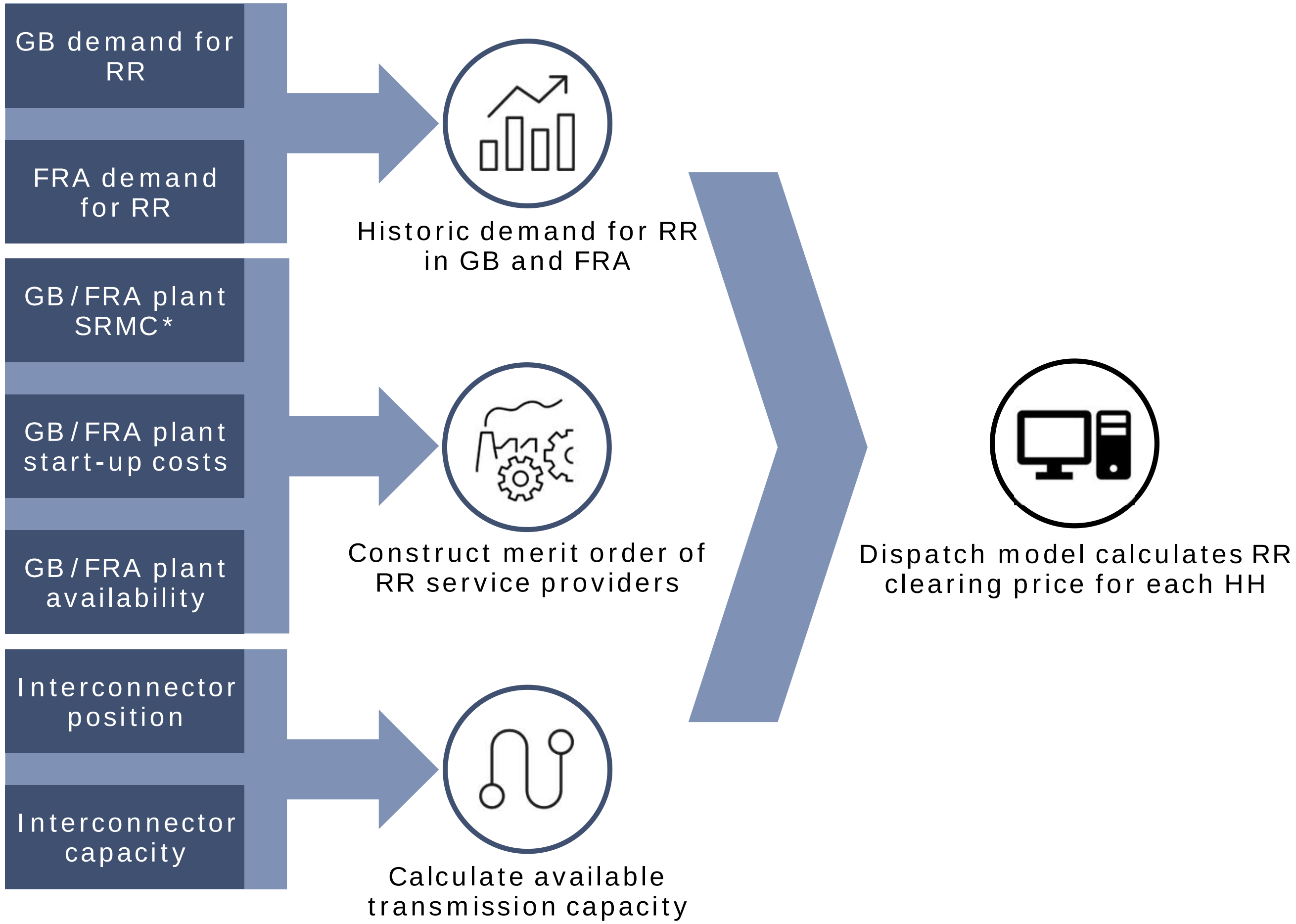
We have used a dispatch model to calculate the clearing price of RR in each half-hour period from 2019-2021



High level methodology

- The demand for RR in each Half-Hour (HH) in GB and France has been sourced from NG ESO and ENTSO-E.
- 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 regards to the inclusion of non-variable costs (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.

*SRMC: Short-run marginal costs, including fuel and carbon based on AFRY efficiency assumptions

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We have developed two scenarios for the implementation of a GB-only RR product and will compare these 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 in 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 Balancing Mechanism (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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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, using AFRY assumptions of cost structures, 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 capacity available after trading (based on the physical notification).
  - 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 reduce flows to manage RoCoF, as these create an artificial space for RR to be met across the interconnector, and these actions are not expected to be required once RoCoF issues are 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, constrained by the ATC of IFA1 and theoretical ATC of 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. (This simplifying assumption likely under-states the ATC and over-states 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).
- 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 long-term costs and cost savings.

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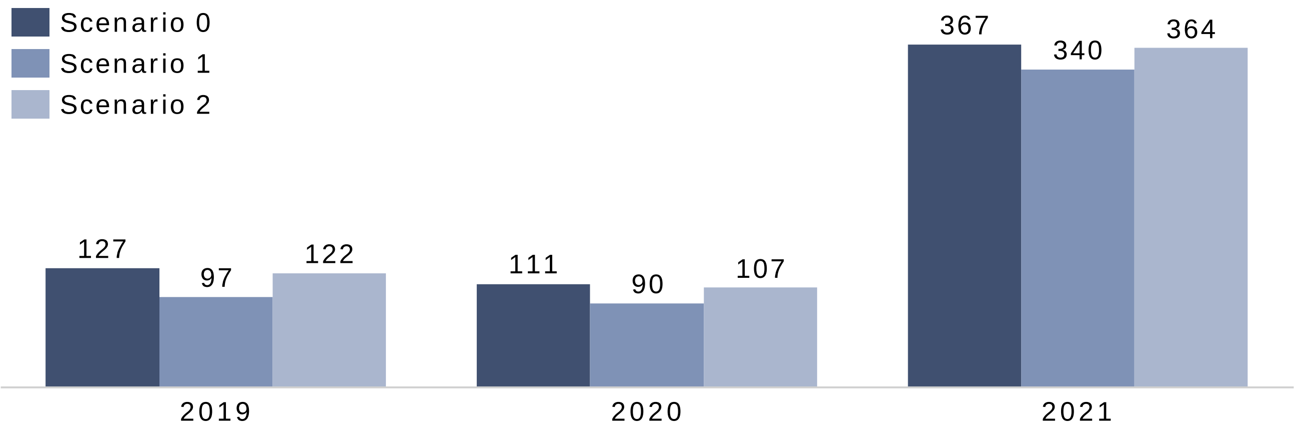
The benefit of a GB only product depends heavily on bidding behaviour

Upward balancing cost (£m)

	2019	2020	2021
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
Delta: 0 to 1	*-30.9*	*-21.0*	*-27.1*
Delta: 0 to 2	*-5.6*	*-4.0*	*-3.8*



Note: GB costs in 2021 have been calculated from Jan-July and extrapolated pro-rata for the remainder of the year.

Commentary

– All years show cost benefits (negative deltas) for a GB only RR product, the levels of which depends heavily on the assumption on bidding behaviour.

– Across the three years, the benefit within each Scenario fall in a similar range.

– Using variable cost bidding (Scenario 1) leads to a benefit of £21m-31m depending on the year.

– In scenario 2, assuming that some established players (as described on page 9) bid to maintain higher margins that they would be able to access in the Balancing Mechanism leads to a lower benefit of £3.8m-5.6m depending on the year.

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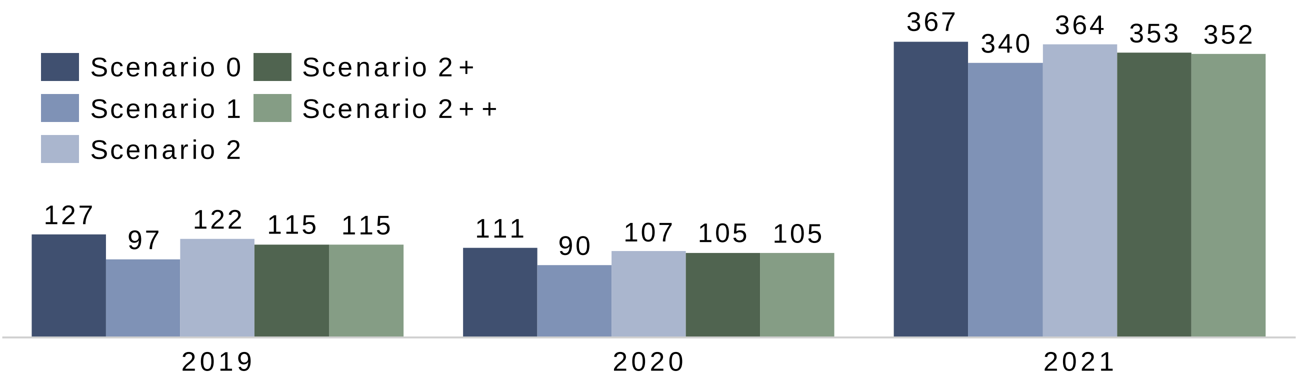
The inclusion of French RR increases the benefits – this is highly variable year-to-year and most pronounced in 2021

Upward balancing cost (£m)

	2019	2020	2021
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	353.5
Scenario 2++ GB plus FR RR - BM opportunity cost bidding + IFA1 + IFA2	114.5	104.5	351.5
Delta: 2 to 2+	*-6.7*	*-1.8*	*-10.1*
Delta: 2 to 2++	*-7.3*	*-2.0*	*-12.1*



Note: GB costs in 2021 have been calculated from Jan-July and extrapolated pro-rata for the remainder of the year.

Commentary

- We see additional benefits when we consider French plants within the analysis.
- In 2019, we see a delta of £6.7m from the connection to French RR. 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. It is plausible that the GB and French markets – if better integrated – would closer react to each others price level, therefore eroding the 2021 delta.
- 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).

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The average cost savings across the scenarios highlights the importance of capturing changing bidding behaviour

Costs and cost savings across the Scenarios (£m)

		2019	2020	2021	Average of 2019/20
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	353.5	
Scenario 2++	GB plus FR RR - BM opportunity cost bidding + IFA1 + IFA2	114.5	104.5	351.5	
Delta: 0 to 1	*Status quo to GB variable cost bidding*	*-30.9*	*-21.0*	*-27.1*	*-26.0*
Delta: 0 to 2	*Status quo to GB opportunity cost bidding*	*-5.6*	*-4.0*	*-3.8*	*-4.8*
Delta: 2 to 2+	*GB only to GB plus France (IFA1)*	*-6.7*	*-1.8*	*-10.1*	*-4.3*
Delta: 2 to 2++	*GB only to GB plus France (IFA1 and IFA2)*	*-7.3*	*-2.0*	*-12.1*	*-4.6*

Note: GB costs in 2021 have been calculated from Jan-July and extrapolated pro-rata for the remainder of the year.

Commentary

- Average costs and cost savings (deltas, in grey) are presented for each scenario.
- In the GB only scenarios, it is estimated that average cost benefits of £4.8m-£26m per annum are achieved, depending on bidding behaviour.
  - As noted previously, opportunity cost bidding is likely to represent the benefits of introducing RR in the short- to medium-term, however variable cost bidding could represent a world with more competition among flexible technologies, hence may be more representative long-term.
  - These cost savings represent a benefit to the consumer to the detriment of domestic BSPs overall (accepting lower margins), however there is likely some movement between BSPs.
- In the GB plus France scenarios, the average cost savings of £4.3m (IFA1) and £4.6m (IFA2) present additional benefit (above GB only scenarios).
  - These cost savings represent a genuine benefit, as cheaper plants are used to meet RR demand, i.e. there is a more efficient dispatch.

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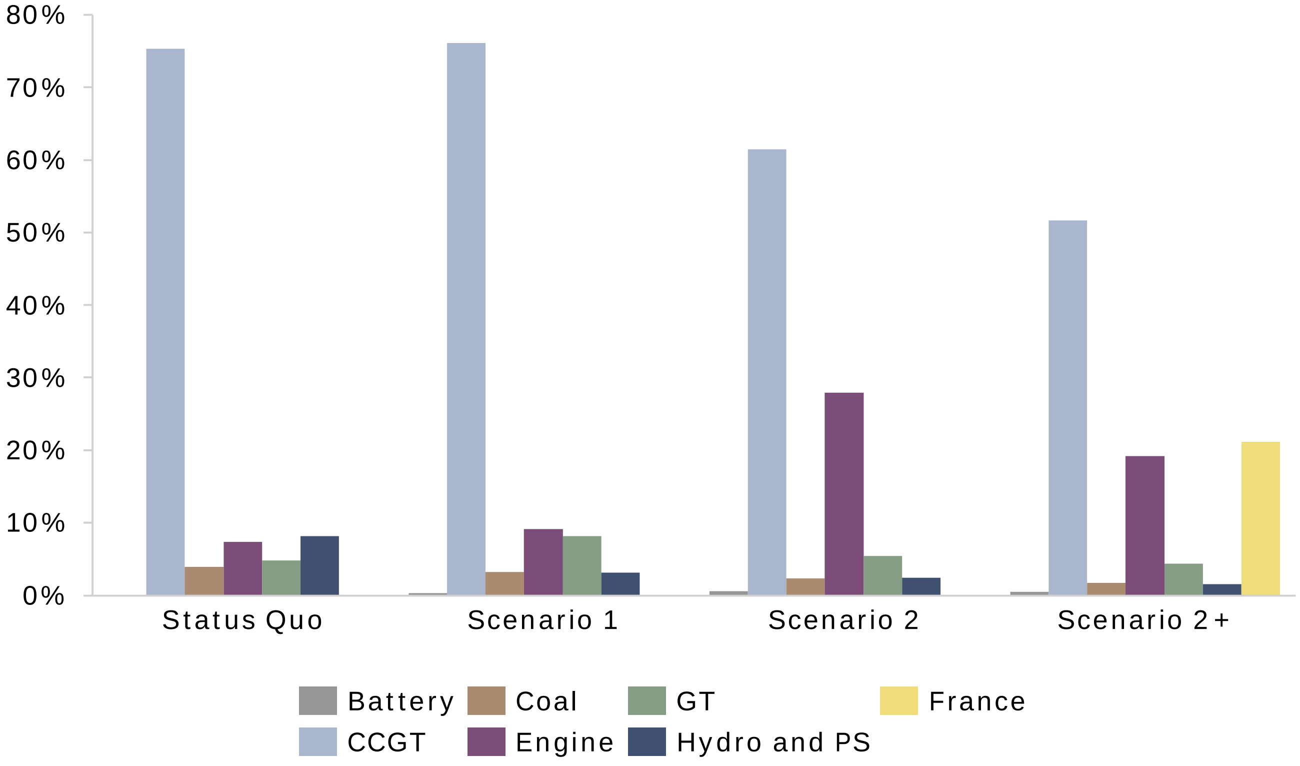
The technology mix providing RR differs across the scenarios, with CCGTs dominating throughout

GB upward RR volumes in 2019, 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 with opportunity cost bidding, 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 GB CCGTs.

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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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There is significant variation in economic viability across the scenarios, however cross-border RR provision with France achieves a positive NPV

Net Present Value analysis

- The Net Present Value (NPV) is a financial metric used to find today's value of a future stream of payments (discounted cashflows). It is typically used to assess the economic viability of investment planning and capital budget allocation.
- In this analysis, we have calculated the NPV of implementing an RR product over a 10-year time horizon and assuming a 3.5% real discount rate.
- There are a number of limitations to this analysis, including:
  - Costs provided by NG ESO are indicative and highly uncertain.
  - This analysis is incomplete; industry costs are not included and quantitative benefits only include upwards balancing in GB.
  - This analysis assumes historic quantitative benefits (average of 2019/20) are reflective of future cost savings – this may not be the case.

	Cost		Benefit	NPV
	CAPEX*	Annual OPEX	Annual Savings	
Scenario 1	-£13.0m	-£4.0m	£26.0m	£164.2m
Scenario 2	-£13.0m	-£4.0m	£4.8m	-£6.1m
Scenario 2+	-£20.0m	-£4.0m	£9.1m	£21.7m
Scenario 2++	-£20.0m	-£4.0m	£9.4m	£24.1m

Note: CAPEX is assumed as a single negative cash flow in year 0. OPEX and cost savings are assumed to remain flat on a real basis and are applied on an annual basis from year 1-10.

Commentary

- For the implementation of a GB only RR product (Scenarios 1 and 2), annual savings of >£5.6m are required to achieve a positive NPV.
  - Scenario 1 achieves a very high NPV, but as previously mentioned, we don't expect universal adoption of variable cost bidding in the short- or medium-term.
  - Scenario 2 infers that a GB only RR product, in which established players bid at levels observed in the BM and new entrants bid their variable cost, results in a negative NPV.
- For the implementation of GB plus France RR product (Scenario 2+ and 2++), annual savings of >£6.5m are required in order to achieve a positive NPV.
  - Despite an increased capital outlay, Scenario 2+ and 2++ achieve positive NPVs of £21.7m and £24.1m, respectively.
  - For Scenario 2+, industry's annualised cost must be <£2.6m for the NPV to remain positive.

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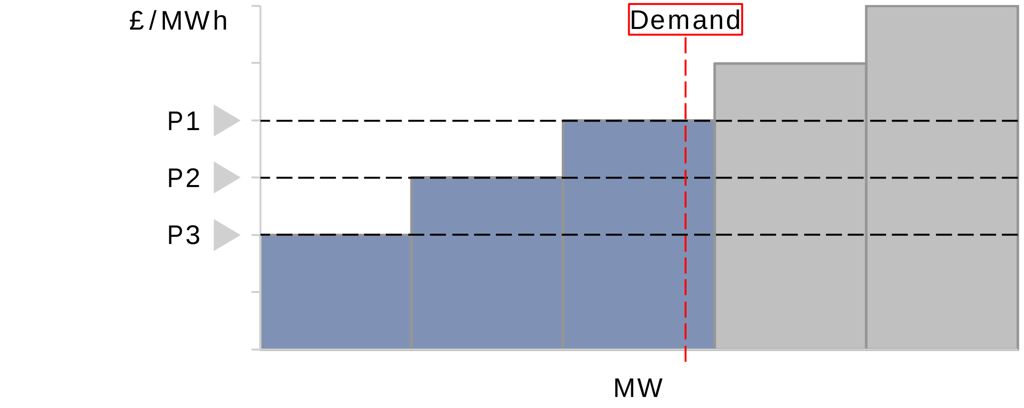
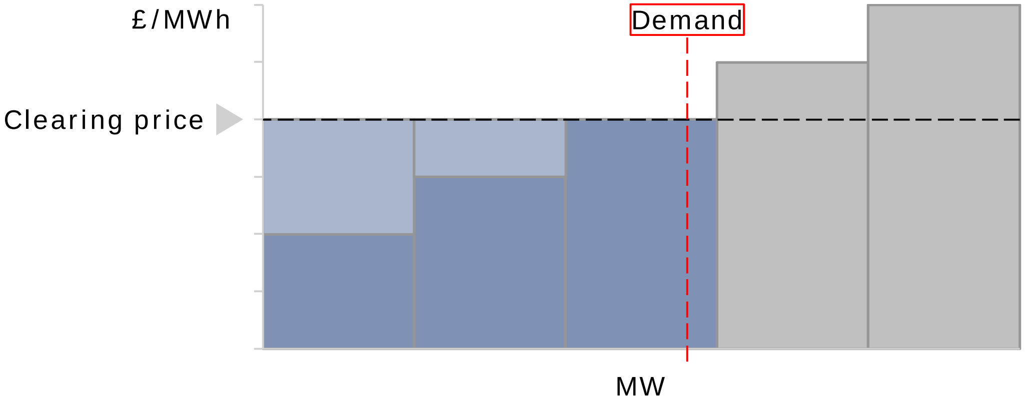
The RR product utilises a pay-as-clear pricing methodology, in contrast to pay-as-bid adopted in the BM

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 BM platform.
- Conclusion: 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.

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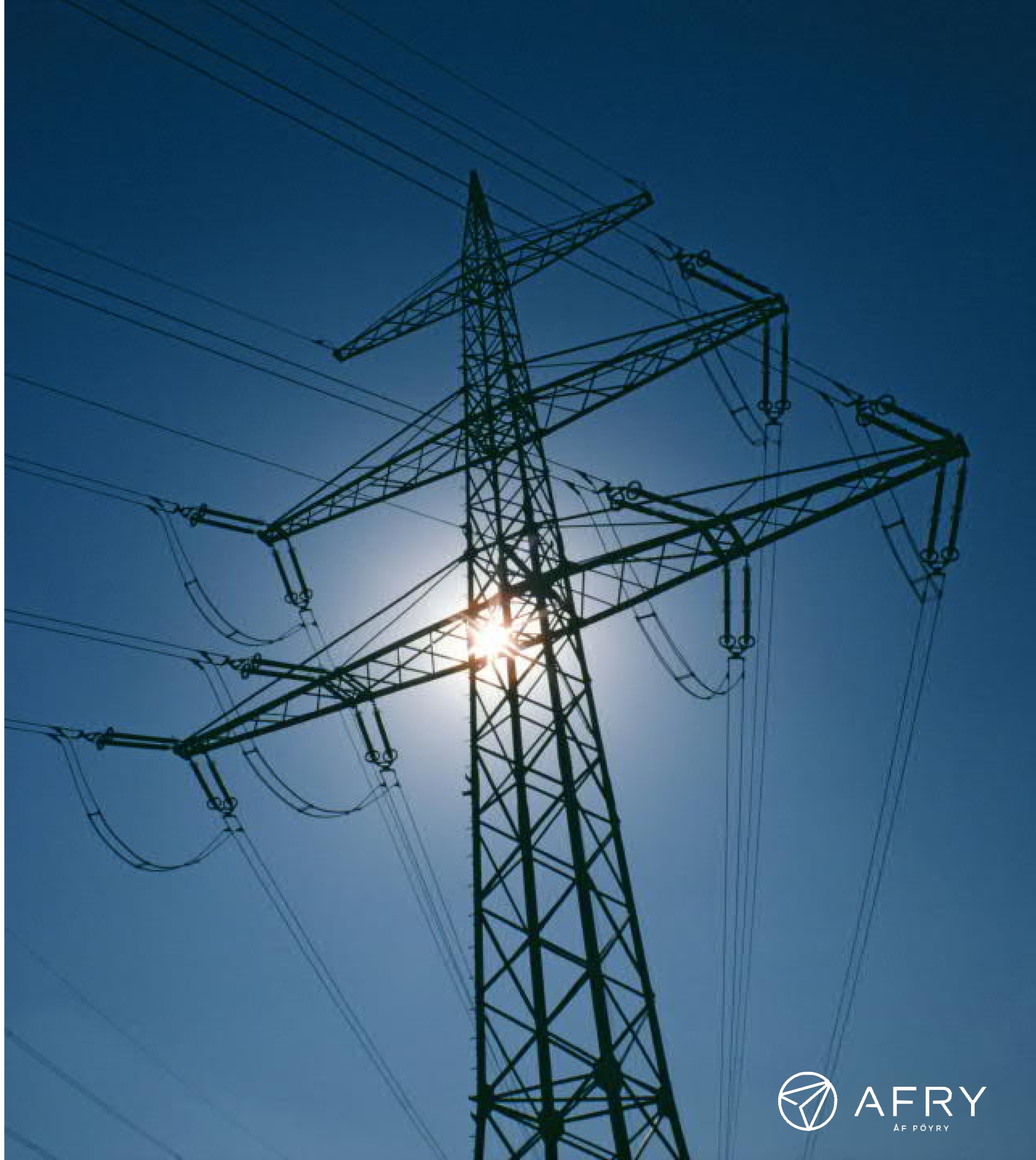
DESIGN CONSIDERATIONS

Frequency of auctions influences availability and cost of restorative actions

- If the RR product were to be introduced, there would be detailed design considerations including the timing and frequency of the auctions; with greater freedom for a GB-only product.
- With infrequent auctions, 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).
- Continuous (or very frequent) trading /auctions would give better opportunities to adapt to changing forecasts in the context of a high-RES system, but it does require pay-as-bid pricing, as there will be limited liquidity in any of the individual markets.
- Conclusion: The detailed design would have implications for the bidding behaviour of the participants, meaning that scenario 2 outcomes (opportunity cost bidding) are more likely than scenario 1 (variable cost bidding)



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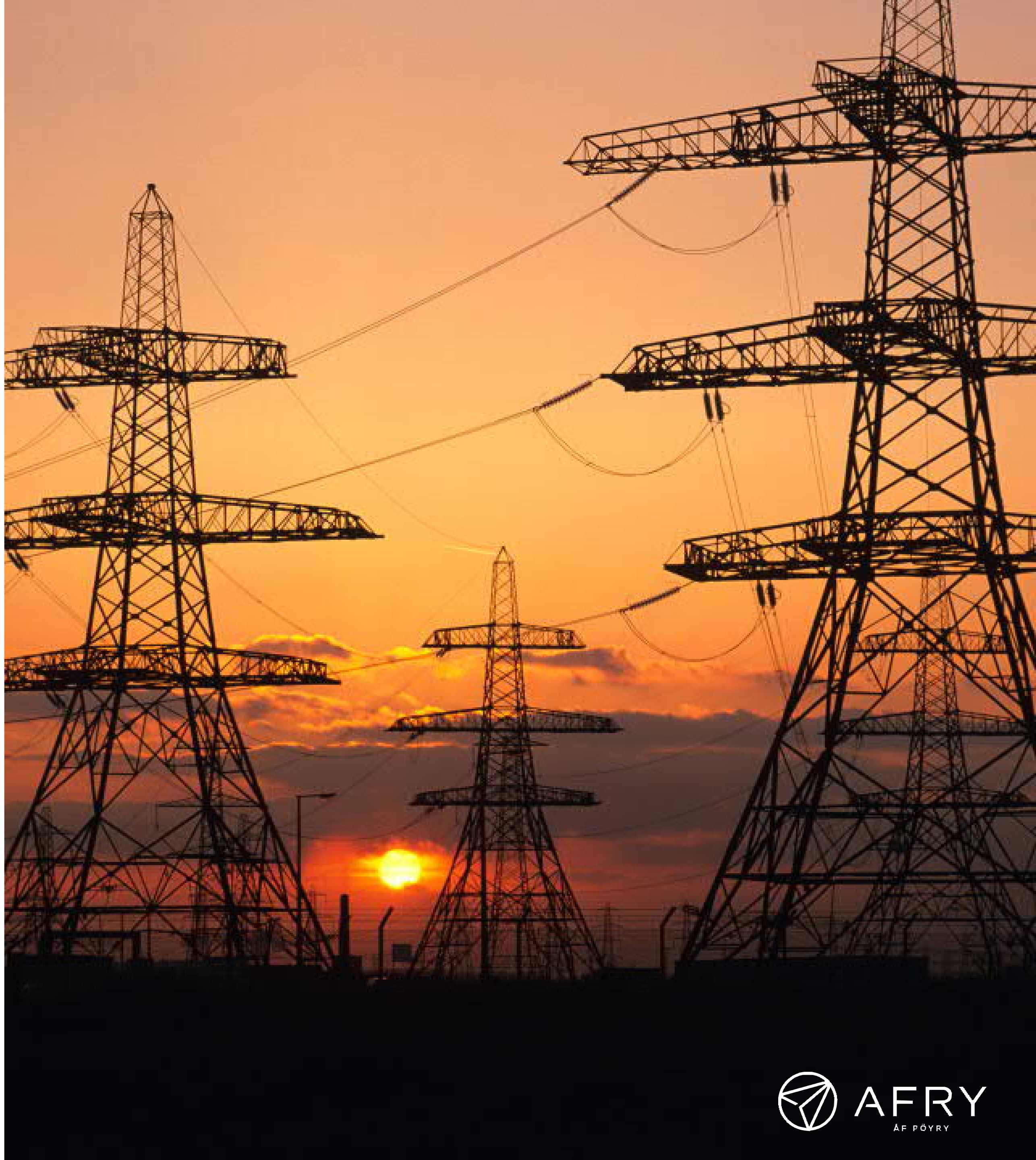
Non-delivery need careful consideration

- 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.
- Non-delivery of Interconnector:
  - Will result in RR imbalance in both regions – potentially very costly.
  - Interconnectors may want to limited liability in certain instances.

- Conclusion: Care is needed to ensure there are no perverse incentives. The detailed design would have implications for the bidding behaviour of the participants.



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Replacement Reserve would sit alongside numerous other GB Products

Existing Products: Dynamic Containment (DC), Firm Frequency Response (FFR), Short Term Operating Reserve (STOR)

Planned Products: Quick Reserve (QR), Slow Reserve (SR), Replacement Reserve (RR)

	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. Previously procured via 3 tenders each year, now day-ahead.	– 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
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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Similarity to STOR and Slow Reserve could lead to some overlap, potentially adding complexity and limiting competition

Impact of Replacement Reserve

1 Impact on STOR/Slow Reserve

- We anticipate some cross over between NG ESO’s use of STOR and Slow Reserve and the potential for Replacement Reserve. There are similarities in the response requirements of providers and the broader aims of the products.
- A key operational difference between an RR product and a STOR/Slow Reserve product is whether the product is firm.
  - RR providers do not get an availability payment and so RR is non-firm.
  - This should be contrasted with STOR/Slow Reserve where, at Day Ahead, the ESO will know how much reserve is available, so STOR/Slow Reserve are firm.
- NG ESO will not be able to estimate if its Need can be satisfied by the RR product until approximately 45 minutes before the utilisation period is due to start.
  - This includes time to validate bids and determine if they cause internal constraint issues.
- If the Need submitted into a RR auction is not met then NG ESO must then go into either BM or STOR/Slow Reserve to make up the shortfall. For this reason, an RR product cannot replace STOR or Slow Reserve until the behaviour of the RR product is better demonstrated.
- However, in the event of an instruction of STOR/Slow Reserve, NG ESO may be able to stand STOR/Slow Reserve down sooner and use RR as an alternative. This has the potential to reduce the expenditure in the STOR/Slow Reserve market.
- In general, having multiple markets available for participants may increase complexity – participants will need to try and optimise across more potential revenue streams. 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.

2 Impact on other products

- We expect limited cross over with the faster acting product; Quick Reserve, Dynamic Containment or Firm Frequency Response.

Conclusion

- Replacement Reserve could sit alongside STOR/Slow Reserve, providing NG ESO with further options for balancing actions from a potentially wider pool of participants, though with greater complexity for participation.

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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.
Downward RR	The benefits in this analysis only quantifies the cost savings of upward balancing in GB, as NG ESO identified this as the predominant use of the RR product.

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