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ANALYSIS OF REFORM OPTIONS FOR STATUS QUO ELECTRICITY BALANCING ARRANGEMENTS

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1 Executive Summary

As part of the Review of Electricity Market Arrangements (REMA) programme, policymakers in DESNZ are considering a number of aspects of the current electricity market design. One important area relates to whether to implement more granular locational signals in the wholesale market in GB. The second REMA consultation from DESNZ recently ruled out a move to locational marginal pricing (LMP) but DESNZ is continuing to consider a move to a zonal wholesale market. One of the suggested benefits of a move to some form of locational pricing relates to greater dispatch efficiency. Ofgem published an assessment of locational pricing options by FTI which suggested that this benefit could be material under both zonal and nodal pricing.

FTI has not assessed the potential for efficient dispatch to be achieved with reform of a national market. However, both Ofgem and DESNZ have signalled the need for work to assess whether the benefits quantified by FTI could be achieved through incremental market reforms. The purpose of this report, commissioned by Scottish Power, is therefore to identify inefficiencies in the current balancing arrangements in GB, identify reforms to address them, and consider the extent to which these reforms could mirror the efficient dispatch assumed by FTI in their analysis of LMP. Even though LMP has been recently been ruled out for GB by DESNZ, and any operational efficiency benefits would likely be smaller in a zonal market, for the purposes of this report we qualitatively assess potential national market reforms relative to the theoretical benefits of LMP.

The Executive Summary is structured as follows:

- First we provide an overview of the current Balancing Mechanism arrangements;
- Then we consider the possible areas of inefficiency associated with the current arrangements;
- Based on these areas of inefficiency, we identify a set of potential reform options; and
- Finally we discuss the implications of these reform options.

1.1 Current arrangements

The GB electricity market operates on the basis of a national market with self-dispatch. Bilateral trading in electricity wholesale markets takes place from years ahead of delivery until gate closure (i.e. one hour ahead of delivery) and relates to energy (MWhs) delivered anywhere on the electricity grid in a half-hour imbalance settlement period (ISP).

Market participants are given incentives to ensure that physical supply and demand match their contracted positions in each ISP. However, demand and supply must be continually balanced on a second-by-second basis at each location on the grid, and the grid has limited

capacity to facilitate energy flows. Therefore, ESO acts as a 'residual balancer' to ensure security of supply, taking actions for reasons of both:

- *energy balancing* to ensure the physical matching of national demand and supply (e.g. due to contractual and physical positions not precisely matching); and
- *system (or locational) balancing* to ensure that national demand and supply conform to the physical constraints of the system. In cases where the grid has limited capacity and supply is physically unable to fulfil demand, then ESO will 'redispatch' energy to ensure the final pattern of demand and supply respects the physical transmission constraints.

While ESO's responsibilities are typically focused on the period post-gate closure, ESO often also takes actions pre-gate closure to ensure the system is balanced. For example, ESO trades with market participants to redispatch interconnectors, and trades with inflexible capacity to ensure adequate reserve capacity is available later in the day.

While the precise arrangements for balancing in any future locational market are as yet undefined, there would be a number of key practical differences between the operation of a locational and a national market. However, in principle, an idealised version of a national market (under either self-dispatch or central dispatch) and an idealised LMP market should result in the same physical dispatch of power (if not the same commercial outcomes for participants). In both an LMP market and a national market with redispatch, at some point ESO runs an optimisation process to work out how to satisfy demand close to and during real time, given the production resources available and the condition of the network. If this is a "perfect" optimisation, and if it is fed consistent inputs across the different forms of market, then it should result in the same outcomes in terms of dispatch of resources.

1.2 Current balancing inefficiencies

From an economic perspective, the BM should operate on a least-cost basis. That means selecting the lowest cost bids and offers, subject to:

- The technical capabilities of the resources on the system (i.e. the technical constraints associated with power plants);
- The best forecasts (e.g. related to variable renewables) available at the point in time that decisions on dispatch must be made; and
- The particular risk appetite of the ESO.

In general, a BM that is unable to minimise costs can be described as sub-optimal. However, while it may be possible to judge with the benefit of hindsight that a certain pattern of dispatch was sub-optimal, in this study we are particularly focused on the extent to which that is a result of the market rules of the BM or the mechanisms by which dispatch decisions are made. In essence we assume that the constraints noted above are fixed, on the grounds that we are

less focused on inefficiency due to the particular physical characteristics of the plants on the system, the forecasting capabilities of ESO, or the particular risk appetite of the ESO.

In this report, we also focus on dispatch cost. In broad terms, minimising dispatch costs will lead to lower customer costs. However, there are complex transfers between generators and customers which may mean, in some specific cases, minimising dispatch costs does not minimise customer costs. We do not consider these specific cases as part of this report.

Based on this definition, if the existing market arrangements are not achieving the level of efficiency which could be achieved by a new LMP market, then this must be because:

- the *information* being fed into the existing optimisation process (i.e. the process by which ESO chooses which BM bids and offers to accept) is "inferior";
- the *optimisation* process being used by ESO is in some way "inferior" (including that the market may not be receiving appropriate information from ESO); or
- the *implementation* of the dispatch process is in some way "inferior" (i.e. that the ESO is not able to implement the dispatch implied by the optimisation process).

We have structured our assessment of the current balancing arrangements and possible reform options around these three potential sources of inefficiency.

Inferior information inputs to optimisation process

We have identified four ways in which the information used by ESO in its current optimisation processes may give rise to inefficiencies.

- First, under the current arrangements, participants in the BM are required to submit a set of technical parameters purporting to describe constraints on the physical operation of the plant. However, the definition of these parameters does not strictly relate to the technical constraints faced by power stations. ESO does not have an ability to run a plant in a manner that deviates from the limits participants submit, even when doing so might be technically feasible and might reduce overall balancing costs after taking into account any additional costs the alternative running pattern might induce.

- Secondly, the parameters provided by storage assets (which are set to play an increasingly important role in the BM in future) do not reflect the true capabilities of the assets. Storage, by its nature, has a limited duration. However, the technical parameters storage assets currently submit do not adequately capture the energy constraints on their output. Without knowing the available stored energy of storage, ESO cannot rely on these assets to be available in the BM. We understand that as a result, ESO has created the '15 minute rule'. The purpose of this rule is to reflect storage capabilities while working within current BM limitations.[1] The rule means storage assets should submit technical

[1] National Grid ESO, *Unlocking Stacking of BOAs with Frequency Response Services*, Section 2; https://www.nationalgrideso.com/document/184466/download

parameters (Maximum Export Limit / Maximum Import Limit) that can be sustained for 15 minutes, which are then updated on an ongoing basis.[2] However this rule does not precisely reflect the state of charge and therefore may limit the way ESO can dispatch assets.

- Third, the BM operates as a pay as bid market, where market participants receive the bid or offer price they submitted. This means market participants are incentivised to bid above their short-run marginal costs to a level at (or just below) the expected marginal bid or offer that would be accepted, in order to capture infra-marginal rents. This creates the risk that a market participant, which otherwise would be in merit, makes an error forecasting the marginal bid, meaning they appear out of merit. As a result, even if ESO accepts bids and offers in a manner that minimises its costs, because the bids and offers on which it optimises may have been distorted, total system costs may not be minimised.

- Fourth, there is a risk that physical notifications, which should reflect users' best estimate of expected import/export of active power (in MW), are inaccurate leading to inefficient balancing actions by ESO. Initial Physical Notifications (IPNs) are submitted pre-gate closure and can be updated up to gate closure at which point they are fixed as Final Physical Notifications (FPNs). BM participants are obliged to submit IPNs and FPNs in accordance to Good Industry Practice, and submitting misleading IPNs and FPNs is in breach of REMIT.[3] However there are limited direct incentives, such as immediate financial penalties, that would disincentivise inaccurate information.

Inferior optimisation process

We have identified three ways in which the optimisation process used by ESO may give rise to inefficiencies.

- First, ESO currently does not operate a national nodal optimisation algorithm to choose which BM bids and offers to accept. Instead, it takes a more 'local' approach, focusing its optimisation in areas in which it identifies constraints. It is difficult to judge the impact of not operating a nodal algorithm. However, by not implementing a national nodal optimisation algorithm, it raises the possibility that ESO may arrive at a suboptimal dispatch, with efficient redispatch options involving assets outside of the immediate area of a locational constraint being missed. It may also mean efficient redispatch options that could potentially contribute to resolving multiple constraints concurrently could be missed.

- Second, we understand that currently ESO does not optimise the operation of storage over multiple periods. This is important, in particular for storage with longer durations compared to an ISP, since the optimisation question for an energy constrained plant

2 ESO can issue BOAs for longer than the 15 minutes if the unit keeps it Maximum Export Limit above zero (or Maximum Import Limit below zero) as the energy is taken from the unit (or put in to the unit).

3 https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/remit-and-wholesale-market-integrity

relates to which period should the energy be used. Optimisation of storage is a complex challenge. However, by not optimising in this way, ESO may miss some opportunities to dispatch storage in a way that reduces overall system costs over time.

- Third, market participants trade on wholesale markets to optimise and ensure balance between their physical and commercial positions. However, the way in which they optimise may also take into account their expectations of ESO's requirements for balancing in the BM, in particular in relation to locational balancing. Currently, while data is provided on historical accepted bids and offers, there is no easy way to compute the value of energy at nodes at which there were no acceptances. If plants do not understand the value of their energy in the BM, then this might reduce availability in the BM to resolve locational balancing issues, leaving ESO with fewer options.

Inferior dispatch process

We have identified two broad areas in which the implementation of dispatch could give rise to inefficiencies. These relate to the processes by which interconnectors and smaller assets are dispatched.

For smaller assets, current arrangements mean that there are sometimes practical challenges associated with coordinating multiple smaller units. When large adjustments are required on short timescales, it requires significantly more coordination to change the schedules of a large number of small units than to accept bids or offers from a small number of large units. These practical challenges can lead to smaller assets not being dispatched, despite being priced lower than the alternative option.

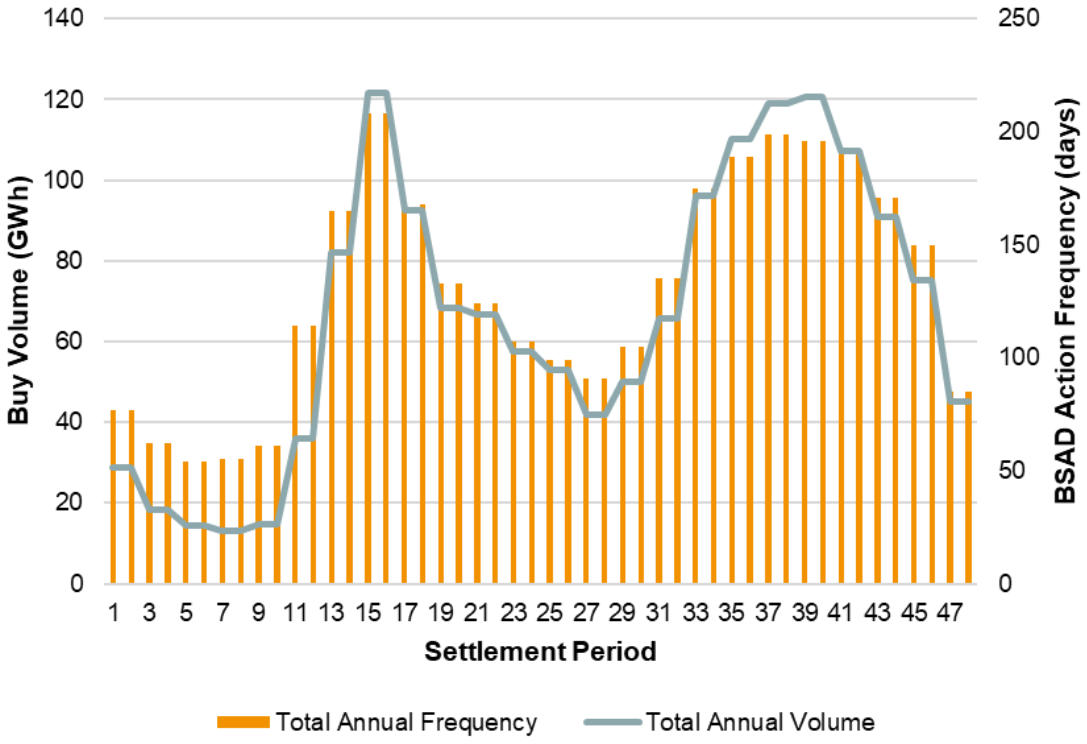
While the inability to dispatch one small asset when to do so would have been the efficient action is unlikely to represent a material inefficiency at the system level, smaller assets taken together represent a significant share of capacity overall. This share is only likely to increase. Therefore inefficient treatment across all of these assets is likely to represent a material issue. This issue is being addressed by ESO as part of the Balancing Programme.[4]

For a number of interconnectors, the current arrangements allow ESO to adjust the flow pre-gate closure relative to the commercial position set by traders in the wholesale market, when the cost of doing so is less than its expected costs of redispatch onshore. ESO can run *ad hoc* auctions during the day, potentially multiple times, for parties to nominate a flow against the direction of the expected commercial flows. These auctions can facilitate efficient redispatch of interconnectors.

[4] National Grid ESO, Balancing Programme; https://www.nationalgrideso.com/what-we-do/electricity-national-control-centre/balancing-programme

Based on analysis of Balancing Services Adjustment Data (BSAD) from 2022, we observe that ESO frequently took actions via the auctions to adjust interconnector flows.[5] Across the five interconnectors in the South East of GB, ESO facilitated 3.2TWh of energy imports across 310 days, and 0.79TWh of energy exports across 88 days in 2022. A summary of BSAD buy volumes (i.e. actions to increase imports) and the number of buy actions by settlement period is shown in Figure 1. This shows that over the course of 2022, ESO has adjusted flows in all periods of the day, but most typically during the early morning, and throughout the afternoon and evening peak periods. This is not directly reflected in FTI's counterfactual, in which when dispatchable gas is available on the system, redispatching interconnectors are assumed to be a more expensive option.[6]

Figure 1 Interconnector BSAD actions in South East England – buy volume



Source: LCP analysis of Balancing Services Adjustment Data
Note: South East England interconnectors considered are IFA, IFA2, BritNed, Nemo and ElecLink

However, while actions by ESO appear to be frequent, we also observe that there may be potential for ESO to make further efficient adjustments to interconnector flows. As an example, on 10 November 2022 there was a constraint on flows from Scotland to England, requiring a reduction of generation (increase in demand) in Scotland, and an increase in

5 BSAD actions refer to balancing actions taken outside of the BM. The majority of BSAD actions represent trades taken following ad hoc auctions run by ESO. However, a small portion will be carried out post-gate closure between system operators i.e. SO to SO trades, which we discuss below.

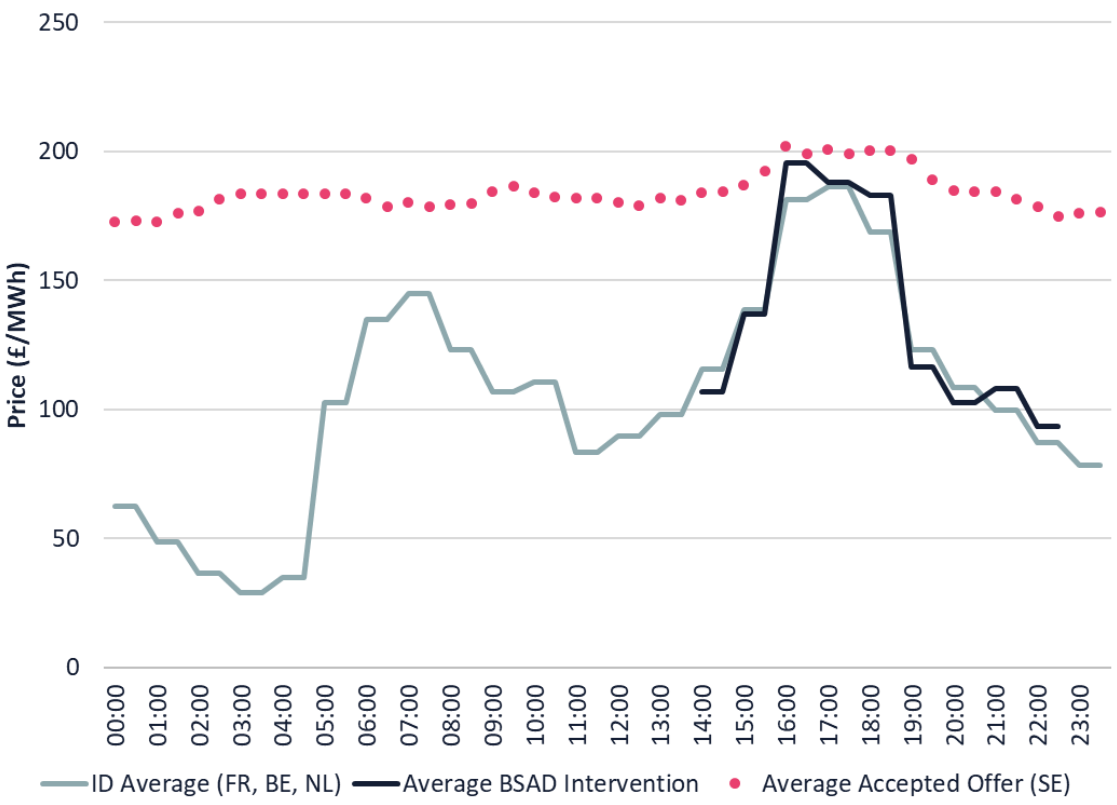
6 In practice, FTI does not assume any interconnector redispatch until 2035.

generation (reduction in demand) in England. As is fairly typical, ESO chose to reduce wind output in Scotland and increase gas generation in England. This is shown in Figure 2, where we can see that throughout the day, ESO accepted offers to increase gas generation with an average half-hourly price that ranged between £175/MWh and £200/MWh.

In addition, over the evening peak ESO made BSAD adjustments to the interconnector flows to reduce exports over the interconnectors in SE England, paying a price very close to the intra-day price on the continent. As a result, as shown in Figure 2, across most of the evening peak period, ESO paid a price to increase the supply of power in England from interconnectors which was below the price it paid to gas generators.

Importantly, we do not observe similar actions being taken at other points of the day when the cost of doing so (for which continental intra-day prices are a reasonable proxy) was likely to have been significantly below the price ESO paid to increase gas generation. In other words, while ESO did take some efficient actions to redispatch interconnectors, based on the historic data available, it would appear that further potential for efficient actions may have existed.

Figure 2 Intraday, BSAD intervention and accepted offer prices



Source: LCP analysis of Balancing Services Adjustment Data

The day illustrated in Figure 2 is not unique. We observe similar behaviour on other example days which are described in Annex A to the main report. It is obviously important to stress that,

given our analysis considers public data, we cannot know precisely why the ESO did not take more action over interconnectors.

However, stepping back from the specific examples, there are a number of reasons why ESO might not be expected to achieve perfectly efficient flows. These include that:

- these *ad hoc* auction arrangements are not currently available across all interconnectors (specifically, they are not present on North Sea Link); and
- to the extent that the outcome of the *ad hoc* ESO auctions requires follow-on actions by some successful bidders to adjust their capacity holding, ESO auctions must be timed to allow such trades to be made in the intraday interconnector capacity auctions, the timing of which will vary by interconnector. This imposes a constraint on how close to gate closure these ESO auctions can take place.

It is also worth noting that these arrangements rely on explicit capacity allocation. If GB were to move to implicitly traded intraday markets, the current ESO arrangements would no longer be feasible since market participants, without explicit rights to capacity, would not be able to guarantee to ESO that they could influence the interconnector flow. Different arrangements, based on SO to SO trades, are in place on the Irish interconnectors, where intraday capacity is allocated implicitly.

The arrangements described above relate to actions pre-gate closure. Post-gate closure, SO to SO trades are in theory available to ESO on some of the continental interconnectors. These would allow the interconnected SO to offer to sell to ESO balancing energy based on the flexibility available on its system (and the commercial terms demanded by its balancing services providers). However, these SO to SO arrangements do not exist on all interconnectors and where they do exist, there are still inefficiencies in the arrangements:

- the pricing of trades is not transparent and may not be reflective of real-time market conditions; and
- there is no obligation for interconnected SOs to accept a request to trade, even if a price has been posted, meaning that on short post-gate closure timescales, ESO may prefer the certainty of a higher priced domestic alternative over the uncertainty of a lower priced SO to SO option.

We have summarised the current pre- and post-gate closure arrangements on all interconnectors in Figure 3.

Figure 3 Summary of current interconnector trading arrangements

Interconnector	Capacity (GW)	Intraday trading arrangements	Number of intraday auctions	SO to SO arrangements
IFA	2.0	Explicit	4	Yes
IFA2	1.0	Explicit	4	Yes
BritNed	1.0	Explicit	4	Yes
East West	0.5	Implicit	2	Yes
Moyle (NI)	0.5	Implicit	2	Yes
North Sea Link	1.4	None	N/A	N/A
Nemo	1.0	Explicit	4	No
Elec Link	1.0	Explicit	2	Yes
Viking Link*	1.4	Explicit	4	TBC

Source: *Based on information from Ofgem, https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/interconnectors; Interconnector Operator information; and BMRS https://www.bmreports.com/bmrs/?q=transmission/*

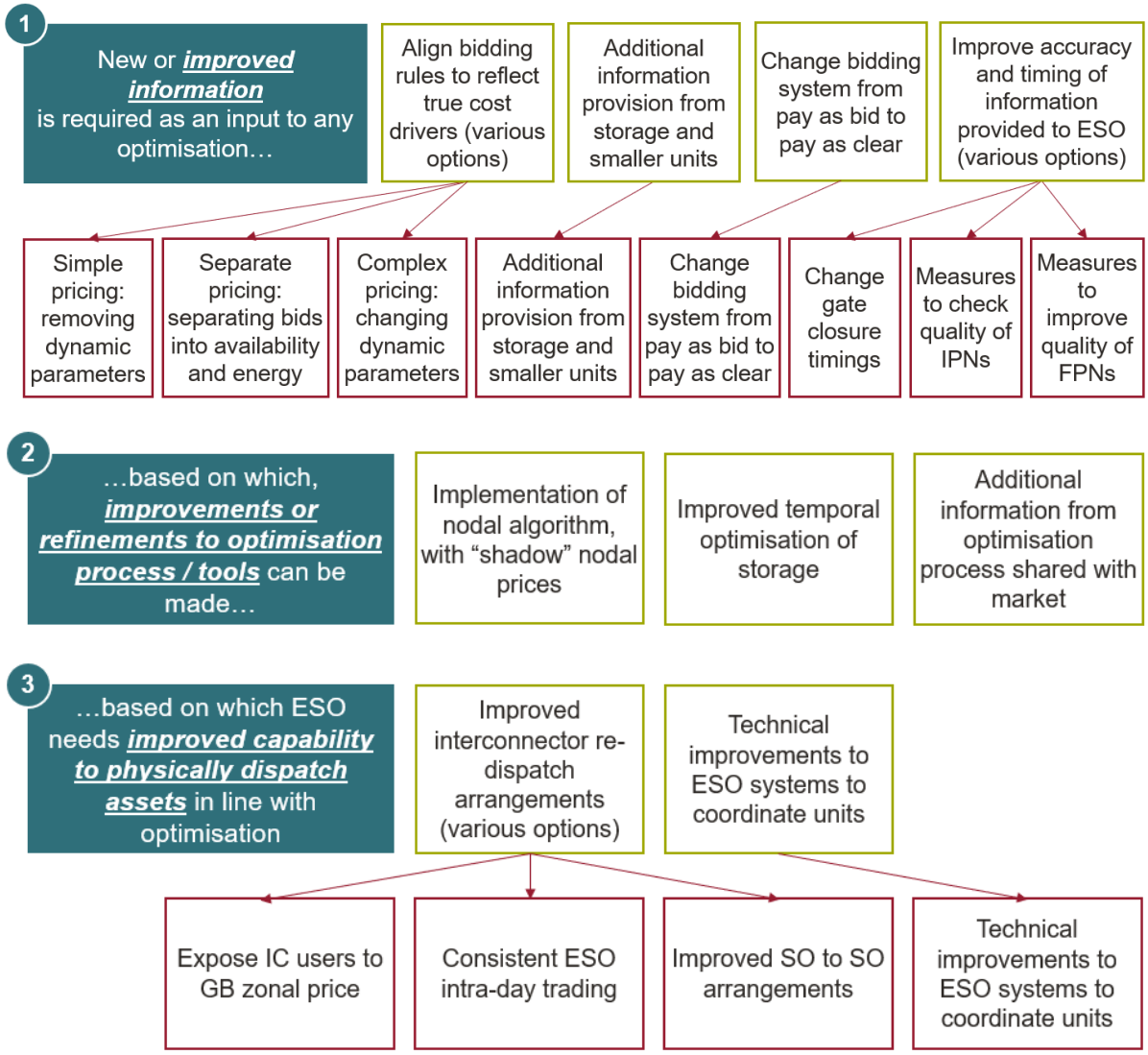
Note: ** Viking Link operations not commenced at time of writing. As far as we understand, there is no publicly available information that describes Viking Link SO to SO arrangements.*

1.3 Identifying potential reform options

The different issues raised above relate to a wide range of aspects of the current balancing arrangements. For each of the issues identified, we have considered a number of reform options at a high level. We summarise the reform options we have considered in Figure 4. We note that:

- some of the options are about making the function of the BM more efficient while some options are about reducing the volume of actions for ESO;
- the options are not generally mutually exclusive; and
- broader REMA reforms (and in particular, a potential move to central dispatch without LMP) would impact on the range of reform options available, and might also change the degree of incremental effort associated with some reforms.

Figure 4 Summary of reform options



Source: Frontier Economics

We have undertaken a high level assessment of each of the reform options, looking at the potential of the reform to improve efficiency of balancing as well as the ease of implementation (or the potential implementation challenges). We stress that, given the wide scope of issues and options, detailed specification and assessment is beyond the scope of this report.

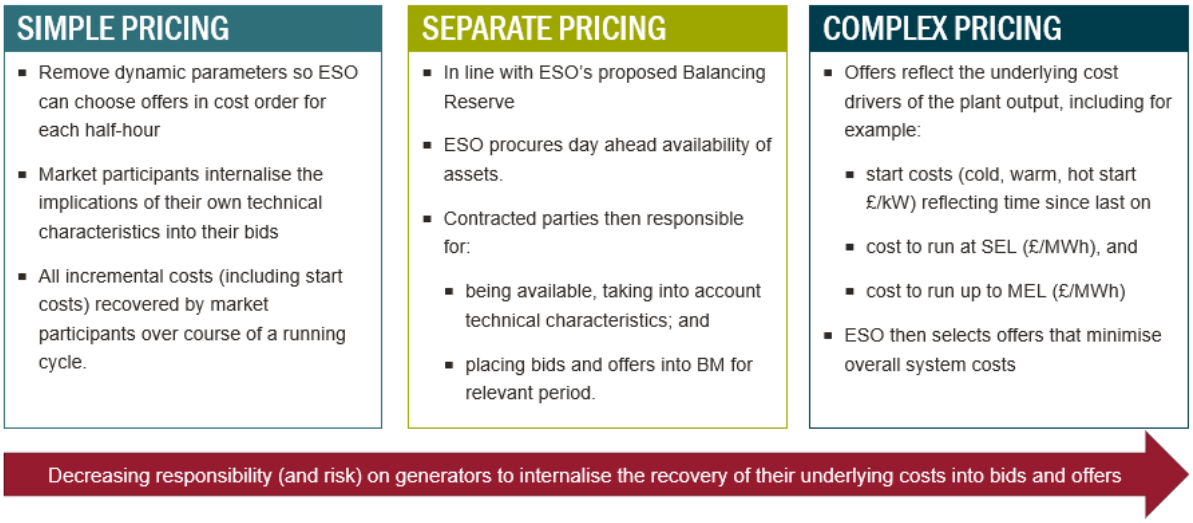
We summarise our high level assessment of the reform options below (and in Table 1). Our analysis suggests that reform to today's market may be possible across a range of areas to improve the efficiency of dispatch. We note that in some of these areas (e.g. improving the information available to ESO on technical parameters and the ability to dispatch large numbers of smaller units), ESO and the industry are already working on reform.

Improved information provided to ESO

As described in Figure 4, there are four potential reform options (with some sub-options) relating to improved information.

With regard to the technical parameters provided by market participants, we have identified a number of different ways in which the bidding rules in the BM could be changed to better reflect the continuous nature of the trade-offs as to how plants are operated. Three of these are summarised Figure 5.

Figure 5 Alternative approaches to bidding arrangements



Source: Frontier Economics

The key difference between the sub-options reflects the extent to which the responsibility for optimising the operation of the plants (and associated risk) rests with ESO or market participants. Simple pricing means removing the dynamic parameters so that participants internalise their own costs in their bids, whereas complex pricing would mean changing the parameters so that they more clearly reflect the underlying cost drivers of plants, an option that maps most closely to the approach taken in LMP markets. ESO has recently introduced a new Balancing Reserve, which is a form of separate pricing, where ESO runs an auction for plants to commit to be available for a specific period day-ahead.

Simple and separate pricing should mean simpler dispatch decisions for ESO, as optimisation of plants taking into account their technical characteristics, would be the responsibility of plant owners. However, separate pricing places an additional burden on ESO to forecast its requirements at the day-ahead stage, locking in availability costs which may ultimately turn out not to be needed. A more complex pricing approach might mean greater optionality and flexibility for ESO to minimise system costs. With that flexibility it could trade-off shorter and longer run times for plants with high start-up costs, and it would make it easier for ESO to see the value of waiting to dispatch inflexible plants. However, a complex approach would create

more challenges for the ESO, in particular in relation to the necessary IT systems and algorithms.

In general, each of these sub-options should allow ESO to optimise on the basis of information that better reflects the underlying cost drivers of the plants. This should in turn give ESO more options to consider when making dispatch decisions. As described in the review of the balancing market, there have recently been a number of high cost days in the BM where impacts might have been somewhat mitigated if ESO had had better information on which to act. [7]

With regard to storage, ESO is engaging with stakeholders to add an additional "state of charge" parameter to the technical information provided by storage plants, to help ESO determine the most appropriate time to dispatch a storage asset. ESO is due to carry out a formal consultation and assessment in 2024.[8] If this can successfully resolve issues associated with dispatching storage, there are likely to be efficiency benefits. For example, removing the "15-minute rule" on battery units may not only allow these units to be operated more frequently, but also for longer. This will become increasingly important as the importance of battery storage increases, and as more medium duration battery storage assets are added to the system.

Moving to a pay as clear market could also potentially bring efficiency benefits over the current pay as bid system. In a pay as clear market, all successful participants receive the market clearing price irrespective of their bid.[9] As a result, it is more likely that dispatch will reflect the lowest cost dispatch available minimising system costs. However if there is market power in a pay as clear market, a participant could potentially manipulate the clearing price. This would distort the prices paid, not only to the participant with market power, but all BM participants. Ultimately, this effect would depend on the level of competition in the BM.

Finally, we also considered a number of options to improve the accuracy of the PNs that ESO receives. Moving the timing of gate closure earlier would provide firmer information and allow ESO more time to optimise the system and determine the most efficient balancing actions. However, it would also reduce the time during which the market could optimise the balance of supply and demand, placing greater reliance on ESO to respond to short-term deviations of volumes in the market. This trade-off is illustrated in Figure 6.

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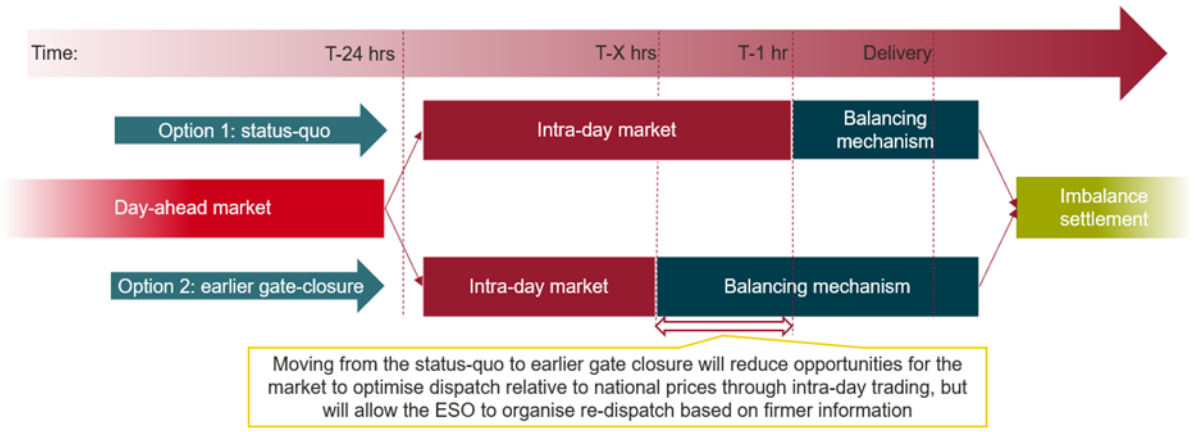
7 https://www.frontier-economics.com/media/l43dzwca/frontier-lcp-cornwall-review-of-the-balancing-market-v2.pdf Section 4

8 National Grid ESO, Grid Code Modifications, GC0166: Introducing new Balancing Programme Parameters for Limited Duration Assets; https://www.nationalgrideso.com/industry-information/codes/gc/modifications/gc0166-introducing-new-balancing-programme-parameters-limited-duration-assets

9 In the context of the BM, this would mean "local" clearing prices for each group of unconstrained nodes in each period. This would be analogous to the application of pay as clear in a nodal market.

Figure 6 Options for gate closure timing: status-quo versus earlier gate closure



Source: Frontier Economics

The overall efficiency impact of this change is therefore difficult to determine. The rationale for the current gate closure time was to increase the opportunity for trading and reduce the role of the system operator. However, the more the system operator has to take decisions more than one hour ahead of real time, the more likely it is to be doing so on the basis of participants' forecast information, which may change. Given the expected increase in importance of ESO redispatch going forward, and the fact that ESO must take some redispatch actions more than 1 hour before delivery (current gate closure timing) there may be more of an argument for allowing ESO more time to optimise for both energy and locational reasons. However, this would be a significant change for market participants who would have less time to balance their portfolios and would face changes to their risk exposure. We note that while DESNZ rules out shortening gate closure in the second REMA consultation, it does not appear to have considered an earlier gate closure.

We have also considered options to strengthen the incentives to submit accurate IPNs and FPNs:

- Ensuring the accuracy and quality of IPNs can help ESO rely on IPNs to make more efficient pre-gate closure actions. To enable this, there could be more systematic checks of the commercial reasons for movements in IPNs. For example, market participants could be required to provide, if requested, information underpinning differences between the PNs. The incremental efficiency impact of this measure depends on extent to which movements in IPNs are driven by non-commercial reasons and relate to non-compliance with current requirements.

- FPNs should provide reliable information regarding expected dispatch to ESO, but further incentives to ensure this is the case could be considered. One option is to use the Information Imbalance Charge. This is an existing incentive mechanism which is currently set to zero but, in theory, this could be set to a non-zero value to further incentivise

accurate FPNs. If this incentivises improvements in FPN accuracy, this could improve the efficiency of ESO BM actions. However ESO would need to determine a fair and well-justified information imbalance price and it would increase risk for generation, particularly for assets with less predictable outputs.

Improved optimisation

We have considered three options for reform relating to improving ESO's optimisation.

- First, it should be feasible for ESO to use a system-wide nodal algorithm to identify the most efficient redispatch actions. If there are no constraints to the dispatch of individual assets, with identical inputs, the dispatch outcome of an LMP algorithm should be identical to the dispatch outcome from a redispatch algorithm. The extent of improvement in dispatch efficiency, relative to ESO's current local constraint optimisation modelling, would depend on the nature and effectiveness of the current ESO optimisation tools, and is therefore difficult to judge without detailed analysis. The implementation would be a material task and would require significant investment in new optimisation software as well as new information provided by market participants to ESO. There would also be interactions with other options we have identified (in particular, in relation to the structure of input data for plant and storage, as any algorithm would need to have a clearly defined set of input data). We note that typically dispatch algorithms make use of data along the lines of the complex bidding information described above (e.g. start costs, no-load costs etc.).

- Second, by considering the optimal use of storage over multiple periods, ESO may be able to reduce overall system costs by using stored energy more efficiently. The efficiency improvement due to this reform ultimately depends on the extent to which there is material value in ESO choosing when to dispatch storage assets. This is increasingly likely to be the case as storage becomes a critical technology in future to balance the expected significant increase in low marginal cost technologies. The ease of implementing temporal optimisation depends on other option choices: if a nodal algorithm is introduced then the incremental challenge of ensuring storage is appropriated treated is likely to be low (as significant changes to ESO's systems and processes would be required in any case). However implementation in isolation is likely to require more complex developments to ESO's existing optimisation tools.

- Third, if ESO provides more locationally granular information about the expected value of balancing energy at each node, asset owners may optimise their plants differently which could improve efficiency of market dispatch by increasing the set of actions from which ESO is able to choose. For example, storage operators may adjust their state of charge in order to be ready to capture value from expected future system conditions (derived from an analysis of historic prices or from explicit forecasts) in a way they would not if they had less information. Provision of historic nodal information would be more feasible with the implementation of a nodal optimisation algorithm. However, in a national market,

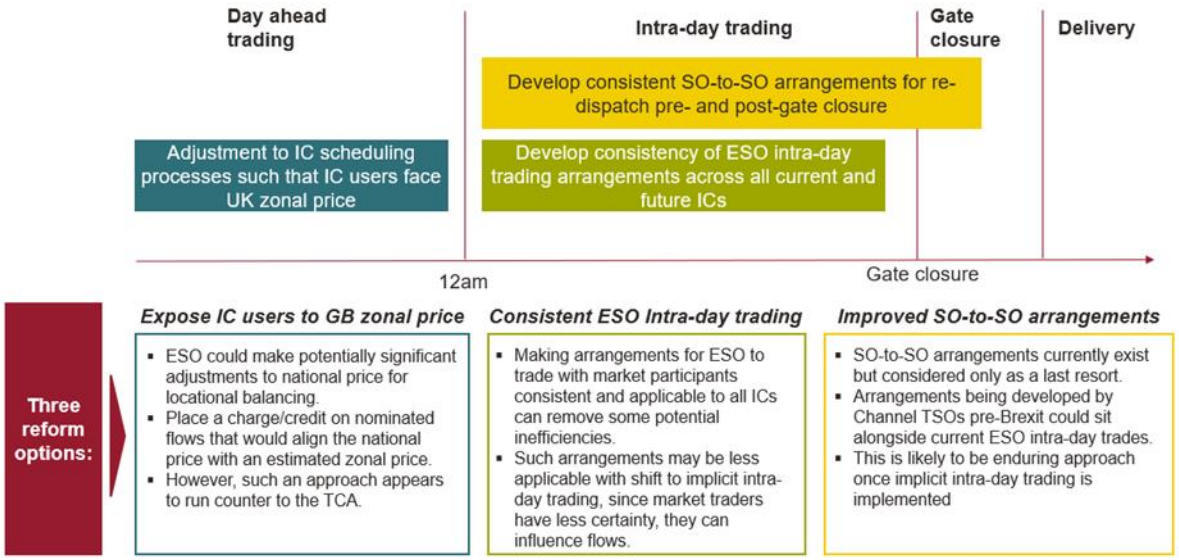
the efficiency effect of additional information to the market should be balanced with concerns about market abuse and gaming.

Improved dispatch

We have considered reforms in relation to the redispatch of interconnectors and smaller assets. In relation to smaller assets, we have already noted the reforms that ESO has recently launched in the discussion of potential inefficiencies so do not consider the issue further here.

With regard to interconnectors, we have identified three options summarised in Figure 7 all of which could in theory work alongside each other.

Figure 7 Interconnector reform options



Source: Frontier Economics

Currently, cross-border interconnector flows are determined by the relativity between GB national prices and the price in the neighbouring market zone. This can result in flows that exacerbate congestion where there is a difference between the national price and the relevant price that would have been the result of a zonal market. A possible reform would be to adjust national prices by placing levies and credits on interconnector flows, effectively applying a zonal price to interconnector users so that cross-border trade reflects congestion in GB without the need for ESO redispatch actions.

From a system perspective, the reform would incentivise market participants to dispatch interconnector flows according to estimated zonal GB prices and therefore reflect expected constraints in the GB market. This should reduce the volume of interconnector redispatch required to be carried out by ESO post gate closure for locational reasons. However, if the levy/credit is set *ex post*, traders would need to predict the value of the GB zonal prices, and the resulting forecasting uncertainty when bidding for interconnector capacity would result in some inefficiency in flows. If the levy/credit is set *ex ante*, it may not accurately reflect actual

system conditions in that hour, but would allow the levy/credit to be taken into account by traders.

However there is a key legal challenge when applying this option, since the Trade and Cooperation Agreement between the UK and EU requires that "*there are no network charges on individual transactions on, and no reserve prices for the use of, electricity interconnectors*" (with a similar agreement existing between UK and Norway).[10] Therefore for all interconnectors to implement this option would either require such charges not to be interpreted as network charges, or a change in the legal text.

The second option would be to develop consistent arrangements for ESO intraday trading across all current and future interconnectors. This would include:

- agreeing arrangements where they currently do not exist (such as on NSL) and ensuring arrangements are in place for future interconnectors; and
- identifying an optimal number of intraday capacity auctions and aligning their number and timing so that ESO has consistent options across all interconnectors.

Expanding the scope and consistency of interconnector trading should lead to ESO having more options and an improved ability to make choices between options, which should therefore improve the efficiency of dispatch. While these benefits will only persist under explicit trading arrangements, given that a move to implicit intraday trading is unlikely in the short term, there is likely to be some short term value in making improvements. The main difficulty is likely to be finalising a set of consistent agreements with a set of connecting countries.

Finally, more dynamic SO to SO arrangements could be developed, in line with those being developed by the Channel TSOs prior to Brexit (the intention at that time being that they would work alongside XBID). Similar arrangements could sit alongside current ESO intraday trades providing pre-gate and post gate closure options as an alternative to domestic balancing options. This would require improved information sharing e.g. with prices offered by each SO based on expected availability of marginal balancing bids and offers in its market, and updated information intraday as expectations of system conditions change. More dynamic arrangements would facilitate interconnector redispatch in the BM, since ESO could more easily compare the cost and effectiveness of interconnector actions against domestic alternatives. This would also represent an enduring solution as the market moves towards implicit trading. While negotiating these arrangements with foreign SOs and interconnector operators is not likely to be straightforward, the challenges may not be insurmountable, given the appetite pre-Brexit.

[10] Trade and Cooperation Agreement (TCA), April 2021, Article 311, para 1(e); https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:22021A0430(01); and Cross-border trade in Electricity agreement, UK and Norway, Article 4 Para 1(d), 16 September 2021; https://assets.publishing.service.gov.uk/media/61431e2cd3bf7f05b2ac2075/TS_18.2021_Agreement_UK_Norway_Cross_Border_Electricity.pdf

Such improvements should help ESO to capture more of the potential for efficient redispatch of interconnectors that was illustrated by the example day presented in Figure 2. As an illustration of the potential savings, if the ESO had been able to fully capture the potential from interconnector redispatch across the course of that day, costs could have been £4.7m lower.[11] We understand that ESO is taking forward work to improve the efficiency of existing interconnector redispatch arrangements.

1.4 Implications of reform options

In many of these areas, the reform options raise questions which would need to be considered in defining the detail of any LMP market. For example, the provision of information by storage assets and the time horizon over which storage is optimised, the nature of technical parameter inputs for any optimisation algorithm, and the design of the optimisation algorithm itself are all questions which would need to be addressed as part of the design of an LMP market. In these areas, it is therefore likely that reforms to the current market could remove scope for differences in dispatch efficiency with an LMP or zonal market.

The key area in which this may not be the case relates to interconnectors.

The intraday reform options on interconnectors which we describe are likely to be subject to similar constraints (e.g. the need to secure agreement on arrangements and timings with interconnected SOs) as would apply under an LMP market. However, the day ahead reform option we describe (the introduction of a levy) is unique to a national market. That said, the introduction of such levy arrangements should ensure that scheduled day ahead flows over interconnectors are similar to (if not the same as) flows under an LMP market. Therefore if our day ahead and intraday reform options for interconnector arrangements were capable of being implemented, it seems likely that scope for differences in dispatch efficiency would be to a large extent removed.

However, if it is only possible to implement reform in relation to intraday arrangements (leaving day ahead arrangements unchanged), the efficiency of dispatch will depend on the effectiveness of those intraday arrangements. A key determinant of the difference between dispatch under an LMP market and that under a reformed national market will relate to the significance of constraints imposed by the need to secure agreement with interconnected SOs.

ESO makes use of intraday interconnector redispatch arrangements today. If constraints relating to the improvement of these arrangements are not material, it may be that the scope for differences in dispatch efficiency between a national market and LMP is reduced or removed. If these constraints are more significant, it might be reasonable to conclude that it will be challenging for a national market to achieve exactly the dispatch efficiency of an LMP market.

[11] The cost reduction assumes that the volumes were available over the interconnector and priced at the continental intraday price (such that volumes could be redispatched over the interconnector without moving the intraday market).

Given there was appetite among TSOs for changes prior to Brexit, the challenges may not be insurmountable.

1.5 Summary of reform options

Table 1 summarises all the reform options and gives a high level assessment of the potential efficiency impact and ease of implementation associated with each option. We also signal which options are being taken forward by ESO. This is based on information published by ESO at the time of writing and does not reflect any reform options considered by ESO internally.

Table 1 Summary of reform options and high level assessment

Reform option	Description	Efficiency	Ease	Taken forward by ESO
Simple bidding	Removing some dynamic parameters with participants internalising plant constraints in price	◑	◑	
Separate bidding	Separate payment for availability from payment for energy by paying capacity to commit to be available (in line with proposed ESO Balancing reserve)	◑	◕	✓
Complex bidding	Updating dynamic parameters so that they better reflect underlying cost drivers	◕	◔	
Improved storage information	Requiring storage assets to provide additional information to ESO	◕	◕	✓
Pay as clear	Move BM to pay as clear basis	◔	◔	
Earlier gate closure	Move gate closure to ensure ESO gets firm information at earlier point in time	◑	◑	
Monitoring differences between IPN and FPNs	Monitoring deviations from IPNs to increase chance of ESO receiving more accurate information	◔	◑	
Improve quality of FPNs	Stronger incentivisation on the submission of accurate FPNs	◔	◕	

Reform option	Description	Efficiency	Ease	Taken forward by ESO
Full optimisation algorithm	Deployment by ESO of a full GB nodal optimisation algorithm (rather than local optimisation)	◑	◔	
Temporal optimisation of storage	Deployment by ESO of optimisation process which looks over extended time period to optimise use of storage	◑	◑	
Additional information from ESO to market	Provision of additional information to the market to allow assets to optimise their availability to respond to system balancing needs	◔	◑	
Improved interconnector dispatch (zonal price levy)	Change to interconnector arrangements to incentivise initial flow programmes which mirror those from a zonal or LMP market design	◕	◔	
Improved interconnector redispatch (intraday auctions)	Implement consistent arrangements on all existing and new links, which maximise opportunities for redispatch	◑	◑	✓
Improved SO to SO arrangements over interconnectors	Implement SO to SO arrangements which provide ESO with firmer options which reflect interconnected system conditions	◕	◔	
Ability to dispatch large numbers of smaller units	Improve ESO systems and processes to allow dispatch of multiple smaller assets leading to fewer “non-economic” skips	◑	◕	✓

Source: Frontier Economics

Note: A filled-in Harvey Ball means the proposed reform option is more efficient or is easier to implement.