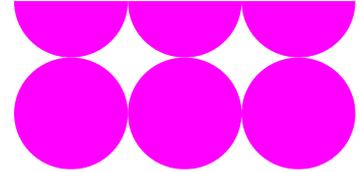


December 2024

# Cross-border arrangements and dispatch options

Report by FTI Consulting for NESO





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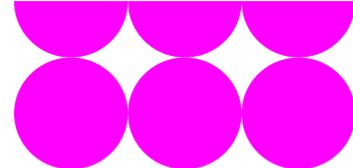
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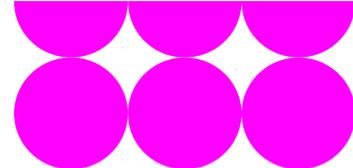
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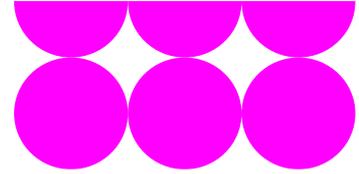


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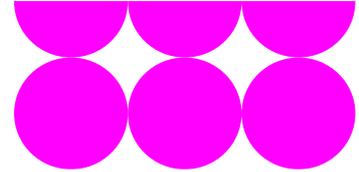


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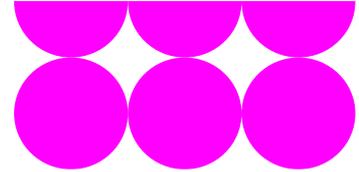


## Glossary

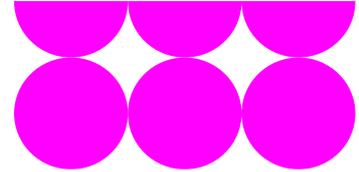
<b>Term</b>	<b>Definition</b>
ACER	European Union Agency for the Cooperation of Energy Regulators
aFRR	automatic Frequency Restoration Reserves
AHC	Advanced Hybrid Coupling
AS	Ancillary Services
BBZ	Bordering Bidding Zone
BM	Balancing Mechanism
BMU	Balancing Mechanism Unit
BSC	Balancing and Settlement Code
CACM GL	Capacity Allocation and Congestion Management Guideline
Cash-outs	The charges paid by BSC Parties when being imbalanced, i.e. for portfolio-level deviations between their contractual positions and metered generation/consumption.
CATO	Competitively Appointed Transmission Owners
CBB	Cross-Border Balancing
CCR	Capacity Calculation Region
CET	Central European Time
CNTC	Coordinated Net Transmission Capacity
Commercial cross-zonal transmission capacity	Available cross-zonal capacity that can be allocated to the DAM or IDM
Commercial price difference	The wholesale price differentials between two interconnected markets
Commercially under-utilised	An IC that is: (i) scheduled intuitively but with an IC flow lower than the maximum possible capacity (after accounting for transmission losses); or (ii) scheduled counterintuitively
Counterintuitively scheduled IC	IC that is scheduled in a direction that goes against the commercial price differential
Critical network elements	Intra-zonal or cross-zonal network elements that are impacted by cross-zonal trade
DA	Day-Ahead
DAM	Day-Ahead Market
DC	Direct Current
DESNZ	Department for Energy Security and Net Zero
DK1	Western Denmark price zone
EB GL	Electricity Balancing Guideline
ENTSO-E	European Network of Transmission System Operators for Electricity



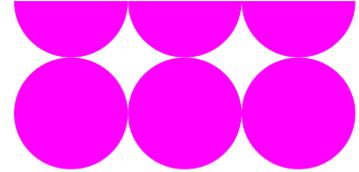
EPAD	Electricity Price Area Differential
EPEX	European Power Exchange
ESO	Electricity System Operator
EU	European Union
EU BBZ	EU Bordering Bidding Zone
EU OBZ	An OBZ that is part of EU's jurisdiction
EU-only countertrading	Countertrading after the GB GCT up to the wholesale GCT in the European IDM
EUPHEMIA	The algorithm that has been developed to resolve the Day-Ahead European Market Coupling problem
EWIC	East-West Interconnector
FCA GL	Forward Capacity Allocation Guideline
FES	Future Energy Scenarios
Flagged actions	An action in the BM undertaken by NESO to resolve system constraints
Flow nomination	The intended volume and direction of flows on the IC declared by IC capacity holders to the relevant SOs
FPN	Final Physical Notification
FR	France
FTI	FTI Consulting
FTR	Financial Transmission Rights
GB	Great Britain
GB BBZ	GB Bordering Bidding Zone
GB CCR	Hypothetical Capacity Calculation Region covering the cross-zonal borders within GB
GB IC zone	Price zone in GB (under Z1 or Z3) containing an IC's landing point
GB NSL zone	Price zone in GB (under Z1 or Z3) where NSL connects
GB OBZ	An OBZ that is part of GB's jurisdiction
GB-Irish ICs	The ICs between GB and Ireland, i.e., currently EWIC and Moyle
GB-system-optimal	Scheduled in line with overall GB system needs
GCT	Gate Closure Time
HM	Home Market
HND	Holistic Network Design
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IC	Interconnector
IC scheduling prices	The price signals used to determine the ICs' schedules
ID	Intraday
ID price forecasting horizon	The time period over which ID prices need to be forecasted that is of relevance for the valuation of the ID IC capacity rights



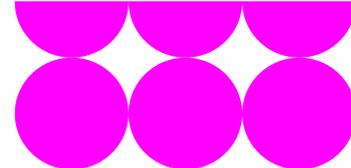
ID3 IC auction	Third intraday interconnector IC capacity auction
IDA	Intraday Auction
IDCZGCT	Intraday Cross- Zonal Gate Closure Time
IDM	Intraday Market
IEM	Internal Electricity Market
IFA	Interconnexion France-Angleterre
Intuitively scheduled IC	IC that is scheduled to flow from the price zone with the lower wholesale price towards the region with the higher wholesale price, while accounting for transmission losses
IPN	Initial Physical Notification
I-SEM	Integrated Single Electricity Market
ISO	Independent System Operator
IU CCR	Ireland-UK Capacity Calculation Region
JAO	Joint Allocation Office
LTR	Long-term Transmission Right
LtW	Leading the Way
MARI	Manually Activated Reserves Initiative
MCO	Market Coupling Operator
mFRR	manual Frequency Restoration Reserves
MPI	Multi-Purpose Interconnector
MRLVC	Multi-region Loose Volume Coupling
MTU	Market Time Unit
N0	The current market design, i.e. self-scheduling with national wholesale pricing and GCT of 1 hour
N0 MRLVC	MRLVC under the current N0 market design
N0 Price Coupling	Price Coupling under the current N0 market design
N0 Status Quo	Status Quo cross-border trading arrangements under the current N0 market design
N1	Self-scheduling with national wholesale pricing and an extended GCT
N1 MRLVC	MRLVC under the N1 market design
N1 Price Coupling	Price Coupling under the N1 market design
N1 Status Quo	Status Quo cross-border trading arrangements under the N1 market design
N2EX	Nord Pool Exchange
N3	Central scheduling with national wholesale pricing
N3 MRLVC	MRLVC under the N3 market design
N3 Price Coupling	Price Coupling under the N3 market design
N3 Status Quo	Status Quo cross-border trading arrangements under the N3 market design



NEMO	Nominated Electricity Market Operator
NESO	National Energy System Operator
NGV	National Grid Ventures
NOA7	Network Options Assessment 7
NO	Norway
NO2	Price Zone 2 in Norway
Non-flagged actions	An action in the BM undertaken by NESO to resolve an energy imbalance
NSI	Non-standard Interconnector
NSL	North Sea Link
NTC	Net Transfer Capacity
NWE	Northwest Europe
OBZ	Offshore Bidding Zone
OHA	Offshore Hybrid Asset
OTC	Over-the Counter
OWF	Offshore Wind Farm
PD	Physical Dispatch
PICASSO	Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
PN	Physical Notification
PTDF	Power Transfer Distribution Factor
PTO	Price Taking Order
PTR	Physical Transmission Rights
PUN	Prezzo Unico Nazionale, i.e. the Italian-wide wholesale price
PX	Power Exchange
REMA	Review of Electricity Market Arrangements
RR	Replacement Reserves
RT	Real Time
RUC	Reliability Unit Commitments
SCED	Security Constrained Economic Dispatch
Scheduling price differential	The price differential used to schedule flows on ICs
SCUC	Security Constrained Unit Commitment
SDAC	Single Day-Ahead Coupling
Shadow nodal price	The marginal cost of electricity at a transmission node determined via a SCUC/SCED
SIDC	Single Intraday Coupling
SO	System Operator
SO-SO	System Operator to System Operator



TCA	Trade and Cooperation Agreement
TERRE	Trans-European Replacement Reserves Exchanges
TSO	Transmission System Operator
UIOLI	Use-It-Or-Lose-It
UIOSI	Use-It-Or-Sell-It
UK	United Kingdom
Unconstrained price	Wholesale price that does not take into account transmission constraints
Virtual IC capacity right	IC capacity right introduced under central scheduling when scheduling ICs based on shadow nodal prices under an explicit cross-border trade arrangement. These IC capacity rights share similarities with both FTRs and PTRs – holders are not able to nominate flows (like FTRs) but are required to take a position in the GB DAM or lose the right to the congestion revenue (like PTRs)
VOLL	Value of Lost Load
XBID	Cross-Border Intraday Coupling
YA	Year-ahead
Z1	Self-scheduling with zonal wholesale pricing
Z1 MRLVC	MRLVC under the Z1 market design
Z1 Price Coupling	Price Coupling under the Z1 market design
Z1 Status Quo	Status Quo cross-border trading arrangements under the Z1 market design
Z3	Central scheduling with zonal wholesale pricing
Z3 MRLVC	MRLVC under the Z3 market design
Z3 Price Coupling	Price Coupling under the Z3 market design
Z3 Status Quo	Status Quo cross-border trading arrangements under the Z3 market design



## Executive summary

### Introduction

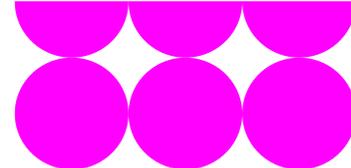
1. The UK Government is currently undertaking a Review of Electricity Market Arrangements (“REMA”), its “flagship policy to enable a net zero power sector by 2035”. Its purpose is to “identify reforms needed to transition to a decarbonised, cost effective and secure electricity system” in Great Britain (“GB”).<sup>1</sup> REMA is evaluating a range of potential design options, including in wholesale electricity pricing (e.g. national and zonal pricing), in scheduling (e.g. central and self-scheduling) and in the wholesale gate closure timings (e.g. an extended gate closure time (“GCT”).
2. These design options have implications for the cross-border trading arrangements in GB, which play a significant and growing role in driving outcomes in GB’s power market. Interconnectors (“ICs”), whether they are simple point-to-point, multi-purpose or non-standard, enable electricity to be traded between GB and connected European countries. As such, they can act as sources of supply and/or demand for GB and can support the GB power market across all three aspects of the energy trilemma. Indeed, there is currently 10.3 GW of IC capacity between GB and its neighbours,<sup>2</sup> which could reach up to 23.7 GW by 2035.<sup>3</sup>
3. Cross-border trading of electricity, if designed well, can play a critical role in delivering GB consumer and societal welfare benefits. Their scale and two-way nature mean that if ICs are not scheduled efficiently, they can fail to deliver the benefits they otherwise could, or even, in some cases, increase the costs of reaching Net Zero. Two main factors impact whether ICs are scheduled efficiently:
  - (i) The extent to which the price signals on which the schedules of ICs are based (“*IC scheduling prices*”) align the ICs’ schedules with GB system needs; and
  - (ii) The extent to which the cross-border arrangement enables ICs to be scheduled in alignment with those IC scheduling prices. This alignment is referred to as the “*commercial utilisation of the IC*”.

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<sup>1</sup> REMA, Department for Energy Security and Net Zero (“DESNZ”) ([link](#)).

<sup>2</sup> Greenlink (500 MW) is included which is expected to be in operation in early 2025.

<sup>3</sup> Future Energy Scenarios (“FES”) 24 data workbook, ES.19.



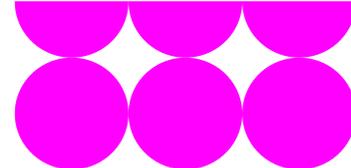
4. Inefficiencies in the scheduling of ICs arise today due to both factors. With regards to the first factor, ICs frequently need to be redispached close to delivery as their scheduled flows would aggravate rather than relieve internal GB transmission constraints. This can happen even when an IC's schedule is perfectly aligned with the differential between the GB wholesale price and the wholesale price in the connecting market. For example, the current single national GB wholesale price can often incentivise ICs in the South of GB to be scheduled for export from GB towards Europe, even though doing so may, at times, exacerbate intra-GB constraints that require costly redispach actions to resolve.<sup>4</sup> The frequent failure in aligning IC schedules and GB system needs has been one of the drivers for considering changes to the current national wholesale pricing and/or self-scheduling arrangements in GB, both of which are examined in this report.
  
5. With regards to the second factor, after the exit of the the United Kingdom ("UK") from the European Union ("EU"), most GB ICs shifted from a previous implicit Price Coupling arrangement with the EU to an explicit cross-border trading arrangement.<sup>5</sup> In contrast to Price Coupling, explicit trading on ICs has led in some instances to the commercial under-utilisation of ICs and even the scheduling of counterintuitive flows, e.g. ICs scheduled against the outturn wholesale price difference between GB and the connecting market.<sup>6</sup> For example, IC capacity holders have, from time to time, nominated their IC rights based on forecasts of wholesale price differentials between GB and the connecting market that turned out to be incorrect. Alternative cross-border trading arrangements are being actively considered to mitigate the downsides of explicit trading on most GB ICs, for example, Multi-Region Loose Volume Coupling ("MRLVC") or a potential return to some form of Price Coupling.

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<sup>4</sup> Electricity System Operator ("ESO") analysis to support Ofgem's Third Cap and Floor Window and Multi-Purpose Interconnector ("MPI") Pilot Regulatory Framework, ESO, August 2022, p.10, 11 ([link](#)).

<sup>5</sup> Except for the North Sea Link ("NSL") IC between GB and Norway, and the various ICs between GB and Ireland ("GB-Irish ICs"), which continued to have implicit trading arrangements.

<sup>6</sup> 'The value of international electricity trading', report commissioned by Ofgem ([link](#)).



6. In this context, FTI Consulting (“FTI”) has been commissioned by National Energy System Operator (“NESO”) to examine the interactions between potential REMA reforms and current/potential future cross-border trading arrangements shown in Table 1.<sup>7, 8, 9</sup> Specifically, FTI has been requested to systematically map out the feasibility, efficiency and commercial impacts of all combinations across the relevant market timeframes.

**Table 1: Combinations of cross-border and market design arrangements examined**

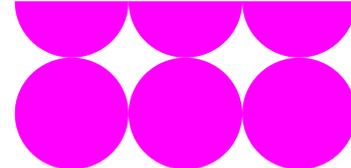
Market design → Cross-border arrangement ↓	Self-scheduling with national pricing and extended GCT (“N1”)	Self-scheduling with zonal pricing (“Z1”)	Central scheduling with national pricing (“N3”)	Central scheduling with zonal pricing (“Z3”)
<b>Status Quo</b>	For each combination, the forward, day-ahead, intraday and post-gate closure timeframes are examined.			
<b>MRLVC</b>				
<b>Price Coupling</b>				

7. In performing this analysis, FTI has not sought to comment on the preferred option(s) for cross-border trading arrangements nor on the desirability of the specific REMA design outcomes. FTI has also not assessed any legal implications or potential interactions with the Trade and Cooperation Agreement (“TCA”). Rather, FTI has taken the four potential REMA market designs as given and, in turn, examined: (i) how different cross-border trading arrangements could be developed or adapted in order to be compatible with the different market designs; (ii) whether any of the considered market designs lead to significant shortcomings when combined with certain cross-border traarrangements; and (iii) what the potential benefits and drawbacks of different cross-border trading arrangements might be. This study has been performed purely qualitatively, and, where relevant, FTI has identified the need for additional empirical assessment to refine the evaluation.
8. The rest of this Executive Summary draws out the seven key findings from the study. A comprehensive survey of all twelve combinations of cross-border trading arrangements and considered market designs is provided in the following ‘Introduction and Report Summary’.

<sup>7</sup> The Status Quo arrangements include explicit trading arrangements on all ICs except for implicit price coupling on: (i) NSL (GB-Norway) in the day-ahead timeframe; and (ii) on the GB-Irish ICs in the intraday (“ID”) timeframe.

<sup>8</sup> For the avoidance of doubt, there is no “Z2” or “N2” design option included in this report. The nomenclature is aligned with NESO’s assessment ([link](#)).

<sup>9</sup> Under the central scheduling arrangements (N3 and Z3), there is a choice to schedule ICs based on shadow nodal prices or unconstrained national (N3)/zonal(Z3) prices.



## Seven key findings of the study

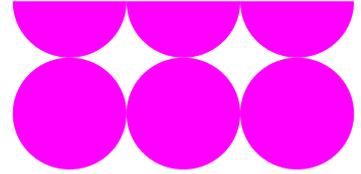
**Key Finding #1:** Other things being equal, it is preferable to schedule cross-border assets: (i) based on prices that signal GB system needs; and (ii) under a cross-border arrangement that ensures that IC schedules are aligned with those price signals.

9. It is preferable for IC scheduling prices to reflect GB system needs, as this helps to reduce the volume of redispatch actions that NESO needs to take to balance the system, and, in turn, leads to lower redispatch costs (which are ultimately borne by consumers). Shadow nodal prices, which are calculated based on demand, supply and transmission network constraints for each node on the GB system, best reflect GB system needs in any given time period and can be used to schedule ICs under central scheduling (N3 and Z3).<sup>10</sup>
10. Zonal unconstrained prices can be considered the next best alternative to shadow nodal prices (albeit the design of the zones affects the extent to which these are a good proxy for the main transmission constraints on the network). Finally, national unconstrained prices, as under the current market design, often fail to reflect GB system needs properly and therefore frequently result in inefficiencies when used to schedule ICs.<sup>11</sup> These inefficiencies translate into a need to redispatch ICs (or other assets) close to real time, thus leading to additional consumer costs. While ICs are flexible assets and can be rescheduled to address GB system needs (and thus help balance the system), it is preferable for ICs (from a GB consumer perspective) to be scheduled in line with the GB system needs at the outset rather than through redispatch actions.

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<sup>10</sup> An additional complexity when scheduling ICs based on shadow nodal pricing is that this can lead to flows that are intentionally scheduled in a counterintuitive direction (e.g. against the wholesale price differential they are exposed to). This implies that additional transfer payments to 'make-whole' ICs are likely to be required to maintain the appropriate incentives and limit the IC owners' risk exposure.

<sup>11</sup> Modelling the GB power system from 2030 to 2040 under the FES 2022 Leading the Way ("LtW") with Holistic Network Design ("HND") + Network Options Assessment 7 ("NOA7") refresh assumptions, we find that under self-scheduling with national wholesale pricing the direction of the scheduled flows across all ICs is not in line with the GB-system-optimal IC schedules in 10-20% of the hours. Source: 'Assessment of the benefits of alternative dispatch (scheduling) models', FTI report for NESO (to be published in 2025).



11. It is also preferable that the cross-border arrangements in place ensure that IC schedules are aligned with the scheduling prices that ICs (or IC capacity holders) are exposed to. Forecast errors under explicit trading and imperfect information sharing under MRLVC can lead to unintentional misalignments of the IC schedules with the outturn scheduling prices that IC capacity holders (or owners) are exposed to. Assuming scheduling prices are well-defined (see ¶19 above), this would imply an efficiency loss compared to when IC schedules are perfectly aligned with the prevailing IC scheduling prices. This alignment is guaranteed under Price Coupling, as wholesale prices and IC schedules are simultaneously determined.<sup>12</sup>

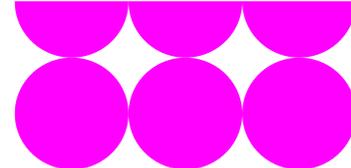
**Key Finding #2:** However, the two objectives (from Key finding #1) conflict with each other and thus make a first-best approach infeasible.

12. The first-best outcome, based on the discussion above, would entail scheduling ICs in line with GB system needs (e.g. using central scheduling where ICs are scheduled based on shadow nodal prices), while simultaneously having Price Coupling between GB and the connected countries in place.
13. In practice, this would mean the existing EUPHEMIA algorithm<sup>13</sup> would need to accommodate potentially hundreds of additional GB nodes in the market clearing process. This is not feasible in the short to medium term for computational reasons. Moreover, GB would likely not be willing or able to provide the required GB network information (physical parameters of all intra-GB transmission lines) to the European Market Coupling Operator (“MCO”) for security reasons. Nor does it seem likely that the EU would be willing to make very significant changes to the EUPHEMIA algorithm in order to accommodate GB’s market design choices. Hence, the first-best combination does not appear possible currently and a compromise is necessary.

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<sup>12</sup> Disregarding potential impacts from balancing actions and IC ramping limits. Further, intentional counterintuitive flows are possible under Flow-Based Market Coupling (which does not apply for the direct current (“DC”) ICs between GB and the connecting European market).

<sup>13</sup> EUPHEMIA is the Price Coupling algorithm that is used in the Single Day-Ahead Coupling (“SDAC”) to calculate electricity wholesale prices and simultaneously allocate cross-zonal transmission capacity across Europe.



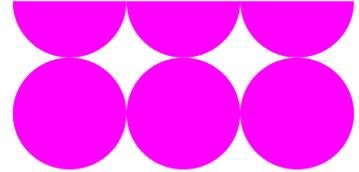
**Key Finding #3:** A zonal wholesale market design is the only variant that can be combined with Price Coupling without leading to significant downsides. Its key benefit relative to a national wholesale market design is that, under both self-scheduling (Z1) and under central scheduling (Z3),<sup>14</sup> it better aligns scheduling prices faced by ICs with GB system's needs at that time.

14. If Price Coupling was a priority for policy makers, then the zonal designs (Z1 and Z3 with unconstrained zonal prices) are the key market design options identified in this study that would be compatible with it. Zonal pricing combined with Price Coupling has been successfully operating for many years in several European countries, e.g., Sweden, Norway, Denmark and Italy. As discussed in Key Finding #2, central scheduling while using shadow nodal prices to schedule ICs is not compatible with Price Coupling.
15. While zonal prices are less reflective of GB system needs compared to shadow nodal prices, they are an improvement on a national GB unconstrained price (noting that the extent of this improvement depends on how well the zones are aligned with the main transmission constraints on the network).<sup>15</sup> As such, they help to align scheduling prices faced by ICs with GB system needs. This would manifest itself in reduced volumes of redispatch actions required to take place on ICs under a zonal market design (compared to a national self-scheduling market design).
16. This design is also future proof as it can accommodate updates to the zonal setup in GB, as well as directly incorporate new Offshore Bidding Zones ("OBZs"). Since a modest number of OBZs (e.g. fewer than 10) are likely to be introduced in the short to medium term, it is expected that these could be included in the central market clearing algorithm along with other European price zones without significant additional computational complexity.

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<sup>14</sup> As described in Footnote 9, under the Z3 design there are two options for scheduling ICs: using shadow nodal prices or using unconstrained (zonal) prices. In Key Finding #3 we refer to the option where unconstrained prices are used to schedule ICs.

<sup>15</sup> From the perspective of the efficiency of cross-border scheduling, there is limited difference between Z1 and Z3 (when scheduling ICs based on unconstrained zonal prices). However, there may be additional benefits of having central scheduling in place. These could include increased visibility of the scheduling of assets within zones (e.g. reducing the costs of managing intra-zonal congestion) and the facilitation of the co-optimisation of energy scheduling and ancillary services, but these have not been explored in this report.



**Key Finding #4:** Scheduling ICs based on shadow nodal prices under the market designs with central scheduling is feasible with explicit trading or MRLVC variants<sup>16</sup>, but its efficiency is limited by forecast errors and compromises on the information being used in IC scheduling, respectively. Nevertheless, scheduling ICs based on shadow nodal prices under central scheduling with national wholesale pricing (N3) could be an attractive option if zonal pricing is not adopted. However, it is a complex and novel option that has to our knowledge, at the time of drafting this report, not been tested in practice.

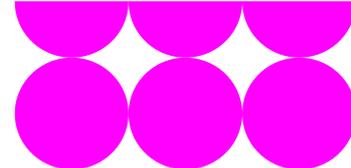
17. Central scheduling with national wholesale pricing in which ICs are scheduled based on shadow nodal prices appears to be feasible under explicit trading. However, various potentially complex measures would need to be developed to maintain appropriate incentives for IC capacity holders and limit their risk exposure. This would likely be cumbersome and complex to implement.
18. This market design also appears feasible under MRLVC, although there would be additional complexity with regards to the information that NESO would need to provide to the MRLVC clearing algorithm. The extent to which the information provided to the MRLVC algorithm is simplified will affect the extent to which flows are scheduled in line with shadow nodal prices and are thus GB-system-optimal under MRLVC.
19. If policymakers choose to retain the current national pricing arrangements, then explicit cross-border trading or MRLVC variants of central scheduling with national pricing would enable ICs to be scheduled in line with system needs (using shadow nodal prices). Both explicit and MRLVC options would likely entail potentially material transfer payments to 'make-whole' IC capacity holders (or IC owners) when ICs are intentionally scheduled against the commercial price differential.<sup>17</sup> In turn, this would be funded by consumers.
20. However, FTI is, at the time of drafting this report, not aware of any precedent where national wholesale pricing has been combined with central scheduling where ICs are scheduled using shadow nodal prices.<sup>18</sup> As such, this option would be breaking new ground in terms of market design with attendant risks.

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<sup>16</sup> As discussed in Key Finding #2, central scheduling while using shadow nodal prices to schedule ICs is not compatible with Price Coupling.

<sup>17</sup> The commercial price differential is the difference between the national/zonal unconstrained price in GB (which are used to compensate market participants) and the wholesale price of the connecting European bidding zone. For example, it can be that the unconstrained national GB price is £30/MWh, the price in the connecting European market is £50/MWh and the shadow nodal price at the IC landing point in GB is £60/MWh. This would mean that the IC is scheduled to import in GB based on the GB shadow nodal price, e.g. against the commercial price difference.

<sup>18</sup> A practice that would come closest to the described approach would be the near real-time coordination of the scheduling of interties, i.e. transmission lines between North American Independent System Operators ("ISOs") that have nodal wholesale pricing in place.



**Key Finding #5:** While Price Coupling is also in principle compatible with scheduling ICs on unconstrained national wholesale prices under central scheduling (N3), it would lead to major inefficiencies and significantly weaken the case for central scheduling.

21. In this option, central scheduling would be introduced in GB (N3) and all assets (except cross-border ones) would be scheduled based on shadow nodal GB prices. Somewhat incongruously, in this design, ICs would be scheduled based on unconstrained national wholesale prices. In principle, Price Coupling is technically feasible when scheduling ICs on unconstrained national wholesale prices; indeed, this mirrors the pre-Brexit arrangements. However, two issues make this option significantly less attractive compared to combining Price Coupling with zonal market designs (Z1 or Z3 when scheduling ICs based on unconstrained zonal prices).
- First, instances of scheduling of ICs in a manner that is sub-optimal from the GB system's perspective based on a national wholesale price have become more prevalent and are one of the drivers behind rising constraint costs in GB (as has been evidenced in the latest Window 3 Cap and Floor assessment by Ofgem).<sup>19</sup> The benefits case of transitioning to central scheduling would be significantly reduced if ICs were the only asset class that would continue being scheduled based on national wholesale prices – indeed it appears incongruous for GB to transition to a central scheduling arrangement but continue to schedule the large volume of flexible two-way ICs using (unconstrained) national GB prices.
  - Second, pre-Brexit ID cross-border arrangements were explicit, which allowed for countertrading with the connecting markets via IC capacity holders.<sup>20</sup> Today, Price Coupling has also been rolled out in the ID timeframe in Europe, e.g. via the so-called Single Intraday Coupling (“SIDC”). In the scenario that GB would also join the SIDC when being part of the SDAC, it is uncertain (both from legal and regulatory perspectives) whether countertrading in the ID timeframe between GB and the connecting markets would still be possible and how it could be implemented efficiently.<sup>21,22</sup>

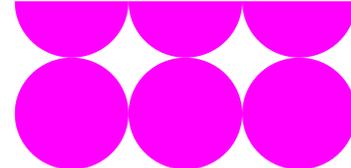
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<sup>19</sup> See ‘Cap and Floor Window 3 and OHA pilot scheme Needs Case Assessment ESO modelling report’ by ESO ([link](#)) and ‘NESO System Impact Assessment Report Cap and Floor Window 3 and OHA Pilot Scheme Needs Case Assessment: post-consultation analysis, report commissioned by Ofgem’ by NESO ([link](#)).

<sup>20</sup> Countertrading helps to redispatch flows on ICs that exacerbate intra-GB constraints. These arrangements are also in place today on most ICs (but not on NSL and the GB-Irish ICs).

<sup>21</sup> Countertrading in the ID market is currently in place between the Western Denmark price zone (“DK1”) and Germany (Tennet) ([link](#), [link](#)). However, it is unclear whether such arrangement could easily be replicated for GB and the relevant connecting European market.

<sup>22</sup> Similar adaptations to countertrading arrangements would be required when scheduling ICs based on (unconstrained) zonal prices when combined with Price Coupling, but countertrading is less vital under a zonal market design as constraint volumes would be expected to be lower (albeit, as noted, this depends on how well zonal boundaries reflect intra-GB transmission constraints).



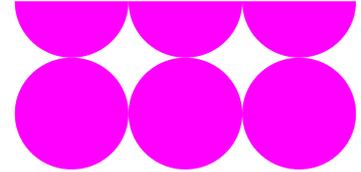
22. Overall, introducing central scheduling while continuing to schedule ICs using unconstrained GB national prices (as opposed to shadow nodal prices) would likely perpetuate the existing misalignment between IC schedules and GB system needs, while making it potentially more challenging for NESO to balance the system via redispatch actions on ICs.

**Key Finding #6:** Under the Status Quo cross-border trading arrangements, explicit trading arrangements are compatible with scheduling ICs based on (i) unconstrained zonal prices (Z1 or Z3); or (ii) shadow nodal prices (N3 or Z3). However, moving away from national scheduling prices for ICs would lead to frictions with the current implicit arrangements on the GB-Irish ICs and NSL. The implicit Status Quo arrangements would therefore likely need to be amended, with a fallback option being a return to explicit trading for those ICs.

23. The current explicit arrangements on the Northwest Europe (“NWE”) ICs are compatible with scheduling ICs based on zonal prices (Z1 or Z3) or shadow nodal prices (N3 or Z3).
24. However, if scheduling of ICs based on shadow nodal prices (N3 or Z3) were to be implemented, the continuation of the implicit cross-border trading arrangements on GB-Irish ICs and NSL would be challenging. Maintaining implicit Price Coupling would imply that a single entity was to jointly define prices in GB and the Integrated Single Electricity Market of Ireland (“I-SEM”)/Norwegian Price Zone 2 (“NO2”) and associated flows on the relevant ICs. This role could be for example performed by NESO, SEMOpX (for GB-Irish ICs) or N2EX (for NSL) – but it is unclear whether any of these options would be viable for security reasons.<sup>23</sup> If none of the options are viable, alternative arrangements would need to be identified for the GB-Irish ICs and NSL (with moving back to explicit trading as a backstop option).
25. Similarly, when scheduling ICs based on (unconstrained) zonal prices (Z1 or Z3), the continuation of the implicit arrangements would be challenging (GB-Irish ICs) and not future proof (NSL).
- If the GB-Irish ICs would connect to different zones in GB, the concurrent clearing of the I-SEM with the relevant GB zones via a British-Irish coupling would (from time to time, though not necessarily always) implicitly determine specific intra-GB cross-zonal flows. Given that intra-GB cross-zonal capacity would be implicitly cleared via a separate mechanism, the continuation of the implicit arrangement on the GB-Irish ICs would likely lead to an inefficient use of the intra-GB network.

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<sup>23</sup> Security concerns relate to risks associated with the sharing of GB detailed network and/or asset information, required for central scheduling algorithm to operate. For example, sharing such information with a non-GB entity could be seen as posing a security risk; and vice versa if a connected country were to share sensitive network or generation asset-specific information with the GB MCO.



- This issue would not arise under the implicit NSL arrangements, as there is currently only one IC between GB and Norway. However, this current arrangement is not future proof to new ICs that may connect to different zones in GB and/or Norway than NSL.

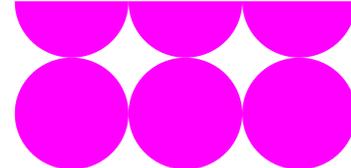
26. If the existing implicit arrangements were not viable under this design, alternative options may need to be considered. As a fallback option, the current implicit arrangements on the GB-Irish ICs and NSL could be replaced by an explicit arrangement. Everything else equal, replacing an implicit (for GB-Irish ICs and NSL) with an explicit cross-border trade arrangements would likely result in an efficiency loss. This loss would need to be compared to the efficiency gains arising from scheduling all ICs on shadow nodal (N3 or Z3) or zonal prices (Z1 or Z3) rather than on national GB wholesale prices. It appears to us that the efficiency gains of the latter would likely outweigh the efficiency loss of the former, however, this would need to be examined further.

**Key Finding #7: Benefits of extending the GB GCT per se are uncertain, and would lead to increased misalignment with Europe (including potentially preventing a return to Price Coupling).**

27. One proposed approach to potentially reduce intra-GB constraint costs has been to keep the current market design in place but extend the wholesale GCT (NI).
28. The overall impact on GB system costs when extending the wholesale GCT in GB beyond the current 1 hour is uncertain. There are two countervailing effects: on the one hand, NESO has more time to perform redispatching actions which could help lower system costs, whereas on the other hand, NESO would need to play a greater role in managing energy imbalances (e.g. driven by potentially larger forecast errors given the GCT would take place further away from real time), which could lead to higher GB system costs. The balance of these two effects would need to be examined in more detail.
29. This is further complicated by ongoing market reforms in Europe to shorten the intraday cross-zonal GCT (“IDCZGCT”) to 30 minutes. Under the Status Quo cross-border arrangements, there would be a reduced overlap in the post-GCT period between GB and Europe. This would shorten the window during which redispatch actions can be taken unless European Transmission System Operators (“TSOs”) are: (i) willing for NESO to perform System Operator to System Operator (“SO-SO”) trades before their European wholesale GCT; or (ii) willing to continue countertrading after the GB wholesale GCT.
30. If GB would need to comply with the Internal Electricity Market (“IEM”) Regulations under Price Coupling, it would mean that the IDCZGCT would need to be at most one hour ahead of delivery.<sup>24</sup> This would imply that, under Price Coupling, the NI market design is not possible.

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<sup>24</sup> From the 1<sup>st</sup> of January 2026 the IDCZGCT shall not be more than 30 minutes ahead of delivery.



## Summary of key findings

31. The assessment of the efficiency of each cross-border trading and market design arrangement combination is summarised in Figure 1 below. In this figure, it is mapped out how: (i) IC scheduled flows align with scheduling prices, on the y-axis; and (ii) IC scheduling prices reflect GB system needs, on the x-axis. As shown below, GB is currently in the “fourth-best” world (bottom left). Of the combinations considered:

- Price Coupling with shadow nodal pricing is the first best option (Key Finding #1) but is not feasible (Key Finding #2).
- The second-best option is the combination of a zonal wholesale market design with Price Coupling (top middle box) which is well-established and has been successfully implemented in several EU countries (Key Finding #3).
- If retaining a single national wholesale price is the preferred policy choice, an alternative could be to introduce central scheduling where ICs are scheduled based on shadow nodal prices (and explicit or MRLVC cross-border arrangements). However, this is a novel option that to our knowledge, at the time of writing, has not been implemented in any jurisdiction (Key Finding #4).
- Amongst the third-best options, the choice for policy makers will depend on the feasibility of MRLVC (which is uncertain), on the willingness of the EU to accommodate GB policy choices, and on GB’s policy preferences for locational wholesale pricing.<sup>25</sup>
- Combining Price Coupling with scheduling ICs based on (unconstrained) national wholesale prices could lead to reliability risks under high constraint volumes. Adaptations to the current countertrading arrangements would be required; the feasibility depends on the willingness of European TSOs to accept such adaptations (Key Finding #5). Further, Price Coupling is not feasible with an extended wholesale GCT in GB (NI) when assuming GB would need to comply with the IEM Regulations under Price Coupling (Key Finding #7).
- Finally, implicit Status Quo arrangements (for GB-Irish ICs and NSL) would likely need to be amended when moving away from (unconstrained) national wholesale prices to schedule ICs, with a fallback option being a return to explicit auctions for those ICs (Key Finding #6).

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<sup>25</sup> MRLVC under zonal pricing would work in a broadly similar way to MRLVC under national pricing. The main difference is that the power exchanges would need to submit GB order books on a zonal rather than national basis to the MRLVC algorithm. We envisage the most robust option would be to submit the order books of all GB zones to the MRLVC operator. This would render MRLVC more computationally burdensome compared to MRLVC under national pricing. However, by doing so (and not, for example, only submitting the order books of GB zones that are directly connected to an overseas European market) the impact on the effectiveness of MRLVC from having zonal pricing in place in GB, rather than national pricing, is expected to be limited.



# 1. Introduction and report summary





## Introduction

- 1.1. Cross-border interconnectors (“ICs”), whether point-to-point, multi-purpose or non-standard<sup>26</sup>, play a key role in Great Britain’s (“GB”) electricity market, offering system flexibility and supporting security of supply, affordability, and decarbonisation. As more ICs are built – with capacity growing from the current 10.3 GW of IC capacity<sup>27</sup>, to potentially up to 23.7 GW by 2035<sup>28</sup> – the role that the cross-border markets play in GB’s system will increase.
- 1.2. The direction of the scheduled flows on ICs is determined by the wholesale price differentials between connected markets, with energy generally flowing towards the higher priced market (while reflecting transmission losses). Currently, GB ICs are increasingly required to be redispatched close to real time (“RT”) due to wholesale prices not reflecting GB system needs. One of the Review of Electricity Market Arrangement (“REMA”) reforms under consideration, the move to a zonal wholesale market, aims at improving these wholesale price signals so they better reflect the operational needs of the GB system. In parallel, the review of scheduling and dispatch arrangements under REMA considers various design options that could alter the interactions between cross-border markets and wholesale markets at different timeframes. Indeed, National Energy System Operator (“NESO”) has found that there is a case for change to the current market design.<sup>29</sup>

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<sup>26</sup> In this report the term ‘interconnectors’ (“IC”) is used to describe primarily point-to-point ICs. The implications of offshore hybrid assets (“OHAs”) (e.g. Non-standard Interconnectors (“NSIs”) and Multi-purpose Interconnectors (“MPIs”)) are separately examined in Chapter 7.

<sup>27</sup> Greenlink (500 MW) is included which is expected to be in operation in early 2025.

<sup>28</sup> Future energy scenarios (“FES”) 24 data workbook, ES.19.

<sup>29</sup> GB scheduling and dispatch – A case for change ([link](#)).

## 1. Introduction and report summary

1.3. In this context, NESO has commissioned FTI Consulting (“FTI”) to qualitatively evaluate the impact of potential reforms of the wholesale scheduling approach and locational granularity on GB cross-border trading arrangements. Specifically, FTI has been asked to examine how various cross-border trading arrangements could be combined with the following four design options:<sup>30</sup>

- Self-scheduling with extended gate closure time (“GCT”) under national wholesale pricing (“N1”);
- Self-scheduling with zonal wholesale pricing (“Z1”);
- Central scheduling with national wholesale pricing (“N3”); and
- Central scheduling with zonal wholesale pricing (“Z3”).

1.4. These four market designs are overlaid with three different cross-border trading arrangements (considering each in turn), which are:

- Status Quo cross-border trading arrangements;<sup>31</sup>
- Multi-Region Loose Volume Coupling (“MRLVC”); and
- (Implicit) Price Coupling.

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<sup>30</sup> There are other potential designs, where national/zonal pricing is combined with central scheduling with a hybrid scheduling approach. NESO refers to these as N2/Z2. In the hybrid design, after ICs are scheduled based on national or zonal GB wholesale prices, the system operator (“SO”) would run a Security Constrained Economic Dispatch (“SCED”) model to account for network constraints in the scheduling process. The objective of the SCED optimisation would be to minimise the cost of assets (excluding ICs) for deviating from their schedules. IC schedules would be considered firm. FTI Consulting was not asked to cover the N2/Z2 designs, but when analysing the central scheduling market designs (N3/Z3) we consider the case when ICs are scheduled based on unconstrained national/zonal prices, while all other assets are scheduled based on shadow nodal prices. Such approach resembles the N2/Z2 designs.

<sup>31</sup> Including explicit trading arrangements on all ICs except for Price Coupling on: (i) the North Sea Link (“NSL”) in the day-ahead (“DA”) timeframe; and (ii) the ICs connecting GB with the Integrated Single Electricity Market (“I-SEM”) (“GB-Irish ICs”) in the intraday (“ID”) timeframe.

## 1. Introduction and report summary

- 1.5. The report is started by mapping the functioning of the three cross-border trading arrangements on the current market design, e.g., self-scheduling with national wholesale pricing and GCT of 1 hour (“N0”). Then each of the four of the market designs described above (N1, N3, Z1 and Z3) are considered in turn and it is described how different cross-border trading arrangements could be combined with these designs. How other market reforms could affect the evaluation is also evaluated. In performing the analysis, **FTI examines the extent to which the different combinations of market designs and cross-border trading arrangements are feasible (potentially with adaptations) and their potential advantages and disadvantages from consumer, societal and IC owner perspectives.**
- 1.6. This chapter consists of four sections, which are:
- Introduction of the key terms that are used throughout the report;
  - Description of the key concepts and definitions relating to scheduled flows on ICs and an overview of the three considered cross-border trading arrangements;
  - Overview of the specific market reforms that may interact with potential changes to cross-border trading arrangements; and
  - Summary of the key findings on the combinations of cross-border trading arrangements and market designs, including how additional market reforms could interact with the considered market designs and cross-border trading arrangements.

### Key terms related to the scheduling of IC flows

- 1.7. In this section, key terms that are used throughout this report are defined: “commercial utilisation”, “commercial price differences”, “intuitive IC flows”, “counterintuitive IC flows”, “commercially under-utilised”, “GB-system-optimal IC flows”, “shadow nodal prices”, “IC scheduling prices” and “unconstrained prices”.
- 1.8. The **commercial utilisation** of an IC is determined by the extent to which ICs are scheduled to flow at maximum capacity in the direction indicated by wholesale price differentials of the two interconnected markets (“**commercial price difference**”).

1. Introduction and report summary

- 1.9. IC flows are described as **“intuitive”** when they are scheduled from the region with the lower wholesale price towards the region with the higher wholesale price, while accounting for transmission losses.<sup>32</sup> **“Counterintuitive”** IC flows are defined as flows where the scheduled direction goes against the commercial price differential.
- 1.10. An IC is considered **“commercially under-utilised”** if it is either: (i) scheduled intuitively but with an IC flow lower than the maximum possible capacity (after accounting for transmission losses); or (ii) scheduled counterintuitively.
- 1.11. As wholesale prices are determined at national or price zone<sup>33</sup> level, in some instances the wholesale price is unable to reflect the true marginal value of energy at the IC landing point, e.g. the value of energy considering of transmission constraints within the national wholesale market or price zone. When GB wholesale prices diverge substantially from the true marginal value of energy at the IC landing point, intuitive IC flows may not be **“GB-system-optimal”**. This means that the scheduling of the IC (even if intuitive) can increase the volume of required redispatch actions and therefore potentially lead to higher system costs, compared to when the IC would have been scheduled in line with overall GB system needs.
- 1.12. The closer GB wholesale prices are to the true marginal value of energy at the IC landing point in GB, the more the scheduled IC flows are GB-system-optimal, e.g. IC schedules are in line with GB system needs.

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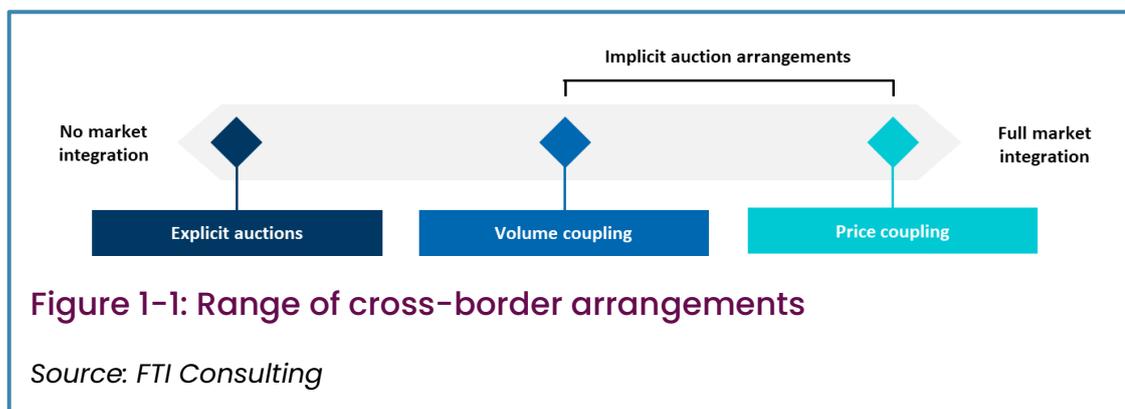
<sup>32</sup> The EU Joint Allocation Office (“JAO”) defines intuitive flows as *“flows that are enforced to go from higher price areas to lower ones”*. See ‘Explanation of the difference between the flow-based plain and flow-based intuitive market coupling approach’, JAO, 2020 ([link](#)).

<sup>33</sup> Price zones are often also referred to as bidding zones, i.e. the geographical area over which there is one wholesale price determined per market time unit (“MTU”). Throughout the report we use the two terms interchangeably.

1.13. An alternative to IC scheduling based on commercial price differences is the scheduling of ICs based on the differences between the true marginal value of energy (“**shadow nodal prices**”) at GB IC landing points and wholesale prices in the connected market. This is explored for the market designs with central scheduling (N3 and Z3). In this case, the “**IC scheduling prices**” diverge from the commercial prices the IC is exposed to. Scheduling ICs based on shadow nodal prices is potentially possible under central scheduling because the schedule of assets is determined by the central scheduling algorithm that considers transmission limitations.<sup>34</sup> The option to introduce central scheduling where ICs remain scheduled based on an “**unconstrained price**” of electricity in GB is also examined, e.g. where shadow nodal prices are used to determine the schedule for all assets except ICs. In that case ICs are scheduled using a would-be national (or zonal) wholesale electricity prices that do not reflect intra-GB (or intra-zonal) transmission constraints.

## Cross-border trading arrangements

1.14. Cross-border trading arrangements vary depending on the level of market integration between the connected countries. As illustrated in Figure 1-1 below, three main categories of cross-border arrangements are differentiated which differ depending on the level of market integration: (i) Explicit auctions; (ii) Volume Coupling; and (iii) Price Coupling. Both Volume Coupling and Price Coupling are forms of implicit cross-border trading arrangements.



1.15. In the following paragraphs the main characteristics of these types of cross-border trading arrangements are described, as they have been implemented or considered in the European context.

<sup>34</sup> Shadow nodal prices are an output of a central scheduling algorithm but not used for commercial settlement under a national (N3) or zonal (Z3) market design.

## 1. Introduction and report summary

- 1.16. The main feature of **explicit auctions** is that physical transmission capacity is auctioned separately from power. Market participants who buy IC capacity also, separately, bid into the connected power markets, to obtain the necessary energy positions. Subsequently, IC capacity holders declare to the relevant SOs the intended volume and direction of flows on the IC (“flow nomination”), thereby using their IC capacity that they procured previously.
- 1.17. The timeframe of the IC capacity auction is driven by the relevant rules in both markets, agreements between countries and the owner of the IC asset, but can range from forward markets several years ahead to intraday markets (“IDMs”) taking place only a few hours before the wholesale GCT.<sup>35</sup>
- 1.18. To ensure efficient use of the IC assets, the IC capacity rights can be prescribed by regulators to be Use-It-Or-Sell-It (“UIOSI”), meaning that capacity bought on earlier auctions (e.g., forward) but not nominated before the relevant auction is reauctioned later (e.g. day-ahead).<sup>36</sup> Alternatively, IC capacity may be subject to Use-It-Or-Lose-It (“UIOLI”) rules (e.g. IC capacity procured via DA auctions but subsequently not nominated would be ‘lost’ to the buyer).
- 1.19. Whether IC flows are intuitive under explicit trading will be driven by the accuracy of forecast of wholesale prices in the relevant wholesale markets by IC capacity holders. If the direction of the price difference forecasted by the IC capacity holders does not match the realised wholesale price difference, the IC could be commercially under-utilised (scheduled intuitively but with an IC flow lower than the maximum possible capacity or scheduled to flow in the counterintuitive direction).
- 1.20. Under **Volume Coupling**, the volume and direction of flows between connected markets are determined before wholesale prices are determined. Market participants only submit bids to buy and sell power in the wholesale markets of the two connected markets and there is no explicit auction for IC capacity (and hence no need to ‘nominate’ IC capacity by market participants).

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<sup>35</sup> ‘Explicit and implicit capacity auction’, NordPool ([link](#)).

<sup>36</sup> The main rationale behind UIOLI/UIOSI conditions is to prevent larger market players from hoarding IC capacity rights which would negatively impact competition. Under UIOLI, IC capacity holders who purchase physical transmission rights (“PTRs”), but do not nominate flows lose their capacity rights and receive no compensation. Under UIOSI, IC capacity that was not nominated is automatically reauctioned and the IC capacity holders receive the clearing price for their IC capacity rights, making UIOSI PTRs similar to financial transmission rights (“FTRs”). Source: ‘What does the term UIOSI/UIOLI means and how can I calculate it?’, JAO ([link](#)).

## 1. Introduction and report summary

- 1.21. Market operators active in the connected markets first aggregate all order books containing wholesale market bids and offers for each relevant market. That information is forwarded to the operator of a central volume coupling algorithm alongside other necessary technical data. The volume coupling algorithm determines the shadow wholesale prices in the two coupled markets, which in turn determines the volume and direction of scheduled flows on the ICs. The shadow wholesale prices determined by the volume coupling algorithm are solely used to determine the volume and direction of the scheduled flows and are not used to determine wholesale electricity prices in the two markets.
- 1.22. Volume Coupling covers a wider range of arrangements which vary depending on the coordination and the level of data shared between the market operators. **Loose Volume Coupling** refers to arrangements where coordination and data exchange is more limited, while **tight Volume Coupling** describes arrangements with closer integration.<sup>37</sup> Loose Volume Coupling will lead to lower quality outputs (which could, for example, mean a greater likelihood of counterintuitively scheduled IC flows) compared to tight Volume Coupling.<sup>38</sup> There is no well-defined distinction between the two arrangements though; rather, they exist on a continuous spectrum.
- 1.23. The extent to which IC flows are scheduled intuitively under Volume Coupling depends on how closely the shadow prices forecast by the volume coupling algorithm match the (subsequent) wholesale prices determined in the two markets. However, commercial under-utilisation of ICs can occur even under tight Volume Coupling.<sup>39</sup>
- 1.24. Under **Price Coupling**, flows between markets are determined simultaneously with wholesale electricity prices. Market participants submit bids to buy and sell power in the two connected wholesale markets and there is no explicit auction for IC capacity (and also no need to 'nominate' IC capacity). Market operators in each market collate these bids into order books, which are fed into a central price clearing algorithm operated by market coupling operator ("MCO"), which simultaneously determines both the wholesale prices in all connected markets and the flows between markets.<sup>40</sup>

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<sup>37</sup> 'Market coupling', TenneT ([link](#)).

<sup>38</sup> 'Market coupling', TenneT ([link](#)).

<sup>39</sup> 'Cost Benefit Analysis of MRLVC', CEPA, April 2021 ([link](#)).

<sup>40</sup> 'Price Coupling of Regions (PCR)', Nord Pool, ([link](#)).

## 1. Introduction and report summary

1.25. Price Coupling ensures that ICs flow in an intuitive manner and are commercially fully utilised in the direction dictated by the wholesale price difference, with commercially under-utilised or counterintuitive flows only taking place due to balancing actions or technical limitations (e.g., ramp rates).<sup>41,42</sup>

1.26. In this report, FTI has been asked to assess three types of cross-border arrangements between GB and other European countries<sup>43</sup> and how they could work under different GB wholesale electricity market designs. The cross-border arrangements FTI considered in this report are:

- **Status Quo:** The current arrangements on GB ICs to Europe, which include: (i) explicit auctions on Interconnexion France-Angleterre (“IFA”), IFA2, ElecLink, Nemo Link, Viking Link and BritNed (“Northwest Europe (“NWE”) ICs”); and (ii) Price Coupling for NSL connecting to GB with Norway and the GB-Irish ICs, the East-West Interconnector (“EWIC”) and Moyle connecting GB with the I-SEM.
- **MRLVC:** This is a form of Volume Coupling, which was set out in the Trade and Cooperation Agreement (“TCA”) between the United Kingdom (“UK”) and the European Union (“EU”) as the basis for post-Brexit electricity trading between GB and the EU at the DA timeframe. The exact implementation details of the MRLVC mechanism are still under development. For the purposes of this report, FTI has relied on NESO and EU Transmission System Operators’ (“TSOs”) joint view as of September 2024 on how the mechanism would function. All GB-connected ICs are assumed to be included in the MRLVC.<sup>44</sup> MRLVC is assumed to only be in place in the DA timeframe.
- **Price Coupling:** GB is assumed to be fully price-coupled with the Internal Electricity Market (“IEM”) and effectively becomes part of Europe’s Single Day-Ahead Coupling (“SDAC”) and, under GB market designs with an ID timeframe, Europe’s Single Intraday Coupling (“SIDC”). All GB-connected ICs are assumed to be price-coupled in both the DA and ID timeframe.

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<sup>41</sup> ‘Measuring inefficiency in international electricity trading’, Montoya et al., 2020 ([link](#)).

<sup>42</sup> Intentional counterintuitive flows are possible under Flow-Based Market Coupling (which does not apply for the direct current (“DC”) ICs between GB and the connecting European market).

<sup>43</sup> As discussed above, a wide range of cross-border trading arrangements is in principle possible, but this report only focuses on three specific forms, agreed with NESO as the most relevant variants for GB.

<sup>44</sup> ‘Trade and Cooperation Agreement’, European Union, 2021 ([link](#)): Annex 4 (pdf page 1656).

1.27. Table 1-1 below summarises the various combinations of cross-border and market design arrangements that are examined in this report. For each combination, the end-to-end process across the forward, DA, ID and post-gate closure timeframes are discussed, and for any market design, commercial and practical challenges or compatibility issues identified.

**Table 1-1: Combinations of cross-border and market design arrangements examined**

Market design → Cross-border arrangement ↓	N1 (Self-scheduling with national pricing and extended GCT)	Z1 (Self-scheduling with zonal pricing)	N3 (Central scheduling with national pricing)	Z3 (Central scheduling with zonal pricing)
Status Quo	In this report, the forward, day-ahead, intraday and post-gate closure timeframes are examined for each combination.			
MRLVC				
Price Coupling				

## Interactions with other market reforms

1.28. In this report, the interactions between cross-border arrangements and market designs with the following relevant market reforms are discussed:

- Introduction of OHAs which are integrated projects that typically combine offshore wind farms (“OWF”) and ICs<sup>45</sup> to allow OWFs to directly connect to multiple price zones. Potential interactions with the two designs for OHA market arrangements currently under consideration in Europe and GB (Home Markets (“HMs”) and Offshore Bidding Zones (“OBZs”)) are discussed;
- Potential market reforms in GB as part of the REMA and potential market reforms in the EU, in particular: (i) shortening of settlement periods or MTUs; (ii) changes in wholesale GCTs; and (iii) bidding zone splits in the EU.

## Summary of our analysis

1.29. In the remainder of this section, the analysis of the feasibility of the different cross-border arrangements under each market design is summarised, as well as their potential advantages and disadvantages from consumer, societal and IC owner perspectives.

<sup>45</sup> They may also integrate other assets, e.g., offshore sources of demand. In this report the simplest forms of OHAs are considered which only include OWF and transmission assets.



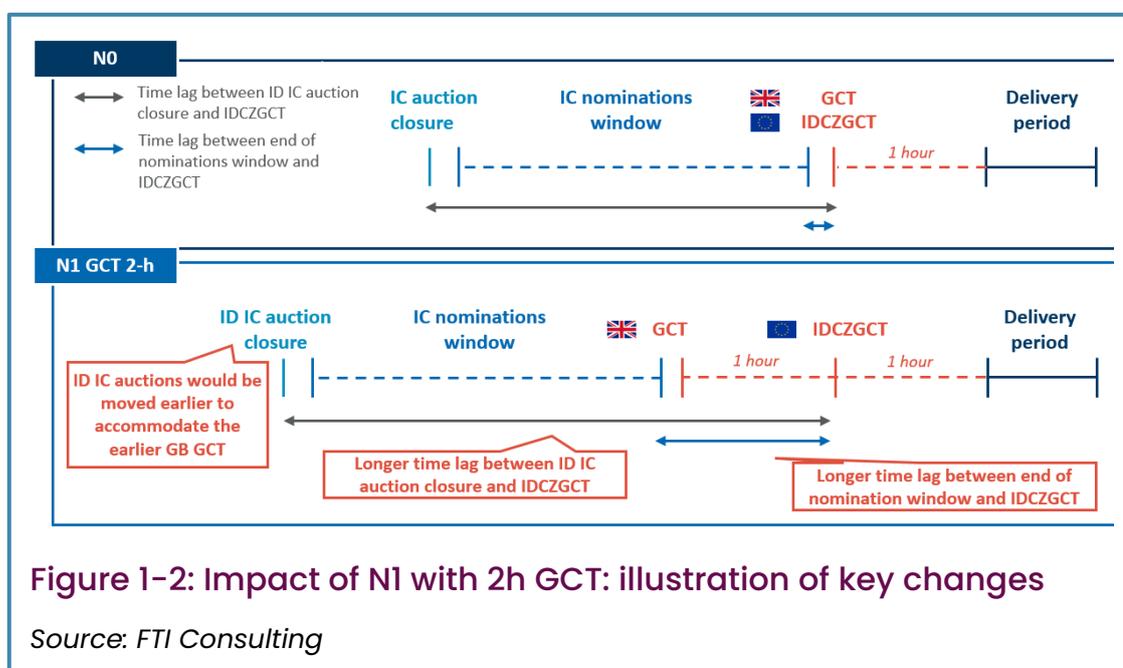
## Design N1: Self-scheduling with extended gate closure time under national wholesale pricing

- 1.30. In this sub-section it is discussed how each of the three types of cross-border trading arrangement would work under the N1 market design – that is, if GB were to continue with self-scheduling under national wholesale pricing but extended its wholesale GCT beyond 1 hour. FTI assumes that the extension would, at most, be a few hours, and therefore this design would only affect the ID and post-gate closure timeframes but not the GB DA market (“DAM”).
- 1.31. Having an earlier wholesale GCT could potentially lead to lower GB system costs, as it would provide more time for NESO to perform re-dispatch actions. However, market participants would be required to close their contractual positions (and submit their final physical notification (“FPN”)) earlier than in the Status Quo market design (N0). As such, there would also likely be larger and more frequent differences between the contracted generation/demand and metered generation/demand due to forecast errors. NESO would have to play a greater role in managing energy imbalances, which in turn could lead to higher GB system costs. The overall impact of an extended GCT on GB system costs would therefore depend on the balance of these two countervailing effects and would need to be empirically tested.
- 1.32. FTI finds that N1 can be made compatible with the **Status Quo** cross-border arrangements in the ID timeframe if the explicit ID IC auctions on NWE ICs and implicitly coupled ID auctions on the GB-Irish ICs are moved earlier to accommodate the earlier wholesale GCT.<sup>46</sup>
- 1.33. For explicitly traded ICs, the earlier GCT could negatively impact:
- The valuation of IC capacity rights: As shown in Figure 1-2 below, under N1 there is a longer time lag between the ID IC auction closure and the wholesale GCT. Relative to N0, this could increase the difficulty for traders to form their expectations of the value of ID IC rights (based on forecasts of the wholesale prices). In addition, IC nominations in GB would need to take place earlier relative to intraday cross zonal gate closure time (“IDCZGCT”), when there is potentially less liquidity on the European side. This could make it more difficult for market participants to forecast prices or find a counterparty to execute trades with – both of which are risks that market participants would likely price into their valuations, and;

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<sup>46</sup> Trading on NSL is not affected, as it is currently implicitly coupled in the DA timeframe.

- The commercial utilisation of ICs: There is a longer time lag between the end of the nomination window in GB and the European wholesale GCT. This increases the likelihood of the ID price differential changing over the period and therefore the likelihood of under-utilised ICs or the scheduling of counterintuitive flows.



- 1.34. For the implicitly traded GB-Irish ICs, the ID implicit auction would need to be moved further away from I-SEM GCT to accommodate the earlier GB wholesale GCT. Market participants will be able to trade in the I-SEM continuous ID market up to the current GCT of 1-hour (in line with the IDCZGCT). Due to the longer time lag between the ID implicit auction and the I-SEM wholesale GCT, this increases the likelihood of the ID price differential changing over the period and could negatively impact the commercial utilisation of the ICs.
- 1.35. Under N1, the change in GCT would mean that more of the IC rescheduling instructed by NESO would likely move from pre-GB GCT to post-GB GCT. This would imply that the need for (and role of) system operator to system operator (“SO-SO”) trades increases at the expense of countertrading (at least the way it is currently organised). NESO therefore would need to be able to: (i) start SO-SO trades before the GCT in the connecting market and/or; (ii) continue countertrading after the GB wholesale market GCT. If there was limited willingness by European TSOs to adopt either of these two options, the benefits case of an extended GCT in GB would be significantly reduced.
- 1.36. There are no interactions between **MRLVC** and N1, as the MRLVC is a DA trading solution and it is assumed that the extended wholesale GCT does not affect the GB DAM.

- 1.37. It is assumed that GB will need to comply with IEM regulations if it is **Price Coupled** with the EU. IEM regulations currently require the IDCZGCT to be at most one hour ahead of delivery, which will be shortened to no more than 30 minutes ahead of delivery from 1 January 2026. This implies that it is not feasible to combine an extended wholesale GCT in GB with Price Coupling.

### Design Z1: Self-scheduling with zonal wholesale pricing

- 1.38. In this sub-section, it is assessed how each type of cross-border trading arrangement could work under the Z1 market design, in which GB retains self-scheduling but moves to zonal wholesale pricing.
- 1.39. All else being equal, zonal wholesale market pricing leads to more optimal scheduling of ICs from a GB system perspective compared to N0. That is, the scheduling of ICs under a zonal wholesale market design (regardless of the type of cross-border trading arrangement) is expected to relieve rather than aggravate internal congestion in GB to a greater extent than N0 would have done. The extent to which Z1 indeed schedules ICs more in line with the GB system needs would be driven by the extent to which the GB zones are aligned with the main transmission boundaries of the system. Zonal pricing in GB could also impact wholesale prices and constraint volumes in connected markets relative to when having national wholesale pricing in place in GB.
- 1.40. Under the **Status Quo** cross-border trading arrangements, explicit cross-border trading arrangements are compatible with Z1. However, to the extent that zonal wholesale prices could (in some regions and in some periods) become more volatile, compared to national wholesale prices, the valuation of IC capacity rights could be affected. This could be either a positive impact (if the potentially increased volatility led to wider price spreads between the GB IC zone (price zone in GB under Z1 or Z3 containing an IC's landing point) and the connected European zone), or a negative impact (if the potentially increased volatility discouraged trading). The balance of these two impacts would need to be further assessed empirically.

## 1. Introduction and report summary

- 1.41. However, it is challenging to combine implicit cross-border trading arrangements for the GB-Irish ICs with ZI. This is because there are multiple GB-Irish ICs that would likely connect to different GB zones (e.g. Moyle to a zone in Scotland and EWIC to a zone at the Wales/England border). The concurrent clearing of the I-SEM with several GB zones via a GB-Irish coupling would (from time to time, though not necessarily always) implicitly determine specific intra-GB cross-zonal flows. For example, the clearing on GB-Irish ICs could imply a particular flow pattern between Scotland and Wales. This pattern may not represent the most efficient use of intra-GB cross-zonal capacity (indeed, intra-GB transmission capacity should, under a zonal GB design, be implicitly allocated via a separate process). This inefficiency is driven by two separate market clearing processes that would take place in this design: (1) the intra-GB zonal market coupling and (2) the GB-Irish market coupling. While there are options for reserving capacity and other workarounds, the outcomes of having two separate market clearing processes are highly likely to lead to an inefficient use of intra-GB cross-zonal transmission capacity.
- 1.42. As currently there is only one IC between Norway and GB, this issue does not pose itself for the implicit arrangements on NSL. However, the current implicit arrangement is not future proof to new ICs to Norway that may connect to different zones in GB and/or Norway than NSL.
- 1.43. If the existing implicit arrangements were not viable under this design, alternative options may need to be considered. As a fallback option, the current cross-border trading arrangements on the GB-Irish ICs and NSL could be replaced by an explicit arrangement. Everything else equal, replacing implicit cross-border arrangements (for GB-Irish ICs and NSL) with an explicit cross-border trading arrangement would likely result in an efficiency loss. This loss would need to be compared to the efficiency gains of ZI across all GB ICs (e.g. from scheduling all ICs on zonal prices rather than on national GB wholesale prices). It appears to us that the efficiency gains of the latter would likely outweigh the efficiency loss of the former, but this would need to be examined further.
- 1.44. It is found that **MRLVC** under ZI would work in a broadly similar way to N0. The main difference is that the power exchanges (“PXs”) would need to submit GB order books on a zonal rather than national basis to the MRLVC algorithm, which is a design element that has not yet (as far as FTI is aware) been examined in the ongoing discussions on the MRLVC design. Two options for the geographical coverage of the order books are envisioned – order books can cover all GB zones (Option 1) or only bidding zones in GB that contain IC landing points, so called GB bordering bidding zones (“GB BBZs”) (Option 2). Our view is that Option 1 is more robust. Although the computational burden of Option 1 is higher compared to Option 2, it is more future-proof and would reduce the likelihood of commercially under-utilised ICs.

- 1.45. **Price Coupling** is fully compatible with ZI. Compared to explicit cross-border arrangements and MRLVC, there is no risk of ICs being commercially under-utilised. Relative to N0/N1, ZI is likely to be more computationally burdensome for EUPHEMIA.<sup>47</sup>

### Design N3: Central scheduling with national wholesale pricing

- 1.46. In this sub-section it is assessed how each type of cross-border trading arrangement could work under the N3 market design, in which NESO centrally schedules assets using GB shadow nodal prices that reflect system constraints but market participants are compensated based on national unconstrained wholesale prices. Across all cross-border trading arrangements, there are two potential options that NESO could use to schedule ICs:

- **Option 1:** Based on the price difference between the GB shadow nodal price at their landing point and the wholesale price in the connected market (which is consistent with other GB resources under central scheduling). This would likely require transfer payments to 'make-whole' ICs when they are intentionally scheduled to flow counterintuitively to the commercial price differential.
- **Option 2:** Based on the price difference between GB national unconstrained wholesale price and the wholesale price in the connected market, which is consistent with the Status Quo market design (N0) and how the IC capacity holders currently earn congestion rents (but different from other GB resources under central scheduling).

- 1.47. Other things being equal, Option 1 is preferable from a GB system perspective as it ensures that IC flows are scheduled in alignment with GB system needs. However, the costs of compensating ICs via 'transfer payments' would need to be empirically assessed. Applying Option 2 is expected to result in a GB schedule that is suboptimal from a GB system perspective, as GB assets would need to be nodally scheduled around IC flows that are determined by the prevailing unconstrained national wholesale prices. This could lead to additional costs and a potentially infeasible GB schedule, therefore making the benefits case of moving to central scheduling weaker.

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<sup>47</sup> "EUPHEMIA" is the market-clearing algorithm used in Europe to determine the prices and volumes of electricity trades in the SDAC. Its primary objective is to maximise overall welfare of coupled markets. 'Price Coupling of Regions (PCR)', NordPool ([link](#)).

1.48. It is found that with suitable adaptations, the N3 market design can be made compatible with Status Quo, MRLVC and/or Price Coupling, although significant trade-offs arise under all three cross-border arrangement options.<sup>48</sup> It is found possible to schedule ICs using the unconstrained GB national price across all cross-border trading arrangements, however as described above, this would likely result in a more costly GB DA schedule and potentially would require to readjust IC schedules after the GB DAM. This could significantly weaken the case for moving to central scheduling.

1.49. It is found possible to schedule ICs using shadow nodal prices under **explicit trading arrangements**, although various measures would need to be developed to maintain appropriate incentives for IC capacity holders and limit their risk exposure. This would likely be cumbersome to implement and could have potential unintended consequences. To the knowledge of FTI, at the time of writing of the report, such arrangement has not been implemented anywhere. In addition, several challenges under N3 relative to N0 are identified:

- Scheduling ICs based on shadow nodal prices in GB (and an expectation of outturn European wholesale prices) would indirectly impact the prices in connected markets. This could make it more difficult to forecast those wholesale prices, and in turn negatively impact the extent to which IC scheduling is optimal from a GB system perspective;
- EU policy makers would have to implicitly accept that the IC flows determined by GB SCED are firm and independent of the outturn wholesale prices in the relevant European bidding zones;
- A transfer payment mechanism would likely need to be developed to ensure that IC capacity holders retain the appropriate incentives while bearing risks that they can efficiently manage themselves. These transfer payments would compensate IC capacity holders for the potential cost incurred when ICs are intentionally counterintuitively scheduled by the central scheduling algorithm and the potential foregone revenues due to that schedule;

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<sup>48</sup> Many of these inherent trade-offs and challenges could be mitigated by introducing a zonal design (the Z1 and Z3 designs).

## 1. Introduction and report summary

- There are potentially increased risks for IC capacity holders under N3 relative to N0, as they do not have access to an ID market to unwind positions in the event of forecast error. This increased risk could lead to no market participants would be willing to take a position opposite to the expected commercial price differential, which would lead to a potential inefficiency in the utilisation of the IC (at times when the scheduling price differential ends up having the opposite sign of the anticipated commercial price differential). This will likely have commercial impacts for IC owners (and may need to be reflected in the transfer payment mechanism described above).
- 1.50. It is also possible to schedule ICs based on shadow nodal prices under **MRLVC**. However, it is likely infeasible for the MRLVC algorithm to be able to accommodate market participants' technical details at the same time as including detailed GB network information that would be needed to include the full shadow nodal aspect. NESO would therefore need to simplify the information submitted to the GB DAM (e.g. by creating net import/export curves for each IC) that would be, in turn, submitted to the MRLVC operator. The MRLVC algorithm would then jointly clear the simplified information with the EU Bordering Bidding Zones ("BBZ") order books. Equally as under explicit trading, a transfer payment mechanism for the IC owners would likely have to be developed.
- 1.51. There is a trade-off between the computational burden and the accuracy of the (simplified) information fed into the MRLVC algorithm, which in turn affects the extent to which ICs are scheduled in a GB system optimal manner under N3 MRLVC. The balance between those two factors would need to be empirically tested.
- 1.52. Scheduling ICs based on shadow nodal prices is not feasible under **Price Coupling**. For there to be Price Coupling, the GB DAM and the (EU) SDAC would, by definition, simultaneously clear within a single algorithm. This would mean the existing EUPHEMIA algorithm would need to accommodate hundreds of additional GB nodes in the market clearing process. This is not feasible in the short to medium term for computational reasons. Moreover, GB would likely not be willing or able to provide the required GB network information (physical parameters of all intra-GB transmission lines) to the European MCO for security reasons. Even if it were technically possible to integrate the EU+GB algorithm in the long term, it would require an overhaul of the EUPHEMIA clearing algorithm and increase running times, which would require the EU to accept and accommodate GB's needs.

- 1.53. Price Coupling would therefore currently only be possible if ICs were scheduled based on the unconstrained GB national price under N3, which as explained above, would result in a GB schedule that is suboptimal from a GB system perspective. These arrangements would significantly weaken the benefits case of moving to central scheduling (as ICs would continue to be scheduled on unconstrained national wholesale price, e.g., frequently in a non-GB-system-optimal manner). If Price Coupling is a priority, one potential alternative would be to introduce zonal pricing (discussed under Z1 and Z3).
- 1.54. As scheduling ICs based on shadow nodal prices is feasible under explicit capacity trading but not under Price Coupling, it follows that under **N3 Status Quo**, either (i) different GB ICs would be scheduled based on different (and potentially conflicting) GB price signals; (ii) all ICs would need to be scheduled based on unconstrained national prices; or (iii) alternative cross-border trading arrangements would need to be developed for NSL and GB-Irish ICs, with a fallback option being explicit trading of capacity.

### Design Z3: Central scheduling with zonal wholesale pricing

- 1.55. In this sub-section it is assessed how each type of cross-border trading arrangement could work under the Z3 market design, in which GB moves to central scheduling and zonal wholesale pricing.
- 1.56. Of all market design options examined in this report, implementing Z3 would require the most change relative to N0 as GB would need to move to central scheduling while overlaying a zonal market design to determine the unconstrained GB schedule and zonal prices.
- 1.57. Like N3, under each Z3 cross-border trading arrangement, NESO could either schedule ICs based on the following options:
- **Option 1:** Based on the price difference between the GB shadow nodal price at their landing point and the wholesale price in the connected market. Under this option, the end-to end process for each cross-border arrangement under Z3 would be virtually identical to that under N3. Compared to N3, the IC transfer payments are expected to be lower under Z3 as scheduling price differentials are more likely to be closer to commercial price differentials. This is because unconstrained IC zonal prices (e.g., the wholesale prices in the GB zones where ICs connect) are expected to be closer to the IC shadow nodal prices (e.g., shadow nodal prices at the respective IC landing points in GB) than GB unconstrained national wholesale prices are to the same IC shadow nodal prices.

- **Option 2:** Based on the price difference between GB unconstrained zonal wholesale price and the wholesale price in the connected market. This option is more relevant under Z3 compared to under N3 because the downsides are expected to be less severe relative to N3 (assuming that the zonal boundaries align reasonably well with transmission bottlenecks). Under this option, the end-to-end process of the market would be the same as N3, but the cross-border arrangements would be more similar to Z1. In particular, scheduling ICs based on unconstrained zonal prices would imply that there would be no need for IC transfer payments (as the IC scheduling price differential would be the same as the commercial price differential).

- 1.58. It is found that, similar to N3, it is feasible to schedule ICs based on shadow nodal prices under **Status Quo** (explicit trading) and **MRLVC**, but not under **Price Coupling**. The issues identified in N3 Status Quo (explicit trading) and N3 MRLVC, which arise due to the divergence between the scheduling and commercial price differentials, continue to apply to Z3. However, they are likely to be less significant as the IC scheduling and commercial price differentials are more likely to be aligned under Z3.
- 1.59. Other things being equal, it is more efficient from a GB system perspective to schedule ICs based on GB shadow nodal prices (Option 1) than the unconstrained GB price (Option 2), but this would likely require transfer payments to 'make-whole' ICs. Scheduling ICs based on unconstrained zonal prices would make cross-border arrangements significantly simpler under explicit trading and MRLVC. Importantly, scheduling ICs based on unconstrained zonal prices is feasible with Price Coupling (making Z3 and Z1 the only identified options that can be combined with Price Coupling without severe downsides).<sup>49</sup>
- 1.60. How the gains in simplifying cross-border arrangements when scheduling ICs based on unconstrained zonal prices compare against the efficiency losses from not scheduling ICs based on shadow nodal prices would need to be empirically tested. Relative to Z1, Z3 combined with ICs scheduled based on unconstrained zonal prices would still allow for leveraging the potential benefits of central scheduling such as earlier resolving of transmission constraints, potential for the co-optimisation of energy and ancillary service scheduling and more transparency for NESO.

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<sup>49</sup> Price Coupling is also feasible under N0 and N3 but unlikely to be attractive for efficiency reasons, particularly due to the current situation in which a significant volume of scheduled IC flows aggravates rather than relieves intra-GB congestion.

## 1. Introduction and report summary

1.61. Under Z3 Status Quo, the continuation of the existing implicit trading arrangements on NSL and GB-Irish ICs would be challenging. A fallback option would be to revert to explicit trading arrangements. This statement holds regardless of whether ICs are scheduled based on shadow nodal prices or unconstrained zonal prices. If ICs are scheduled based on:

- Shadow nodal prices, a single entity would need to jointly define prices in GB and the connecting zone and associated flows on the implicitly traded ICs, which appears impracticable and raises security concerns (as discussed in N3 in ¶1.52).
- Unconstrained zonal prices, challenges would arise for GB-Irish ICs and NSL for the same reasons, and with the same implications, as under Z1 (see ¶1.41).

### Interactions with other market reforms

1.62. In this sub-section we discuss how the various cross-border arrangements and market designs examined in this report interact with a selection of potential market reforms set out in the previous section.

#### *Offshore bidding zones*

1.63. As long as the total number of OBZs remains relatively modest compared to the number of GB and EU zones (such that there are no computational issues incorporating them into the GB or EU markets), no material implications for the feasibility of the various market designs and cross-border trading arrangements are anticipated.

1.64. The valuation and commercial utilisation of explicitly allocated IC capacity would be impacted by potential forecast errors by market participants. The likelihood of forecast errors is expected to increase as the price formation in the OBZ is more 'discrete' relative to onshore zones. In addition, the OWF generation must be forecast when calculating the IC capacity available for wholesale trade on the OHA.

1.65. Similarly, the commercial utilisation of ICs under MRLVC is impacted by the accuracy of the information fed into the MRLVC algorithm. The likelihood of imperfect information is higher with OHAs for similar reasons as set out above.

1.66. Considering the additional difficulties and complexities of combining OHAs with explicit trading and MRLVC, it appears to us that as OHAs play a greater role in cross-border trading, this would create additional incentives for GB to move to Price Coupling. In turn, as discussed earlier, a zonal wholesale market design (Z1 or Z3) is the only variant that can be combined with Price Coupling without significant downsides.



### Other market reforms

1.67. With regards to other market reforms examined in this report, it is found that:

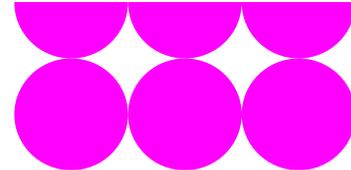
- A shorter MTU would likely have implications for the computational intensity of all cross-border trading arrangements. The additional computational burden arising under a shorter MTU in the EU could also potentially interfere with zonal GB pricing being computationally feasible under Price Coupling.
- A reduced GCT to 30 minutes in the EU is expected to create potential complications with countertrading and SO-SO trades under explicit trading arrangements and MRLVC. This could potentially lead to NESO having less means to resolve intra-GB constraints. Under Price Coupling, to the extent that GB is required to follow IEM regulations, this would imply that GB would also need to reduce its GCT. This would imply NESO would have less time to resolve intra-GB constraints. Thus, across all cross-border arrangements, a shorter GCT in the EU may lead to more difficulties for NESO to resolve intra-GB constraints. As such, it is considered that this reform is more compatible with market designs with lower constraint volumes, such as a zonal market design (Z1, Z3) and the N3 market design where ICs are scheduled based on shadow nodal pricing.
- Bidding zone splits on the EU side could potentially lead to more volatile wholesale prices in the smaller price zones. This could increase the likelihood of forecast errors, which would likely have a negative impact on the commercial utilisation and valuation of explicitly traded IC capacity. With more EU bidding zones in place, more data would also need to be shared with the MRLVC algorithm (regardless of the GB market design). Depending on the way European bidding zones are reconfigured, this could impact the computational complexity and/or the effectiveness of MRLVC.<sup>50</sup> Given this, similar to OHAs (albeit to a lesser extent), bidding zones splits on the EU side would create greater incentives for GB to move to Price Coupling which, in its turn, creates greater incentives to adopt a market design that reduces constraint volumes, such as a zonal market design.

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<sup>50</sup> Splitting European bidding zones could lead to having more EU BBZs, i.e. European bidding zones that are connected to GB, which could lead to: (i) more EU-BBZ to EU-BBZ borders that would need to be optimised in the MRLVC algorithm; and/or (ii) more borders between EU BBZs and other EU bidding zones that are not connected with GB, for which the flows would have to be forecasted. The former would increase the computational complexity of the MRLVC algorithm, while the latter would likely negatively impact the effectiveness of MRLVC. At the same time, the size of the order books submitted to the MRLVC algorithm could become smaller, which would reduce the computational complexity of the MRLVC algorithm (e.g. if Germany were to be split into multiple zones, only the order books of the German Northern zone(s) would likely need to be submitted to the MRLVC algorithm rather than the entire German order book).

# 2.N0: Self-scheduling with national wholesale pricing





In this chapter, we set out how each of type of cross-border trading arrangement (Status Quo, MRLVC and Price Coupling) would work under national market design with self-scheduling (N0), which is currently in place in GB. We start this chapter with a section where we introduce the key market design assumptions under N0.

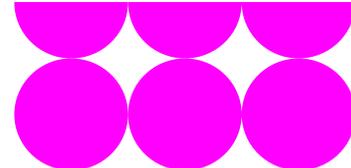
## Key market design assumptions

2.1. The key market design features under the N0 market design are as follows:

- Market participants self-schedule and bidding is portfolio-based. In practice, this means that market participants can directly substitute resources located across GB to comply with their contractual positions;
- Bidding formats are simple and block bids that are technology-agnostic;
- Market participants have firm access to the transmission network;
- Forward energy contracts are settled based on the national wholesale price. Over-the Counter (“OTC”) trading is possible as well across GB;
- The GB DAM: (i) clears prior to the SDAC under the current status quo arrangement; (ii) would run alongside the SDAC under MRLVC; and, (iii) be part of the SDAC and therefore clear simultaneously under Price Coupling;
- Under N0, the GB DAM is organised by two PXs, the European Power Exchange (“EPEX”) and Nord Pool Exchange (“N2EX”), who each perform their separate market clearing, leading to two GB DAM prices per MTU. Under MRLVC, the same arrangements are assumed to be kept in place. Under Price Coupling, the GB DAM clearing would effectively be integrated into the SDAC and SIDC, and the market clearing algorithm (e.g. EUPHEMIA) will be operated by the European MCO, which is a cooperation of PXs and EU Nominated Electricity Market Operators (“NEMOs”). This would be akin to the current arrangements in the SDAC and SIDC, where PXs feed in bids from market participants into the central clearing algorithm and are responsible for the settlement.
- The wholesale market GCT, e.g. the moment up to which trading in the IDM is possible and market parties must communicate their FPN to NESO, is one hour before RT. NESO uses the Balancing Mechanism (“BM”) to balance the GB market in RT (e.g. for the 1 hour between the GCT and RT). The settlement period used to calculate imbalance charges<sup>51</sup> (“cash-outs”) is 30 minutes.

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<sup>51</sup> These are the charges paid by Balancing and Settlement Code (“BSC”) Parties when being imbalanced, i.e. for (portfolio-level) deviations between their contractual positions and metered generation/consumption.



## NO Status Quo

- 2.2. Currently, there are three categories of cross-border trading arrangements for existing GB ICs connecting to:
- Norway: The GB DAM is implicitly price-coupled with Price Zone 2 in Norway (“NO2”) via NSL;<sup>52</sup>
  - Ireland: The I-SEM is implicitly price-coupled with GB at the ID stage under two intraday auctions (“IDAs”) via the GB-Irish ICs, i.e. Moyle and EWIC;<sup>53</sup> and
  - NWE ICs run a combination of DA and ID explicit auctions prior to the GB DAM or ID wholesale market for their IC capacity. Auction timings differ across individual ICs.<sup>54</sup>
- 2.3. In the following sections we describe the cross-border trading arrangements for GB ICs in chronological order, starting from forward markets, through DA, ID to post-GCT. Where relevant we refer to the three categories of GB ICs, e.g. the NSL, the GB-Irish ICs, and the NWE ICs, as their respective arrangements differ.
- 2.4. We have only considered the cross-border arrangements for GB ICs that are currently operational in this report. We assume that the arrangements for GB ICs that are currently under construction will fall under one of the three categories described above.<sup>55</sup> We have not considered how the Celtic IC (between Ireland and France) would, when commissioned, couple the I-SEM and the EU IEM, which could potentially affect the Status Quo arrangements.

## Forward market

- 2.5. European TSOs perform forward calculations of capacities between bidding zones for the year and month-ahead market timeframes to determine the optimal amount of long-term cross-zonal capacity for allocation of long-term transmission rights (“LTTRs”).<sup>56</sup>

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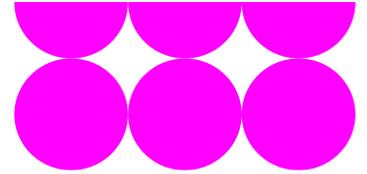
<sup>52</sup> ‘Trial operation at NSL starts on 1 October’, Statnett, 2021 ([link](#))

<sup>53</sup> ‘Intraday Auctions Market’, SEMOpx ([link](#)).

<sup>54</sup> Timings for BritNed, IFA, IFA2 and Nemo Link shown at: ‘GB Market Post-Brexit’, EPEX SPOT ([link](#)).

<sup>55</sup> The access rules for the Greenlink IC, for example, are the same as the Irish ICs. ‘Access Rules and Charging Methodology for the Greenlink IC’, Ofgem, 2024 ([link](#)).

<sup>56</sup> The calculation of available capacity on High Voltage Direct Current (“HVDC”) links is straightforward as HVDC lines are controllable. Capacity calculation for cross-zonal High Voltage



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- 2.6. GB and European market participants can then place bids in the LTRs auctions organised through either the JAO, which acts as the Single Allocation Platform in Europe or through the IC's own platform. These platforms publish the prices for the capacity of LTRs offered in the auction. IFA, IFA2, ElecLink, Nemo Link, and Viking Link currently participate in JAO forward auctions and offer capacity for various market timeframes (e.g. year-ahead ("YA"), month-ahead).<sup>57</sup> BritNed offers capacity through its own platform 'Empire',<sup>58</sup> while NSL and the GB-Irish ICs do not currently offer these products.<sup>59</sup>
- 2.7. LTRs can be PTRs<sup>60</sup> or FTRs,<sup>61</sup> and enable market participants to hedge their positions across electricity price zones. Currently PTRs with UIOSI provision are in place for the NWE ICs.<sup>62</sup>
- 2.8. Market participants and IC capacity holders (though not IC owners themselves) can also trade bilaterally in the forward market.
- 2.9. The forward arrangements under N0 Status Quo are summarised in Figure 2-1 below.

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Alternating Current ("HVAC") lines is more complex. In that case, European TSOs' long-term scenarios and grid models currently use the Coordinated Net Transmission Capacity ("CNTC") approach. 'Forward calculation of capacities between bidding zones', ACER (European Union Agency for the Cooperation of Energy Regulators) ([link](#)). 'Explanatory Note of the common long term capacity calculation methodology for SEE Capacity Calculation Region ("CCR")', ACER, 2019 ([link](#)).

<sup>57</sup> 'Auctions', JAO ([link](#)).

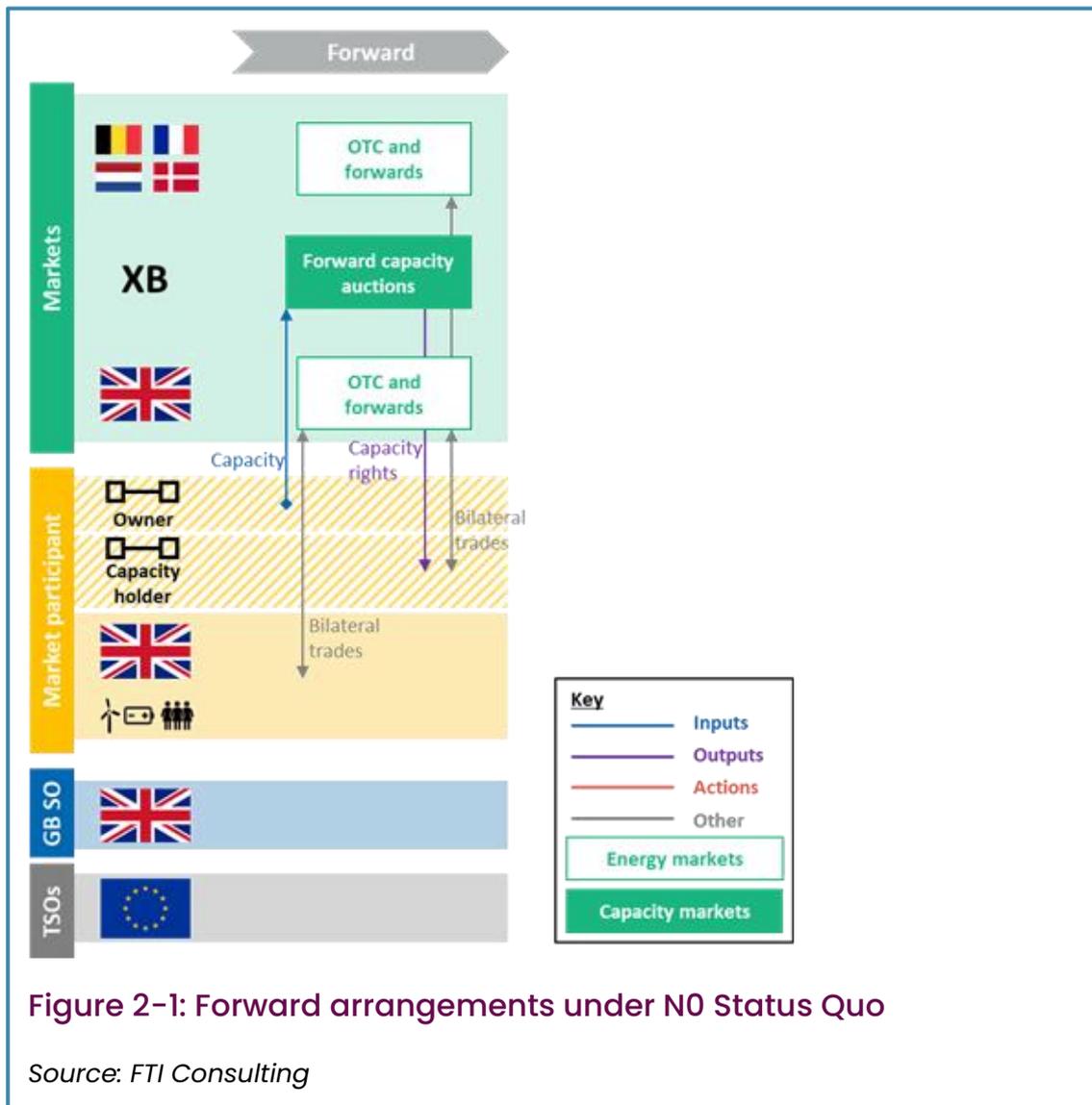
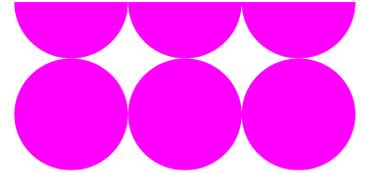
<sup>58</sup> 'Empire - Trading and Nomination Platform', BritNed ([link](#)).

<sup>59</sup> In principle, NSL and GB-Irish ICs could also participate but currently no LTRs are offered for those ICs (see also Footnote 62).

<sup>60</sup> PTRs entitle the holder to physically transmit a specified amount of electricity on the IC. PTRs that are purchased but non-nominated are automatically made available for DA capacity allocation (UIOSI principle). In that sense, non-nominated PTRs turn into FTRs.

<sup>61</sup> FTRs do not involve the physical delivery of electricity. Instead, they entitle the holder to receive or pay the price difference between two market zones (e.g. between two countries or regions).

<sup>62</sup> For implicitly coupled ICs (e.g. the current arrangement for NSL and the GB-Irish ICs), in case LTRs were to be offered in the form of FTRs, there would be no impact on how much IC capacity can be implicitly allocated on the respective ICs. In case PTRs were to be offered, the volume of nominated PTRs would need to be considered when calculating the available IC capacity that can be implicitly allocated on the respective ICs.



### Day ahead market

2.10. Post-Brexit, GB is no longer part of IEM and does not participate in the SDAC in Europe, which price-couples wholesale electricity markets and allocates cross-border transmission capacity between different regions using the EUPHEMIA algorithm.

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- 2.11. Instead, IC capacity for the NWE ICs is explicitly traded on separate DA auctions, which take place before GB's DAM (run by the EPEX and N2EX)<sup>63</sup> and before the SDAC. After IC capacity holders and other market participants establish their positions on the GB DAM and SDAC, the holders of PTRs then submit their flow nominations and Initial Physical Notifications<sup>64</sup> ("IPNs") to NESO and the European TSOs.
- 2.12. Since IC capacity holders secure capacity before trading electricity, their valuation of the IC capacity will be determined by their forecast of the difference in wholesale market prices of the connected regions. Inaccurate wholesale price forecasts can lead to commercially under-utilised ICs, implying that the ICs are either: (i) scheduled intuitively (e.g. flowing from a low-priced to a high-priced area) but with an IC flow lower than the maximum possible capacity (after accounting for transmission losses); or (ii) counterintuitively scheduled, i.e., scheduled to flow against the commercial price differential.
- 2.13. The sequence of events is summarised in Figure 2-2 below.

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<sup>63</sup> EPEX runs a GB DAM auction with a GCT at 09:20 D-1 and 60 min products. Subsequently EPEX also runs a DAM auction with a GCT at 15:30 D-1 and 30-minute products. N2EX runs a DA auction with the GCT at 09:50 D-1 with 60-min products. In the 60-min and 30-min auctions, market participants trade electricity across hourly and half-hourly blocks respectively for delivery the following day. There are currently two GB DAM prices, as these PXs do not jointly clear all orders, but each perform their own market clearing. The Department for Energy Security and Net Zero ("DESNZ") is currently pursuing legislative action for N2EX and EPEX Spot to re-couple their DA markets for cross-border trade (see: 'GB Wholesale Electricity Market Arrangements', DESNZ, 2023 ([link](#))).

<sup>64</sup> This is the market participant's expected generation or demand for a Settlement Period. 'The Electricity Trading Arrangements A Beginner's Guide', Elexon, 2019 ([link](#)).

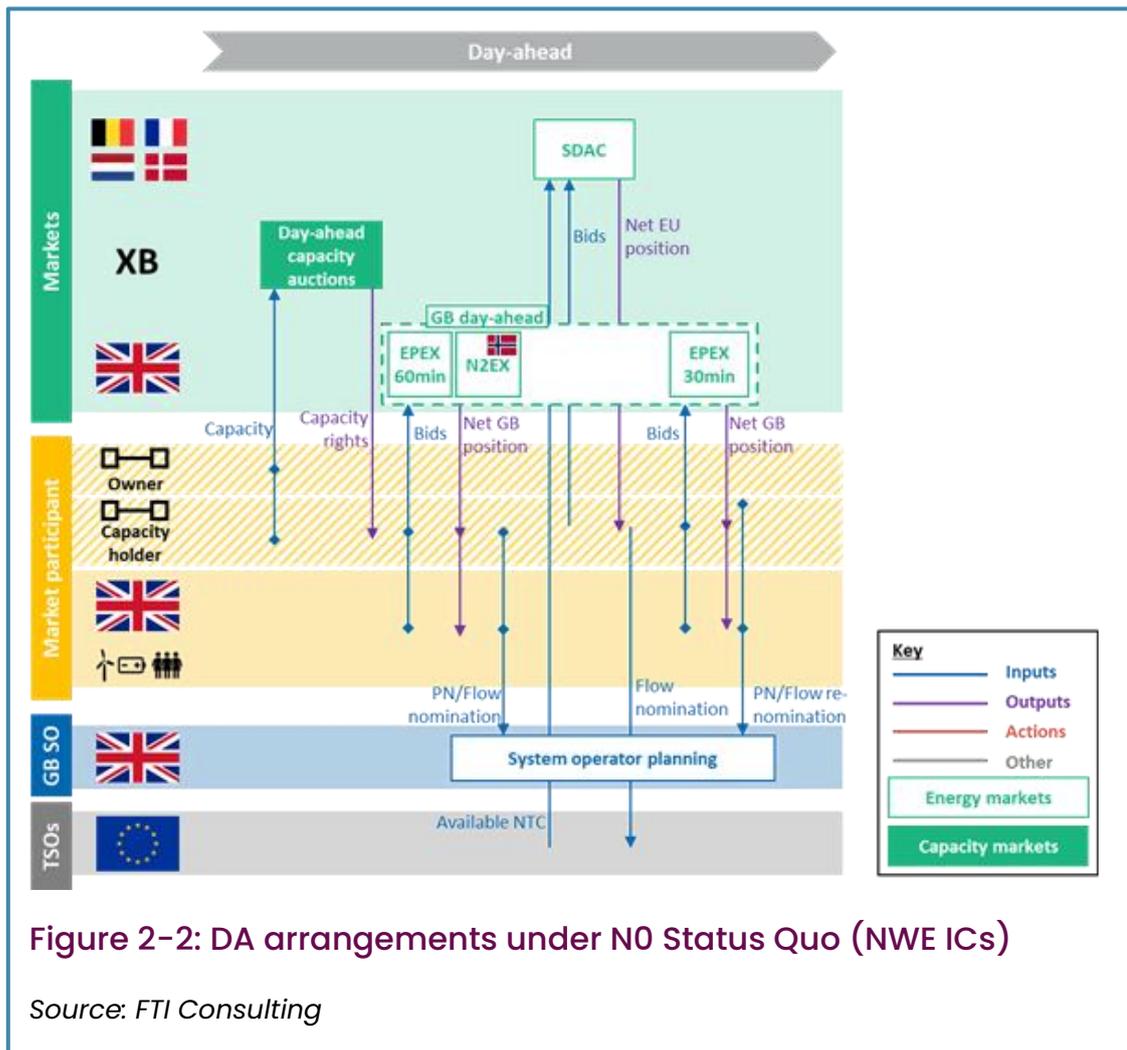
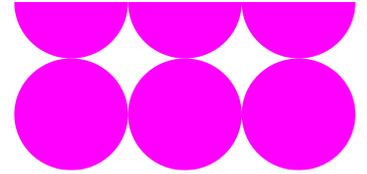


Figure 2-2: DA arrangements under N0 Status Quo (NWE ICs)

Source: FTI Consulting

2. N0: Self-scheduling with national wholesale pricing

2.14. We expand on the DAM auction run by N2EX, which implicitly price-couples NO2 and GB via NSL, as shown in Figure 2-3 below.<sup>65</sup> NSL is obligated to offer all technically available IC capacity to the N2EX DA auction, which may subsequently be amended by either NESO or Statnett to ensure system security (e.g. via countertrading or imposing Net Transfer Capacity (“NTC”) limits). The implicit auction uses an algorithm (conceptually similar to SDAC’s EUPHEMIA) to allocate NSL capacity jointly with buy/sell orders for electricity trade (such that NSL’s DA capacity is not directly traded by market participants – hence it is ‘implicitly price-coupled’). The algorithm simultaneously produces market prices for GB and NO2, as well as the volume of firm flows on NSL for each hour of the next day.<sup>66</sup> As N2EX and SDAC both include NO2, there are two spot prices in NO2.<sup>67</sup>

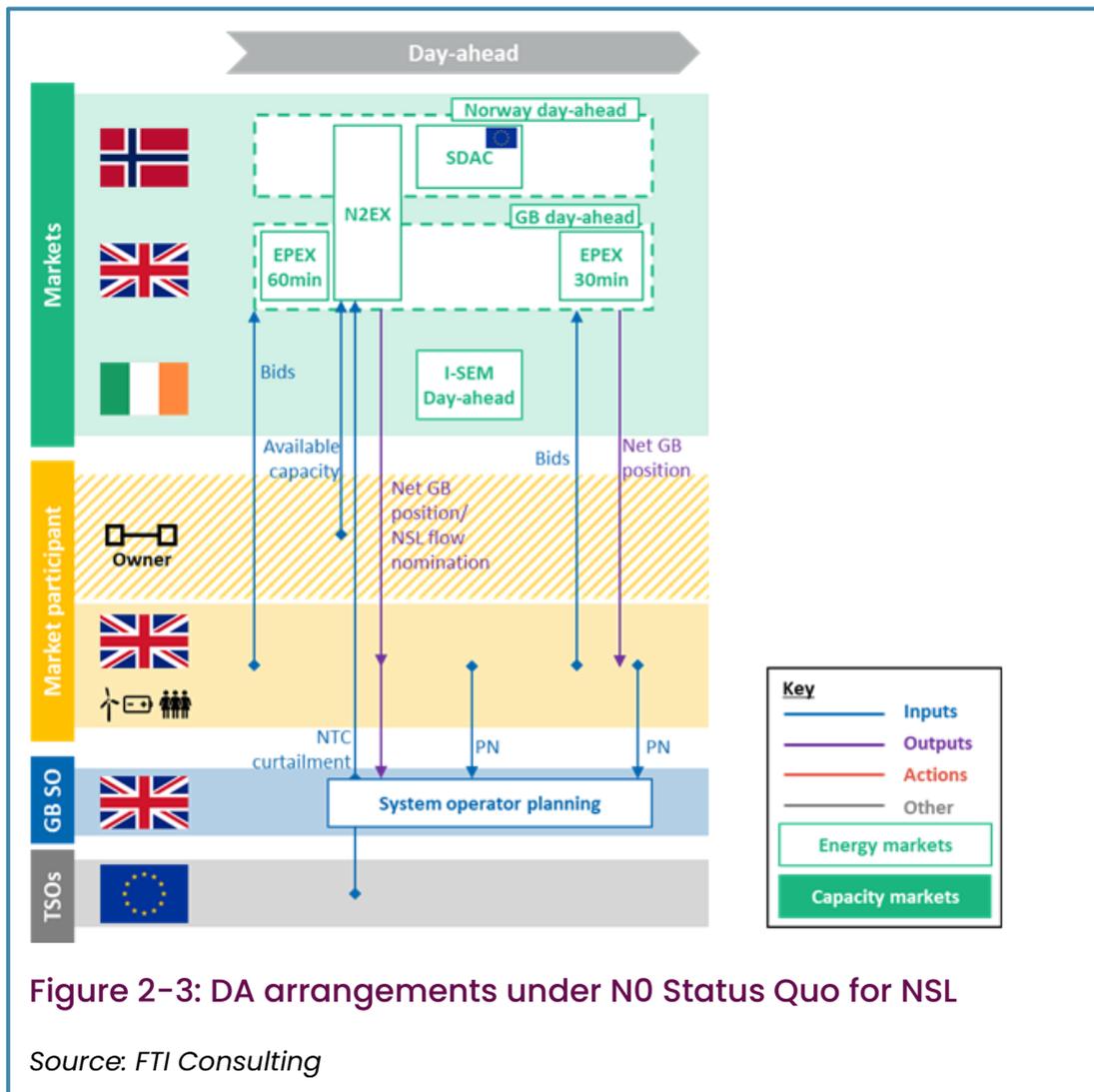
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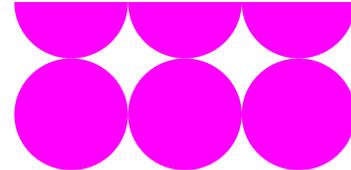
<sup>65</sup> ‘NSL Access Rules and Charging Methodology’, National Grid, 2021 ([link](#)). ‘Trial operation at NSL starts on 1 October’, Statnett, 2021 ([link](#)).

<sup>66</sup> ‘NSL Access Rules and Charging Methodology’, National Grid, 2021 ([link](#)). ‘Trial operation at NSL starts on 1 October’, Statnett, 2021 ([link](#)).

<sup>67</sup> ‘Trial operation at NSL starts on 1 October’, Statnett, 2021 ([link](#)).

2. N0: Self-scheduling with national wholesale pricing





## Intraday market

2.15. As summarised in Figure 2-4 below, there are various IDMs in Europe and GB:

- The SIDC in Europe comprises: (i) a continuous IDM<sup>68</sup> which uses the Cross-Border Intraday Coupling (“XBID”) system to enable continuous cross-border trading of electricity in Europe until one hour before delivery;<sup>69</sup> and (ii) IDAs that are run three times a day.<sup>70,71</sup> The SIDC was initially launched in 2018 and has since expanded to cover 25 European countries.<sup>72</sup>
- IC capacity on the NWE Europe ICs is explicitly traded in four ID capacity auctions per IC, run by the JAO or the IC’s own platform.<sup>73</sup>
- The GB IDM was not integrated into SIDC prior to Brexit (and, consequently, the EU SIDC markets are not part of the Status Quo design).<sup>74</sup> The GB continuous IDM runs in parallel to the SIDC continuous IDM (albeit they have different market opening times).<sup>75</sup>
- EPEX also operates two GB IDAs that are coupled with I-SEM via the GB-Irish ICs. The flows on the GB-Irish ICs are determined implicitly.<sup>76</sup>

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<sup>68</sup> In continuous IDMS, traders continuously submit bids and offers to the order book until delivery. When a bid matches an offer, the exchange clears the transaction through a contract between parties. ‘Basics of the Power Market’, EPEX SPOT ([link](#)).

<sup>69</sup> ‘Single Intraday Coupling (SIDC)’, European Network of Transmission System Operators (“ENTSO-E”) ([link](#)).

<sup>70</sup> The IDAs were implemented to enable the pricing of ID cross-border capacities (which is not possible in the continuous IDM) to reflect their value at a given time. ‘Intraday Auction – IDA’, ENTSO-E ([link](#)).

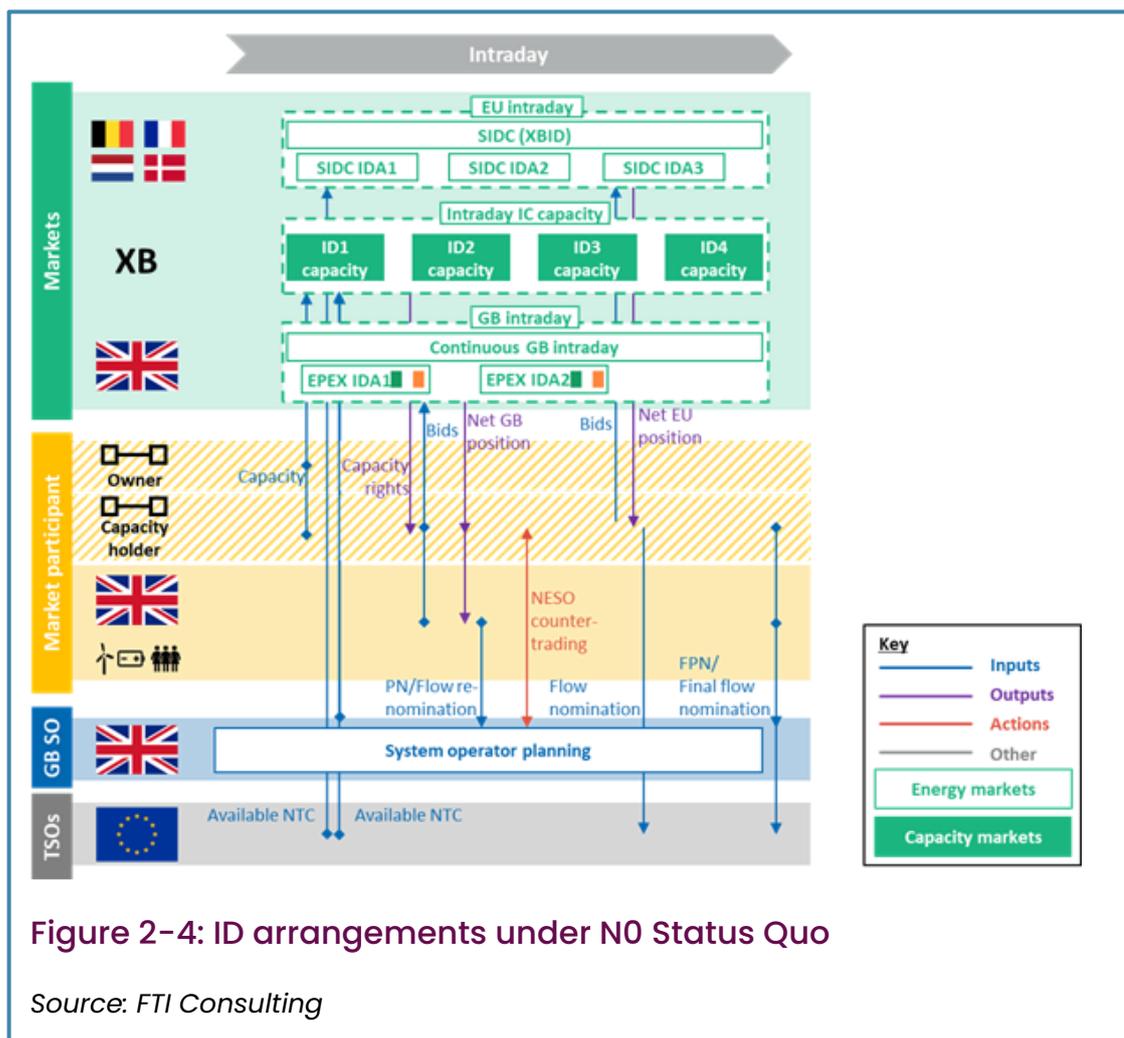
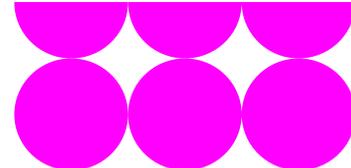
<sup>71</sup> The ID solution supports both explicit allocation (where approved by the respective National Regulatory Authorities) and implicit continuous trading. ‘Confirmation of the go-live date for Intraday Auctions on 13 June 2024’, EPEX SPOT ([link](#)).

<sup>72</sup> ‘Single Intraday Coupling (SIDC)’, ENTSO-E ([link](#)).

<sup>73</sup> ElecLink has only IDAs per day – ‘Auctions’, JAO ([link](#)). Therefore, overall, there are 22 separate IDAs.

<sup>74</sup> XBID was being rolled-out at the time when GB left the EU, while the first wave of implementation took place in June 2024. ‘Single Intraday Coupling (SIDC)’, ENTSO-E ([link](#)).

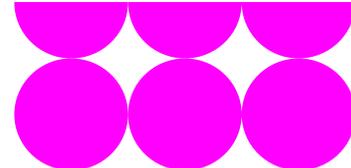
<sup>75</sup> The GB continuous IDM opens at 00:00 (GMT) D-1 (‘Trading Products’, EPEX SPOT, ([link](#))). SIDC opens at 14:00 Central European Time (“CET”) D-1 for Nordics, Baltic, Poland, Netherlands and Belgium, and 13:00 (CET) D-1 for Germany, France and Austria. ‘SIDC gate opening and closing times’, NordPool, 2024 ([link](#)).



2.16. Similar to the DA stage, after establishing their positions on the GB and EU IDAs, PTR holders and other market participants update their flow nominations and physical notifications (“PNs”) to the European TSOs and NESO, which become final flow nominations and FPNs at GCT.<sup>77</sup>

<sup>76</sup> There are currently no ID trading arrangements in place for NSL. Statnett is currently considering introducing IDAs for NSL. ‘NSL consultation’, Statnett, 2024 ([link](#)).

<sup>77</sup> ‘The Electricity Trading Arrangements A Beginner’s Guide’, Elexon, 2019 ([link](#)).



2.17. Pre-GCT, NESO has the ability<sup>78</sup> to adjust IC flows through:

- Capacity restriction: NESO and European TSOs calculate and allocate cross-border capacity to market parties, which may lead to a reduction in the allowed NTC for the IC;<sup>79</sup> and
- Countertrading: NESO conducts auctions with Registered Trading Partners, who bid to provide capacity on ICs to meet requirements. Trades are not limited to only ICs – NESO can also initiate trades with other parties (e.g. suppliers or generators).<sup>80</sup> As countertrading takes place in parallel with the IDM, measures would need to be put in place to ensure that subsequent ID trades do not unwind the countertrades.

### Post-gate closure time

2.18. After GCT (currently set at one hour before delivery), no further trading in the wholesale market is allowed, and NESO takes control of balancing the electricity system via the BM. Similar arrangements are in place in Europe.

2.19. ICs currently do not participate in the BM. However, as shown in Figure 2-5 below, NESO can adjust IC flows closer to RT through:

- **SO-SO trades:** These are trades between NESO and the relevant European TSO to increase, decrease or reverse IC flows, and can be requested and rejected by either SO.<sup>81</sup> The payment terms for SO-SO trades are governed by trilateral agreements between NESO, the relevant European TSO and each relevant IC owner, and depend on the market conditions at the time of dispatch.<sup>82</sup>
- **Emergency services:** These take place under unforeseen circumstances where NESO or European TSOs must adjust IC flows close to delivery.<sup>83</sup>

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<sup>78</sup> EU TSOs also have an ability to adjust IC flows, but we do not focus on this aspect of market design in this report.

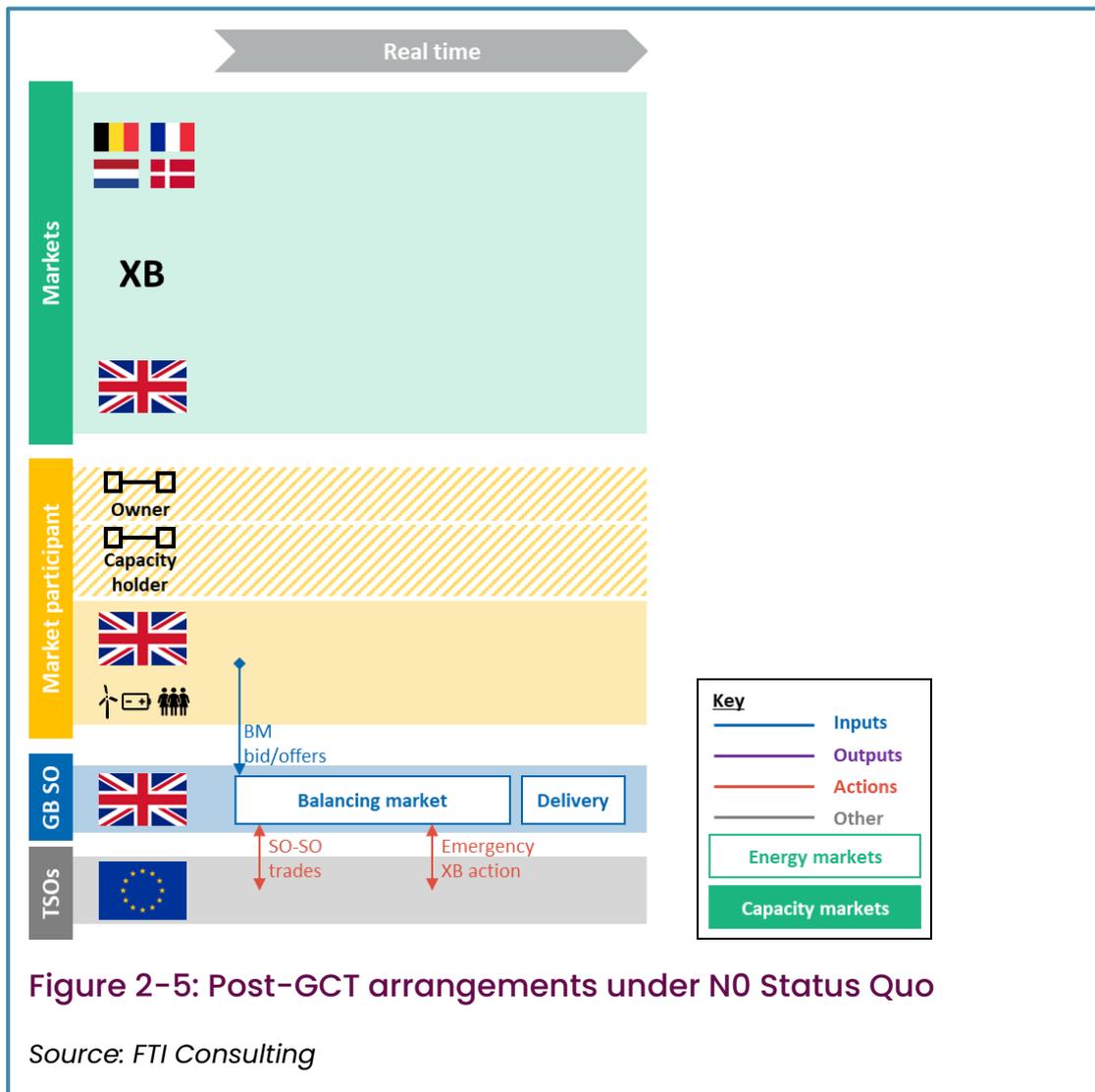
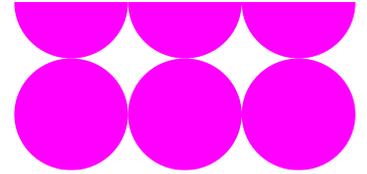
<sup>79</sup> 'Methodology for GB Commercial Arrangements relating to IC Capacity Calculation', NESO, 2023 ([link](#)).

<sup>80</sup> 'IC Trades – Procurement Framework', NESO ([link](#)).

<sup>81</sup> 'Operational Transparency Forum', NESO ([link](#)): slide 17.

<sup>82</sup> 'System operator to system operator (SO to SO)', NESO ([link](#)).

<sup>83</sup> There are two forms: (i) emergency assistance, which can be requested by either SO if in an alert or emergency state and can only be rejected by the assisting SO if it would otherwise cause their system to enter into an emergency state; and (ii) emergency instruction, which is used to reduce IC flows to 0MW immediately if all other available actions to restore system security have been exhausted. 'ESO Operational Transparency Forum', NESO ([link](#)).



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2.20. Under the current market design and cross-border trading arrangements, GB does not participate in cross-border balancing platforms such as Trans European Replacement Reserves Exchange (“TERRE”), Manually Activated Reserves Initiative (“MARI”) and Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (“PICASSO”) <sup>84</sup> (which are still under development) due to Brexit. NESO has previously explored several high-level options for cross-border balancing (“CBB”), which include:<sup>85</sup>

- (i) Establishing a GB CBB platform, which could run ahead or in parallel with the BM and EU cross-border balancing platforms;
- (ii) Indirect participation of GB in the EU balancing platforms. This would require developing a technical interface to ensure that RT orders in GB are compatible with the products traded on these platforms;<sup>86</sup> and
- (iii) Direct exchange of balancing products between NESO and European TSOs.

## NO MRLVC

2.21. As set out in the TCA between the UK and the EU, the post-Brexit trading of electricity between GB and the EU at the DA timeframe is intended to be based on MRLVC.<sup>87</sup> This is a volume coupling mechanism in which the volumes and direction of cross-border flows are first jointly determined, while DA wholesale prices are set separately in the EU and GB after flows have been determined. . As illustrated earlier in Figure 1-1, the MRLVC sits on a spectrum between explicit market arrangements and (implicit) Price Coupling. In this report, in agreement with NESO, we assume that when implemented, the MRLVC would apply to all GB ICs (including NSL and the GB-Irish ICs).

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<sup>84</sup> TERRE, MARI and PICASSO are platforms to manage and optimise the cross-border European exchange of replacement reserves (“RR”), manual frequency restoration reserves (“mFRR”), and automatic frequency restoration reserves (“aFRR”) respectively. The TERRE platform has been operational since January 2020, and the MARI and PICASSO platforms came into operation in December 2022. See ‘TERRE’ ([link](#)) ‘Manually Activated Reserves Initiative’ ([link](#)) and ‘PICASSO’ ([link](#)), ENTSO-E.

<sup>85</sup> ‘Study on Cross-Border Balancing Market Design: Presentation to stakeholders’, FTI-CL Energy, 2023 ([link](#)).

<sup>86</sup> This would not be unprecedented – Article 12(3)(d) of Commission Regulation (EU) 2017/2195 ([link](#)) requires TSOs that use central scheduling to provide “*information regarding how balancing energy bids from specific products or from integrated scheduling process have been converted into balancing energy bids from standard products*”.

<sup>87</sup> ‘Trade and Cooperation Agreement’, European Union, 2021 ([link](#)): Annex 4 (pdf page 1656).

## 2. N0: Self-scheduling with national wholesale pricing

2.22. In this section, consistent with the rest of the report, we describe the cross-border arrangements under N0 with MRLVC in chronological order. However, while the exact implementation details of the MRLVC mechanism are still under development, we note that the MRLVC is intended to be a DA trading solution, with limited (if any) new arrangements proposed under the TCA for other timeframes, and therefore we assume that MRLVC is only implemented at the DA stage in this report.

### Forward market

2.23. As a DA trading solution, introducing the MRLVC would not have any impact on the forward arrangements under N0 Status Quo as described in ¶12.6, where ICs can choose to participate in JAO forward auctions and offer capacity for various market timeframes.<sup>88</sup>

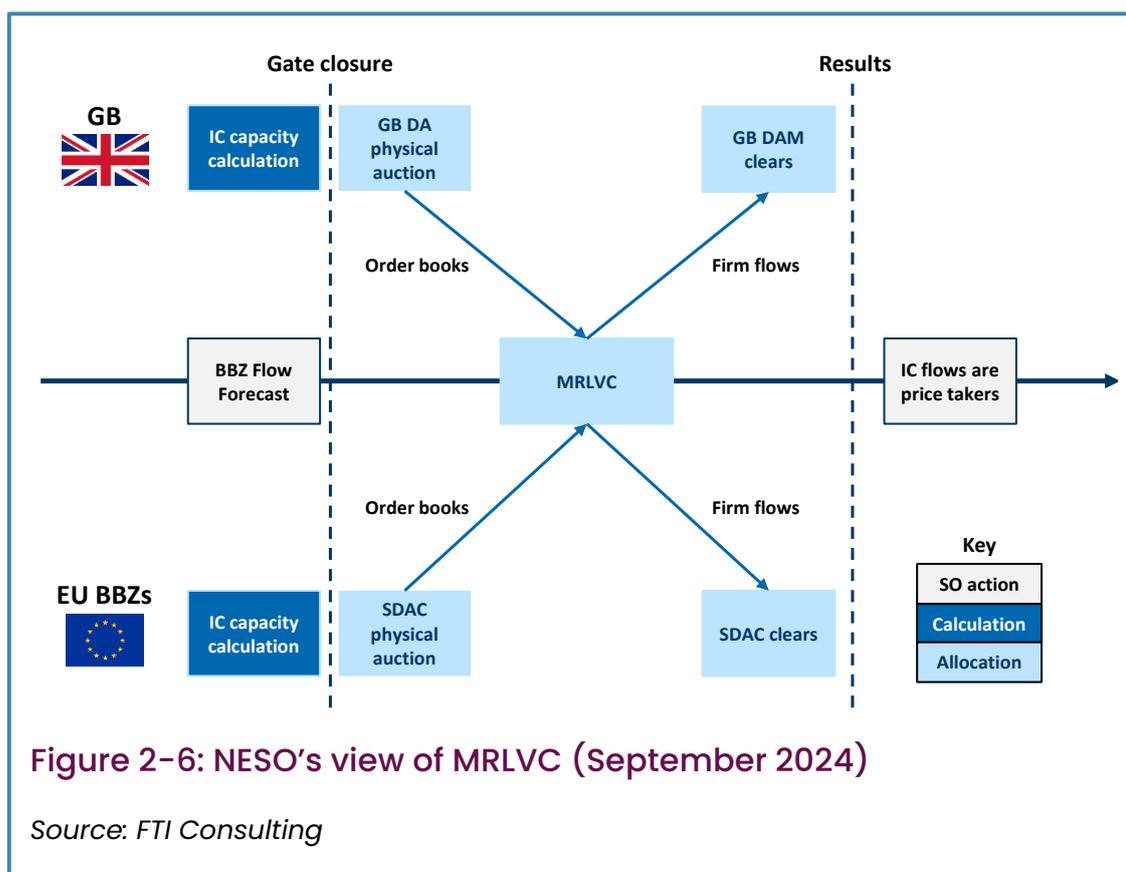
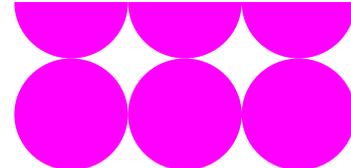
### Day-Ahead market

2.24. As pointed out above, the exact implementation details of the MRLVC mechanism are still under development. Figure 2-6 below illustrates the latest joint view of NESO and the European TSOs (which has been communicated to DESNZ), as of September 2024, of how the mechanism would function. We describe the key design assumptions in the following paragraphs.<sup>89</sup>

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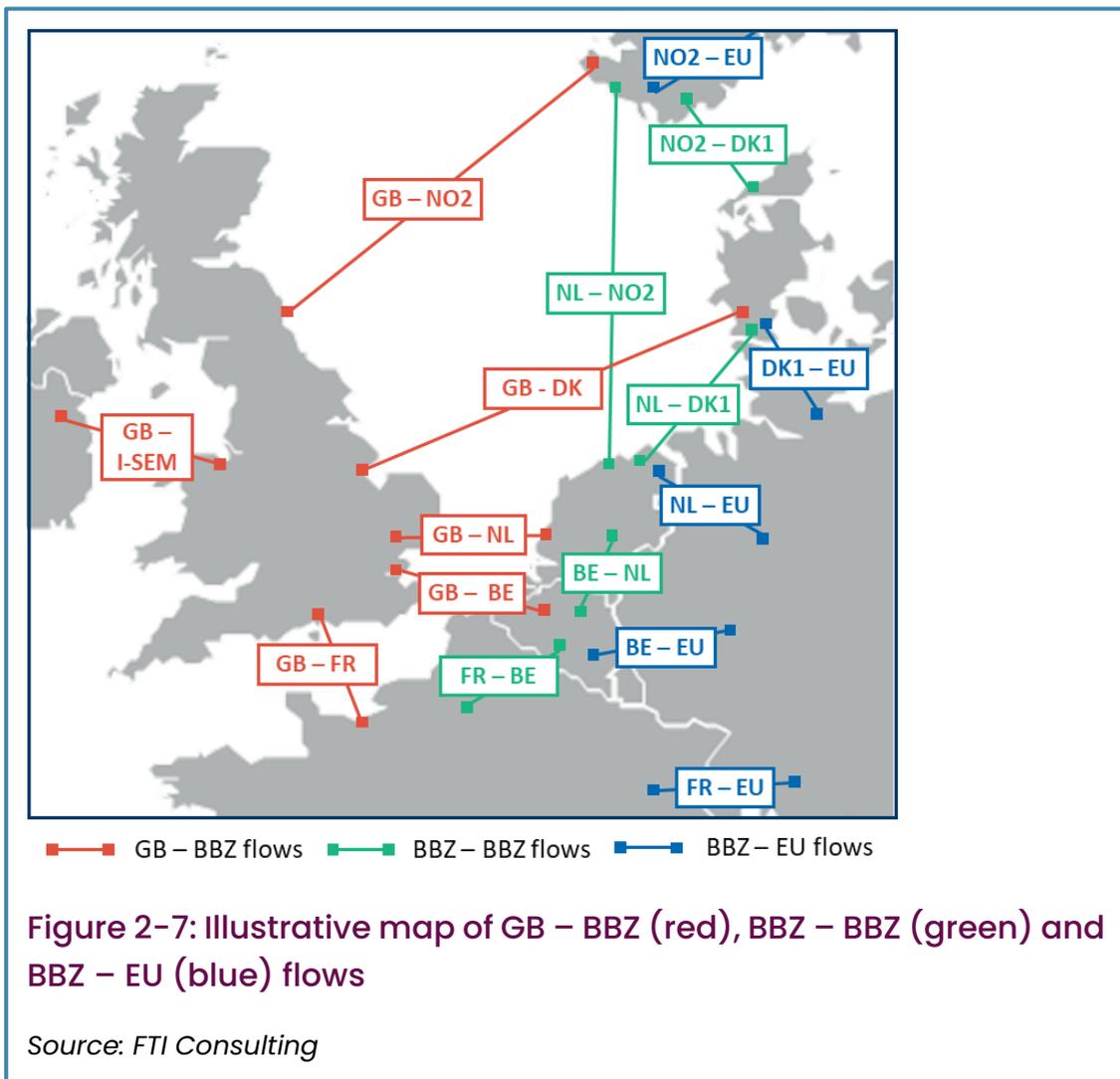
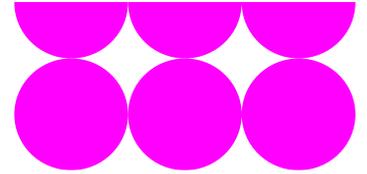
<sup>88</sup> Currently, only IFA, IFA2, ElecLink, Nemo Link, Viking Link and BritNed participate in these auctions. In principle, NSL and the GB-Irish ICs could also participate.

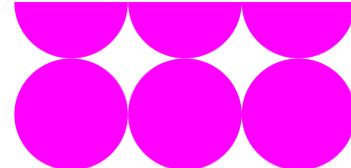
<sup>89</sup> We recognise that the development of the MRLVC mechanism is still underway, and this report should not be interpreted as providing any views or recommendations as to the MRLVC final design. This report simply presents working assumptions on the MRLVC design, in agreement with NESO, to enable an assessment of the cross-border trading arrangements under different wider market designs.



2.25. The core design assumption of the MRLVC design is that the Volume Coupling would focus on the interface between GB and the BBZs e.g. the subset of EU zones covered by the SDAC which are directly connected to GB. In the current setup, the relevant BBZs would include: France, Belgium, Netherlands, the Western Denmark price zone (“DK1”), I-SEM and NO2. Separately, the power flows between the BBZ and other zones covered by the SDAC (e.g. flows between France and Spain) would be forecasted prior to the MRLVC, and such estimates would serve as inputs into the MRLVC process. In the description below we therefore distinguish between: GB-BBZ flows (which are the key output of the MRLVC process), BBZ-BBZ flows (which are an output of the MRLVC, but then reoptimized in the SDAC)<sup>90</sup> and the BBZ-EU flows (the forecast of which is an input into the MRLVC process).

<sup>90</sup> The MRLVC guidance document is not explicitly clear on how BBZ-BBZ flows are determined, but we understand that this would be the case, as flows between BBZs would necessarily have to be calculated to determine each BBZ's net position relative to the rest of the SDAC.





2.26. As shown in Figure 2-7 above,<sup>91</sup> the MRLVC process is currently expected to run as follows:<sup>92</sup>

- **BBZ-EU Flow Forecast (blue links in Figure 2-7):** The TCA includes a restriction that the MRLVC may only use the order book data from GB and the BBZs. The MRLVC algorithm therefore requires a forecast of the net position of each BBZ relative to the rest of the SDAC (the “BBZ-EU Flow Forecast”). The BBZ-EU Flow Forecast is run prior to GB DAM and SDAC market closure, e.g. the point in time up to which market participants can submit DA bids or offers.<sup>93</sup>
- **Calculation of available GB-BBZ IC capacities (red links in Figure 2-7) and BBZ-BBZ transmission capacities (green links in Figure 2-7):** The available IC capacity on GB to EU ICs for market participants is also determined by NESO and the BBZ TSOs prior to DA market closure, and the lower IC capacity figure calculated by either side will be made available to the market. The available transmission capacity on the BBZ-BBZ border (and/or relevant transmission-related parameters for those borders) needs to be as well calculated by the relevant BBZ TSOs.
- **Common Order Book submission:** After the DAM closure, which takes place simultaneously for the GB DAM and SDAC, the GB power market operators<sup>94</sup> and NEMOs<sup>95</sup> combine the received orders in GB and the BBZs and submit the Common Order Book<sup>96</sup> to the operator of the MRLVC algorithm (the entity performing this function has not been defined, but could potentially be an existing PX or a new entity).
- **MRLVC algorithm:** The algorithm then optimises GB-BBZ and BBZ-BBZ IC flows based on the Common Order Book and taking the BBZ-EU Flow Forecast as an exogenous input. The MRLVC algorithm implicitly computes ‘DA prices’ as well (e.g. relative marginal values of electricity in relevant bidding zones, which would underpin the determination of the relevant cross-border direction of flows), but these are only “shadow” prices. The final DA prices are determined later separately by the relevant PXs.

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<sup>91</sup> The map illustrates the categorisation of borders based on existing price zones and ICs. The commissioning of ICs on new borders or bidding zone splits could lead to the reclassification of existing borders and the creation of new borders.

<sup>92</sup> ‘Responses from the TSO group to the technical questions on MRLVC’, ENTSO-E, 2023 (link): Section 4.3.

<sup>93</sup> It is unclear what information, if any, about other zones is included in the MRLVC. For now, we assume the MRLVC operator makes reasonable assumptions about expected flow patterns based on anticipated market conditions, time of day, and other external factors, and that this information would be reflected in the BBZ Flow Forecast described earlier.

- **Submission of firm flows to SDAC and GB DAM:** For the GB-BBZ ICs, the (firm) flows from the MRLVC calculation are converted into PTOs<sup>97</sup> and sent to the GB power exchanges and EU NEMOs for validation. The PTOs are then submitted to the GB DAM and SDAC respectively, which would take the firm flows as inputs in their respective algorithms (e.g. “optimise around” the MRLVC flows). BBZ-BBZ flows are not converted into PTOs and are reoptimised in Price Coupling auctions closer to RT (e.g. SDAC, SIDC).

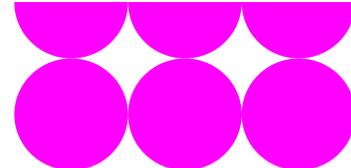
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<sup>94</sup> We assume that both N2EX and EPEX Spot continue to operate each their DAM clearing algorithm, but note that this appears potentially duplicative. It is also not clear how the Price Taking Orders (“PTOs”) would be split between the two PXs. DESNZ is currently pursuing legislative action for N2EX and EPEX Spot to re-couple their DAMs for cross-border trade (see: ‘GB Wholesale Electricity Market Arrangements’, DESNZ, 2023 ([link](#))).

<sup>95</sup> EU NEMOs are the organisations that are mandated to run the DAM and IDMs. ‘About the All NEMO Committee’, NEMO Committee ([link](#)).

<sup>96</sup> There are currently two MRLVC design options under consideration: (i) Common Order Books, in which final BBZ order books are input into the MRLVC; and (ii) Preliminary Order Books, which uses preliminary BBZ order books in the MRLVC calculation and market participants in the SDAC BBZs are able to submit new orders or amend orders already submitted up until SDAC GCT. For the purposes of this report, we assume that Common Order Book design would apply. ‘Cost Benefit Analysis of MRLVC’, The EU and UK TSOs MRLVC group, 2021 ([link](#)): slides 8 and 10.

<sup>97</sup> To guarantee that PTOs are cleared in the DA schedule PTOs for imports to GB represent additional generators at the bottom of the merit order, who submit offers to the market at the lowest price allowed by the market operator, while PTOs for exports from GB represent additional non-flexible demand in the clearing algorithm priced at the value of lost load (“VoLL”).



2.27. MRLVC is intended to achieve some of the trading efficiency benefits of Price Coupling but requires significant information exchange between GB and Europe (albeit less than that required under full implicit Price Coupling).<sup>98</sup> Actual flows on ICs may sometimes lead to a commercial under-utilisation of the ICs:<sup>99</sup>

- **Imperfect information:** The flows identified by the MRLVC algorithm are optimised based on Common Order Book data and assumptions about broader European supply, demand, and flows. However, determined flows between GB and the BBZs will inevitably be inaccurate, particularly as only a subset of EU zones are included in the MRLVC algorithm.<sup>100</sup> This could be improved by greater information sharing on the expected flows between BBZs and the rest of EU,<sup>101</sup> and by running the BBZ-EU Flow Forecast as close as possible to DAM closure such that the latest information is input into the MRLVC algorithm;<sup>102</sup> and
- **Computational complexity:** Due to the size of the optimisation problem, the algorithm used in the MRLVC algorithm might output slightly different results than the algorithms used by the PX in GB and the SDAC even under the same inputs. In that regard, the MRLVC computation time is estimated to be between 13 to 42 min.<sup>103</sup> This would necessarily extend SDAC run times compared to the current arrangements – as shown in Figure 2-6 above, after SDAC market closure, the MRLVC algorithm must clear before it can be input into EUPHEMIA for SDAC to clear. Although the EU is legally obligated under the TCA to make some concessions to accommodate the implementation of the MRLVC, such an extension may not be acceptable to the EU. It is not within the scope of this report to design a feasible MRLVC, but we note that there is a trade-off between accuracy and computation time, such that reaching the shorter end of the time range may require accepting some reduction in calculation quality that could on some occasions lead to flows against commercial price differentials.

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<sup>98</sup> Trading efficiency benefits are here defined as scheduling IC flows intuitively, e.g. in the same sense as the commercial price difference. As discussed in the introduction, intuitive IC flows are not always optimal from a GB system perspective.

<sup>99</sup> The coupling on the Kontek cable between Germany and Denmark, for example, was stopped after ten days due to the high frequency of counterintuitive flows. 'Cost Benefit Analysis of MRLVC', The EU and UK TSOs MRLVC group, 2021 ([link](#)): slide 103.

<sup>100</sup> Enhancing the quality information feeding into the MRLVC process could lead to better outcomes: e.g. improved forecasts of the BBZ flows (which, as discussed earlier, serve as an input into the MRLVC) would lead to MRLVC flows that would be closer to the fully price coupled scenario.

2.28. A consequence of implementing the MRLVC would be that the GB DAM clearing must take place concurrently with SDAC. This would be a departure from the current status quo arrangements, in which the GB DAM takes place slightly ahead of the SDAC. European TSOs have also noted that the implementation of the MRLVC would also require alignment of GB procedures with the EU – for example, timing of the publication of results will need to be coordinated so that the different bidding zones have access to the same information at the same time.<sup>104</sup>

### Intraday market

2.29. Potential post-Brexit ID trading arrangements have yet to be explored; given this, we assume that there would be no MRLVC process in the ID timeframe, which would thus be the same as that under N0 Status Quo.

2.30. Price-coupled I-SEM and GB IDAs would work in the same way as described in N0 Status Quo. Price coupled IDAs on any other ICs could also be accommodated, if these were introduced at a later stage.<sup>105</sup> For ICs covered under these arrangements, flows from the MRLVC would be reoptimized under the relevant price-coupled auctions.

2.31. For other ICs that are currently subject to an explicit cross-border trading arrangement, the relevant ID IC auctions could remain in place. In addition, NESO could use the processes described in N0 to redispatch IC flows before GCT, such as countertrading or NTC curtailment.

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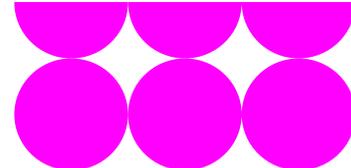
<sup>101</sup> Another option would be to increase information sharing between GB and wider EU (e.g. expanding beyond the BBZs), but for the purposes of this report, and given our understanding of the MRLVC design, we assume that this is not a credible option.

<sup>102</sup> If computational time were no issue, the BBZ Flow Forecast could also be run after DAM closure.

<sup>103</sup> 'Responses from the TSO group to the technical questions on MRLVC', ENTSO-E, 2023 ([link](#)): page 2.

<sup>104</sup> 'Responses from the TSO group to the technical questions on MRLVC', ENTSO-E, 2023 ([link](#)): page 3.

<sup>105</sup> For example, Statnett and National Grid Ventures ("NGV") are currently exploring the possibility of establishing price-coupled IDAs between GB and NO2, once the current arrangements expire in 2026. 'Public consultation on new trading arrangements on the NSL interconnector.', Statnett and NGV, June 2024, ([link](#)).



## Post-gate closure time

2.32. Introducing MRLVC at the DA stage would not have any impact on the post-GCT arrangements described in N0 Status Quo. As per ID, no potential changes have been suggested, so we presume the current arrangements, in which NESO takes control of balancing through the BM and can adjust or reverse flows on ICs through SO-SO trades and emergency services would continue.

## N0 Price Coupling

2.33. Below, we describe the scenario where GB is fully price-coupled with the IEM and effectively becomes part of the SDAC and SIDC under the current market design (“N0 Price Coupling”). We assume that if Price Coupling were implemented, it would apply to all GB ICs.

## Forward market

2.34. We assume that GB would participate in the forward market for cross-border transmission rights the same way as other European countries. NESO, along with the European TSOs, would perform forward calculations of capacities on the cross-border ICs to determine the available amount of IC capacity for LTTR allocation.

2.35. Assuming that under Price Coupling, GB must follow the relevant EU Regulations covering the IEM unless exemptions are granted, ICs would likely be required to offer IC capacity in the forward timeframe per the Forward Capacity Allocation Guideline (“FCA GL”).<sup>106</sup> Further, as explained in ¶12.5-2.8:

- Market participants in GB and Europe would place bids in the auction for LTTRs organised through the JAO107, which would then publish the price for the capacity of LTTRs offered in the auction;

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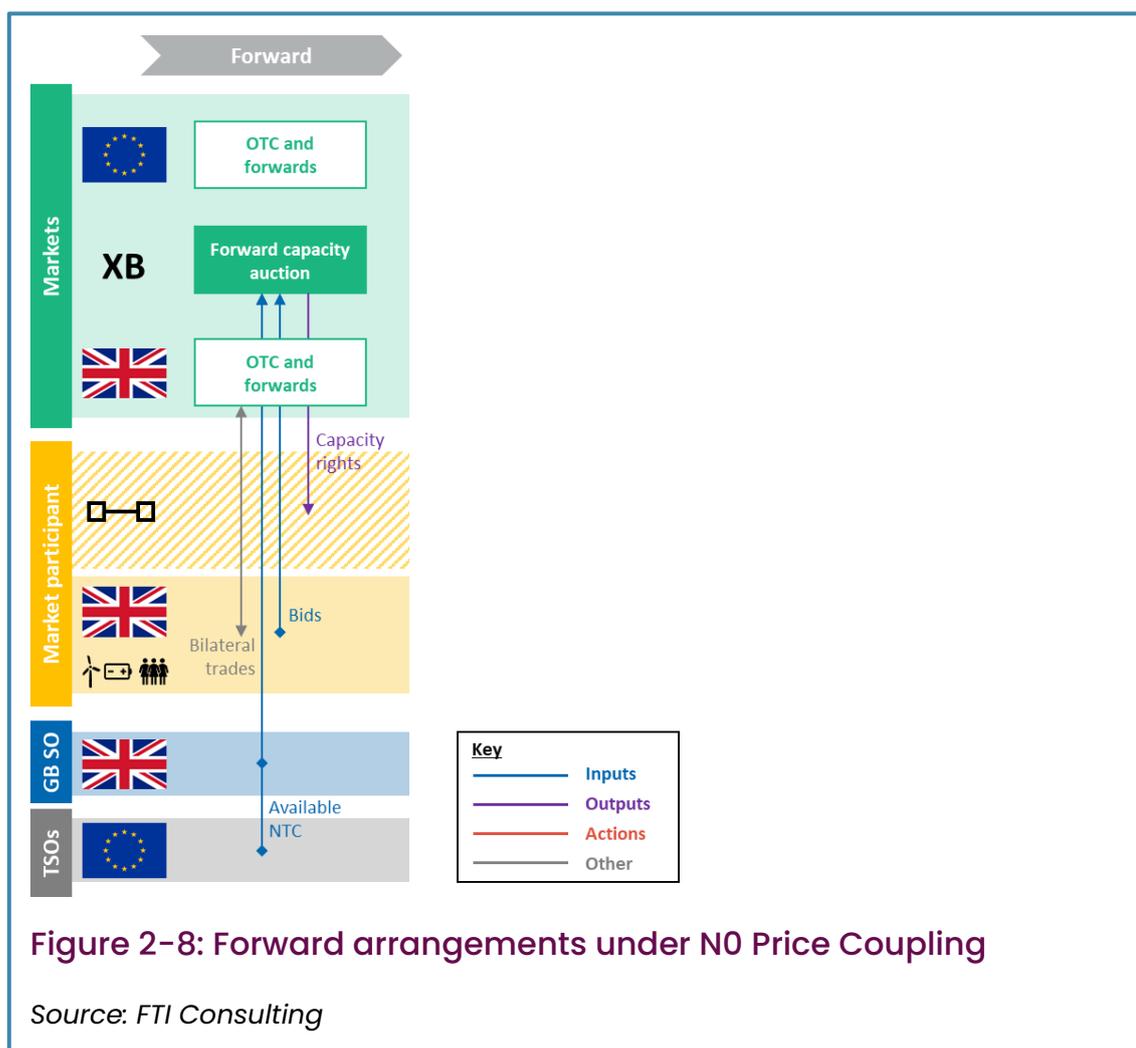
<sup>106</sup> The FCA GL states in Art. 30(1) that: “TSOs on a bidding zone border shall issue long-term transmission rights unless the competent regulatory authorities of the bidding zone border have adopted coordinated decisions not to issue long-term transmission rights on the bidding zone border. When adopting their decisions, the competent regulatory authorities of the bidding zone border shall consult the regulatory authorities of the relevant capacity calculation region and take due account of their opinions.” Further in Art. 30(3) it is stated that: “The decisions pursuant to paragraphs 1 and 2 shall be based on an assessment, which shall identify whether the electricity forward market provides sufficient hedging opportunities in the concerned bidding zones [...]”.

<sup>107</sup> The mandatory use of JAO applies only to long-term capacity sales. As stated in the FCA GL, short-term sales of cross-zonal transmission capacity can be organised on other platforms.

2. N0: Self-scheduling with national wholesale pricing

- LTRs can be PTRs (with UIOSI provisions) or FTRs both of which would enable market participants to hedge their positions between the GB and the SDAC bidding zones;
- Market participants and IC capacity holders (though not IC owners themselves) can also trade bilaterally in the forward market.

2.36. The forward arrangements under N0 Price Coupling are summarised in Figure 2-8 below.



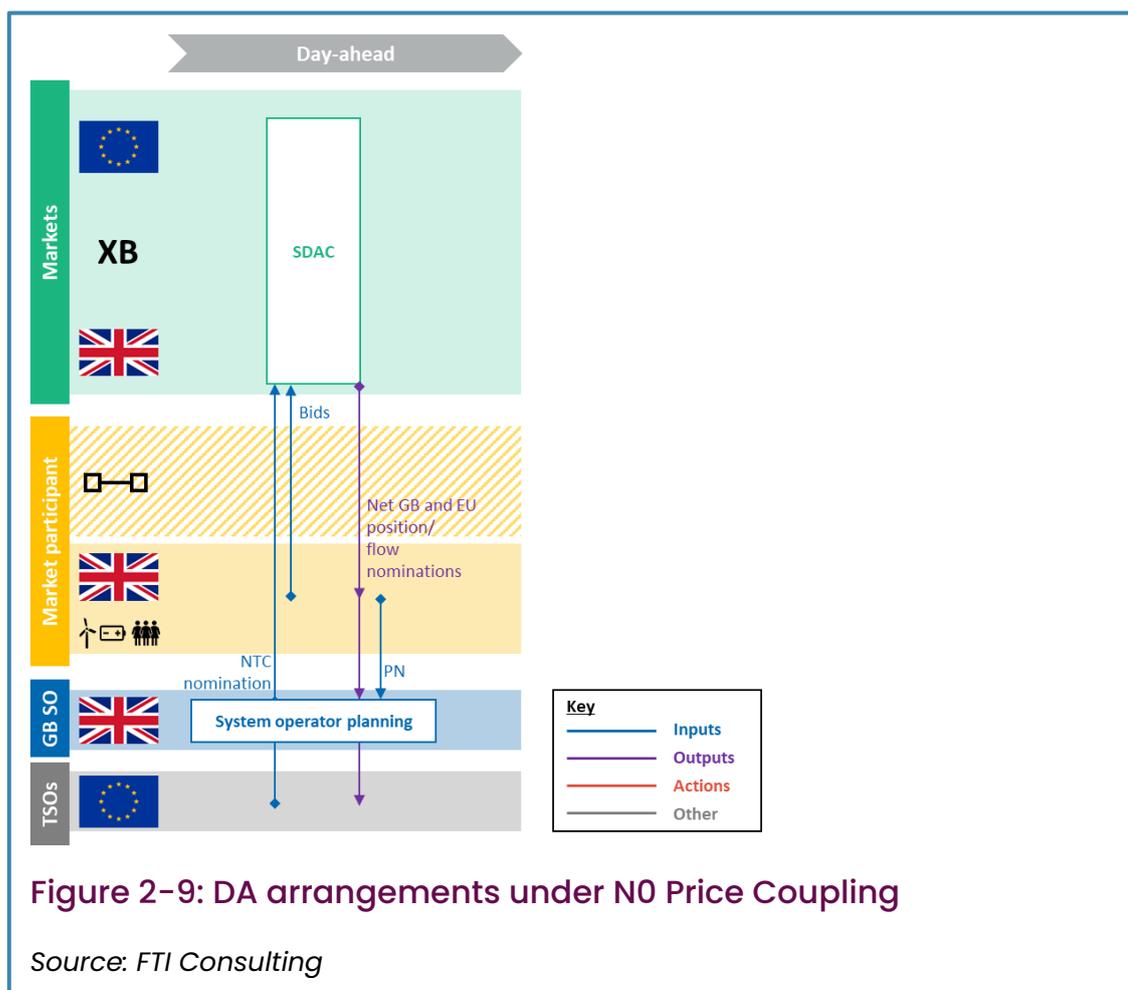
Day-Ahead market

2.37. For there to be full implicit Price Coupling, GB would effectively need to become part of SDAC such that the clearing of the GB DAM would be integrated into EUPHEMIA (that is, akin to pre-Brexit arrangements) to simultaneously determine national and zonal prices in Europe and GB, as well as the flows on all GB ICs.

2. N0: Self-scheduling with national wholesale pricing

2.38. If the GB DAM would be integrated into EUPHEMIA, we assume that the existing GB DAM auctions (organised by EPEX and N2EX) would not take place and PXs would instead feed their order books into SDAC.

2.39. As summarised below in Figure 2-9, this would result in a single auction at the DA timeframe across Europe and GB.



2.40. For GB to become part of the SDAC, GB market design would need to comply with the Guideline on Capacity Allocation and Congestion Management (“CACM GL”) unless exemptions are granted. The CACM GL requires cross-zonal borders in the IEM to be part of CCRs in which the relevant TSOs coordinate the calculation of transmission capacity within a region (either using the NTC or flow-based approach).

## 2. N0: Self-scheduling with national wholesale pricing

- 2.41. Before Brexit, GB ICs were part of two CCRs, both of which used the NTC methodology: (i) the Channel CCR, which included all ICs between GB and mainland Europe; and (ii) the Ireland-UK CCR (“IU CCR”), which covered ICs between GB and I-SEM.<sup>108</sup> The Channel and IU CCRs no longer exist, but we assume that they would be reinstated if GB were to be price coupled again with the IEM (albeit their composition would need to be updated to reflect new IC capacity between GB, EU and I-SEM commissioned since Brexit).<sup>109</sup> We also assume that the CCRs would retain the NTC methodology for calculating capacity on the GB ICs.<sup>110</sup>
- 2.42. Following the conclusion of the SDAC auction, market participants that have established positions on the GB market would submit their PNs to NESO. There is no need for explicit flow nominations from IC capacity holders, as the flows are determined implicitly as part of the EUPHEMIA algorithm.

### Intraday market

- 2.43. As shown above in Figure 2-3 and described in ¶12.15, there are currently various IDMs in the IEM and in GB, including a continuous IDM and several IDAs in each jurisdiction. Price Coupling at the ID stage does not have any direct precedent from the pre-Brexit arrangements – as explained in ¶12.15– since GB has never been part of the SIDC.
- 2.44. As shown below in Figure 2-10, we assume that under Price Coupling, all of the GB IDMs (continuous and explicit auctions) would be integrated into (and hence be replaced by) the SIDC IDAs and ID continuous market.

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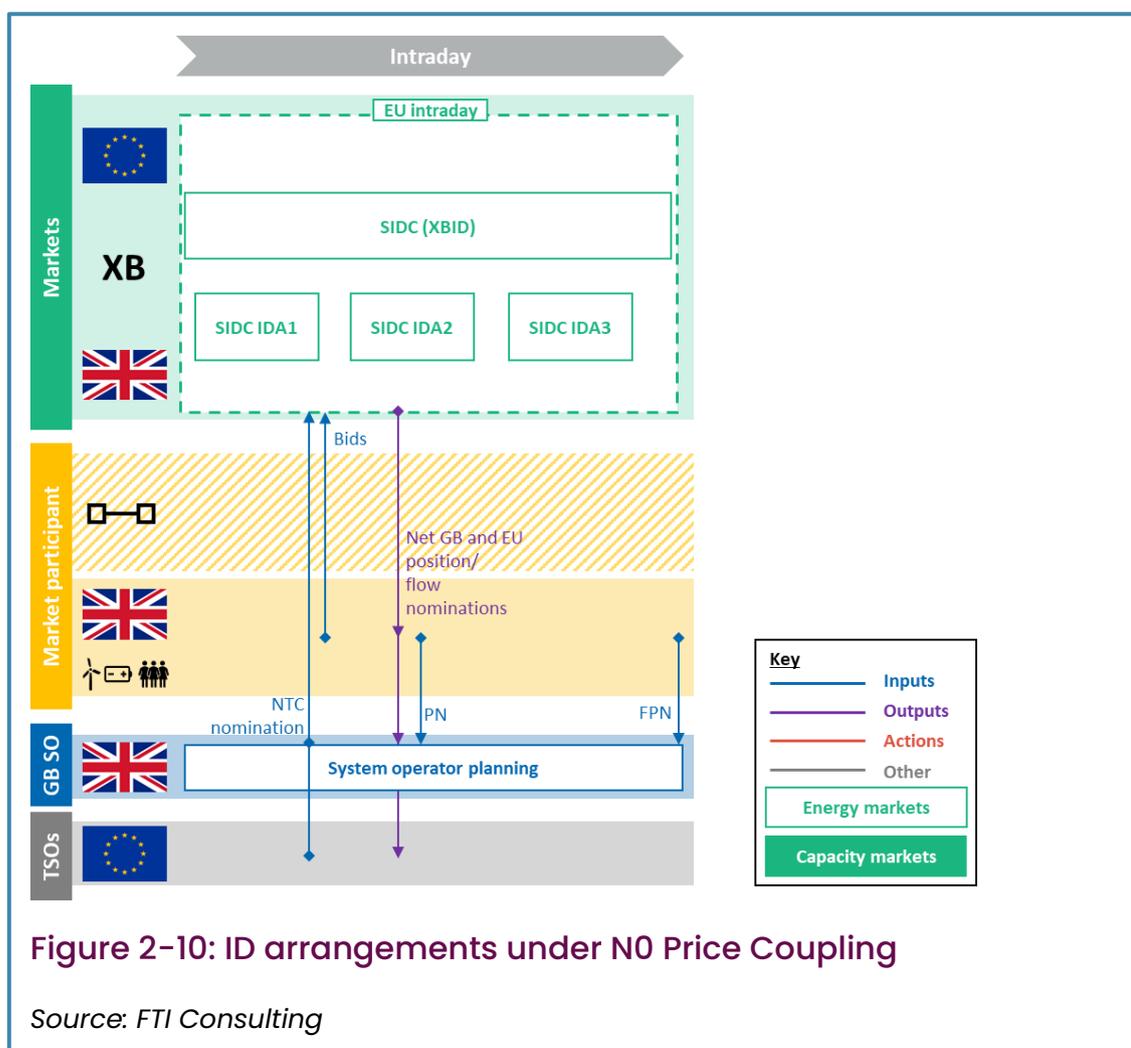
<sup>108</sup> ‘Capacity Calculation Regions’, ENTSO-E ([link](#)).

<sup>109</sup> For instance, Eleclink and Greenlink would both add to existing Channel and IU CCR capacity; NeuConnect, NSL and Viking Link would all create new GB – EU bidding zone borders which would need to be added to an existing or new CCR (such as Nemo Link; see ‘Approval of the amended determination of Capacity Calculation Regions’, Ofgem, 2017 ([link](#))).

<sup>110</sup> Currently there are multiple approaches to determine NTCs, but the target methodology described in CACM GL is the flow-based methodology for regions with higher interdependent flows between cross-zonal borders. As all ICs between GB and the EU (and Norway) are HVDC, flows on the different ICs are not directly interdependent and the standard coordinated NTC approach would suffice. The commissioning of new IC capacity between GB and Europe (also I-SEM and France) since then is likely to necessitate updates to these regions. ‘Capacity Calculation Regions’, ENTSO-E ([link](#)).

2. N0: Self-scheduling with national wholesale pricing

2.45. Further, we also assume that the I-SEM would be integrated into the SIDC in this scenario, such that the currently price-coupled IDAs between GB and the I-SEM would no longer be necessary. We consider this plausible, as the I-SEM could become part of SIDC when Celtic IC becomes operational.<sup>111</sup>



2.46. Similarly to the DA stage, the available NTC for the SIDC would be determined by NESO and other TSOs who are part of the same CCR. After market participants establish positions on the EU continuous market and IDAs, they submit their IPNs to the European TSOs and NESO, which become FPNs at GCT.<sup>112</sup> There is no longer a need for flow nominations following any changes to the DA schedule, as these are determined implicitly as part of the EUPHEMIA algorithm.

<sup>111</sup> 'Strategic Markets Programme', SEMO, 2024 ([link](#)).

<sup>112</sup> 'The Electricity Trading Arrangements A Beginner's Guide', Elexon, 2019 ([link](#)).

2.47. Pre-Brexit ID cross-border arrangements were explicit, which allowed for countertrading with the connecting markets via IC capacity holders. If GB would also join the SIDC, it is uncertain (both from legal and regulatory perspectives) whether countertrading in the ID timeframe between GB and the connecting markets would still be possible and how it could be implemented efficiently.<sup>113</sup> As countertrading would take place in parallel with the SIDC, measures would need to be put in place to ensure that subsequent SIDC trades do not unwind the countertrades.

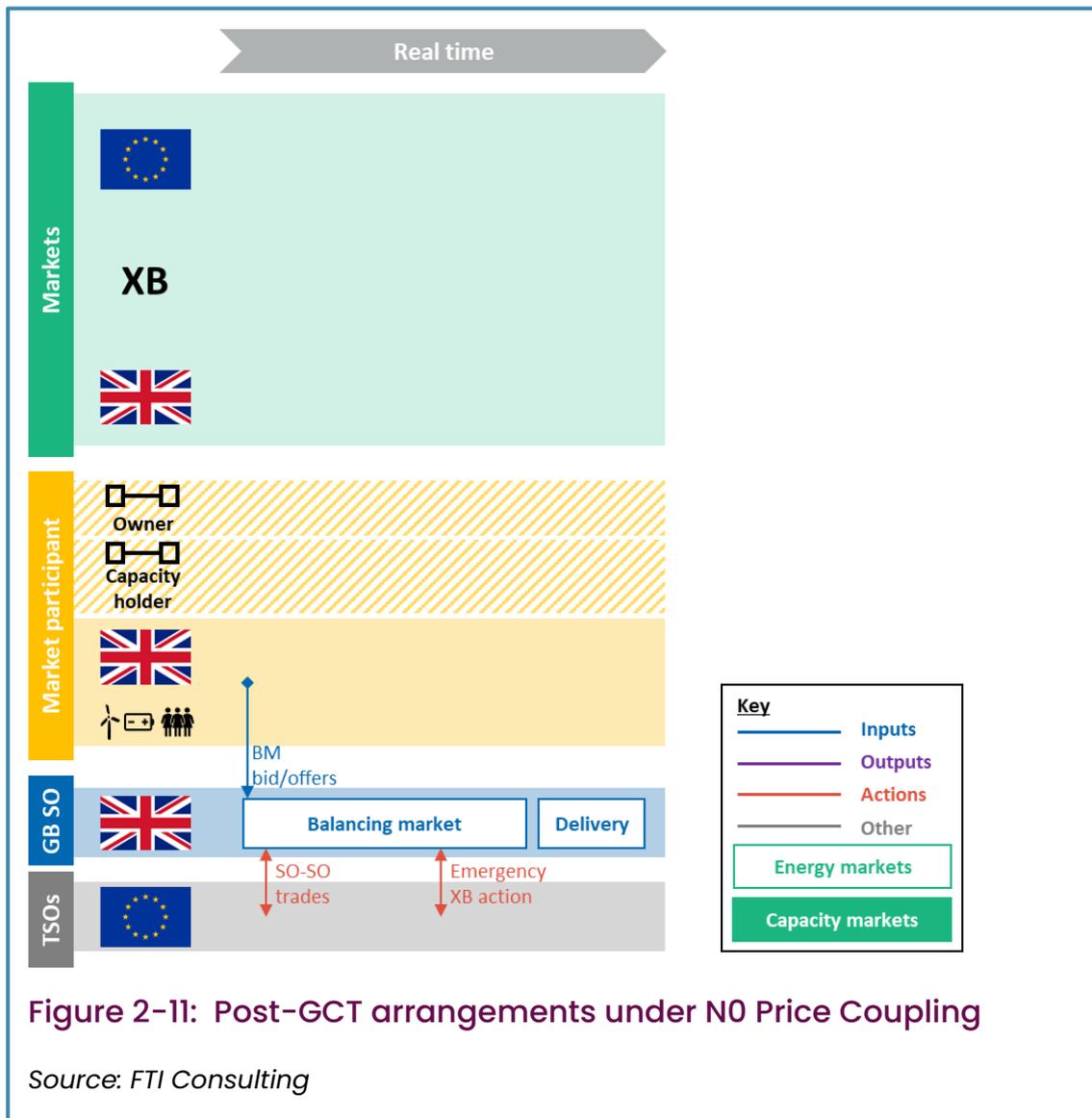
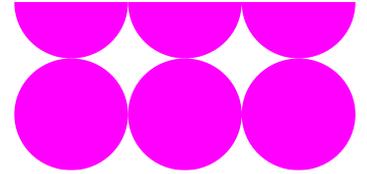
### Post-gate closure time

2.48. As shown in Figure 2-11, Price Coupling would have no impact on the post-GCT arrangements. We assume that the current arrangements, in which NESO takes control of balancing through the BM and can adjust or reverse flows on ICs through SO-SO trades and emergency services (see ¶12.19) would not change.

2.49. We further assume that cross-border BMs would need to be developed to be compatible with EU balancing platforms. As discussed in ¶12.20, NESO has previously considered various options for this.

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<sup>113</sup> Countertrading in the IDM currently in place between DK1 and Germany (TenneT) ([link](#), [link](#)). However, it is unclear whether such arrangement would easily be replicated for GB and the relevant connecting European market.



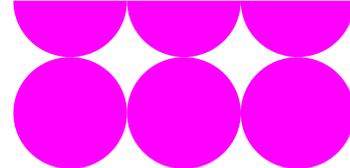
# 3.N1: Self-scheduling with national wholesale pricing and an extended gate closure time



In the previous chapter, we explained how each type of cross-border trading arrangement would work under N0 (self-scheduling with national wholesale price and 1-hour GCT). In this chapter, we discuss how this would be impacted by an extension of wholesale GCT beyond 1 hour. We first describe more generally the implications and rationale for an extended GCT, before discussing each type of cross-border trading arrangement (Status Quo, MRLVC and Price Coupling) in turn. We assume that the wholesale GCT would at most be extended by a few hours (but not as long as, say, 24 hours), with the implication being that the extended wholesale GCT would not impact the functioning of the GB DAM. Therefore, when discussing the various cross-border arrangements we focus only on the implications of the NI market design in the ID and post-GCT timeframes.

### General implications of and rationale for an extended gate closure time

- 3.1. By moving the wholesale GCT further ahead of delivery, e.g. more than one hour, market participants would be required to close their contractual positions (and submit their FPN earlier than the Status Quo (N0)). An earlier wholesale GCT would have two major impacts:
  - It will likely lead to larger and more frequent differences between the contracted generation/demand and metered generation/demand. BSC Parties would be able to adjust their positions via the IDMs, but this would not be as close to delivery as under N0. Rather than leaving most generation and load forecasting (and hence balancing supply and demand at GB-wide level) to the market, NESO would take over a more significant part of that role between the earlier GCT and delivery. The relative importance of NESO versus the market in balancing supply and demand would be proportional to the length of the extension of the GCT (with an earlier GCT giving a greater role to NESO).
  - It can give NESO the opportunity to initiate redispatching actions earlier ahead of time, e.g. allowing units with longer ramping times to be used, without running the risk that ID trades would unwind those instructed redispatching actions.



3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.2. While NESO forecasts generation and load for various purposes as well under N0 (e.g. reserve dimensioning, analysis to countertrade on ICs before the GCT etc.), with an extended GCT the impacts of NESO's forecasts on the final dispatch would likely increase. Concretely, by extending the wholesale GCT, the responsibility to adjust the schedule close to delivery in response to changes in supply and demand conditions is transferred from market participants to NESO. The extent to which this responsibility is transferred, e.g. self-balancing is replaced by "central balancing", depends on the extent to which the GCT moves forward.
- 3.3. Transferring the responsibility to adjust schedules ahead of delivery from market participants to NESO might lead to a system cost increase to manage energy imbalances. One argument is that market parties, compared to NESO, would have more information about the portfolio of assets and/or customers they manage and, as such, would be able to provide better forecasts. Further, extending the GCT would mean that portfolio-bidding is not allowed as close to delivery compared to under N0. Some stakeholders argue that portfolio-bidding is beneficial over unit-based bidding as not all technical parameters of thermal units can be accurately represented in unit-based bidding formats.<sup>114</sup> Another, potentially more controversial argument, is that market parties would provide better forecasts because they have stronger commercial incentives to improve forecasting. Market parties face the volatile cash-out price when misforecasting and improvements in forecasting would reduce the risk of exposure to imbalance charges. In contrast, NESO's objective in performing forecasting would not be commercially driven, but rather driven by a combination of security of supply and reputational concerns. This can potentially lead to more conservative forecasts by NESO (compared to market participants) and increased imbalances to manage closer to delivery. This would likely imply needing costlier balancing actions compared to a situation where the imbalance was resolved earlier. To the extent that there is merit in this argument, it suggests that NESO would need to be exposed to adequate incentives to mitigate this concern.

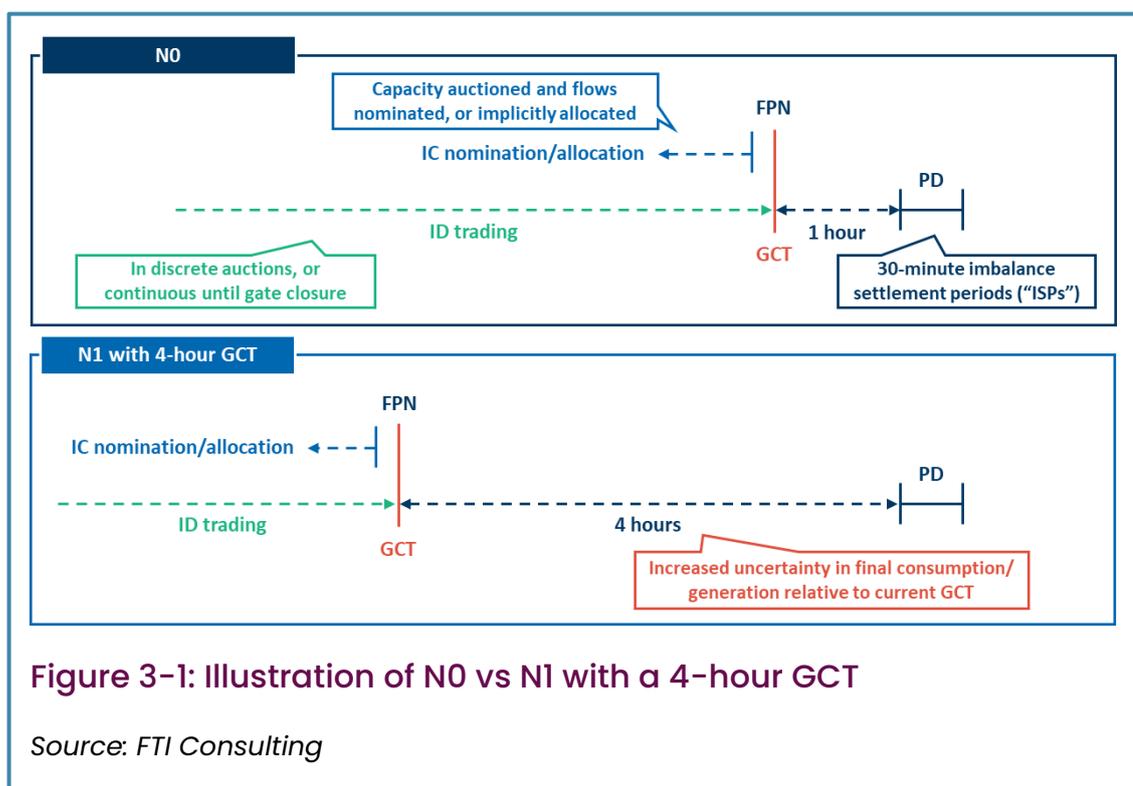
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<sup>114</sup> Unit-based bidding formats are in place for balancing mechanism units ("BMUs") participating in the post-GCT BM.

3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.4. On the other hand, NESO having the opportunity to start redispatching earlier might lead to system cost savings. NESO would have access to a wider pool of resources to resolve transmission constraints (e.g. units with a significant ramping and/or start-up times) and might be able to better optimise the usage of batteries in the BM as the optimisation horizon is longer. In addition, an extended GCT could allow NESO to exploit more synergies between the rescheduling of assets to resolve energy imbalances ahead of delivery (due to changes in supply/demand conditions) and the need to resolve transmission constraints (resulting from the wholesale market schedule at GCT).
- 3.5. The net impact of an extended GCT on GB system costs, reflecting the two factors above, would need to be empirically tested. In particular, it would be important to examine the trade-off between potentially better forecasting performance by market parties and the lack of visibility over transmission constraints that these market parties have, relative to NESO's potentially decreased forecasting performance coupled with full visibility over transmission constraints and a wider pool of resources to resolve transmission constraints.
- 3.6. With an extended wholesale GCT in place the nominations of IC capacity (under an explicit arrangement) or the allocation of IC capacity (under an implicit arrangement) likely also will have to occur earlier, e.g. at least at the same time as the extended wholesale GCT or before. Moving the moment of the nomination/allocation of IC capacity earlier will impact the extent to which the FPN of the IC, indicating its schedule at the wholesale GCT, is different from the metered flow on the IC in RT. Here we refer to the metered flow on the IC in RT as the physical dispatch ("PD") of the IC.
- 3.7. Figure 3-1 below indicates a potential implementation of NI, with a wholesale GCT occurring 4 hours before the start of the PD, versus the current design, with a GCT occurring 1 hour before the start of the PD.

3. N1: Self-scheduling with national wholesale pricing with an extended GCT



3.8. Differences between the FPN and PD can occur due to three reasons:

- Unexpected failure (or tripping) of the IC which will result into imbalance charges; or
- a change from the FPN instructed via the BM by NESO, for which there can be again two main reasons:
  - a change in the supply-demand energy balance at system-wide level due to forecast errors or outages of BSC parties ("non-flagged actions"); or
  - a need to reschedule the ICs to accommodate intra-GB transmission constraints, which are not reflected under a national market design ("flagged actions").
- a change from the FPN instructed by the connected TSO.

### 3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.9. An extended GCT in GB could lead to an increased divergence between the FPN and PD of ICs mostly driven by two factors: (i) an increased risk that the tripping of an IC occurs after the GCT than before the GCT (though this is likely to be a minor effect); and, (ii) a potential increase in the need to reschedule ICs to resolve energy imbalances<sup>115</sup> (non-flagged actions).
- 3.10. Whether an extended wholesale GCT impacts the extent to which NESO would instruct ICs to reschedule to resolve intra-GB transmission constraints (flagged actions) is ambiguous. The total volume of transmission constraints is not expected to change (on average) by moving the wholesale GCT to an earlier point in time.<sup>116</sup> However, as mentioned above, an earlier wholesale GCT allows NESO to potentially deploy more cost-efficient redispatch to resolve transmission constraints. Hence, the total cost of resolving transmission constraints could be lower. Whether NESO would rely more on the rescheduling of ICs to resolve transmission constraints with an extended GCT compared to the current GCT is uncertain and also depends on agreements with the connecting TSOs.

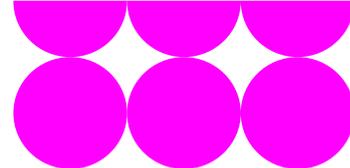
## NI Status Quo

- 3.11. In the following sections we describe the cross-border trading arrangements for GB ICs for the IDM and the post-gate closure timeframe. Where relevant we refer to the three categories of GB ICs, e.g. NSL, GB-Irish ICs, and NWE ICs, as their respective arrangements differ.
- 3.12. We assume that capacity restrictions and countertrading would still be possible in the ID timeframe as under N0. However, given that they would still take place before GB wholesale GCT, they would become less important when extending the GB wholesale GCT (compared to the current GCT). This is because with an extended GCT, NESO would likely rely more on options to reschedule ICs after the GB GCT, rather than choosing to take actions (such as capacity restrictions and/or countertrading) prior to the GB GCT. As discussed in detail in the subsection covering the post-GCT timeframe, relying on rescheduling IC after GCT would depend on the willingness of the connected TSO to redispatch the IC and the actual cost of such actions compared to the cost of countertrading.

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<sup>115</sup> The energy imbalances are potentially higher under an extended GCT for reasons described earlier in ¶13.3.

<sup>116</sup> Unless there was evidence that a different GCT would lead to systematic differences in wholesale trading strategies.



## Intraday market

3.13. An extended wholesale GCT can significantly impact the organisation of the ID cross-border trading under the Status Quo arrangements. Concretely, we see two direct impacts on the Status Quo cross-border trading arrangements:<sup>117</sup>

- An increase in the time lag between: (i) the GCT of the explicit ID IC auctions or implicit ID auction (for ICs between GB and I-SEM);<sup>118</sup> and, (ii) the start of the MTU that are covered by the respective auctions. Everything else being equal, this would mean that potentially fewer MTUs can be covered by the ID IC auctions.
- An increase in the time lag between: (i) the nomination GCT for the ID IC rights; and, (ii) the start of the relevant MTU. This is only relevant for the explicit ID auctions for the NWE ICs.

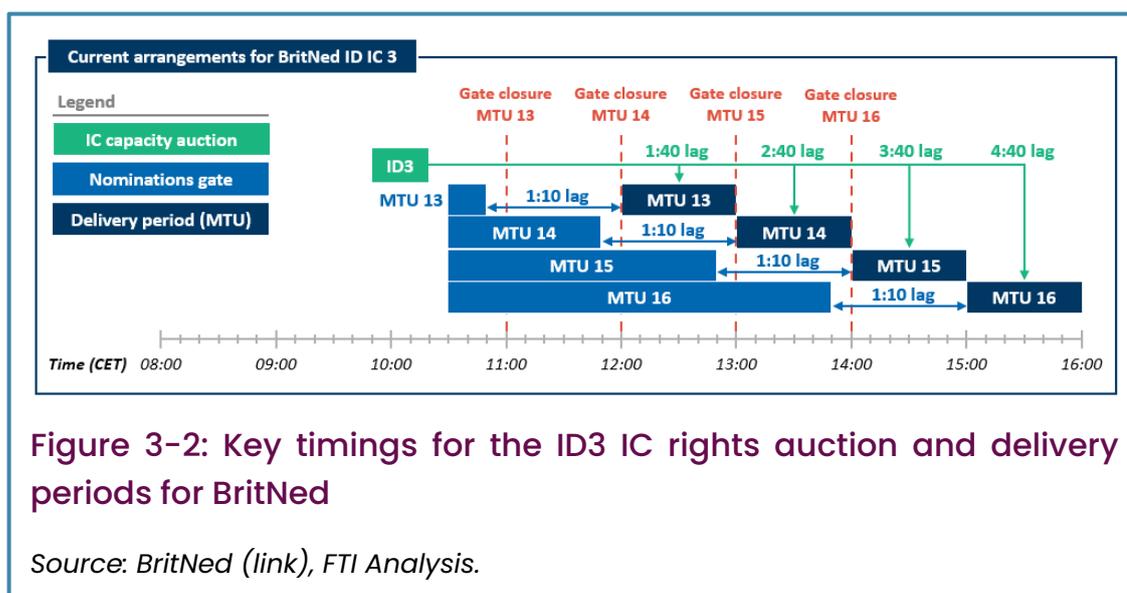
3.14. In what follows, we provide an example based on the third ID IC auction (“ID3 IC auction”) for BritNed. However, the general logic applies to all ID IC explicit auctions. Where relevant we highlight where there would be different implications for the implicit ID arrangement on the GB-Irish ICs.

3.15. For the BritNed ID3, orders can be submitted between 9:50–10:20 CET, covering the MTUs from 12:00–16:00 CET (4 hourly MTUs), as shown in Figure 3-2 below. This means that there is a 1h 40 min time lag between the ID3 auction closure time and the start of the first MTU (shown as a green arrow in Figure 3-2). The time lag increases by an hour for the subsequent MTUs (e.g. there is a 2h 40 min time lag for MTU 14, etc.).

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<sup>117</sup> We do not cover NSL as currently there are no ID arrangements in place for NSL.

<sup>118</sup> The two ID auctions that couple GB with the I-SEM start at 17:30 D-1 and 08:00 D and cover all MTUs and 11:00–23:00, respectively ([link](#)).



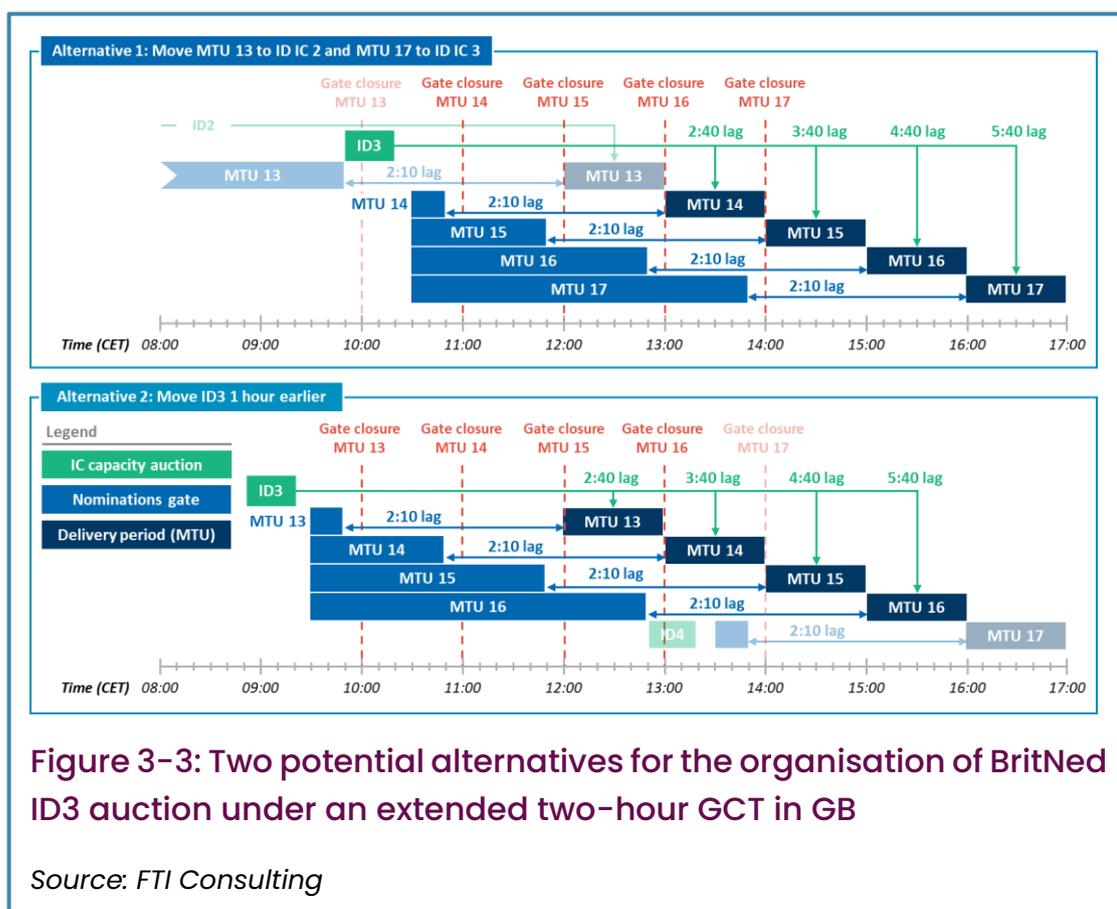
3.16. If the wholesale GCT was extended by, for example, one hour, this would increase the time lag between ID3 closure time and the start of the first MTU to 2h 40 min. This means that ID3 could now only cover the MTUs from 13:00 (2h 40min after the ID3 closure at 10:20) – that is, as shown in the figure below, MTU 13 can no longer be covered by ID3. As illustrated in Figure 3-3 below, there are two potential options to deal with this:

- Option 1:<sup>119</sup> Change the coverage of each ID IC auction. ID3 would instead cover MTUs from 14:00 up to and excluding 17:00 CET (that is, MTU 14 to MTU 17). MTU 13 would instead be covered by ID2; or
- Option 2:<sup>120</sup> Reschedule the time of the ID IC auctions. The ID3 auction for BritNed, for example, could be organised one hour earlier, e.g. allowing for orders to be submitted between 8:50–9:20 CET to be able to cover the same MTUs as currently is this case.

<sup>119</sup> Depending on the extension of the wholesale gate closure Option 1 might not be feasible for MTU 1 and would require the first ID IC auction to be moved forward (as under Option 2).

<sup>120</sup> Alternatively, MTU 17 might not be included in ID3, but more ID IC auctions can be organised. We do not cover this option here.

3. NI: Self-scheduling with national wholesale pricing with an extended GCT



3.17. The same issue, e.g. possibly having to move the ID IC auction earlier or possibly having the ID IC auction covering different MTUs, would occur for the implicit ID arrangements between GB and I-SEM. This would be especially relevant for IDA 2 which takes place at 8am and covers all MTUs from 11am onwards.<sup>121</sup>

<sup>121</sup> IDA 1 takes place at 17:30 D-1 for all MTUs of the next day and would likely be less affected by an extended wholesale GCT in GB.

3. NI: Self-scheduling with national wholesale pricing with an extended GCT

3.18. The nominations period for all MTUs covered by the BritNed ID3 opens at 10:30 CET (see Figure 3-2) 10 min after the IC capacity auction has closed. During this period, IC capacity holders can secure an ID price spread between the GB ID market and the SIDC<sup>122</sup> and subsequently nominate the ID IC capacity. Taking the first MTU (MTU 13) as an example:

- The nominations period for MTU 13 lasts for 20 minutes and closes at 10:50 CET. This is 30 min after the closure of ID3 (10:20 CET);
- The GB wholesale GCT for MTU 13 takes place 10 minutes after, e.g. at 11:00 CET; and
- MTU 13 starts at 12:00, 1 hour after the wholesale GCT.

3.19. Under either alternative shown in Figure 3-3 above, the nomination GCT would need to be extended by at least 50 minutes to allow it to occur before the wholesale GCT. We assume that the time lag between IC nomination GCT and the GB wholesale GCT would continue to be 10 minutes.

3.20. Overall, an extension of the GB GCT would require ID IC auction schedules to be revised and adapted by relevant IC owners to ensure that the right MTUs are captured. This could vary across different ICs depending on their preferences.

3.21. In the following subsections, we consider the impact of an extended wholesale GCT on: (i) the valuation of explicitly auctioned ID IC capacity; and (ii) the utilisation of the capacity of explicitly auctioned ID IC capacity or implicitly allocated ID IC capacity.

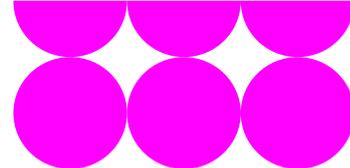
*Impact of NI on the valuation of explicitly auctioned ID IC capacity*

3.22. In the case of a continuous IDM, the value of ID IC capacity rights is based on the expectation of the price spread between the GB ID market and the SIDC that can be captured by nominating the ID IC right. We see two ways that an extended wholesale GCT could impact the expectation of this price spread and hence the value of ID IC capacity rights:

- An increase in the time period over which ID prices need to be forecasted that is of relevance for the valuation of the ID IC capacity rights (“ID price forecasting horizon”);

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<sup>122</sup> The IDCZGCT is currently 1-hour (except for the Finnish-Estonian bidding zone border at the time of writing) but national wholesale GCTs for European markets can be later. For simplicity, we disregard the national wholesale GCT.



### 3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- A need for ID IC capacity holders to trade in the continuous ID market of the connecting market further away from the GCT of the connecting country. The liquidity in the continuous ID market can be lower in MTUs that are further away from the wholesale GCT in the connecting country.<sup>123</sup>

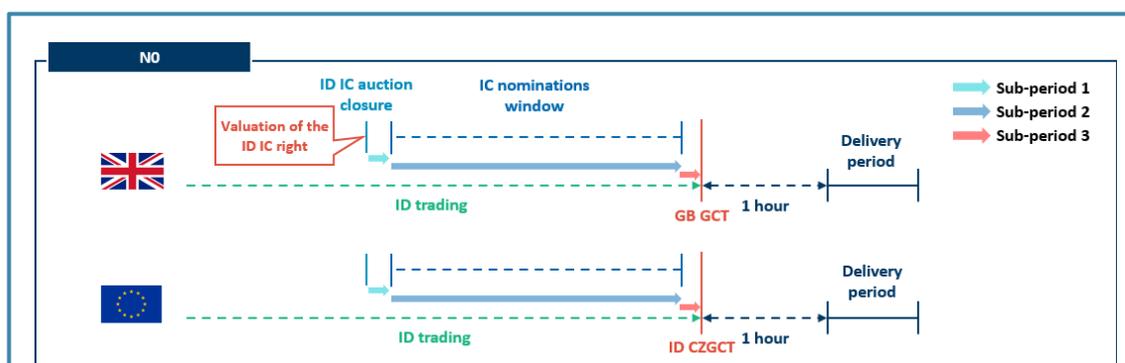
3.23. The period that is of relevance for the expectation of the ID price spread is the period an ID IC capacity holder can secure an ID spread and hence earn revenues from its acquired ID IC right. This period occurs between: (i) ID IC auction GCT; and (ii) the wholesale GCT at the GB and European side. This period can be broken down in three sub-periods as illustrated in Figure 3-4 below:

- **Sub-period 1:** an IC capacity holder can take a position in both relevant ID markets but not yet nominate the ID IC right. This period is quite short and still relatively far from the wholesale GCT where most ID trading occurs. Therefore, it is likely that this sub-period is not the most relevant.
- **Sub-period 2:** an IC capacity holder can take a position in both relevant ID wholesale markets and nominate the ID IC right. This is likely the most relevant period for the valuation of the ID IC right as securing an ID spread in this period and subsequently nominating the ID IC right implies a certain revenue from the ID IC right nomination.
- **Sub-period 3:** an IC capacity holder can take a position in both relevant ID wholesale markets but must have already nominated the ID IC right in a prior period. This is likely a riskier strategy compared to taking a position in the relevant ID wholesale markets during sub-period 2 as the ID price spread is not known at the time of the ID IC nomination.

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<sup>123</sup> For example, 40-60% of all continuous trade in SIDC occurs in the last two hours before delivery. See Figure 50 in All Nemo Committee, 2024. CACM Annual Report 2023 ([link](#)).

3. N1: Self-scheduling with national wholesale pricing with an extended GCT

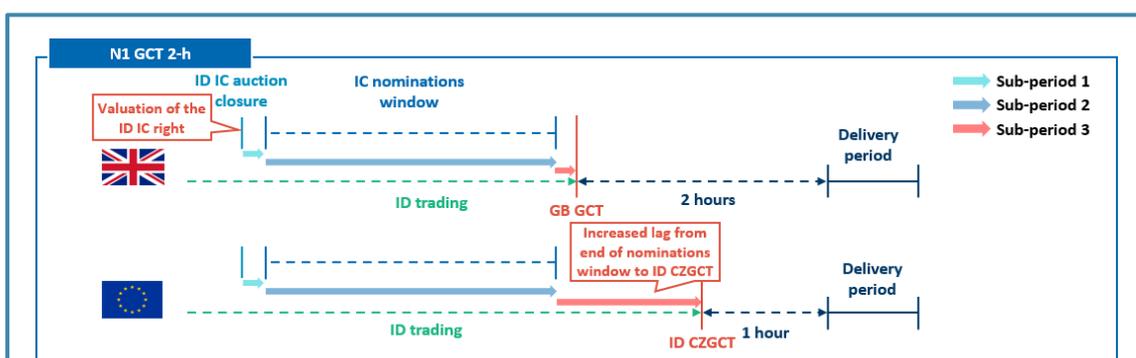


**Figure 3-4: Relevant periods for the valuation of ID IC capacity rights under N0**

Source: FTI Consulting

3.24. As illustrated in Figure 3-5 below, when extending the GB wholesale GCT:

- The time lag between the ID IC auction closure and the delivery period increases both for the GB and European market while the wholesale GCT in the European market does not change. Consequently, the length of the period between the end of the IC nomination window and the wholesale GCT on the European side (sub-period 3) has increased.
- However, the length of the period between the ID IC auction closure and the start of the IC nomination window (sub-period 1) does not change. Similarly, the length of the IC nomination window (sub-period 2) does not change.



**Figure 3-5: Relevant periods for the valuation of ID IC capacity rights under N1 with 2H GCT**

Source: FTI Consulting

3. NI: Self-scheduling with national wholesale pricing with an extended GCT

3.25. Considering the increase in the length of sub-period 3 on the European side, the ID price forecasting horizon becomes longer due to an extension of the GB wholesale GCT. An increase of the ID price forecasting horizon increases uncertainty and thus can impact the valuation of the ID IC right. The impact depends on the trading strategies adopted by market participants:

- To the extent that ID IC capacity holders opt to secure an ID spread during the nomination window (e.g. during sub-period 2), an extension of the GB wholesale GCT would have limited impact on the valuation of ID IC rights.
- To the extent that ID IC capacity holders opt to nominate the ID IC right before securing an ID spread, an extension of the GB wholesale GCT would have an impact on the valuation of ID IC rights. In that case ID IC capacity holders would take an ID position in the connecting market after the GB wholesale GCT (e.g. during sub-period 3). In general, given that this strategy increases the risk of the market participant holding capacity in a counterintuitive direction, we expect that this would lead to a negative impact on the valuation of the ID IC rights (as prospective buyers of the ID IC capacity would be pricing in the additional risk). However, the size of this impact is uncertain.

3.26. Overall, based on the above, the impact of the extended GB wholesale GCT can be expected to be relatively limited as relying on ID price changes after the ID IC nomination period (sub-period 3) is likely a risky strategy. The ID price forecasts that seem more relevant for the ID IC rights valuation can be expected to be the ID prices during sub-period 2 for which the forecast horizon does not change under NI.

3.27. However, so far, we have assumed that the liquidity of the ID market is independent of how far ID trade from the wholesale GCT occurs. Currently the majority ID trade occurs close to the wholesale GCT (see Footnote 123). The current GCT in GB is relatively similar to the GCT in the connecting EU markets. This means that under N0 the ID IC nomination period materially overlaps with the period in the connecting European ID market with the highest ID liquidity.

3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.28. If the GB wholesale GCT was extended, simultaneously the ID IC nomination period would also be pushed to an earlier point in time (see Figure 3-5 above). As such, there is a risk that the overlap between the ID IC nomination period (sub-period 2 in Figure 3-5) and the period in the connecting European ID market with the highest ID liquidity may be significantly reduced (unless the liquidity in the SIDC would move further away from the IDCZGCT). Concretely, the GB continuous ID market would see highest liquidity at around T minus 2-3h, while the SIDC would see highest liquidity at around T minus 1-2 hours. Decreased liquidity could potentially lead to more difficulties for market parties to (i) forecast the ID price in the connecting market<sup>124</sup>; and/or (ii) find a counterparty to execute trades with. Consequently, this might negatively impact the valuation of the ID IC right, as market participants would need to price in both risks (e.g. the reduced confidence in the price forecast and the risk of not being able to execute the trade). This can be especially problematic when the GCT in GB would be extended significantly (e.g. more than 2 hours) and for connecting European markets with limited liquidity (e.g. Belgium vs Germany).
- 3.29. The extent of decrease in liquidity is an empirical question. It is possible that some liquidity currently observed in the EU market close to the IDCZGCT could shift to an earlier time, to coincide with the peak liquidity in the GB wholesale market (e.g. if there was a large volume of cross-border trade and EU market participants were interested in trading just before the GB wholesale gate closure), but this is uncertain and would need to be examined further.
- 3.30. Overall, considering all the impacts discussed above, we expect that an extended wholesale GCT in GB likely negatively impacts the valuation of ID IC rights, though the quantum of this effect would need to be empirically tested.

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<sup>124</sup> Less liquidity in the continuous IDM can lead to more unpredictable discrete price movements.

### *Impact on utilisation of the IC under explicitly auctioned ID IC capacity and implicitly allocated ID IC capacity*

#### *Impact under explicitly auctioned ID IC capacity*

- 3.31. An extended wholesale GCT might, to a limited extent, impact the commercial utilisation of the ICs. IC capacity holders are not exposed to the risk of forecast errors when they nominate flows after they secured an ID spread in the continuous ID trading (sub-period 2 in Figure 3-5.). As such, assuming all ID IC capacity holders would secure their ID spread before nominating the ID IC capacity right, no flows against the obtained ID price differential are expected.<sup>125</sup> However, it is possible that ID IC capacity holders nominate their ID IC right while only securing an ID spread after the nomination window (sub-period 3 in Figure 3-5). In that case, counterintuitive flows are possible.<sup>126</sup>
- 3.32. For example, an ID IC capacity holder in the direction from GB to France might buy electricity in the GB ID market at £12/MWh and subsequently nominates the ID IC capacity. At that moment in time, the French ID wholesale price is around £20/MWh but the ID IC capacity holder decides to not yet sell electricity in the French bidding zone. The ID IC capacity holder expects it will be able to sell in the SIDC (French bidding zone) at a higher price closer to the IDCZGCT. However, due to a sudden change of system conditions in the French power system, the French ID price moves to £5/MWh. The ID IC capacity holder would likely still sell the electricity at £5/MWh (given that the holder has already nominated the IC capacity in the direction from GB to France). This is because, if they did not sell electricity in the French market at £5/MWh, the ID IC capacity holder would be exposed to potentially high imbalance charges as it has an unbalanced position in the French bidding zone. As a result of the unanticipated movement in the ID price in the French market, the IC flows would be counterintuitive, and the IC capacity holder's cross-border trade would be loss-making.
- 3.33. As sub-period 3 (during which this is possible) is longer under NI (at least on the European side), it might be that counterintuitive flows are more likely. However, we expect this impact to be limited as this would be a risky strategy for an ID IC capacity holder.

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<sup>125</sup> Note that in a continuous IDM the spread that each ID IC capacity holder secured when nominating the ID IC right can be different.

<sup>126</sup> Another reason for counterintuitive flows can be ramping limits on ICs.

3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.34. The potential lower liquidity on the European side during the ID IC nomination window (sub-period 2) might also impact on the commercial utilisation of the ID IC capacity rights. Given the IC traders are facing lower (concurrent) wholesale market liquidity, there may be fewer wholesale positions that can be taken (e.g. lack of counterparty). This can lead to a lower volume of ID IC capacity sold (and thus lower volume of IC capacity nominated).
- 3.35. Above we discussed the commercial utilisation of an ID IC capacity right from the perspective of an individual ID IC capacity holder, however, an extended wholesale GCT can also have wider system impacts on how ID IC capacity rights are scheduled. The main driver of the system impact is that it is possible that the ID price differential at the wholesale GCT – which reflects the most up-to-date system conditions (excluding transmission constraints) – is different than it was at the time the IC capacity holder nominated its ID IC capacity. If such situation would occur, from a system perspective, it would have likely been more optimal if the IC was nominated closer to delivery (and hence based on the ID price spread that better reflects system conditions).
- 3.36. The likelihood of the ID price differential at the wholesale GCT being different than it was at the time the IC capacity holder nominated its ID IC capacity is higher under NI compared to N0. As shown in the example for the BritNed ID3 auction (Figure 3-2) under N0, the current period between the closure of the nominations period and the GB wholesale GCT is 10 minutes for all MTUs. The time lag remains at 10 minutes with an extended GB GCT under both options shown in Figure 3-3. However, the period between the end of the nomination window and the wholesale GCT can become much longer at the European side. As such, there can be a negative impact on the IC's scheduling.

*Impact under implicitly allocated ID IC capacity between GB and I-SEM*

- 3.37. Under an implicit arrangement as between GB and I-SEM, there is neither under N0 nor NI a risk for counterintuitive flows due to trading decisions from market participants.
- 3.38. However, the concern of a system impact on the IC schedule due to an extended wholesale GCT in GB remains under an implicit arrangement. The reason being that the implicit auction would likely have to be moved further away from the I-SEM gate closure. As such, the ID implicit auction will take place at a moment when less information about the final system conditions is known. Hence, there is higher likelihood that at the I-SEM GCT the IC is not scheduled in line with the most up-to-date system conditions (excluding transmission constraints).

### 3. NI: Self-scheduling with national wholesale pricing with an extended GCT

3.39. Market participants will be able to trade in the I-SEM continuous ID market up to the current GCT of 1-hour (in line with the IDCZGCT). Due to the longer time lag between the ID implicit auction and the I-SEM wholesale GCT, the I-SEM continuous ID price near the I-SEM GCT is expected to diverge more from the ID price determined by the implicit ID auction compared to under N0.

### Post-gate closure time

3.40. Having an extended wholesale GCT in GB would impact the timing of when ICs could be rescheduled by NESO post-GCT. Currently with the one-hour GCT in place, apart from emergency services, NESO can reschedule ICs via SO-SO trades post GCT (at the least the ICs for which there is an agreement for SO-SO trades). With an extended GCT in place in GB, it would be likely that more of the IC rescheduling instructed by NESO moves from pre-GB GCT to post-GB GCT. This could imply that the role of SO-SO trades increases at the expense of countertrading (at least the way it is currently organised).

3.41. The extent to which an increased trend of SO-SO trading would materialise also depends on the wholesale GCT of the connecting EU market. Here we assume that the GCT of the connecting markets remains unchanged: one hour for the IDCZGCT, and possibly a later (national) GCT for trade within a European bidding zone. In that case, two scenarios can be thought of:

- SO-SO trade is directly possible after the GB GCT, thus while the ID market is still open in the connecting market; or
- SO-SO trade is only possible after wholesale GCT in the connecting market.

3.42. Under the first scenario, the potential issue is that ID trades in the connecting zone done when SO-SO trades are executed could lead to internal grid issues within the relevant connecting zone which were not anticipated at the time of the SO-SO trade.<sup>127</sup> Considering this, the EU TSO would most likely refuse to engage with the GB SO in SO-SO trades until their wholesale GCT. We therefore do not consider the first scenario to be very likely.

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<sup>127</sup> SO-SO trade would take place at a time when the EU TSO does not yet have full knowledge of how its resources will self-schedule.

### 3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.43. Under the second scenario, NESO would have to anticipate whether the connecting TSO would approve an SO-SO trade closer to delivery (and if yes, the cost of redispatching ICs) when it can already redispatch other assets to resolve internal congestion (which is likely one of the key arguments to have an extended GCT in GB as discussed in ¶13.1). This uncertainty might lead to avoiding reliance on SO-SO trades, which could mean that potentially more expensive (intra-GB) redispatch actions would have to be relied on to relieve internal GB congestion. However, the bigger point is that not being able to effectively use the extended GCT to (re-)schedule a critical asset class such as ICs would render the extended GCT in GB a partially fruitless exercise.
- 3.44. Under the second scenario an alternative would be to keep countertrading in place after the GB GCT up to the wholesale GCT in the European SIDC (“EU-only countertrading”). NESO would trade with IC capacity holders who can still adapt their position in the relevant connecting European market after the GB wholesale GCT. From the European perspective this might be problematic as European TSOs would no longer be able to countertrade in the GB market. Instead, the European TSOs would need to revert to SO-SO actions. If there was limited willingness from European TSOs to allow countertrading after the GB GCT, the benefits case of an extended GCT would be significantly reduced.

## NI MRLVC

### Intraday market

- 3.45. We do not assume the introduction of MRLVC in ID while the existing ID arrangements under NI Status quo could continue to be in place, hence, the impact of an extended wholesale GCT would be the same as that discussed under NI Status Quo.

### Post-gate closure time

- 3.46. As above, the same impact of an extended wholesale GCT can be expected as discussed under NI Status Quo.

## NI Price Coupling

### Intraday market

- 3.47. Assuming that GB would need to comply with the IEM Regulations under Price Coupling, it would mean that IDCZGCT would need to be at most one hour ahead of delivery, and from the 1st of January 2026 the IDCZGCT shall not be more than 30 minutes ahead of delivery.<sup>128</sup> This would imply that under Price Coupling an extended wholesale GCT (NI) is not possible. Shortening the GB wholesale GCT to comply with the IEM Regulations would likely be problematic under a national wholesale market design due to the large volume of BM actions required post GCT.
- 3.48. It could be that an exemption from the requirement to have a 30 minutes IDCZGCT is approved, and an alternative approach is agreed to integrate the GB ICs in the SDAC without the need for GB to be governed by the relevant IEM.<sup>129</sup> In that case, the position of the GB-EU/Norway ICs would need to be firm at the time of the GB wholesale GCT. From that point onwards, ID trade would still be possible in the SIDC in the EU/Norwegian markets but not anymore in GB. We do not examine the feasibility of a potential exemption further in this report.

### Post-gate closure time

- 3.49. If NI were possible under Price Coupling, it is likely that the exchange of balancing energy between GB and the connecting zones, via EU balancing platforms or other initiatives, would technically still be feasible. However, as balancing processes in GB may become increasingly divergent from balancing processes in the connecting EU zones (having a later GCT), this could lead to greater complexity in the exchange of balancing energy (e.g. different products could be developed and different timings of the GCT for balancing energy bids).

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<sup>128</sup> See Art. 5(1) of Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design ([link](#)).

<sup>129</sup> A coalition of industry parties ([link](#)) proposes to allow the inclusion of ICs to the GB market (and North Sea hubs) in the SDAC allocation process, but as a distinct service extension. It is argued that by doing so the GB market would not become a member of SDAC but would instead procure a clearly defined (and limited) service provided by SDAC which remains under EU control.

### 3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- 3.50. Similarly, as discussed under NI Status Quo, having an extended GCT in GB would impact the timing of when ICs could be rescheduled by NESO post-gate closure. Other than under an emergency, currently with the one-hour GCT in place NESO can reschedule ICs via SO-SO trades. With an extended GCT in place in GB, it would be likely that more of the IC rescheduling instructed by NESO moves from pre-GB to post-GB wholesale GCT.
- 3.51. However, unlike in NI Status Quo, countertrading (after the GB GCT but before the GCT in the connecting market, if possible) would not be done with IC capacity holders. Whether NESO would be able to countertrade in the SIDC (directly or via a third party) is a legal and regulatory question which we do not address in this report.<sup>130</sup>

## NI Conclusions

- 3.52. In our discussion above, we have assessed the potential feasibility of combining three selected cross-border arrangements (Status Quo, MRLVC and Price Coupling) with the NI market design (which features an extended GB wholesale GCT). In doing so, we have not sought to comment on the preferred option(s) for cross-border trading arrangements nor on the desirability of the NI design itself. Rather, we have taken the NI market design as given and examined how different cross-border trading arrangements could be developed or adapted in order to be compatible with the NI market design.
- 3.53. We assume that the wholesale GCT would at most be extended by a few hours (but not as long as, say, 24 hours), with the implication being that the extended wholesale GCT would not impact the functioning of the GB DAM. Therefore, NI market design only interacts with cross-border trading arrangements in the ID and post-gate closure timeframes.
- 3.54. We find that, with suitable adaptations, NI market design can be made compatible with the Status Quo cross-border arrangement although trade-offs arise. We do not assume an ID arrangement under MRLVC, so there are no changes under NI relative to N0 other than for the post-gate closure timeframe. NI is found to be incompatible with Price Coupling if Price Coupling would imply that GB needs to abide by all relevant IEM Regulation. We summarise our conclusions below:

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<sup>130</sup> Technically it would likely be possible as countertrading in the ID timeframe is currently in place between DK1 and Germany (TenneT) ([link](#), [link](#)).

3. NI: Self-scheduling with national wholesale pricing with an extended GCT

- (i) A general implication of NI is that NESO would take over a greater part of the responsibility of forecasting generation and load from the market compared to Status Quo market design arrangement (N0). This might lead to a system cost increase to manage energy imbalances but would also give NESO the opportunity to start redispatching earlier which, conversely, might lead to system cost savings. The net impact of an extended wholesale GCT on GB system costs, reflecting the two factors above, would need to be empirically tested.
- (ii) NI is compatible with both explicit and implicit ID arrangements under the Status Quo cross-border arrangement. However, the explicit ID IC auctions and implicitly coupled ID auctions would likely have to be moved to an earlier point in time to accommodate the longer wholesale GB GCT. This could negatively impact the valuation of ID IC rights. The extent to which ICs are scheduled (under both explicit and implicit arrangements) in line with ID market prices closest to delivery could also be negatively impacted. The size of this impact is uncertain.
- (iii) Under both the Status Quo cross-border arrangements and MRLVC, NESO would need to be able to: (i) start SO-SO trades before the wholesale GCT in the connecting market; and/or (ii) continue countertrading after the GB wholesale GCT. If there was limited willingness by European TSOs to adopt either of these two options, the benefits case of an extended GCT in GB would be significantly reduced.
- (iv) Assuming GB would need to comply with the IEM Regulations under Price Coupling, it would mean that IDCZGCT would need to be at most one hour ahead of delivery, and from the 1st of January 2026 the IDCZGCT shall not be more than 30 minutes ahead of delivery. This implies that an extended wholesale GCT in GB (NI) is not possible under Price Coupling.

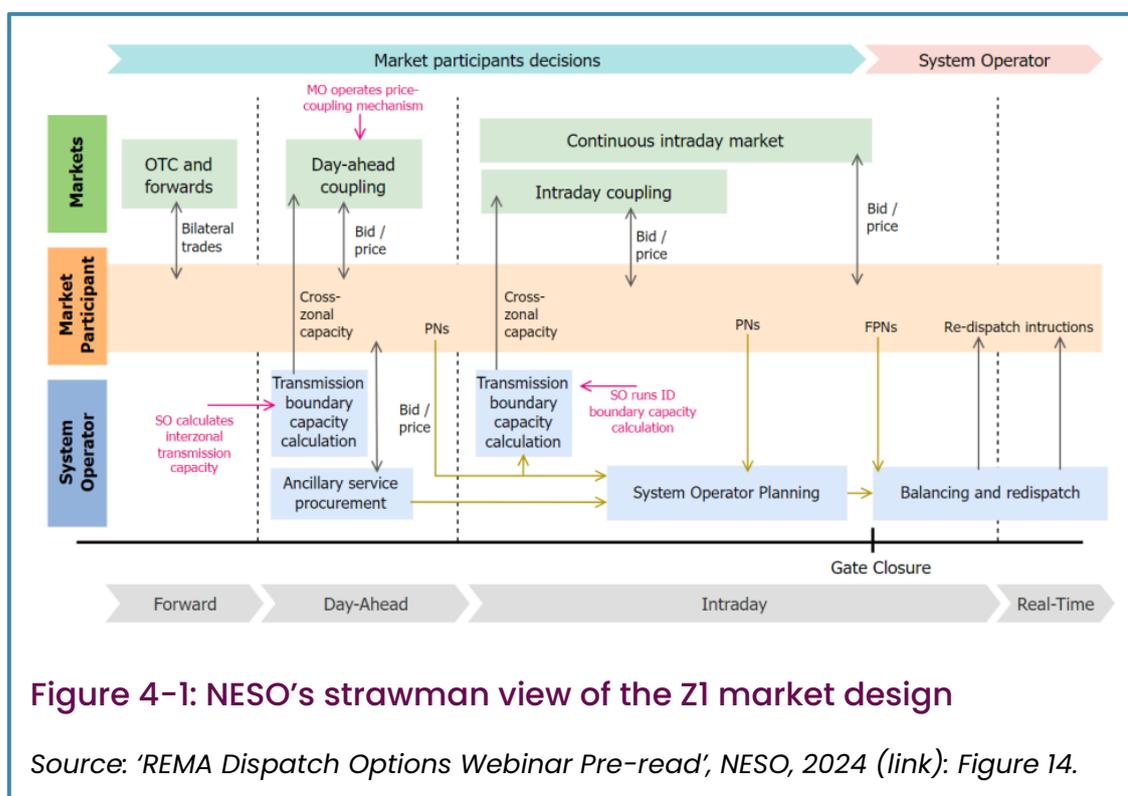
# 4. Z1: Self-scheduling with zonal wholesale pricing



In this chapter we discuss how the Status Quo cross-border arrangements, MRLVC and Price Coupling could potentially operate under the Z1 market design, in which GB retains self-scheduling but moves to zonal wholesale pricing. We start this chapter with a section where we introduce the key market design assumptions under Z1.

## Key market design assumptions

4.1. NESO’s strawman view of the Z1 dispatch model is set out in Figure 4-1 below.



**Figure 4-1: NESO’s strawman view of the Z1 market design**

Source: ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 (link): Figure 14.

4.2. In the remainder of this section, we describe the key assumptions under Z1 market design which are as follows:

- As per N0, market participants self-schedule and bidding would be portfolio based (rather than unit based), however the geographical footprint of a portfolio would be limited by zone. In practice, this means that market participants would no longer be able to directly substitute resources in their portfolio located in different zones without exposing themselves to price risk. However, as discussed below, there are options to manage this risk;
- Bidding formats would remain the same as under the N0 (that is, simple and block bids);
- Market participants only have firm access to the transmission network within their zone, but not outside their zone;

## 4. Z1: Self-scheduling with zonal pricing

- Forward energy contracts can be settled based on zonal wholesale prices or hub prices (e.g. average load-weighted zonal price). OTC trading would be limited to market participants within the same zone unless market parties would obtain cross-zonal PTRs as discussed below;
- Forward GB cross-zonal transmission rights would be implemented in GB to enable market participants to hedge prices across GB zones. These GB cross-zonal rights could be PTRs or FTRs, both of which would be used to hedge the basis risk. Basis risk appears when market participants enter into forward contracts settled on a price different than the zonal price they receive in the wholesale market. Holders of GB cross-zonal PTRs would also be able to nominate cross-zonal flows in GB wholesale markets. There are several detailed design options for the implementation of these GB cross-zonal transmission rights. However, the discussion of these options is outside the scope of this report. For this section, we assume that GB has a well-functioning market for forward transmission rights that provides market participants with sufficient opportunities to hedge inter-zonal price risk;<sup>131,132</sup>
- Zones in GB would be implicitly price coupled with each other in the DA and ID timeframes. The GB DAM would simultaneously clear each zone and, implicitly, the associated cross-zonal capacities based on zonal portfolio bids and available cross-zonal capacity via a Price Coupling algorithm (conceptually similar to EUPHEMIA that performs this function in Europe). Compared to N0, where the outcome of the GB DAM is a single GB national price, under Z1 the outcomes would be a wholesale price for each GB zone, alongside volumes and direction of cross-zonal flows.

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<sup>131</sup> Options include a US-style FTR market, where independent system operators (“ISOs”) sell FTRs, which are then settled against hub prices using the outturn congestion rent. In Europe, a similar approach to the US market is observed in Italy, which uses FTRs settled against the prezzo unico nazionale (“PUN”), a load-weighted average of zonal prices. An alternative option is a Nordic-style exchange traded financial instrument which hedge zonal prices against the unconstrained Nordic system price, known as electricity price area differentials (“EPADs”). See ‘EU’s Electricity Forward Markets’, ENTSO-E, 2022 ([link](#)): page 40.

<sup>132</sup> Depending on the implementation choices made for GB cross-zonal transmission rights, these could also be integrated into the JAO platform. However, this has not been the practice for European countries with zonal arrangements. Italy, Norway, Sweden, and Denmark all have dedicated platforms for their cross-zonal forward products. For Italy, see ‘CCC Copertura contro il rischio di volatilità del Corrispettivo di assegnazione della Capacità di trasporto’, Terna ([link](#)), as well as ‘Regolamento per l’assegnazione degli strumenti di copertura contro il rischio di volatilità del corrispettivo di utilizzo della capacità di trasporto (CCC) per l’anno 2024’, Terna, 2023 ([link](#)). For Nordics, see ‘Our Products’, Nasdaq ([link](#)), as well as ‘Trading Appendix 2 / Clearing Appendix 2 – Contract Specifications – Commodity Derivatives’, Nasdaq Oslo ASA and Nasdaq Clearing AB, 2024 ([link](#)): pages 97 to 107.

## 4. ZI: Self-scheduling with zonal pricing

- As discussed under each cross-border arrangement below, we assume that the GB DAM would: (i) as per NO Status Quo, clear prior to the SDAC under ZI Status Quo; (ii) run alongside the SDAC under ZI MRLVC; and, (iii) be part of the SDAC and therefore clear simultaneously under ZI Price Coupling;
- NESO would determine the available cross-zonal capacity that can be allocated to the DAM (“commercial cross-zonal transmission capacity”). As we discuss in each subsection below, NESO’s approach to determining available capacity has implications for each cross-border trading arrangement. It can either be based on the:<sup>133</sup>
  - NTC methodology, which calculates capacities between bidding zones based on transmission capacity limits between zones and a reliability margin to account for uncertainties (e.g. unexpected grid conditions or forecast deviations); or
  - Flow-based methodology, which simultaneously optimises electricity flows between the GB zones accounting for interdependencies between the volume of available commercial cross-zonal capacity that can be allocated per zonal boundary.<sup>134</sup> This is more dynamic compared to the NTC methodology, and typically results in higher available cross-zonal capacity for trading and more efficient use of the transmission network.

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<sup>133</sup> ‘Market-based congestion management’, TenneT ([link](#)); ‘Capacity calculation methodologies explained Flow Based market coupling (FB) & CNTC’, Energinet, Svenska kraftnät, Fingrid, Statnett ([link](#)).

<sup>134</sup> Under the flow-based methodology, NESO would need to calculate available margins of network elements that are impacted by cross-zonal trade (“critical network elements”) and zonal power transfer distribution factors (“PTDFs”), which are used as inputs in the GB Price Coupling algorithm. Zonal PTDFs describe the linear relationship between the physical flow in a critical network element and the net exchange position of a specific bidding zone. Under the flow-based methodology, the commercial cross-zonal capacity available on one zonal border is no longer independent from the commercial cross-zonal capacity available on another zonal border. The “flow domain”, i.e. all potential combinations of feasible flows on the different cross-zonal borders, is offered to the Price Coupling algorithm which then co-optimises the allocation of commercial cross-zonal transmission capacity across zonal borders and the zonal schedule.

## 4. Z1: Self-scheduling with zonal pricing

- Under both options, NESO would need to account for any GB cross-zonal PTRs sold on the forward timeframe for which the buyer has nominated flows ahead of the DA timeframe. Other options may become available in the future, but these are not examined in this report.<sup>135</sup>
- Under all cross-border arrangements, both EPEX Spot and N2EX could retain all other functions associated with running these markets (the so-called pre- and post-coupling functions). However, under Price Coupling, the GB wholesale market clearing would effectively be integrated into the SDAC and SIDC. The market clearing algorithm (e.g. EUPHEMIA) will be operated by the European MCO, which is a cooperation of PXs and EU NEMOs. Under Status Quo cross-border trading arrangements and MRLVC, the GB Price Coupling algorithm would be run by a single GB MCO (which could be one of the PXs, a cooperation of PXs or a third party – potentially NESO). This would be akin to the current arrangements in the SDAC and SIDC, where PXs feed in bids from market participants into the central clearing algorithm and are responsible for the settlement.
- NESO would continue balancing the GB market post-GCT via the BM with the GCT set to one hour.

4.3. It is possible that zonal wholesale prices may become more volatile than national wholesale prices in some GB zones in some periods. The mechanism behind a potential increase in price volatility is that wholesale prices at a zonal level can be more sensitive to minor changes in the (zonal) supply and demand conditions than national wholesale prices when cross-zonal transmission is congested. Whether an increase in price volatility materialises depends on the exact shape of the demand and supply curves. The potential impact of a zonal design on the sensitivity of wholesale prices to changes in supply and/or demand would also be driven by the size of the GB zone relative to national GB market. Everything else being equal, the smaller the zone, the more sensitive zonal wholesale prices can be expected to be.<sup>136</sup>

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<sup>135</sup> According to the Article 2 of the Second amendment of the Day-Ahead Capacity Calculation Methodology of the Core CCR, TSOs in the Core CCR are required to have developed and implemented advanced hybrid coupling (“AHC”) by March and June 2025 respectively ([link](#)). AHC would enable a more efficient coordination between the scheduling of the ICs connecting GB with the SDAC applying the NTC approach and the zones subject to flow-based market coupling in Europe (in both CORE and the Nordics). AHC could also be implemented on the GB-side of the IC if GB were to opt for the flow-based approach to allocate the GB inter-zonal capacity.

<sup>136</sup> An extreme case of this would be an OBZ with no native demand and a single OWF). This is discussed in Chapter 7.

## 4. ZI: Self-scheduling with zonal pricing

- 4.4. A zonal configuration that fails to reflect accurately intra-GB transmission constraints might lead to more convergence of zonal wholesale prices and hence potentially very similar price volatility as under a national market design. However, this would come at the expense of more complexity for assets to forecast BM revenues, which would represent a larger share of their total revenues (relative to under a zonal configuration that better reflects intra-GB zonal transmission constraints).<sup>137</sup> Overall, the extent to which zonal wholesale prices would be more or less volatile and/or sensitive to changes in supply/demand than national wholesale prices would need to be empirically tested.
- 4.5. For all cross-border trading arrangements under ZI, IC flows would be scheduled based on zonal prices (rather than national prices under the current Status Quo market arrangements (NO)). These represent “unconstrained zonal wholesale prices”, which reflect transmission constraints between GB zones but not within the zone. The main implications of this are as follows:
- To the extent that zones are aligned with the main transmission boundaries of the GB system, scheduled IC flows would more likely be in line with the physical realities of the GB system. While some redispatch and/or countertrading actions may still be required if some of the scheduled IC flows turn out not to be physically feasible, the volume of such actions is expected to be significantly smaller compared to NO. The extent of the reduction would depend on the detailed design of the zones and, in particular, how well they reflected intra-GB transmission constraints.
  - Scheduling IC flows according to zonal prices would likely result in materially different scheduled IC flows relative to NO, which would in turn impact wholesale prices in the connected European countries. If zonal prices in the GB zone in which the IC landing point is located (referred to as a “GB IC zone”) are lower than the national price, the IC will be more likely to be scheduled to flow out of GB, which in turn would likely lead to a price decrease in the connected European wholesale market (and vice versa). An example is that zonal pricing could lead to more export to Norway via NSL, which is connected to North England where zonal prices could potentially be lower than the current national wholesale price. This would lead to lower wholesale prices in NO2 under a zonal market design in GB compared to when GB would keep a national wholesale market design in place; and

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<sup>137</sup> In addition, volatile zonal wholesale prices can be hedged as discussed in ¶4.2 while volatile BM revenues cannot.

#### 4. Z1: Self-scheduling with zonal pricing

- The exact zonal delineation in GB is currently uncertain and may be designed such that the GB-Irish ICs connect to different GB IC zones. A systematic divergence of zonal prices in GB (e.g. higher wholesale prices in the north of Wales where EWIC connects and lower prices in the south of Scotland where Moyle connects) could potentially result in I-SEM acting as a transit network between Scotland and South Wales for the GB electricity network, risking increasing transmission constraints within the I-SEM.

### Z1 Status Quo

4.6. In this subsection, we set out how the Status Quo cross-border trading arrangements in GB (that is explicit trading for all NWE ICs and implicit trading on NSL and GB-Irish ICs) could work under the Z1 market design. Effectively, this section seeks to overlay zonal self-scheduling, as defined in the Z1 design, on the current cross-border arrangements (albeit with some adjustments where they appear necessary).

### Forward market

4.7. As summarised in Figure 4-2 below, the forward market for cross-border transmission rights under Z1 Status Quo would operate in a broadly similar way as that in N0 Status Quo explained in ¶2.5-2.8 :

- NESO and the relevant European TSOs would calculate the available capacity on the explicitly traded NWE ICs. The LTTRs for various timeframes would be auctioned via JAO forward auctions (though alternatives are possible, e.g. the 'Empire' platform for BritNed).
- Cross-border LTTRs could be either PTRs or FTRs and would enable market participants to hedge their positions for the price difference between the GB IC zone and the connecting European price zone. Market participants may choose to acquire additional GB cross-zonal transmission rights to hedge price risk between the GB IC zone and other GB zones and/or a GB hub.
- In principle, NSL and GB-Irish ICs could also participate but currently no LTTRs are currently offered for those ICs.
- Market participants and IC capacity holders (though not IC owners themselves) can also trade cross-border LTTRs bilaterally in the forward market.

4. Z1: Self-scheduling with zonal pricing

4.8. A potential difference between Z1 and N0 is that the wholesale prices in the GB IC zones could potentially become more volatile (in some zones during some periods) than the counterfactual national wholesale price (as under N0) as described in 4.3-4.4. The extent to which increased wholesale price volatility would materialise under zonal pricing could affect the valuation of cross-border transmission rights. This could be either a positive impact (if the increased volatility led to wider price spreads between the GB IC zone and the connected European zone), or a negative impact (if the increased volatility discouraged trading). The balance of these two impacts would need to be further assessed empirically.

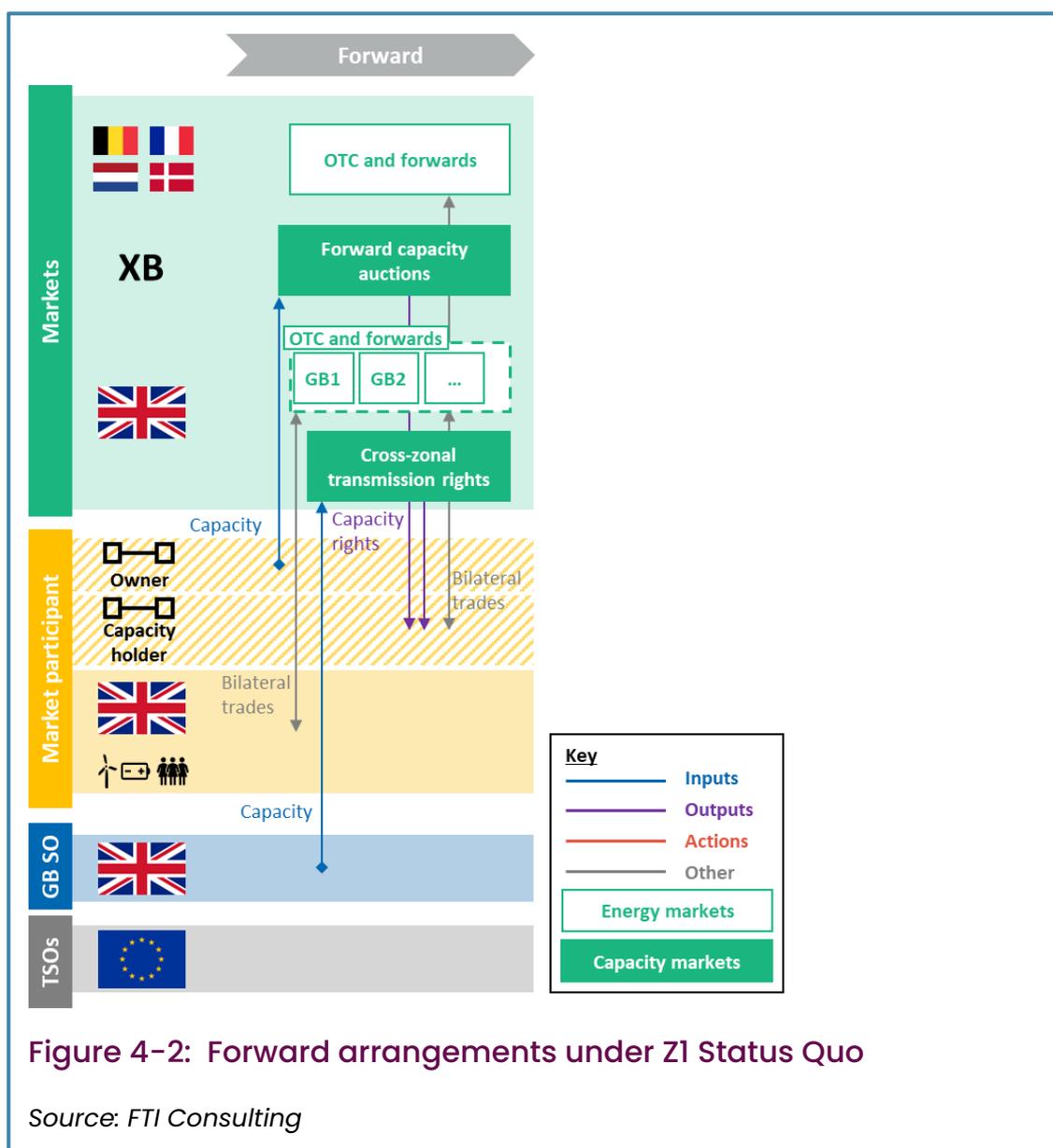
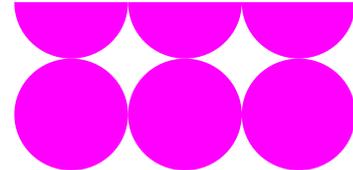


Figure 4-2: Forward arrangements under Z1 Status Quo

Source: FTI Consulting



## Day-Ahead market

4.9. In this section we discuss how the current DA cross-border trading arrangements would need to be adjusted to be compatible with the ZI market design. We consider the explicit (NWE ICs) and implicit (NSL and GB-Irish ICs) arrangements in turn.

### *Explicit*

4.10. We do not foresee any substantial changes required to the existing process of explicit DA trading arrangements of NWE ICs.

4.11. We expect the current DA IC capacity auctions to remain in place, and we also expect that market participants would continue to obtain cross-border IC capacity to facilitate flows between GB and the SDAC. The value of these rights would reflect the expected price difference between the relevant GB IC zone and the connecting SDAC zone (rather than the expected difference between the GB national price and the connecting SDAC zone under N0 Status Quo). The extent to which zonal GB wholesale prices are potentially more volatile could have a positive or a negative impact:

- To the extent that the individual settlement period-by-settlement period GB IC zone prices become more volatile, this could increase the spreads between GB and the connected European countries and hence create additional congestion rent opportunities for ICs.
- Conversely, to the extent that increased volatility discourages trading, market participants could be more cautious in bidding for capacity to avoid incurring additional costs to unwind their position if their forecasts are incorrect. This could result in the DA IC capacity auctions clearing at lower values and the commercial under-utilisation of the IC.

4.12. IC capacity holders would also need to establish net energy positions in both price zones as per the current market arrangements. However, on the GB side, this position would need to be established in GB IC zone.

## 4. ZI: Self-scheduling with zonal pricing

4.13. IC capacity holders' bids would likely continue to be based on the expectation of prices in the connected SDAC market (see Appendix 1). As per N0 Status Quo, we assume that the GB DAM would run before the SDAC. This means that IC capacity holders would need to forecast the wholesale price in the connecting SDAC market when taking a position in the GB DAM. Assuming that the volatility of wholesale prices of the SDAC zones is not materially impacted by GB having a zonal rather than a national wholesale market in place (indeed, this would be a second-order effect), we expect that the level of forecast error, and therefore the likelihood of the commercial under-utilisation of ICs to be similar as under N0.<sup>138</sup> We provide an example of how ZI can impact the valuation of DA IC capacity rights but not their scheduling below in Box 4-1.

#### Box 4-1: Example of the impact of ZI on the valuation and scheduling of DA IC capacity rights

A market participant has been successful in the DA IC capacity auction for IC rights in the direction from GB to France. The market participant estimated the DAM price in the GB IC zone<sup>139</sup> to be £20/MWh lower than the French DAM price and was the marginal bidder. Because both the GB DAM and the SDAC are cleared after the DA IC auction, the market participant had to forecast both the DAM price in the GB IC zone and in the French DAM to come up with the £20/MWh bid. Thus, the bid of the market participant in the DA IC capacity auction was impacted by GB moving from national to zonal pricing (as the national wholesale price would have been likely different from the wholesale price in the GB IC zone). Hence, the valuation of DA IC capacity rights is impacted by GB moving from national to zonal pricing.

After the DA IC capacity rights auction, the GB DAM takes place. In the GB DAM the IC capacity holder would need to take a position as a buyer, assuming they are planning to export from GB to France in line with the IC capacity position they have acquired. The offer the DA IC capacity rights holder would most likely formulate is its expectation of the French DAM price (see also Appendix 1), e.g. £40/MWh.<sup>140</sup> After submitting its bid, the GB DAM clears, and the GB IC DAM price is £30/MWh. The

<sup>138</sup> However, if the SDAC were to be cleared ahead of the GB DAM, IC capacity holders would instead need to estimate the price in the GB IC zone. In this case, the level of forecast error under ZI might to be different relative to N0, which would increase the frequency of counterintuitive flows.

<sup>139</sup> As discussed in ¶4.2, under ZI Status Quo and MRLVC we anticipate having one GB MCO in place. This would imply there would only be one GB DAM price per GB zone (and not two as currently is the case with two separate GB DA market clearings as explained in ¶2.11).

<sup>140</sup> In case the SDAC were to take place before the GB DAM, the IC capacity holder would instead need to take a position in the SDAC as a seller and forecast the wholesale price in the GB IC zone.

zonal GB IC DAM price (£30/MWh) is lower than the IC capacity holder's offer (£40/MWh), thus the IC capacity holder obtains a buyer position in the GB IC zone. After, the SDAC opens, and the IC capacity holder would likely bid in the French market at the zonal GB IC DAM (outturn) price (£30/MWh). If the French DAM price clears higher than £30/MWh (disregarding IC losses) the IC capacity holder can earn a revenue from the spread and will likely nominate the IC right.

There are two important observations:

- (i) The IC capacity right holder has acquired the transmission capacity prior to the GB and European DAM clearing. The price at which they acquired such right was based on an expectation of both the GB DAM wholesale price and the French DAM wholesale price. The DA IC auction price expectation is impacted by a move from national to zonal pricing (as now the zonal GB IC DAM price and not the national GB DAM price needs to be forecasted). However, once acquired, the IC capacity right becomes a sunk cost and does not affect the IC capacity holder's subsequent bids in the GB and French wholesale markets. The only choice that the IC capacity holder can make is whether to nominate that IC capacity.
- (ii) The IC capacity right holder did not have to forecast the GB DAM price when taking a position in the GB DAM market to potentially nominate the IC right or not. Hence, the scheduling of the IC under an explicit arrangement is not impacted by GB moving from national to zonal pricing. This is a consequence from the GB DAM to clear before the SDAC. In case the SDAC were to clear before the GB DAM, the IC capacity holder would need to forecast the GB DAM when taking a position in the SDAC to potentially nominate the IC right or not. In that case, GB moving from national to zonal pricing would impact the scheduling of an IC under an explicit arrangement.

- 4.14. After IC capacity holders and other market participants establish their positions on the GB DAM and the subsequent SDAC, the holders of the (physical) IC capacity rights (obtained in any timeframe before GCT) then submit their flow nominations and PNs to NESO and the European TSOs. The sequence of events is summarised in Figure 4-3 below. In what follows we describe in more depth the options for the implicit arrangements with NSL under Z1.

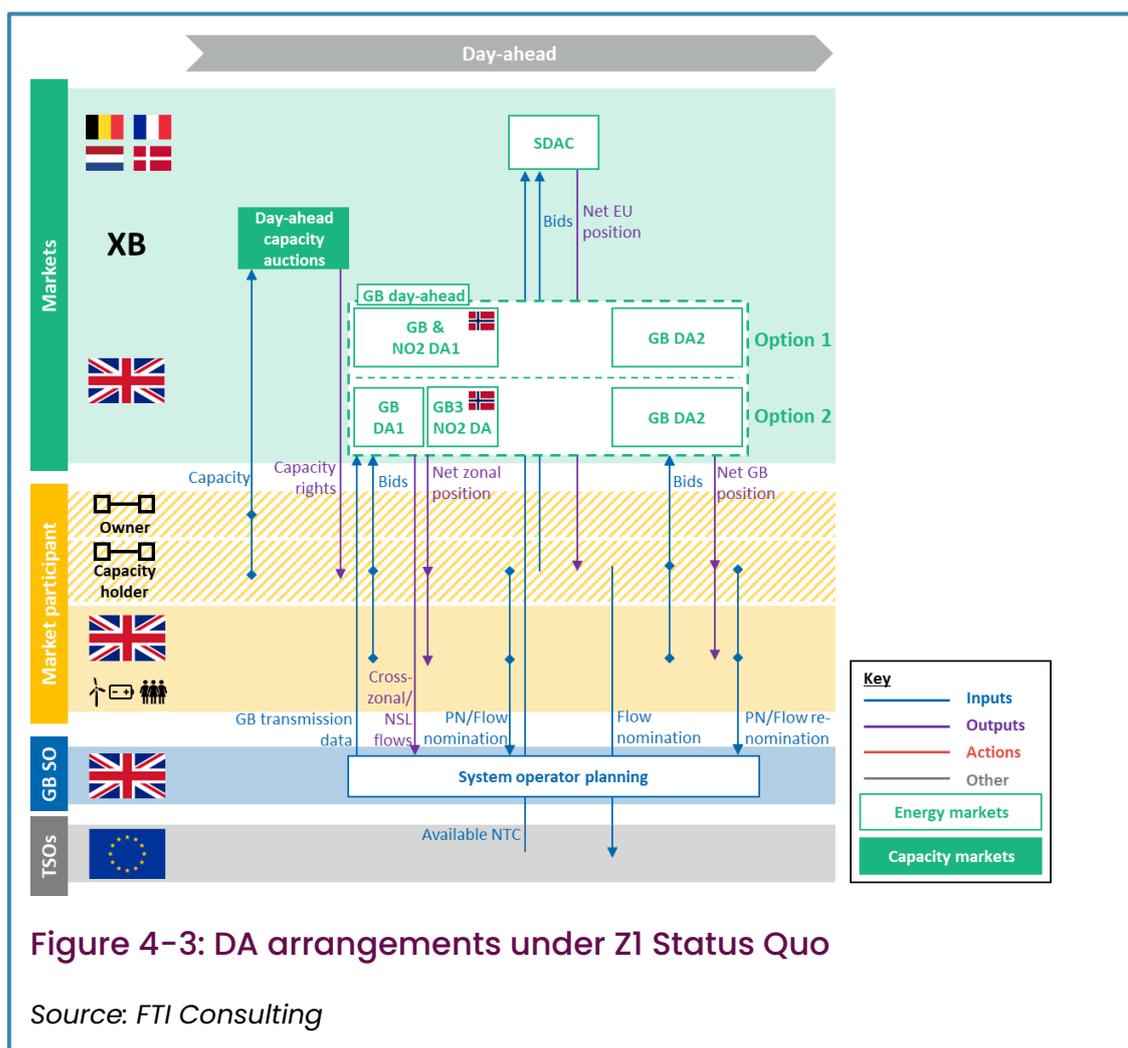
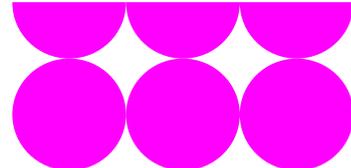
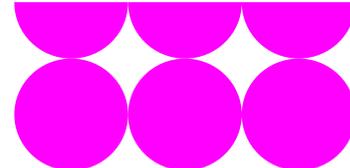


Figure 4-3: DA arrangements under Z1 Status Quo

Source: FTI Consulting

### Implicit

4.15. Unlike explicit arrangements, the current implicit coupling on NSL would need to be adjusted to make the arrangement compatible with Z1. Under the current DA arrangements, there can be multiple DA markets for each bidding zone (i.e. there are multiple DA auctions for GB run by EPEX and N2EX as described in 4.2.11). However, the flows between bidding zones that are implicitly coupled are determined by a single market operator (e.g. only N2EX determines the flows between GB and NO2 via NSL; only SDAC determines the flows within the IEM). The coverage of each market operator under N0 is summarised in Table 4-1 below.



**Table 4-1: Coverage of N2EX 60min, EPEX 60min and SDAC market under N0**

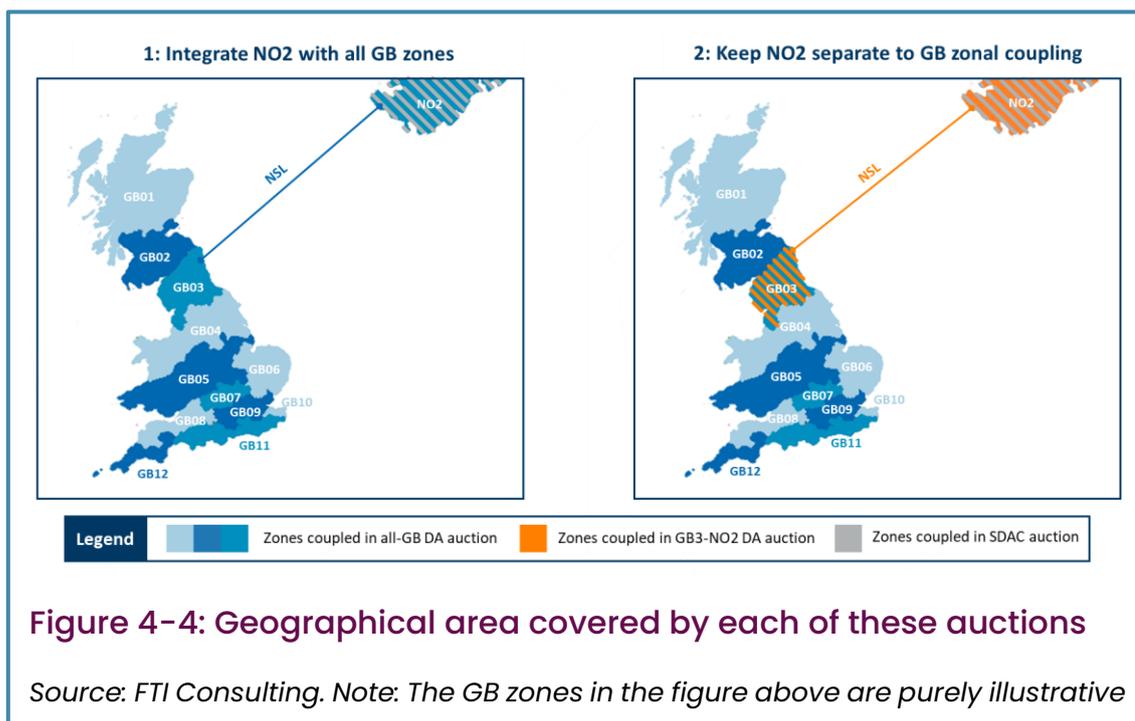
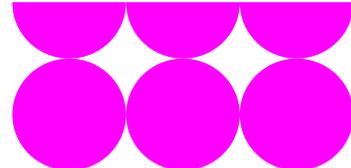
Market operator	Relevant bidding zones	Flows between zones
N2EX 60 min	GB, NO2	NSL
EPEX 60 min	GB only	None
SDAC	All IEM zones (including NO2)	All flows between IEM zones

4.16. As explained in 4.2, under Z1 we assume that all GB zones and flows between GB zones would be cleared by a single GB MCO. This means that the current market arrangements (N0) in which N2EX covers the whole of GB, NO2 and NSL would not be feasible anymore, as it would mean that the flows across GB zones would be cleared by both N2EX and the GB MCO.<sup>141</sup> There are two options for NSL to remain price coupled with the GB DAM, as reflected above in Figure 4-3, and a fallback option:

- **Option 1:** The clearing of GB-NO2 flows on NSL could be integrated into the intra-GB Price Coupling process. In this case, N2EX would no longer be responsible for the market clearing of GB and NO2, nor for determining the flows on NSL; or
- **Option 2:** The Price Coupling process between NO2 and the relevant GB zone could be kept separate from the intra-GB Price Coupling process. In this case, N2EX would be responsible for the market clearing of only the relevant GB price zone where NSL connects, NO2 and the flows on NSL;
- **Fallback option:** Move away from implicit coupling of NSL and GB and instead introduce an explicit cross-border arrangement on NSL.

4.17. The two options that could be introduced to let NSL remain implicitly coupled with the relevant GB zone are illustrated in Figure 4-4 below, in which we assume that GB has 12 hypothetical price zones and NSL connects to the hypothetical GB03 price zone. We discuss each option in more detail below.

<sup>141</sup> Having multiple PXs in charge of separate DAM clearings would either lead to conflicting intra-GB cross-zonal flows, or it would require that the intra-GB cross-zonal transmission capacity is somehow 'split' between the operators, so that each would be in charge for a portion of it. This would be inefficient due to coordination issues in the allocation of the available GB cross-zonal capacity across the different PXs relative to the allocation of supply and demand in the wholesale market.



- 4.18. Under **Option 1**, NO2 would be covered by the GB (price coupled) DAM. The NO2 price would be jointly determined along with prices in individual GB zones, flows between GB zones and flows between GB03 and NO2. In this approach we also assume that NO2 continues having two separate DA wholesale prices: one that would be determined by the GB (price coupled) DAM and one that would be, separately, determined by the SDAC process. This would represent an extension of the current arrangements where NO2 already has two prices: one cleared alongside NSL and one cleared via SDAC.
- 4.19. The feasibility and attractiveness of this option from a GB perspective largely depends on the implications of including a foreign price zone in the GB Price Coupling process. This may require involving the relevant Norwegian TSO in the development of the intra-GB market coupling process, as well as in the design and operation of the GB Price Coupling process, which we assume would very likely be unacceptable for GB. From a Norwegian perspective, it would mean that an NO2 price (e.g. more precisely one of the two NO2 prices) is determined by the intra-GB MCO, which seems equally unlikely to be acceptable (although this could be examined further, given that Norway has been able to accept having one of its two NO2 prices being determined by N2EX).

4. Z1: Self-scheduling with zonal pricing

4.20. Under **Option 2**, N2EX<sup>142</sup> would cover NO2 and NSL (as per the current arrangement under N0) but only the hypothetical GB03 zone in GB (rather than all of GB). The flows between GB zones would continue to be determined by the GB DAM. There would be two GB03 prices (determined by N2EX and the GB Price Coupling process) and two NO2 prices (determined by N2EX and SDAC).

4.21. While Option 2 seems more feasible from a governance perspective than Option 1, the attractiveness of Option 2 would mostly depend on two factors:

- **Sustainability of two prices in a GB zone:** Statnett has examined the implications of having two prices for NO2 and found that the adverse effects of having two outturn wholesale prices are limited, as long as the outturn prices remain close to each other and there is no systematic difference in any particular direction.<sup>143</sup> Whether this is the case for the relevant GB zone would largely depend on the liquidity in the zone and would need to be carefully examined;

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<sup>142</sup> We refer to N2EX as they are currently responsible for Price Coupling on NSL. However, in principle, another party could take this role.

<sup>143</sup> 'NO2 and NSL auctions', Statnett SF, November 2019 ([link](#)).

- **Anticipation of flows in subsequent markets:** As the GB DAM, N2EX and the SDAC are cleared sequentially, participants in earlier markets would have to anticipate the flows and prices that are cleared in later markets. We assume that as per N0 Status Quo, the SDAC would clear last. However, it is an open question as to which of the GB DAM or N2EX would clear first. It may be sensible that the market that determines the larger volume of flows to/from the GB NSL zone (GB03 in the example above) would ideally be cleared first, as it is likely to have a larger impact on the price formation in the zone. As it is likely that the transmission capacity between the GB NSL zone and its BBZs within GB is higher than NSL's capacity, the cross-zonal flows would likely have a larger impact on the price formation in the GB NSL zone than flows on NSL.<sup>144</sup> As such, it appears to us that it would be more optimal to clear the GB DAM ahead of N2EX.<sup>145</sup>

4.22. However, Option 2 is not future proof against another IC being built between Norway and GB that is connected not connected to the same GB and Norwar ("NO") zone that NSL is also connected to. We discuss why this is the case in more depth for the implicit coupling between I-SEM and GB in the ID timeframe (see next section). Currently, two ICs connect I-SEM and GB which could potentially connected to different GB zones. If the existing implicit arrangements were not viable under this design, alternative options may need to be considered. As a fallback option, the current implicit arrangements on NSL could be replaced by an explicit arrangement.

## Intraday market

4.23. We assume that under Z1, the GB continuous IDM would run in parallel to the SIDC continuous IDM, as it does under N0. We also assume that the current wholesale and ID IC auctions would remain in place.

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<sup>144</sup> For instance, suppose GB03 (the hypothetical zone that NSL connects to) has 5GW of transmission capacity to GB02, 4GW to GB04, and 1.4GW to NO2 (NSL). If the GB03-NO2 coupled auction clears first, market participants would be required to make assumptions on the outcome of the full-GB coupled auction – in particular, the GB03 supply-demand balance when preparing their bid. The GB03 supply-demand balance would depend on both the local generation and demand, as well as the direction and volume of flows towards GB02 and GB04, e.g. assumptions on up to 9GW (5GW + 4GW) of intra-zonal transmission capacity. However, if the GB DAM cleared first, market participants would only be required to make assumptions on the 1.4GW of flows on NSL that are determined in the GB03-NO2 coupled auction – and as the lower volume (1.4GW vs 9GW). The latter sequence of market clearings is likely to have less impact on the GB03 price formation.

<sup>145</sup> It appears to use that there is no case of running the market clearings simultaneously as then for both market clearings the flows and prices of the other market clearing would need to be anticipated. When sequentially clearing the market clearings at least for the outcome of the market that is cleared first is known when clearing the second market.

## 4. Z1: Self-scheduling with zonal pricing

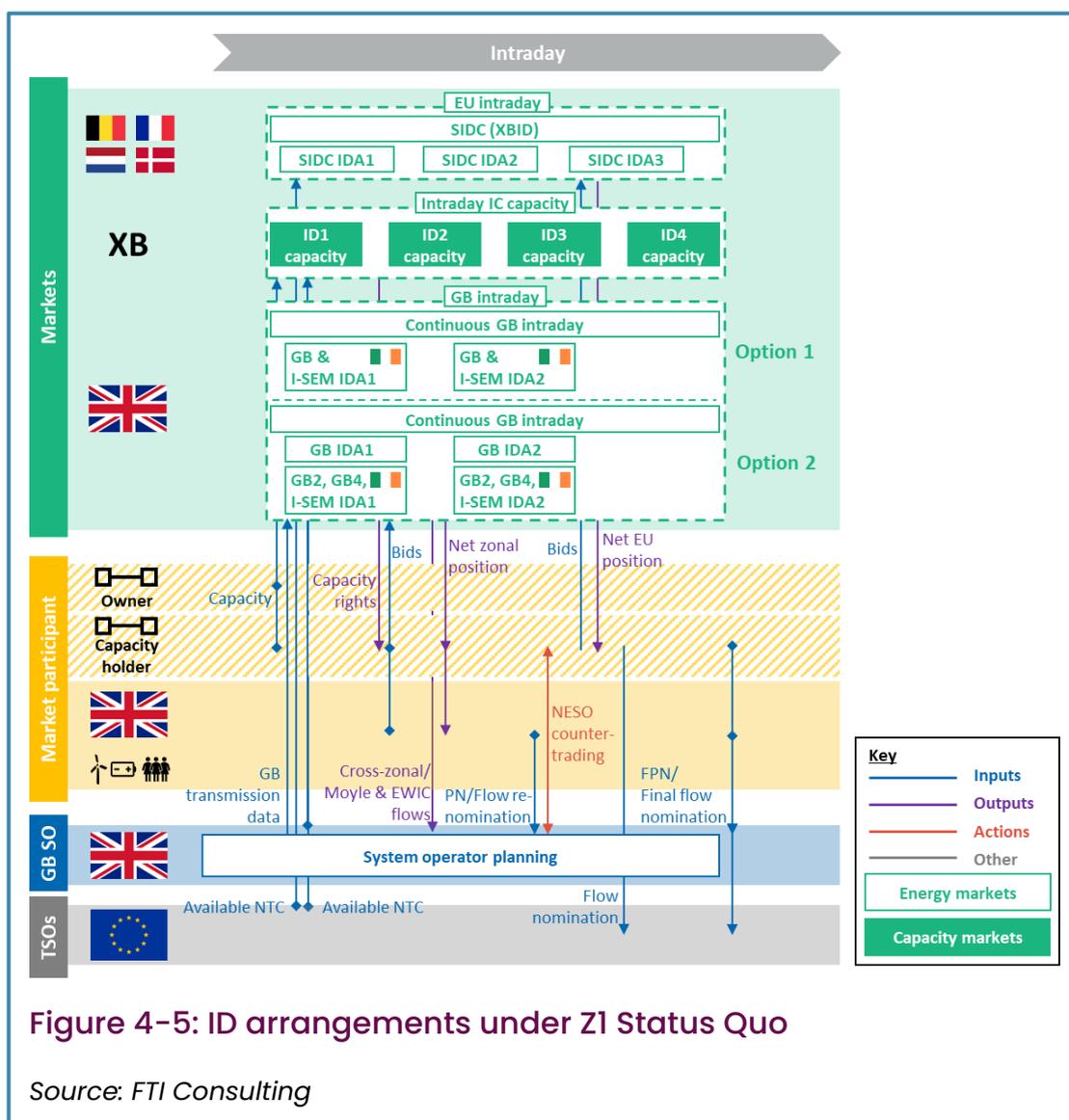
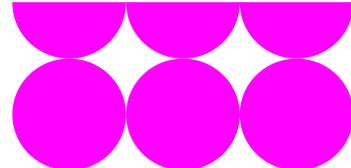
- 4.24. Akin to the DAM, no changes would be required to the process of explicit cross-border trading. The value of cross-border rights would similarly reflect the difference between the GB zonal price and the price of the connected bidding zone (such that IC capacity holders would need to forecast the GB zonal price rather than the GB national price).
- 4.25. Under NO Status Quo, I-SEM is coupled with GB via the GB-Irish ICs in the ID timeframe (under IDA1 and IDA2). Similar to NSL at the DA stage, there are two options for I-SEM to remain coupled with GB in the ID timeframe and a fallback option:
- **Option 1:** Integrate I-SEM and the GB-Irish ICs into the GB ID Price Coupling process (via IDA1 and IDA2);
  - **Option 2:** Keep the Price Coupling process of GB and Ireland separate from the Price Coupling process of the GB zones;
  - **Fallback option:** Move away from implicit coupling of I-SEM and GB and instead introduce an explicit cross-border arrangement (in the DA or ID timeframe).
- 4.26. Under **Option 1**, in contrast to the current arrangement where the IDAs coupling I-SEM and GB are operated by SEMOpx, the IDA1 and IDA2 prices in I-SEM would be determined by the intra-GB MCO jointly along with ID prices in GB zones, flows between GB zones and flows on all GB and I-SEM ICs. Similar to that described for NSL in ¶4.19, the feasibility and attractiveness of this option from a GB perspective largely depends on the implications of including a price zone in a foreign country in the GB ID zonal Price Coupling process, and whether these are acceptable to GB. Similarly, we assume it unlikely to be acceptable for Ireland and the EU to allow the intra-GB MCO to determine the ID price for the I-SEM.
- 4.27. Under **Option 2**, IDA1 and IDA2 would cover I-SEM and the GB-Irish ICs (as per the current arrangement). To the extent that the various GB-Irish ICs are connected to different price zones in GB, IDA1 and IDA2 would need to cover all GB IC connecting price zones. There would therefore be two prices in each of the connecting IC price zones (one determined by the intra-GB MCO and one determined by the IDAs where GB is coupled with the I-SEM). The same question arises which of the market coupling process would run first. Considering the argumentation described in ¶4.21 that ideally the market that determines the larger volume of flows to/from the GB-Irish IC zones would ideally be cleared first, it appears to us that it would be more optimal to clear the intra-GB MCO ahead of the GB-Irish coupling.

4. Z1: Self-scheduling with zonal pricing

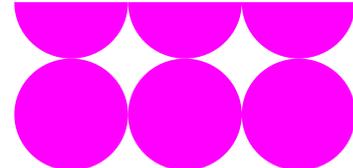
- 4.28. Trade-offs for Option 2 mirror the ones for NSL, with the added complexity of multiple ICs between GB and I-SEM potentially connecting to different GB zones. The concurrent clearing of the SEM with several GB zones via the GB-Irish coupling would imply that (from time to time, though not necessarily always) specific directions of flows between GB zones, which are not covered by the GB-Irish coupling, is assumed. The determination of such cross-zonal flows via the GB-Irish clearing would interact with the implicit coupling of GB zones by the single GB MCO, which is a process that takes place separately. In practice this could imply having to reserve cross-zonal capacity within GB for the GB-Irish clearing which is highly likely to be complex and, more importantly, inefficient.<sup>146</sup>
- 4.29. Figure 4-5 below summarises the IDM under Z1. Options 1 and 2 are reflected in the two possible designs for the GB IDM.

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<sup>146</sup> Once the Celtic IC is operational and I-SEM is physically connected to the SDAC, the market coupling process between GB and I-SEM would also impact cross-zonal capacities in the SDAC (e.g. there would be an electrical link between Ireland and the GB via zones that are part of the SDAC), which would lead to the same issue.



- 4.30. As per N0 Status Quo, we assume that NESO would retain the ability to adjust IC flows pre-GCT via countertrading or ex-ante capacity restrictions (see ¶12.17). As countertrading would take place in parallel with the GB IDM, measures would need to be put in place to ensure that subsequent ID trades do not unwind the countertrades.
- 4.31. Compared to N0, we expect the need for countertrading (and/or capacity restrictions) to decrease under Z1, conditional upon the zonal boundaries reflecting intra-GB transmission bottlenecks.



### Post-gate closure time

4.32. We do not expect any changes to the current post-GCT arrangements under zonal self-scheduling. No further cross-border trading would take place and only NESO would be able to alter flows at this timeframe, using SO-SO trades or emergency services as described in ¶12.19.

### ZI MRLVC

4.33. In this subsection, we set out how the MRLVC design (see Section N0 MRLVC for more details) could potentially work under the ZI design (“ZI MRLVC”). Effectively, this section seeks to overlay zonal market design, as defined in ZI, on the MRLVC cross-border arrangements. As explained above, we assume that when implemented, the MRLVC would apply to all GB ICs (including NSL and the GB-Irish ICs) and would only be implemented in the DA timeframe. “Hybrid arrangements”, e.g. applying MRLVC at the DA stage and explicit arrangements in the ID timeframe, are outside the scope of the report.

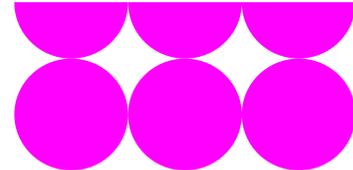
### Forward market

4.34. The forward market for cross-border transmission rights under ZI MRLVC would work in a similar way as in ZI Status Quo, where ICs can choose to participate in forward auctions and offer capacity for various market timeframes.<sup>147</sup> As explained in ¶14.7:

- Market participants in GB and Europe would place bids in the auction for LTTRs on JAO or potentially another platform, which would then publish the price for the capacity of LTTRs offered in the auction.
- LTTRs can be PTRs (with UIOSI provisions) or FTRs, both of which would enable market participants to hedge their positions between the relevant connected GB zone and SDAC market;
- Market participants and IC capacity holders (though not IC owners themselves) can also trade bilaterally in the forward market; and
- Market participants wishing to hedge their exposure to price differences between a GB IC zone and other zones in GB, can procure transmission rights between the relevant GB price zones, along with the LTTRs on ICs.

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<sup>147</sup> Currently, only IFA, IFA2, ElecLink, Nemo Link, Viking Link and BritNed participate in these auctions. In principle, NSL and GB-Irish ICs could also participate.



### Day-Ahead market

4.35. Under Z1, the MRLVC process on the European side would remain unchanged from NO MRLVC. The process would only include order books for EU BBZs. Expectations of flows between EU BBZs and other EU zones would still be calculated ahead of MRLVC and fed into the process as a fixed (exogenous) input.

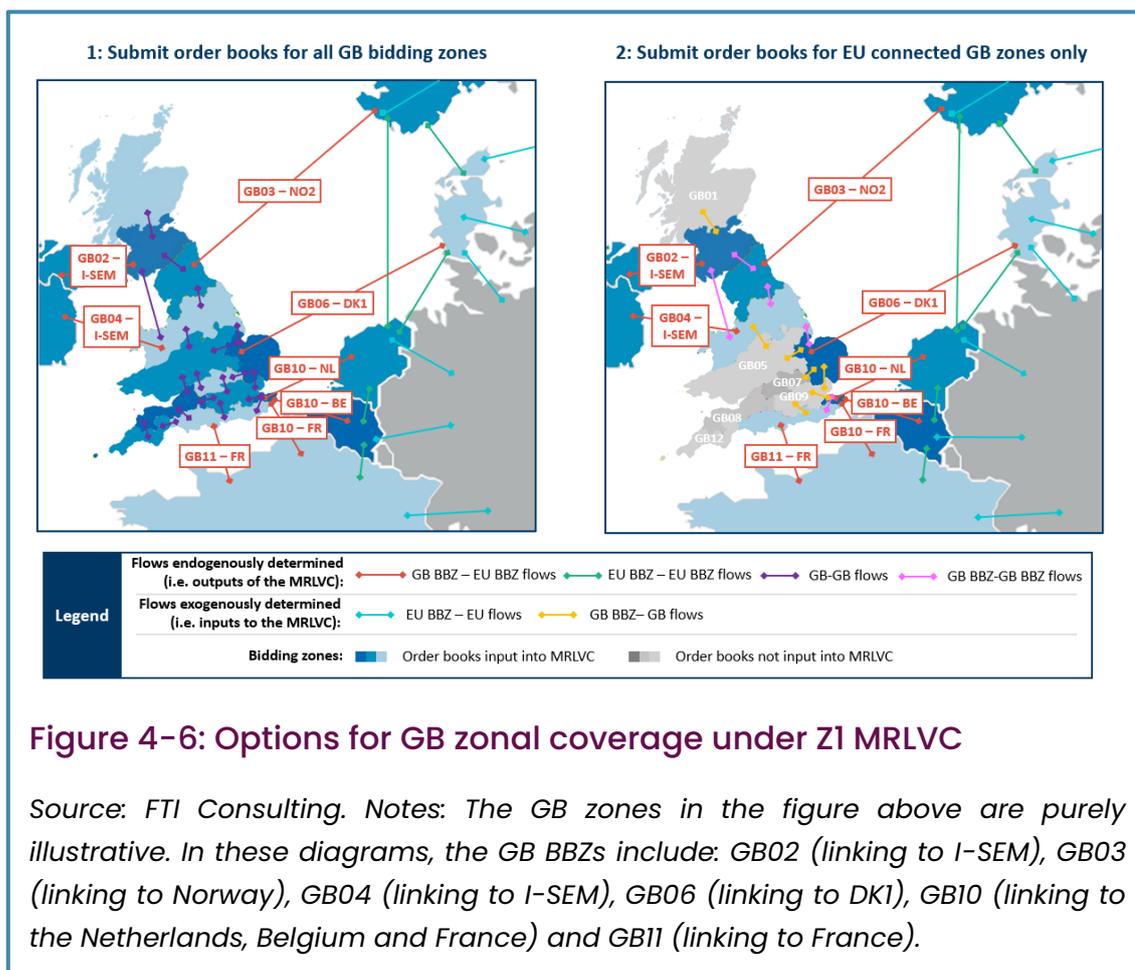
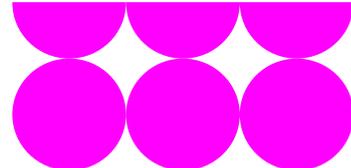
4.36. However, on the GB side, there are now two potential options on the geographical coverage of order books that the PXs would submit into the MRLVC:

- **Option 1:** Submit order books for all GB bidding zones and NTCs between the GB zones (or, alternatively, the necessary data for flow-based optimisation), including GB zones that are not directly interconnected with other European countries (noting this is asymmetrical relative to how flows between EU BBZs and wider EU zones are treated);<sup>148</sup>
- **Option 2:** Submit order books only for GB BBZs. In this option, net flows between GB BBZs and other GB zones are forecasted and those forecasts are then treated as fixed in the MRLVC process (this is symmetrical to how flows between EU BBZs and wider EU zones are treated).

4.37. We visualise these two options in Figure 4-6 below.

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<sup>148</sup> A potential variation of this option is one where GB submits order books for all zones, but not the NTCs between the GB zones. In this case IC flows would be optimised based on the national GB price. We consider this variant to be suboptimal compared to Option 1 and only applicable if GB NTCs cannot be accommodated in the MRLVC algorithm. However, if this was the case, then Option 2 appears to be preferable and, as such we do not examine this potential variation further in our report.



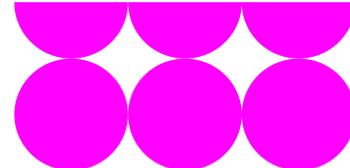
**Figure 4-6: Options for GB zonal coverage under Z1 MRLVC**

Source: FTI Consulting. Notes: The GB zones in the figure above are purely illustrative. In these diagrams, the GB BBZs include: GB02 (linking to I-SEM), GB03 (linking to Norway), GB04 (linking to I-SEM), GB06 (linking to DK1), GB10 (linking to the Netherlands, Belgium and France) and GB11 (linking to France).

4.38. The MRLVC process would be expected to run as follows:<sup>149</sup>

- (i) **EU BBZ–EU Flow Forecast (light blue links in both panels of Figure 4-6) and, only for Option 2, GB BBZ–GB Flow Forecast (yellow links in the right panel of Figure 4-6):** Akin to N0 MRLVC, EU BBZ–EU forecasts would be run ahead of SDAC market closure. Under Option 2, NESO would also forecast the net flow between GB BBZs and other GB zones. Similarly to the EU BBZ–EU flows, these would be exogenously fixed inputs in the MRLVC process. We provide an example for the Viking Link below in Box 4-2.

<sup>149</sup> 'Responses from the TSO group to the technical questions on MRLVC', ENTSO-E, 2023 ([link](#)): Section 4.3.



### Box 4-2: Example of EU BBZ-EU flows and GB BBZ-GB flows for the Viking Link (GB06-DK1)

As can be seen in Figure 4-6, the EU BBZ-EU flows for the Viking Link (GB06-DK1) would be DK1-DE, DK1-DK2 and DK1-SE3 while the GB BBZ-GB flows would be GB06-GB05, GB06-GB07 and GB06-GB09.

- (ii) **Calculation of the available IC capacity on the GB BBZ- EU BBZ borders (red links in both panels of Figure 4-6), transmission capacity for the EU BBZ-EU BBZ borders (green links in both panels of Figure 4-6) and: (i) all GB-GB zonal borders (purple links in the left panel of Figure 4-6) for Option 1; or (ii) the GB BBZ-GB BBZ borders (pink links in the right panel of Figure 4-6) for Option 2:** The available IC capacity on GB BBZ-EU BBZ ICs for market participants is also determined by NESO and the BBZ TSOs prior to DA market closure, and the lower IC capacity figure calculated by either side will be made available to the market. The European TSOs must also provide the transmission-related parameters<sup>150</sup> for the EU BBZ-EU BBZ borders. Under Option 1, NESO must calculate the transmission-related parameters for the borders between all GB zones. Under Option 2, NESO must calculate the transmission-related parameters for any GB BBZ-GB BBZ border, as those are the only zonal boundaries in GB for which the flows are endogenously determined in the MRLVC. We provide an example for the Viking Link in Box 4-3.

### Box 4-3: Example of EU BBZ-EU BBZ flows and GB BBZ-GB BBZ flows for the Viking Link (GB06-DK1)

As can be seen in Figure 4-6, due to the BritNed (GB10-NL), DK1-NL is an EU BBZ-EU BBZ . Similarly, due to NSL (GB03-NO2), DK1-NO2 is also an EU BBZ-EU BBZ . Finally, the only GB BBZ-GB BBZ would be GB06-GB04 due to the presence of EWIC (GB04-I-SEM).

- (iii) **Common Order Book submission:** After the DA market closure, the relevant market operators in GB and EU BBZs submit the Common Order Book to the operator of the MRLVC algorithm. Under Option 1, this would cover zonal order books for all GB zones, while under Option 2 this would only cover the zonal order books for GB BBZs.

<sup>150</sup> Transmission-related parameters can be available cross-zonal transmission capacities under NTC or the relevant flow-based parameters.

- (iv) **Submission of transmission data between EU BBZs:** As per N0 MRLVC, TSOs of the EU BBZs would need to submit the relevant transmission data to facilitate the optimisation of flows between EU BBZs as part of the MRLVC process.
- (v) **Submission of zonal GB transmission data:** Under both options, NESO would submit the transmission data required to optimise flows between GB BBZs as part of the MRLVC process. Under Option 1, NESO would submit the similar data for all borders between all GB zones.
- (vi) **MRLVC algorithm:** As shown on Figure 4-6, under both options, the algorithm then optimises GB BBZ-EU BBZ, EU BBZ-EU BBZ and GB BBZ-GB BBZ flows, while under Option 1 the algorithm would also optimise all GB cross-zonal flows. The MRLVC algorithm computes 'zonal DA prices' for EU BBZs under both options and for all GB zones under Option 1 and GB BBZs under Option 2. These prices are solely for the purposes of determining flows in the MRLVC optimisation. The final DA prices are determined later separately by the relevant wholesale markets in GB and in the EU.
- (vii) **Submission of firm flows to SDAC and GB DAM:** For the GB BBZ-EU BBZ ICs, the (firm) flows from the MRLVC calculation are converted into PTOs<sup>151</sup> and sent to relevant market operators for validation. The PTOs are then submitted to the GB DAM and SDAC respectively. None of the other optimised flows in the MRLVC are converted into PTOs as they are re-optimised in the subsequent Price Coupling auctions (e.g. GB DAM, GB IDM, SDAC, SIDC).

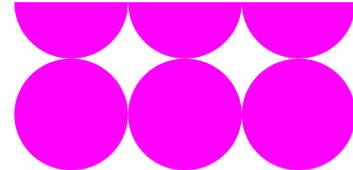
4.39. As discussed above in ¶4.2, flows between zones can be determined using NTC or flow-based approaches. In the EU, for the EU BBZ to other EU BBZ flows (e.g. between France and Belgium), the flow-based approach is currently used. We assume that the MRLVC algorithm will deploy a consistent approach to these flows.

4.40. On the GB side, there is also a choice between NTC- and flow-based approaches. While there are pros and cons to both, for consistency it seems important that the same approach should be used for the MRLVC algorithm and for subsequent GB DAM clearing.<sup>152</sup>

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<sup>151</sup> To guarantee that PTOs are cleared in the DA schedule PTOs for imports to GB represent additional generators at the bottom of the merit order, who submit offers to the market at the lowest price allowed by the market operator, while PTOs for exports from GB represent additional non-flexible demand in the clearing algorithm priced at the VOLL.

<sup>152</sup> Deploying different approaches for the calculation of flows which serve as inputs into the MRLVC and for the clearing of the GB DAM would likely lead to an increased commercial under-utilisation of the relevant ICs.



### Evaluation of options

- 4.41. Since the TCA does not explicitly describe which order books from GB should be submitted into MRLVC,<sup>153</sup> while it also allows for the submission of ‘network capacity data’ into the implicit allocation process,<sup>154</sup> we consider both Option 1 and Option 2 to be compatible with the TCA.
- 4.42. Overall, it appears to us that Option 1 is more credible and practicable. While being more computational complex, it seems likely more future-proof and would more likely result intuitive flows. However, we note that the extent of the difference between Option 1 and Option 2 will depend on the number of zones and ICs in GB – if GB only has a few zones and most of them have ICs to Europe, both options would be very similar.
- 4.43. Option 1 is considered more future proof as it be better at accommodating future ICs connecting to GB (even if they come into a “new” zone that was previously not connected to Europe) and a potential rezoning of GB zones. Future ICs connecting to GB or rezoning of the GB zones is unlikely to require significant changes to the MRLVC process under Option 1, whereas under Option 2, the MRLVC process would need to be updated, which could be a time-consuming process and would introduce additional regulatory risk, especially for new ICs.
- 4.44. As well, the MRLVC would also need to be able to accommodate the significant levels of intra-GB transmission investment planned in GB, which could increase the interdependencies of flows between zones. As the GB transmission network becomes more ‘meshed’ (that is, each GB zone is directly connected to multiple other GB zones via bootstraps like Eastern Green Link 2), it would become harder to exogenously forecast the flows between GB BBZs and other GB zones.
- 4.45. Option 1 is more likely to result in intuitive flows, as it would allow all GB interzonal flows to be optimised as part of MRLVC. Under Option 2, GB BBZ-GB zonal flows need to be forecasted, which can be complex and potentially lead to errors that could impact the GB BBZ-EU BBZ IC flows computed by MRLVC.

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<sup>153</sup> ‘Commercial bids and offers for the day-ahead market timeframe from relevant day-ahead markets in the United Kingdom’, Trade and Cooperation Agreement, December 2020, ([link](#)), Annex 29, page 7.

<sup>154</sup> ‘Network capacity data and system capabilities determined in accordance with the procedures agreed between transmission system operators’, Trade and Cooperation Agreement, December 2020, ([link](#)), Annex 29, page 7.

#### 4. Z1: Self-scheduling with zonal pricing

4.46. However, Option 1 is likely computationally more burdensome. Option 2 therefore provides a fall-back option in case Option 1 is not compatible with the MRLVC time frame. For example, under the example zonal arrangements shown in Figure 4-6 above, Option 1 would require MRLVC to optimise 18 bidding zone borders within GB, rather than only 4 under Option 2. On the other hand, the occurrence of commercial under-utilisation of ICs under Option 2, including counterintuitive flows, would be expected to be higher with more GB zones in place because correctly estimating flows between GB BBZ-GB zones is complex.

#### Intraday market

4.47. The MRLVC is intended to be a DA trading solution and potential post-Brexit ID trading arrangements have yet to be explored. However, the same considerations as discussed in the DA frame would apply to the ID timeframe. Given the uncertainty, as per N0 MRLVC, we do not explore this further.

#### Post-gate closure time

4.48. As per Z1 Status Quo and N0 MRLVC, we do not expect any changes to the current post-GCT arrangements under either zonal self-scheduling or through implementing MRLVC at the DA stage. No further cross-border trading would take place and only NESO and connected TSOs would be able to alter flows at this timeframe, using SO-SO trades or emergency services.

#### Z1 Price Coupling

4.49. In this subsection, we set out how Price Coupling (see N0 Price Coupling for more details) could potentially work under the Z1 design ("Z1 Price Coupling"). Effectively, this section overlays the Z1 market design assuming that GB is fully price coupled with the EU. As explained above, we assume that if implemented, Price Coupling would apply to all GB ICs (including NSL and the GB-Irish ICs).

#### Forward market

4.50. Similarly to N0 Price Coupling and NI Price Coupling, we assume that GB would participate in the forward market for cross-border transmission rights the same way as other European countries. NESO, along with the European TSOs, would perform forward calculations of capacities on the cross-border ICs to determine the available amount of IC capacity for LTTR allocation.

#### 4. ZI: Self-scheduling with zonal pricing

- 4.51. Assuming that under Price Coupling, GB must follow the relevant EU regulations covering the IEM unless exemptions are granted, ICs would likely be required to offer IC capacity in the forward timeframe per FCA GL.<sup>155</sup>
- Market participants in GB and Europe would place bids in the auction for LTTRs organised through the JAO<sup>156</sup>, which would then publish the price for the cross-border transmission capacity of LTTRs offered in the auction;
  - As under N0, LTTRs can be PTRs (with UIOSI provisions) or FTRs, both of which would enable market participants to hedge their positions between the relevant GB IC zone and the SDAC market;
  - Market participants and IC capacity holders (though not IC owners themselves) can also trade bilaterally in the forward market; and
  - As under ZI Status Quo and ZI MRLVC, market participants that wish to hedge their exposure to price differences between a GB IC zone and other zones in GB, can obtain transmission rights between the relevant GB price zones, along with the LTTRs on ICs (for more detail see ¶4.2).

#### Day-Ahead market

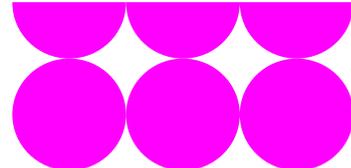
- 4.52. As described in ¶4.2, for there to be full Price Coupling between GB and Europe, the GB DAM would be effectively merged into SDAC.
- 4.53. As discussed in N0 Price Coupling, for GB to become part of the SDAC, GB market design would need to comply with the CACM GL unless exemptions are granted. The CACM GL requires cross-zonal borders in the IEM to be part of CCRs in which the relevant TSOs coordinate the calculation of transmission capacity within a region (either using the NTC or flow-based approach).<sup>157</sup>

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<sup>155</sup> The FCA GL states in Art. 30(1) that: “TSOs on a bidding zone border shall issue LTTRs unless the competent regulatory authorities of the bidding zone border have adopted coordinated decisions not to issue LTTRs on the bidding zone border. When adopting their decisions, the competent regulatory authorities of the bidding zone border shall consult the regulatory authorities of the relevant CCR and take due account of their opinions.” Further in Art. 30(3) it is stated that: “The decisions pursuant to paragraphs 1 and 2 shall be based on an assessment, which shall identify whether the electricity forward market provides sufficient hedging opportunities in the concerned bidding zones [...]”.

<sup>156</sup> The mandatory use of JAO applies only to long term capacity sales as stating in the FCA GL, short-term sales of cross-zonal transmission capacity can be organised on other platforms.

<sup>157</sup> For example, before Brexit, the GB and I-SEM markets were part of the IU CCR. The TSOs involved were EirGrid, Moyle Interconnector, NGET and SONI ([link](#)).



#### 4. ZI: Self-scheduling with zonal pricing

- 4.54. We assume that under ZI Price Coupling, the pre-Brexit Channel and IU CCRs would be reinstated,<sup>158</sup> and that the CCRs would retain the NTC methodology for calculating capacity on the GB ICs. In addition, we anticipate that a new CCR would be created to cover the cross-zonal borders within GB (“GB CCR”), where NESO would be the sole entity that determines the available commercial cross-zonal transmission capacity for the market coupling process.
- 4.55. In defining the transmission capacity NESO would have the choice between using the NTC or flow-based methodology (discussed above in ¶4.2). The CACM GL allows for both methodologies, but strongly recommends that the flow-based methodology should be used for capacity calculations where “*cross-zonal capacity between bidding zones is highly interdependent*”.<sup>159</sup> As the GB market covers one synchronous area, it is likely that GB cross-zonal capacities are interdependent (particularly if there are many zones). Given this, it is likely that the GB CCR would use the flow-based approach to optimise intra-GB cross-zonal capacity. The flow-based approach is more complex and would likely be more computationally burdensome for EUPHEMIA to process relative to if intra-GB zonal capacity would determined based on the NTC approach.
- 4.56. PXs would submit the GB order books to the SDAC and the TSOs operating transmission lines that are part of the respective CCRs would be responsible for providing the necessary transmission data:
- Channel CCR (NESO and bordering European TSOs): NTCs of NSL and the Northwestern ICs;
  - IU CCR (NESO, Eirgrid and SONI): NTCs of the GB-Ireland ICs; and
  - GB CCR (NESO): either available NTC or transmission-related parameters required for flow-based optimisation between zones.

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<sup>158</sup> Reinstating a CCR has so far not occurred in the EU but amending CCRs has been common practice when new ICs come into operation, see e.g. the inclusion of NEMO in the Channel CCR in 2017 ([link](#)). However, we recognise that there may be alternative CCR designs available (e.g. not necessarily directly reinstating previous CCRs).

<sup>159</sup> Recital 7 of the CACM GL states that “*The flow-based approach should be used as a primary approach for DA and intraday capacity calculation where cross-zonal capacity between bidding zones is highly interdependent.*” As discussed in Footnote 135, AHC could also be implemented on the GB-side of the IC if GB were to opt for the flow-based approach to allocate the GB inter-zonal capacity.

#### 4. ZI: Self-scheduling with zonal pricing

4.57. The EUPHEMIA algorithm would then simultaneously determine all zonal prices in GB and Europe and flows between all price zones (including on ICs between GB and Europe, and cross-zonal flows within GB). This is consistent with how the EUPHEMIA algorithm currently operates in EU zonal markets, such as Italy, Norway and Sweden, where it determines cross-zonal flows within those countries. The ICs between GB and the connecting markets, for which the flows would be determined via the Price Coupling algorithm would, by definition, be commercially optimally utilised (e.g. always intuitive and, not accounting for transmission losses, used up to their pre-determined maximum capacity).

### Intraday market

4.58. Similar to NO Price Coupling, under ZI Price Coupling all GB IDMs (continuous and explicit auctions) would be integrated into (and hence replaced by) the SIDC IDAs and ID continuous market. We also assume that the I-SEM would be integrated into the SIDC, such that the currently price-coupled IDAs between GB and the I-SEM would be discontinued. Also, for NSL, this would mean that it would no longer be price coupled only on DA basis but both on a DA and ID basis.

4.59. In line with the DA process described above, the relevant TSOs in the Channel, IU and GB CCRs would provide the necessary transmission data, and PXs would submit the GB order books to the SIDC (continuous and auctions). The SIDC would then jointly determine all European zonal prices and flows, including GB zonal prices and cross-zonal flows.

4.60. Pre-Brexit ID cross-border arrangements were explicit, which allowed for countertrading with the connecting markets via IC capacity holders. If GB would also join the SIDC, it is uncertain (both from legal and regulatory perspectives) whether countertrading in the ID timeframe between GB and the connecting markets would still be possible and how it could be implemented efficiently.<sup>160</sup> As countertrading would take place in parallel with the SIDC, measures would need to be put in place to ensure that subsequent SIDC trades do not unwind the countertrades.

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<sup>160</sup> Countertrading in the IDM currently in place between DK1 and Germany (TenneT) ([link](#), [link](#)). However, it is unclear whether such arrangement would easily be replicated for GB and the relevant connecting European market.

#### 4. Z1: Self-scheduling with zonal pricing

4.61. Compared to N0, we expect the need for countertrading to decrease under Z1, conditional upon the zonal boundaries reflecting intra-GB transmission bottlenecks. Hence, in case there would be obstacles to allow for countertrading under Price Coupling, the associated risks (e.g. having less options to resolve intra-GB transmission constraints) would be less severe under Z1 compared to under N0.

#### Post-gate closure time

4.62. As per N0 Price Coupling, we do not expect that Price Coupling under Z1 would require any changes to the current post-GCT arrangements. No further cross-border trading would take place during this timeframe, and only NESO would be able to alter flows at this timeframe, using SO-SO trades or emergency services .

4.63. We further assume that cross-border BMs would need to be developed to be compatible with EU balancing platforms. As discussed in Chapter 2, NESO has previously considered various options for this.

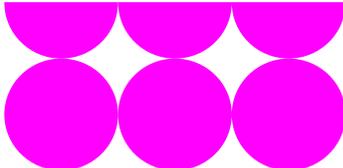
#### Z1 Conclusions

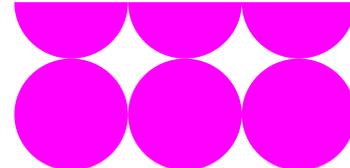
4.64. In our discussion above, we have assessed the potential feasibility of combining three selected cross-border arrangements (Status Quo, MRLVC and Price Coupling) with the Z1 market design. In doing so, we have not sought to comment on the preferred option(s) for cross-border trading arrangements nor on the desirability of the Z1 design itself. Rather, we have taken the Z1 market design as given and examined how different cross-border trading arrangements could be developed or adapted to be compatible.

4.65. We find that the Z1 market design can be made compatible with Status Quo, MRLVC and/or Price Coupling, although there are some material differences with the functioning of these cross-border arrangements relative to the N0 market design. We summarise our conclusions below:

- (i) All else equal, zonal wholesale market pricing will lead to more optimal scheduling of ICs from a GB system perspective compared to N0, across all three types of cross-border arrangements (Status Quo, MRLVC and Price Coupling). That is, the scheduling of ICs under a zonal market design is expected to relieve rather than aggravate internal congestion in GB. The extent to which Z1 indeed schedules ICs more in line with the GB system needs would be driven by the extent to which the GB zones are aligned with the main transmission boundaries of the system. Zonal pricing in GB could also impact wholesale prices in connected EU markets and constraint volumes in I-SEM.

## 4. ZI: Self-scheduling with zonal pricing

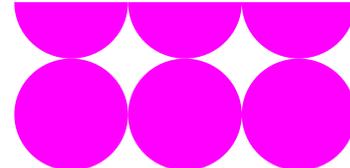
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- (ii) Under the Status Quo, we find that the explicit cross-border trading arrangements are compatible with ZI. However, we find that the implicit cross-border trading arrangement on NSL and the GB-Irish ICs would likely need to be amended when moving away from national wholesale prices to schedule ICs, with a fallback option being a return to explicit auctions for those ICs. Such amendments would come at the expense of an efficiency loss from having to replace the implicit trading arrangements on NSL and the GB-Irish ICs, but this loss appears likely to be outweighed by the efficiency gains from scheduling all ICs on zonal prices rather than on national GB wholesale prices (via an explicit trading arrangement). It appears to us that the efficiency gains of the latter would likely outweigh the efficiency loss of the former, however, this would need to be examined further.
  - (iii) We find that MRLVC under ZI would work in a broadly similar way to N0. The main difference is that the PXs would need to submit GB order books on a zonal rather than national basis to the MRLVC algorithm, which has not yet been examined in the ongoing discussions on the MRLVC design. We envisage that there are two options for the geographical coverage of the order books – they can cover all GB zones (Option 1) or only GB BBZs (Option 2). Our view is that Option 1 is more robust. Although the computational burden of Option 1 is higher compared to Option 2, it is more future-proof and would reduce the likelihood of counterintuitive IC flows.
  - (iv) Price Coupling is fully compatible with ZI. Compared to explicit cross-border arrangements and MRLVC, there is no risk of commercial underutilisation of the ICs. Relative to N0/N1, ZI is likely to be more computationally burdensome for EUPHEMIA. This could prevent Price Coupling from being feasible as the EU might choose to prioritise other updates to the algorithm over the integration of GB zones. It is uncertain whether countertrading in the ID timeframe between GB and the connecting markets would still be possible and how it could be implemented efficiently. However, the associated risks (e.g. having less options to resolve intra-GB transmission constraints) would be less severe under ZI Price Coupling compared to under N0 Price Coupling as constraints volumes are expected to be lower under ZI Price Coupling.



## Z1 – Scheduling based on zonal wholesale prices

- 4.66. Scheduling of ICs under a zonal market design is expected to relieve rather than aggravate internal congestion in GB leading to lower constraint volumes needing to be resolved via the BM. The extent to which a zonal wholesale market design will reduce the constraint volumes relative to N0 will depend on the how well the zones reflect internal transmission constraints in GB. Zonal market design with well-aligned zones would be expected to significantly reduce constraint volumes and associated costs (both for redispatching within GB as countertrading). The materiality of the impact of zonal pricing on constraint volumes would need to be empirically tested.
- 4.67. Scheduling IC flows according to zonal prices could have implications for countries that are interconnected with GB:
- Scheduling IC flows according to zonal prices would likely result in materially different scheduled IC flows relative to the N0, which would in turn impact wholesale prices in the connected European countries;
  - Depending on the zonal configuration in GB, the GB-Irish ICs would likely be scheduled based on different zonal prices in GB (e.g. Scotland, Wales, North-West England), which could potentially result in I-SEM acting as a “GB transit network” between Scotland and South Wales. All else equal this could lead to increased constraint volumes in the I-SEM.

**Conclusion 1:** All else equal, zonal wholesale market pricing will lead to more optimal scheduling of ICs from a GB system perspective compared to N0, across all three types of cross-border arrangements (Status Quo, MRLVC and Price Coupling). That is, the scheduling of ICs under a zonal market design is expected to relieve rather than aggravate internal congestion in GB. The extent to which Z1 indeed schedules ICs more in line with the GB system needs would be driven by the extent to which the GB zones are aligned with the main transmission boundaries of the system. Zonal pricing in GB could also impact wholesale prices in connected EU markets and constraint volumes in I-SEM.



## Z1 – Status Quo cross-border arrangements (explicit and implicit)

### Explicit trading

4.68. The current explicit cross-border trading arrangements are compatible with Z1. However, to the extent that zonal wholesale prices could (in some regions and in some periods) become more volatile compared to national wholesale prices the valuation of cross-border transmission rights could be affected. This could be either a positive impact (if the potentially increased volatility led to wider price spreads between the GB IC zone and the connected European zone), or a negative impact (if the potentially increased volatility discouraged trading). The balance of these two impacts would need to be further assessed empirically. Assuming that the volatility of wholesale prices of the SDAC zones is not materially impacted by GB having a zonal rather than a national wholesale market in place, we expect that the level of forecast error of SDAC prices, and therefore the likelihood of commercial under-utilisation of the ICs (including the counterintuitive flows) to be similar as under N0.

### Implicit trading at DA – NSL

4.69. The current implicit cross-border trading arrangement for NSL at the DA stage can be continued under Z1 but would need to be adapted. The clearing of NSL flows could either be integrated into (Option 1) or could be kept separate (Option 2) from the intra-GB Price Coupling process. As Option 1 would likely result in governance challenges (e.g. GB is unlikely to accept involving Norway in the development of the intra-GB market coupling process), Option 2 appears to us to be more credible.

4.70. Under Option 2, there would be dual prices in both the GB IC zone where NSL connects and NO2. There is precedent for dual NO2 prices, and Statnett has indicated that there is sufficient liquidity in NO2 to sustain two prices, but the full impact of such a dual price in a GB zone would need to be examined carefully before proceeding with this option.<sup>161</sup>

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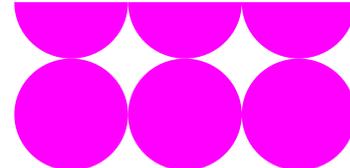
<sup>161</sup> Similarly as this has been studied by Statnett before launching the current implicit coupling between GB and NO2 via NSL ([link](#)).

## 4. ZI: Self-scheduling with zonal pricing

- 4.71. We assume the SDAC to be the market that is cleared last, but it is an open question as to which of the GB DAM or the market clearing in which the GB IC zone and NO2 are implicitly coupled (currently performed by N2EX) would be cleared first. As the markets are cleared sequentially, participants in earlier markets would have to anticipate the flows and prices that are cleared in later markets. As such, the market that determines the larger volumes of flows to/from the connecting GB IC zone would ideally be cleared first, as it likely has a larger impact on the price formation in that zone.
- 4.72. Assuming the inter-zonal transmission capacity between the GB IC zone and the bordering GB zones is larger than the transmission capacity of NSL (and hence the cross-zonal flows would likely have a larger impact on the price formation in the GB IC zone than the flows on NSL), it would seem preferable to clear the GB DAM before the market clearing in which the GB IC zone and NO2 are implicitly coupled.
- 4.73. While we deem Option 2 for NSL to be, at least in principle, workable, we do not consider it future proof to new ICs between Norway and GB that connect to different GB/NO zones than NSL. This is because the cross-zonal capacity within GB and Norway would need to be reserved for the separate market coupling process between GB and Norway, which is likely to be inefficient.

#### Implicit trading at ID – GB-Irish ICs

- 4.74. We do not regard the current implicit cross-border trading arrangement with the I-SEM at the ID stage to be compatible with ZI. Similar to NSL discussed above, the clearing of GB-Irish IC flows can either be integrated into (Option 1) or kept separate from (Option 2) the intra-GB Price Coupling process. We find Option 2 more credible for the governance reasons discussed above in ¶4.69.
- 4.75. However, the implementation of Option 2 for the GB-Irish ICs is more complicated compared to for NSL because there are already multiple GB-Irish ICs that would likely connect to different GB zones. Similar to that discussed in ¶4.73, this means that cross-zonal capacity in GB would need to be reserved for the market coupling process between GB and I-SEM, which is likely to be inefficient.
- 4.76. Considering these complications with the implicit coupling of NSL at DA stage and I-SEM at ID stage under ZI, alternative options may need to be considered. As a fallback option, the cross-border arrangement for these ICs would have to revert back to an explicit cross-border trading arrangement. We expect that the efficiency gains from scheduling all ICs on zonal rather than national GB wholesale prices (albeit via an explicit cross-border arrangement) would outweigh the efficiency loss from having to replace the implicit trading arrangements on NSL and the GB-Irish ICs. However, this trade-off would need to be empirically further investigated.

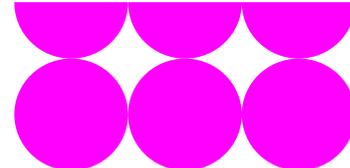


**Conclusion 2:** Under the Status Quo, we find that the explicit cross-border trading arrangements are compatible with ZI. However, we find that the implicit cross-border trading arrangement on NSL and the GB-Irish ICs would likely need to be amended when moving away from national wholesale prices to schedule ICs, with a fallback option being a return to explicit auctions for those ICs. Such amendments would come at the expense of an efficiency loss from having to replace the implicit trading arrangements on NSL and the GB-Irish ICs, but this loss appears likely to be outweighed by the efficiency gains from scheduling all ICs on zonal prices rather than on national GB wholesale prices (via an explicit trading arrangement). It appears to us that the efficiency gains of the latter would likely outweigh the efficiency loss of the former, however, this would need to be examined further.

## ZI – MRLVC

- 4.77. Under ZI, the MRLVC process on the European side would remain unchanged from N0 MRLVC. On the GB side, PXs would need to submit GB order books on a zonal rather than national basis to the MRLVC algorithm. There are two options for the geographical coverage of the order books: (i) all GB zones (Option 1); or (ii) only GB BBZs, while providing forecasts for the flows between GB BBZs and other GB zones (Option 2). The extent of the difference between Option 1 and Option 2 will depend on the number of zones and ICs in GB – if GB only has a few zones and most of them have ICs to Europe, both options would be very similar.
- 4.78. Overall, Option 1 seems more practical and credible than Option 2. Although Option 1 would increase the computational burden of the MRLVC algorithm to some extent, it is more future proof to additional interconnection and intra-GB transmission investment. Option 1 also has lower likelihood of the commercial under-utilisation of ICs, as it would allow for all GB interzonal flows to be optimised as part of the MRLVC.

**Conclusion 3:** We find that MRLVC under ZI would work in a broadly similar way to N0. The main difference is that the PXs would need to submit GB order books on a zonal rather than national basis to the MRLVC algorithm, which has not yet been examined in the ongoing discussions on the MRLVC design. We envisage that there are two options for the geographical coverage of the order books – they can cover all GB zones (Option 1) or only GB BBZs (Option 2). Our view is that Option 1 is more robust. Although the computational burden of Option 1 is higher compared to Option 2, it is more future-proof and would reduce the likelihood of the counterintuitive flows on the ICs.



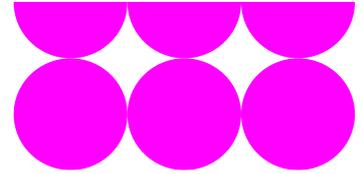
## Z1 – Price Coupling

- 4.79. Under Z1 Price Coupling, we assume that GB would become part of the SDAC and would have to comply with the CACM GL, which requires IEM cross-zonal borders to be part of CCRs. We assume that the pre-Brexit Channel and IU CCRs would be reinstated, and that the CCRs would retain the NTC methodology for calculating capacity on the GB ICs. In addition, we anticipate that a new GB CCR would be created to cover the cross-zonal borders within GB where NESO would be the sole entity that determines the available commercial cross-zonal transmission capacity for the market coupling process (likely using the flow-based methodology).
- 4.80. Compared to the other possible cross-border arrangements, Price Coupling is fully compatible with Z1 with the key advantage being that, by definition, there would not be any counterintuitive flows between GB and the SDAC. In addition, ICs that are scheduled based GB zonal prices would be better aligned with system needs compared to N0 Price Coupling.
- 4.81. Z1, relative to N0, is likely to lead to an increased computational burden for EUPHEMIA. This would be especially the case if the GB CCR adopts the flow-based approach to allocate capacity between the GB zones, as this is more complex than the NTC approach. This could prevent Price Coupling from being feasible as the EU might choose to prioritise other updates to the algorithm over the integration of GB zones. For example, the MTU change could extend the EUPHEMIA timelines and computational intensity to the point that it would not be able to accommodate GB zones.
- 4.82. If GB would also join the SIDC, it is uncertain whether countertrading in the ID timeframe between GB and the connecting markets would still be possible and how it could be implemented efficiently. However, the associated risks (e.g. having less options to resolve intra-GB transmission constraints) would be less severe under Z1 Price Coupling compared to under N0 Price Coupling as constraints volumes are expected to be lower under Z1 Price Coupling.

**Conclusion 4:** Price Coupling is fully compatible with Z1. Compared to explicit cross-border arrangements and MRLVC, there is no risk of commercial underutilisation of the ICs. Relative to N0/N1, Z1 is likely to be more computationally burdensome for EUPHEMIA. This could prevent Price Coupling from being feasible as the EU might choose to prioritise other updates to the algorithm over the integration of GB zones. It is uncertain whether countertrading in the ID timeframe between GB and the connecting markets would still be possible and how it could be implemented efficiently. However, the associated risks (e.g. having less options to resolve intra-GB transmission constraints) would be less severe under Z1 Price Coupling compared to under N0 Price Coupling as constraints volumes are expected to be lower under Z1 Price Coupling.

# 5.N3: Central scheduling with national wholesale pricing





In this chapter, we discuss how the status quo cross-border trading arrangements, MRLVC and Price Coupling could potentially work under the N3 market design, in which GB retains national wholesale pricing but moves to central scheduling. We start with a section introducing the key market design assumptions and a section describing the different prices that can be used to schedule IC flows under N3.

### Key market design assumptions

5.1. NESO’s view of the N3 strawman dispatch model is set out in Figure 5-1.

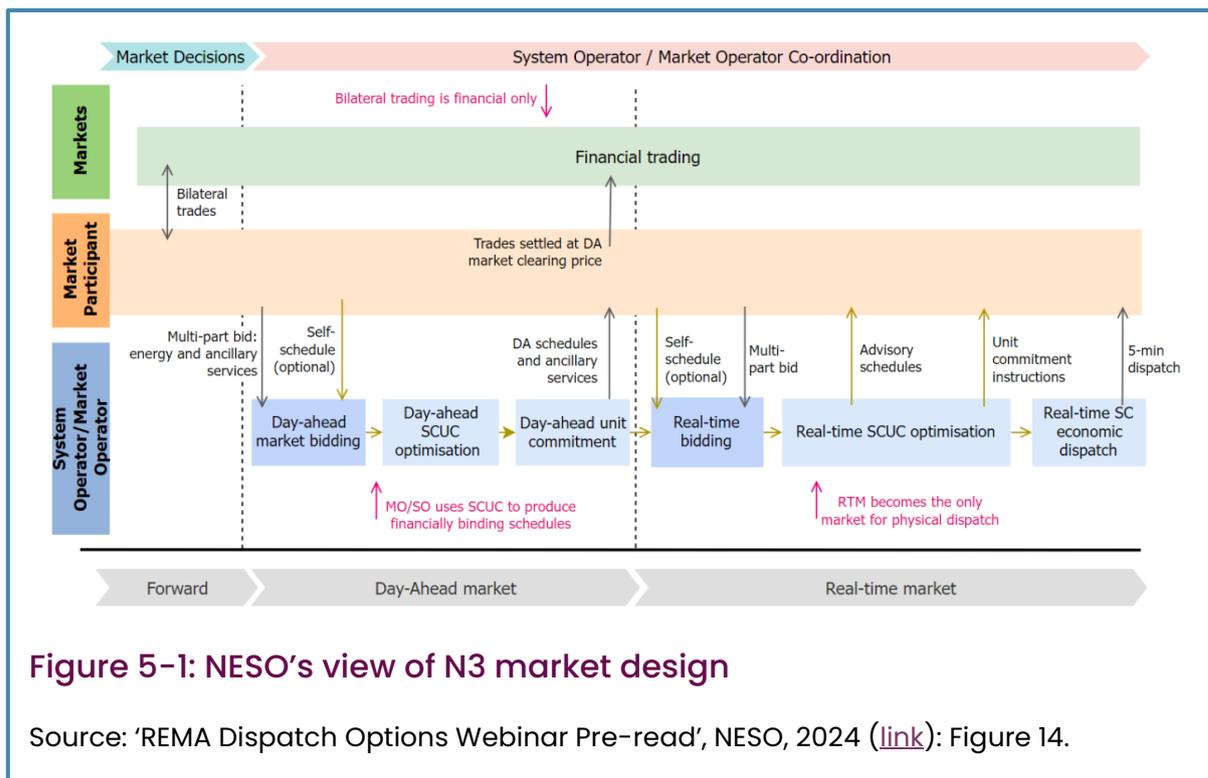


Figure 5-1: NESO’s view of N3 market design

Source: ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 ([link](#)): Figure 14.

5.2. The key market design assumptions under the N3 market design are as follows:<sup>162</sup>

- Forward trading is purely financial. We assume that IC owners and IC capacity holders also only take part in financial trading, and no physical nominations on ICs can take place at any stage other than RT;
- Market participants (e.g. traders) submit bids for each of their units in the GB DAM, rather than a portfolio of assets. Unit-based bidding uses ‘multi-part bids’, which include technical and commercial details (e.g. start-up costs, shut-down costs and no-load costs), availability (e.g. accounting for outages), prices and volumes;

<sup>162</sup> ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 ([link](#)): 4.6

## 5. N3: Central scheduling with national wholesale pricing

- The DA central schedule is defined through the Security Constrained Unit Commitment (“SCUC”) process, which determines the optimal schedule of participating assets so that the power system delivers minimum system cost while respecting physical and security constraints;<sup>163</sup>
- We assume that the DA central schedule is ‘binding’, and that there are rules in place that prevent systematic re-bidding that could unwind the DA schedule (and in particular that would unwind the position that central schedule identified to address intra-GB transmission constraints);<sup>164</sup>
- The central scheduling process produces two sets of GB wholesale electricity prices: (i) shadow nodal prices, which are used to schedule all generation; and (ii) a would-be GB ‘unconstrained’ national price<sup>165</sup> which is used to determine how much load pays to generation;<sup>166,167</sup>

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<sup>163</sup> There is the opportunity for NESO to also introduce the co-optimisation of ancillary services (“AS”) with the energy schedule at DA stage. We do not consider the decision about whether co-optimisation of AS and energy is introduced to be vital for the evaluation of cross-border arrangements and do not examine this variant further in this report.

<sup>164</sup> Different options available in principle – e.g. penalties for deviation tied to the transfer compensation or to the shadow nodal prices; or a physically binding DAM. We are agnostic as to the specific form that the ‘binding’ feature takes, but we assume that market participants do not systematically take positions ‘against’ the intra-GB transmission constraints. Experiences with avoiding such issues exist in Italy that currently has hybrid scheduling with zonal pricing in place. With hybrid scheduling being defined as the running of a SCUC in a forward timeframe (DA or ID) with: (i) exogenously determined flows on the relevant cross-border transmission elements (in the case of Italy scheduled based on zonal wholesale price via the SDAC or SIDC IDAs which precede the SCUC); and (ii) the objective of the SCUC being the minimisation of transfer compensations rather than total scheduling costs.

<sup>165</sup> This is akin to that used in the former GB pool. Source: ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 ([link](#)): 4.6.

<sup>166</sup> In contrast, all US ISOs and New Zealand where central scheduling is in place apply nodal pricing. By applying nodal pricing there is no need to introduce transfer payments.

<sup>167</sup> Relative to the current market design (N0) the potential benefit of central scheduling with a national wholesale price (N3) could be: (i) A reduction in the volume of redispatch actions required in RT by allowing the NESO to make use of assets that may not be available closer to RT (such as thermal plant with long start-up times; and (ii) A reduction in the cost of redispatch actions. This would be the case if NESO was able, at the DA stage, to make use of assets that are available at lower cost if such a need is signalled ahead of time. More generally, the cost of redispatch is likely to be lower at DA stage than close to RT, given the additional costs (e.g. the ability of resources to earn extra additional infra-marginal rents in the BM) involved in rescheduling in tight timeframes. Another benefit of central scheduling is that it facilitates the introduction of the co-optimisation of energy scheduling and ancillary services.

## 5. N3: Central scheduling with national wholesale pricing

- The ‘unconstrained’ national GB price would be determined by performing a market clearing using the same bids and offers as in the SCUC processes but without consideration of intra-GB transmission. To determine the scheduled flows on the ICs in this ‘unconstrained’ market clearing, the bids/offers from the DA IC capacity holders could be used for N3 Status Quo.<sup>168</sup> For N3 MRLVC, the scheduled IC flows as determined by the MRLVC algorithm could be used. For N3 Price Coupling, the IC scheduled flows as determined by EUPHEMIA could be used.
- Under the N3 design, market participants have the option to submit simple or multi-part bids or self-schedule (and become price takers). We assume that market participants are compensated via transfer payments such that they have an incentive to be centrally scheduled. In case no transfer payments were in place, market participants who are expected not to be centrally scheduled could have an incentive to self-schedule based on their expectations on the unconstrained GB price.<sup>169</sup>
- Complementing revenues from receiving wholesale price, there are two potential forms of transfer payments that generation/storage units can receive:<sup>170</sup>
  - Assets that are scheduled to operate but are loss-making when receiving the ‘unconstrained’ price are assumed to be paid a top-up to make them whole. This is an essential feature of centrally scheduled markets without nodal pricing in place. Without such top-up payment the SO would potentially be committing market participants to operate below-cost, which would induce inefficient exit from the market.<sup>171</sup>

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<sup>168</sup> Alternatively, the ICs as scheduled in the GB SCUCs can be used as an exogeneous input in the unconstrained GB zonal DAM clearing.

<sup>169</sup> This would be that for example when a unit is expected not to be centrally scheduled due to intra-GB transmission constraints but has a marginal cost that is lower than the GB unconstrained price.

<sup>170</sup> These are akin to the constraint payments in the former GB pool. See ‘Pool Reform and Competition in Electricity’, Newbery, D. M. (1997) ([link](#))

<sup>171</sup> These top-ups are different from “side payments” that are in place in US ISO markets to recover non-convex costs (e.g. start-ups). Side payments are granted in case the nodal clearing price does not suffice to cover those non-convex costs. In US ISO markets, unless for must-run reasons (e.g. local voltage or stability issues), the nodal clearing price will always be higher than the variable bid (in £/MWh, e.g. short-run marginal cost) of any scheduled asset. This is not the case with transfer payments where the unconstrained price can be lower than the variable bid (in £/MWh, e.g. short-run marginal cost) of a scheduled unit. An example is a thermal generator in the South of GB that is scheduled while there is a lot of wind generation in the North of GB. The high wind generation in the North is partly undeliverable but depresses the unconstrained price.

## 5. N3: Central scheduling with national wholesale pricing

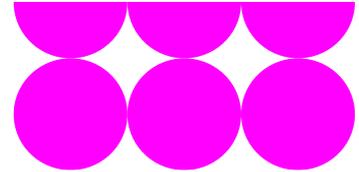
- Similarly, assets that are not scheduled to operate but would have been scheduled in a hypothetical ‘unconstrained’ schedule are compensated for the foregone revenues. Unlike the point immediately above, this particular feature is a design choice. Alternative approaches are possible where such a compensation is not made (although we would note that these might have some perverse incentives on participant bidding behaviour).<sup>172</sup>
- The current N3 design is assumed not to have an ID timeframe, but it is recognised that this could potentially be introduced in the future.<sup>173, 174</sup> Where relevant, we refer to this possibility in the detailed description below, but do not examine the associated detailed market design;
- The balancing RT market is the only physical market that determines which assets are dispatched; and
- Depending on the design variant of the cross-border element, IC capacity holders may be required to bid into the wholesale market. This is explored in the relevant sections below.

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<sup>172</sup> For example, there are no such compensations in Australia where central scheduling is in place, but zonal state-wide prices are used for the settlement of market participants. In other words, under such implementation the access to the transmission network is non-firm. Everything else equal, non-firm transmission access rights would reduce total transfer payments to be paid out by NESO but would lead to important revenue impacts for existing assets which would likely lead to increased risk for new investments. In addition, the lack of compensations would likely trigger gaming in case self-scheduling is allowed and bidding distortions when self-scheduling is not allowed. The latter is referred to as “disorderly bidding” where generators that anticipate not to be scheduled due to transmission constraints would offer at very low prices to ensure being scheduled potentially leading to a suboptimal schedule. For these reasons, we assume compensation for units that would have been scheduled in the ‘unconstrained’ schedule but are not in the SCUC. For more detail, see: FTI Consulting, 2021. Forecast of congestion in NEM. Presentation for ESB ([link](#)).

<sup>173</sup> Alternatively, the market and operational arrangements that we described under “day ahead” could be moved forward to a point closer to delivery. However, moving all DA arrangements closer to delivery would impact the sequence of procedures in GB and the EU, which we do not discuss in detail here.

<sup>174</sup> US ISOs with central scheduling place have processes such as Reliability Unit Commitments (“RUC”), to make significant modifications to the schedule before the RT market. For example, when an outage occurs the ISO can commit additional units ahead of the RT market which would otherwise be too slow to respond on a short notice. Units can adapt their RT market offers/bids prices up to the GCT to better reflect changing system conditions (for example ID gas price swings).



## Prices used to schedule IC flows

- 5.3. Under each N3 cross-border trading arrangement, there are two potential options that NESO could use to schedule ICs:
- **Option 1:** Based on the price difference between the GB shadow nodal price at their landing point and the wholesale price in the connected market.
  - **Option 2:** Based on the price difference between GB national unconstrained price and the price in the connected market, which is consistent with the status quo and how the IC capacity holders currently earn congestion rents.
- 5.4. Under **Option 1**, where ICs are scheduled based on the shadow nodal price in GB, the IC flows would be determined based on the same information as other GB assets as part of the central scheduling process. This would ensure flows on ICs to be scheduled in the “with-price” direction with respect to shadow nodal prices in GB and the (forecasted) wholesale price of the connected market (“scheduling price differential”). As such, the IC flows would be scheduled optimally with respect to the GB system needs. This means that the ICs could be on purpose counterintuitively scheduled, e.g. flowing against the commercial price differential but in line with the shadow nodal GB prices.<sup>175</sup> However, the IC congestion revenues would be settled based on the commercial price differential. This would mean that under Option 1 central scheduling could lead to uneconomic flows from the perspective of IC capacity holders or owners (depending on the cross-border arrangements) that are scheduled to be importing or exporting during those hours.
- 5.5. Considering the potential misalignment between the scheduling price differential and the commercial price differential, NESO would likely need to pay transfer payments to ensure IC capacity holders or owners earn the same revenues they would have earned if the IC were scheduled based on the commercial price difference.<sup>176</sup> Not providing such transfer payments could encourage inefficient exit and discourage efficient entry. Conceptually, transfer payments consist of two components (as illustrated in Box 5-1 below):
- Payments to compensate IC capacity holders or owners for the **negative congestion** rents incurred for flowing against the commercial price differential; and

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<sup>175</sup> A simple example is a situation where the GB unconstrained wholesale price is £30/MWh, and the connected market’s price is £50/MWh, such that the “commercial price differential” is £20/MWh. If the prevailing shadow GB nodal price in the same period is £100/MWh for a given IC, then the central scheduling process would schedule the IC to flow from EU towards GB, which would be “with price” with respect to the GB shadow nodal price, but “against price” with respect to the GB unconstrained price.

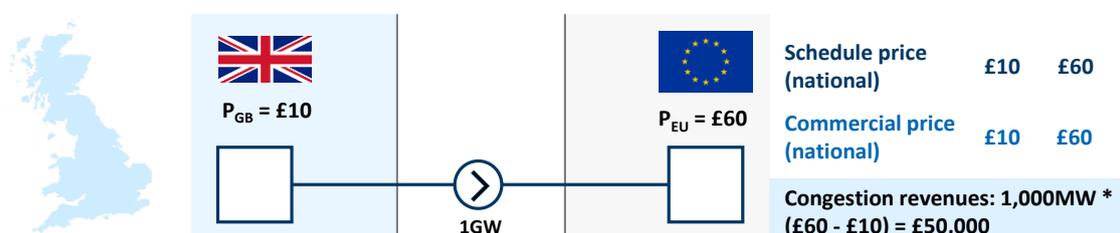
<sup>176</sup> The cost of these transfer payments under Option 1 would need to be empirically estimated, but could be lower than the additional scheduling costs (relative to the cost of a schedule that is optimal from a GB system perspective) under Option 2.

- Payments to compensate IC capacity holders or owners for **foregone** revenues – that is, the revenues they would have earned if ICs were instead scheduled based on the unconstrained national GB price.

### Box 5-1: Worked example of transfer payments to ICs

Suppose there exists 1GW of IC capacity between GB and Europe. In a given hour, the wholesale price of electricity is £60/MWh in Europe. In GB, the unconstrained national price is £10/MWh, but the shadow nodal price at the point of IC connecting to GB is £100/MWh.

If the IC is scheduled based on the unconstrained national price in GB, it would flow from GB to Europe. The congestion rent arising on the cable in that hour would be £50,000 (determined based on the differential of the Europe price of £60/MWh and GB price of £10/MWh) and would be received by the IC capacity holder in the GB to Europe direction.<sup>177</sup>



If the IC is scheduled based on shadow nodal prices in GB, however, it would instead flow from Europe to GB. As the commercial price in Europe of £60/MWh is higher than that in GB of £10/MWh, this results in negative £50,000 congestion rents arising on the cable for the IC capacity holder in the GB to Europe direction.<sup>178</sup>

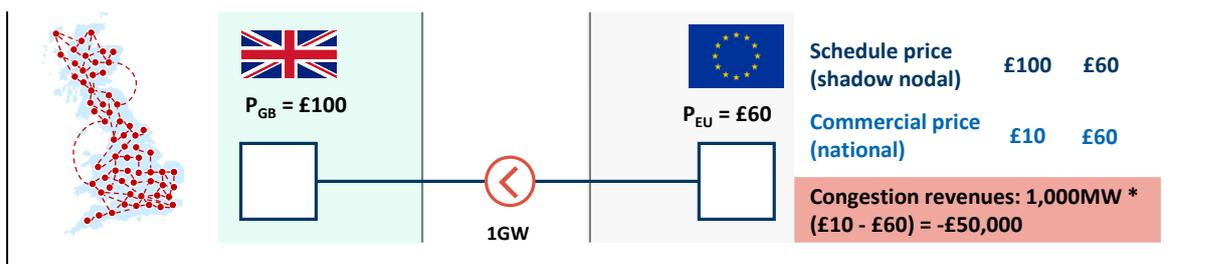
To make the IC capacity holders whole, they would need to be compensated £100,000 comprising of: (i) £50,000 to compensate the Europe-to-GB IC capacity holder or IC owner for the “negative congestion rent”; and (ii) £50,000 for the congestion rents that the GB-to-Europe capacity holder or IC owner would have earned if it was instead scheduled based on the unconstrained price.<sup>179</sup>

<sup>177</sup> Depending on the cross-border arrangement, this could be as well the IC owner.

<sup>178</sup> For simplicity, we assume that the price in Europe is not impacted by the IC flowing against the commercial price differential.

<sup>179</sup> In this scenario, if the IC were instead scheduled based on unconstrained GB price, the scheduled flows on the IC could aggravate intra-GB congestion. Compensating IC capacity holders (or IC owners) at the DA stage due to counterintuitive flows resulting from scheduling based on shadow GB nodal (leading to reduced intra-GB congestion) is likely a less costly solution than having to schedule assets around sub-optimal IC flows and/or potentially having to redispatch the IC or other assets close to RT.

## 5. N3: Central scheduling with national wholesale pricing



- 5.6. Scheduling ICs at the DA stage based on shadow nodal prices could potentially bring benefits compared to scheduling them on the basis of unconstrained GB prices. This should (other things being equal<sup>180</sup>) reduce the cost of the GB schedule. This is because it would enable NESO to create a least-cost schedule across all assets in GB (e.g. including intra-GB and cross-border assets) that respect the physical constraints on the GB network, to the extent these are known at the DA stage. In contrast, when scheduling ICs based on unconstrained prices, GB assets would sometimes need to be scheduled “around” IC flows that are not optimal from a GB system perspective. It is possible that some low-cost GB assets might not be scheduled due to intra-GB physical constraints that arise due to these sub-optimal IC flows. As well, this could potentially lead to an infeasible schedule that requires NESO to reschedule ICs and/or other assets directly after the DA SCUC.
- 5.7. However, it should be noted that there are also downsides associated with scheduling ICs at DA stage based on shadow nodal prices, including increased complexity and the difficulties of combining such scheduling with the different cross-border trading arrangements (as discussed further below). Moreover, the benefits of creating a least-cost schedule at the DA stage (e.g. based on shadow nodal GB prices) need to be considered relative to the size of forecast errors at the DA stage, as this would be a key factor in considering the merits of central scheduling more generally (see Footnote 180).

<sup>180</sup> We recognise that at DA stage not all constraints may be known. For example, uncertainty with respect to RT demand and intermittent generation could mean that the DA schedule would not fully reflect the RT supply and demand balance and in RT additional redispatching is required. The benefit of centrally scheduling assets at DA stage relative to the benefits of enabling market participants to re-position themselves up to GCT (e.g. the benefits of central vs self-scheduling) is an empirical question as is examined in a separate study to this report.

## 5. N3: Central scheduling with national wholesale pricing

- 5.8. Finally, we note that a direct consequence of scheduling ICs based on shadow nodal prices is that IC schedules would be expected to be different to current market arrangements Status Quo (N0), which would impact SDAC prices. We expect that more electricity would be imported from Central-West Europe (leading to higher prices in those countries), whereas more power would be exported to Norway (leading to lower prices in Norway). Finally, the potential for IC flows going intentionally against commercial price differences may impact operational procedures of the European TSOs<sup>181</sup> which might not be acceptable for those European TSOs (we also have not examined whether this would be allowed under the TCA).
- 5.9. Under **Option 2**, where ICs are scheduled (ahead of RT) based on the unconstrained national GB price, the scheduling of the ICs would be aligned with the (forecasted) “commercial price differential” (the difference between the GB unconstrained price and the price in the connected market) and IC capacity holders or owners (depending on the type of cross-border arrangement) would earn the same congestion revenues as under N0 Status Quo.
- 5.10. However, under Option 2, IC scheduling would not take into account transmission constraints on the GB network, and ICs could often<sup>182</sup> be scheduled in a manner that aggravates intra-GB congestion. In these instances, NESO would be required to either (i) schedule the GB assets “around” those IC flows; or (ii) redispatch the ICs themselves. Both of these actions could lead to a more costly schedule compared to a situation where the IC were scheduled optimally from a GB system perspective. Furthermore, in some hours, it may not be physically possible to determine a feasible (nodal) GB schedule, which would lead to a failure to clear the GB DAM. In that case, NESO would be required to rely on a fallback solution involving the rescheduling the IC close to RT (e.g. emergency actions on ICs).

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<sup>181</sup> Everything else equal, scheduling ICs against commercial price differences would create imbalances in the control areas of the EU TSOs. NESO would need to inform the relevant EU TSOs about those anticipated imbalances.

<sup>182</sup> Modelling the GB power system from 2030 to 2040 under FES2022 Leading the Way (“LtW”) with Holistic Network Design (“HND”) + Network Options Assessment 7 (“NOA7”) refresh assumptions, we find that under self-scheduling with national wholesale pricing the direction of the scheduled flows across all ICs is not in line with the GB-system-optimal IC schedules in 10–20% of the hours. Source: ‘Assessment of the benefits of alternative dispatch (scheduling) models’, FTI report for NESO (to be published in 2025).

## 5. N3: Central scheduling with national wholesale pricing

- 5.11. In summary, ahead-time scheduling of ICs based on the unconstrained GB price is likely to diminish the extent to which central scheduling is able to mitigate constraint costs (as highlighted by NESO<sup>183</sup>). Such scheduling of ICs would somewhat undermine one of the key benefits of introducing central scheduling (that is, the ability to consider transmission constraints in the DA market schedule) in the first place.
- 5.12. In the remainder of this chapter, we discuss the end-to-end process for each N3 cross-border arrangement across the forward, DA, ID and RT timeframes. We also comment on the choice of prices used to schedule ICs, and on any design, commercial and practical challenges or compatibility issues identified.

### N3 Status Quo

- 5.13. In this section, we set out how the Status Quo cross-border trading arrangements in GB (that is explicit trading for all NWE ICs and implicit trading on NSL and GB-Irish ICs) would work under the N3 market design (“N3 Status Quo”). Effectively, this section seeks to overlay central scheduling, as defined in the N3 design on the current cross-border arrangements (albeit with some adjustments where they appear necessary).
- 5.14. A major challenge in integrating the Status Quo cross-border trading arrangements with the N3 market design is that N3 does not have an ID market, which is incompatible with the current ID implicit trading arrangements for the GB-Irish ICs.<sup>184</sup> For this section, where relevant, we therefore assume that it would be possible to couple the I-SEM and GB at DA instead of at ID (that is, aligned with GB and NO2 via NSL). We recognise that this would be a significant change to the existing arrangements between GB and the I-SEM, but we also consider this to be a plausible assumption given that I-SEM will likely be required to adapt its arrangements when Celtic IC becomes operational (and I-SEM becomes part of SDAC, hence including DAM coupling with continental Europe).

### Forward market

- 5.15. The forward market under N3 Status Quo (summarised in Figure 5-2 below) would operate in a broadly similar way as that in N0 Status Quo explained in ¶12.5-2.8. NESO and the relevant European TSOs would calculate the available capacity on the explicitly traded NWE ICs. The determined IC capacity would be made available in the various forward market timeframes through JAO or alike.

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<sup>183</sup> ‘Scheduling and Dispatch Options Webinar’, NESO, 2024 ([link](#)).

<sup>184</sup> This would no longer be an issue if, as explained in ¶15.2, an IDM is introduced in the future under the N3 design.

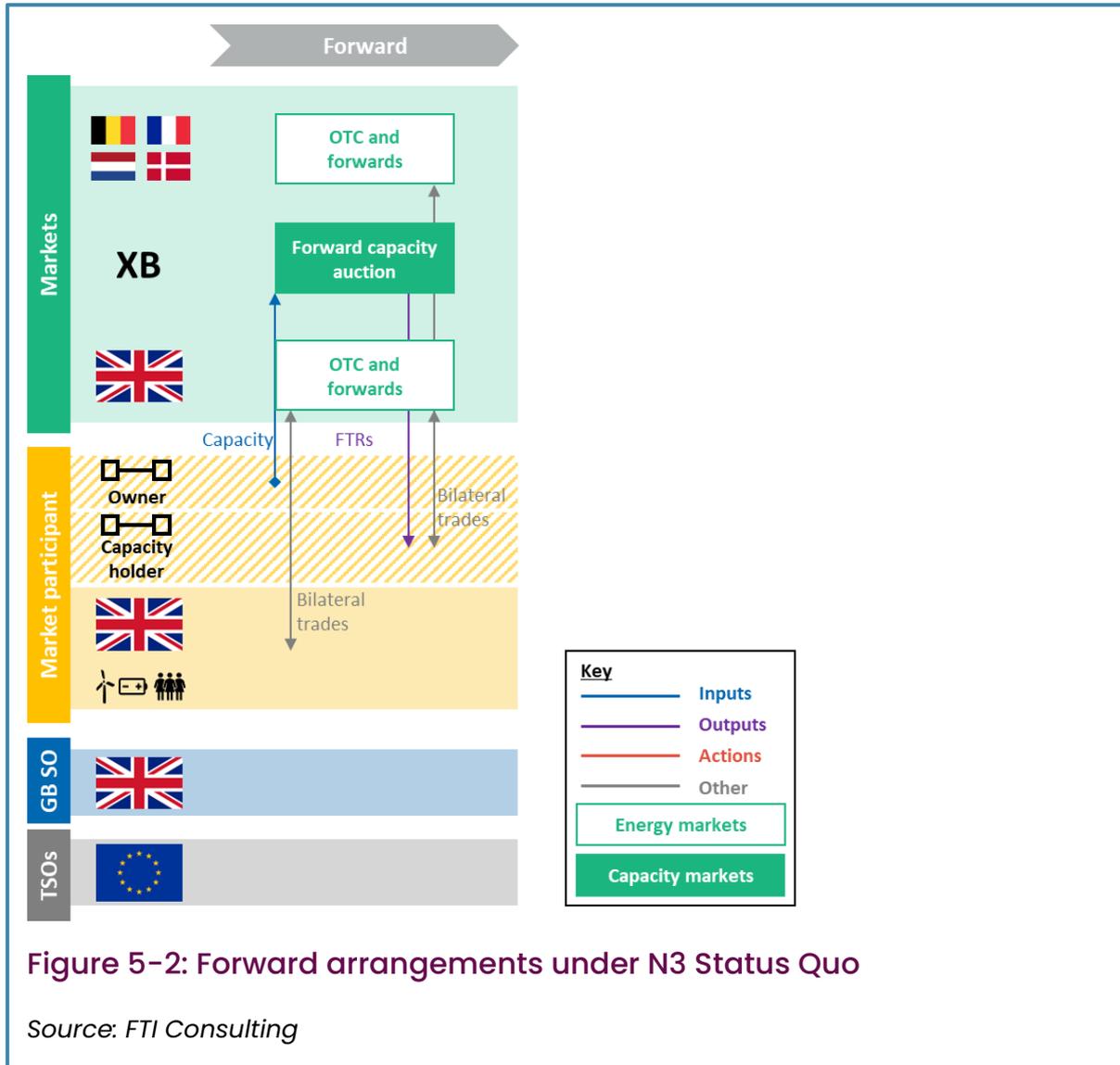
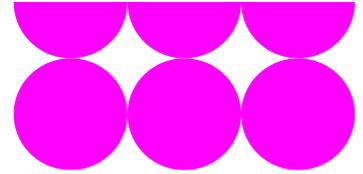
## 5. N3: Central scheduling with national wholesale pricing

- 5.16. However, as forward trading is purely financial under N3,<sup>185</sup> this implies that only FTRs (and not PTRs as per the N0 Status Quo) would be traded in the forward market. This means that the outcomes of the FCA would be purely for hedging purposes and would not have any direct bearing on the physical scheduling of the ICs. Similar to the PTRs existing under N0 Status Quo, FTRs auctioned on the forward market would be linked to particular ICs. We assume that their volume would be limited by the expected physically available IC capacity to ensure that forward contracts can be settled from the revenues of the DA IC capacity auction.<sup>186</sup>

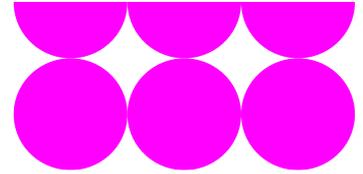
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<sup>185</sup> 'REMA Dispatch Options Webinar Pre-read', NESO, 2024 ([link](#)): page 18.

<sup>186</sup> As FTRs are a financial instrument, the volume of FTRs is not technically limited by the physical capacity of the IC. However, we assume that IC owners would be willing to sell a volume of FTR equal or lower than the expected physical available capacity in the forward market. In case they would sell higher volumes of FTRs they would potentially earn more revenues in the forward IC capacity auction, but they would be exposed to a substantial congestion rent risk. This is because when the available capacity of the IC at the DA stage is lower than volume of FTRs sold, there would be insufficient revenues from the DA IC capacity auction to settle with all FTR holders, which could be problematic if the price in the DA IC capacity auction are unexpectedly high. This assumption is broadly similar to the arrangement for FTR auctions in the US, where revenue adequacy theorem is used to ensure that the volume of FTRs auctioned off does not exceed the physical capacity in normal system conditions and thus ensures that FTR holders can be settled using the settlement surplus. 'PJM Manual 06: Financial Transmission Rights' PJM, 2024 ([link](#)): page 61.



5.17. Under N0 Status Quo (e.g. today’s market design), IC capacity that has been sold via PTRs is only released in the DA IC capacity auction if the IC capacity holder does not nominate any flows. Under N3 Status Quo, holders of FTRs from the forward market would as well have two options before the DA IC capacity auction. They could choose to convert their FTRs in what we term a “virtual IC capacity right” (explained in the next section) which gives its owner the possibility to hedge against the difference between the GB DA national wholesale price and the DA wholesale price in the connected market. Different from a PTR, the virtual IC capacity right does not give the right to the owner to nominate IC flows. When converting the FTR into a virtual IC capacity right, the FTR enables market participants to lock-in a particular price for DA IC capacity. Alternatively, the holders of FTRs can chose to sell their FTR back in the DA IC capacity auction and receive the clearing price of the DA IC capacity auction. We explain the functioning of FTRs under N3 in Box 5-2 below.

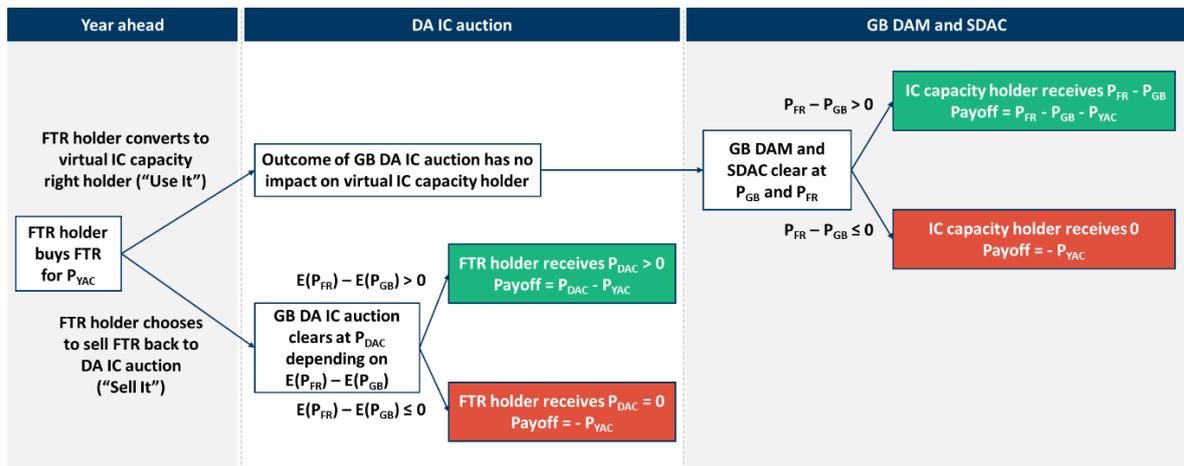


**Box 5-2: FTRs in the forward timeframe under N3 Status Quo**

Suppose there is a 1,000MW HVDC IC between GB and France. The IC owner decides to sell all its capacity in the GB to France direction in a YA FTR holder can either:

- Choose to convert their FTR to a virtual IC capacity right ('Use It') and receive the congestion rents realised after the DA wholesale market clearings (e.g.  $P_{FR} - P_{GB}$  per MW of IC capacity), for which they have "locked in" a price of £10/MW at the YA stage. The outcome of the GB DA IC auction does not have an impact on the payoff to the IC capacity holder; or
- **Choose to sell the right to these congestion rents ('Sell It')**, in which case they receive the DA IC auction price. The DA IC auction clears at  $P_{DAC}$  based on the expected FR-GB (France) price differential ( $E(P_{FR}) - E(P_{GB})$ ) at the time of the DA IC auction.

The outcomes of these are illustrated in the figure below.

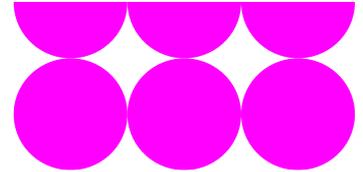


**If the FTR holder chooses to convert the FTR into a virtual IC capacity right**, they will receive congestion rents in the GB DAM for flows from GB to France based on  $P_{FR} - P_{GB}$ . We set out a simplified worked example below, which assumes that there are no forecast errors (that is, the IC capacity holders correctly estimate the DA price in France).<sup>187</sup> Suppose that the GB DAM and SDAC clear such that:

- $P_{FR} = £30/\text{MWh}$ ,  $P_{GB} = £12/\text{MWh}$ , such that  $P_{FR} - P_{GB} = £18/\text{MWh}$ . The virtual IC capacity holder receives congestion rents of £18/MWh, such that its payoff is £8/MWh (after accounting for the £10/MWh that they "locked in" for the IC capacity right at the YA stage);

<sup>187</sup> We discuss the potential impact of forecast errors by IC capacity holders in more detail in Box 5-3.

5. N3: Central scheduling with national wholesale pricing



- $P_{FR} = \text{£}10/\text{MWh}$ ,  $P_{GB} = \text{£}20/\text{MWh}$ , such that  $P_{FR} - P_{GB} = -\text{£}10/\text{MWh}$ . The virtual IC capacity holder receives zero congestion rent (the IC capacity right is not scheduled based on the commercial price difference)<sup>188</sup>, such that its payoff is negative  $\text{£}10/\text{MWh}$  (after accounting for the  $\text{£}10/\text{MWh}$  that they “locked in” for the IC capacity right at the YA stage).

Use It	YA IC	DA IC	GB DAM	SDAC	Congestion rents	Total
	$P_{YAC}$	$P_{DAC} = \text{MAX}(E(P_{FR}) - E(P_{GB}), 0)$	$P_{GB}$	$P_{FR}$	$CR = \text{MAX}(P_{FR} - P_{GB}, 0)$	$CR - P_{YAC}$
$P_{FR} - P_{GB} > 0$	-10		12	30	+18	+8
$P_{FR} - P_{GB} \leq 0$	-10		20	10	+0	-10

If the FTR holder chooses to “sell” the FTR, they receive the clearing price of the DA IC capacity auction, which is based on the expected FR-GB price differential ( $E(P_{FR}) - E(P_{GB})$ ) at the time of the DA IC capacity auction. Suppose that:

- $E(P_{FR}) - E(P_{GB}) = \text{£}12/\text{MW}$ , such that  $P_{DAC} = \text{£}12/\text{MW}$ . The FTR holder has a positive payoff of  $\text{£}2/\text{MW}$ . They paid  $\text{£}10/\text{MW}$  at the YA stage for the capacity, but receive  $\text{£}12/\text{MW}$  at the DA stage.
- $E(P_{FR}) - E(P_{GB}) = -\text{£}15/\text{MW}$ , such that  $P_{DAC} = \text{£}0/\text{MW}$  (the value of an IC capacity right in the GB-FR direction is zero).<sup>189</sup> The FTR holder has a negative payoff of negative  $\text{£}10/\text{MW}$ . They paid  $\text{£}10/\text{MW}$  at the YA stage for the capacity, but received  $\text{£}0/\text{MW}$  at the DA stage.

Use It	YA IC	DA IC	GB DAM	SDAC	Congestion rents	Total
	$P_{YAC}$	$P_{DAC} = \text{MAX}(E(P_{FR}) - E(P_{GB}), 0)$	$P_{GB}$	$P_{FR}$	$CR = \text{MAX}(P_{FR} - P_{GB}, 0)$	$CR - P_{YAC}$
$P_{FR} - P_{GB} > 0$	-10	+12				+2
$P_{FR} - P_{GB} \leq 0$	-10	+0				-10

In summary, the FTR can provide a hedge against the congestion rent between GB-France (in the GB to France direction) if the purchaser chooses to use the right; if they choose to sell it, the FTR has acts as a speculative financial instrument.

5.18. NSL and the GB-Irish ICs currently do not participate in the forward market under N0 status quo (by choice rather than any particular restrictions in the market), but could choose to do so under N3 Status Quo.

<sup>188</sup> Here we do not consider the possibility that the IC would be scheduled based on the shadow nodal price and the IC capacity owners are compensated for the negative congestion rents and/or foregone congestion rents.

<sup>189</sup> In practice, there will be a small option value as at the point of the DA IC capacity auction the wholesale DAM prices are uncertain.

5. N3: Central scheduling with national wholesale pricing

5.19. Market participants and IC capacity holders (but not IC owners) would continue to be able to trade bilaterally in the forward market (and the resulting positions would be financial).

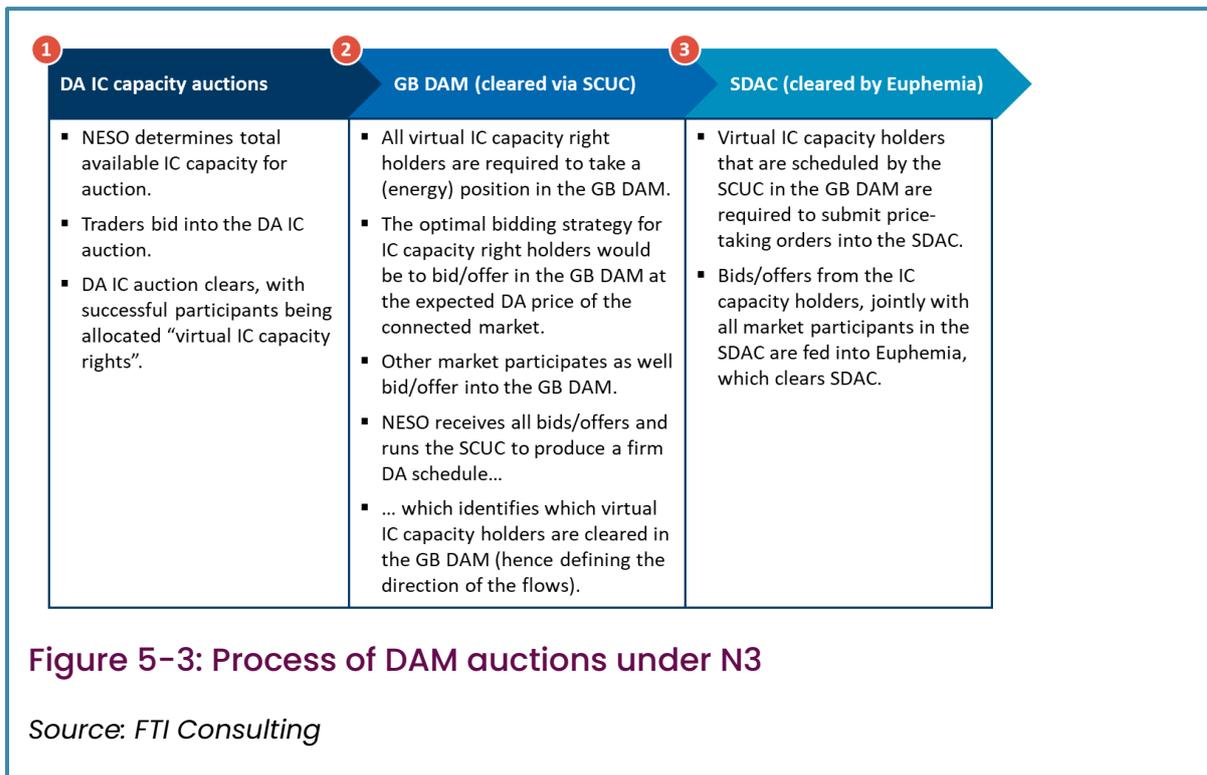
**Day-Ahead market**

5.20. We first describe the functioning of the explicit cross-border trading arrangements for the NWE ICs under N3. After we cover the functioning of the implicit arrangements for NSL and the GB-Irish ICs.

**Explicit cross-border arrangements for the NWE ICs**

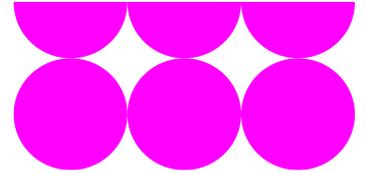
5.21. We assume that as per N0 Status Quo, IC capacity for NWE ICs would continue to be explicitly traded on separate DA IC auctions. This takes place before<sup>190</sup> the GB DAM (during which NESO runs a SCUC to produce a GB central schedule), which in turn runs before the SDAC (cleared via the EUPHEMIA algorithm).

5.22. Figure 5-3 below provides an overview of the process of the DAM auctions under N3.



5.23. We describe the detailed process in each of the three stages below.

<sup>190</sup> We do not consider the alternative assumption, where the GB DAM runs ahead of the DA IC auctions to be plausible, as there would likely be only very low volumes of IC capacity holder participation in the GB DAM given that they would be buying/selling energy without, yet, holding the corresponding IC capacity.

5.24. Under **Stage 1** (DA IC capacity auctions):

- In the DA IC capacity auctions, NESO, the connected TSO and the IC owner would first determine the total available IC transmission capacity.<sup>191</sup> The IC capacity put up for the DA IC auction by the IC owners equals the available IC capacity minus the IC capacity that was sold forward and for which the FTR holders have chosen to convert their FTR into what we term "virtual IC capacity rights".<sup>192</sup>
- Traders would then bid most likely into the DA IC capacity auction based on their expectation of the commercial price differential between GB and the relevant connected market.
- After the DA IC auction clears, successful participants are allocated the auctioned off "virtual IC capacity rights". All holders of these IC capacity rights are:
  - not able to nominate physical flows on the ICs, as these would instead be determined by the SCUC; and
  - required to take an (energy) position in the GB DAM according to the IC capacity they hold (e.g. the IC capacity right holders are also "IC capacity obligation holders"). For example, an IC capacity holder in the direction of GB to France would take a position of buyer in the GB DAM. Conversely, an IC capacity holder in the direction of France to GB would take a position of seller in the GB DAM. The requirement for all virtual IC capacity holders to take a position in the GB DAM gives NESO the ability to schedule all available IC capacity via the SCUC.

5.25. Under **Stage 2** (GB DAM clearing):

- As explained above, virtual IC capacity holders would take (energy) positions in the GB DAM. The bid into GB DAM by IC capacity holders would be based on the expectation of the connected European country's price (which appears to be the optimal bidding strategy as explained in Appendix 1). Simultaneously, other market participants would bid/offer into the GB DAM.

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<sup>191</sup> This is typically straightforward process as the GB ICs are HVDCs and hence their available capacity is not interdependent with the loading on other transmission elements. It would be more complicated for HVACs.

<sup>192</sup> Virtual IC capacity rights would be different compared to both current physical and financial rights. They would be akin to physical rights in the sense that once the right has been obtained, the holders take a position in the GB DAM (they are mandated to do so under N3). Moreover, if IC capacity holders successfully cleared in the GB DAM, then they would subsequently have to take a corresponding position in the SDAC. Therefore, virtual IC capacity holders would become price-takers in the SDAC. This is a significant departure from the existing arrangements, as IC capacity holders would not have an ability to 'not nominate' the capacity they hold. Instead, the nomination of flows would be done by NESO via the SCUC. In that sense, virtual IC capacity rights are similar to financial rights which also do not include the right to nominate flows.

## 5. N3: Central scheduling with national wholesale pricing

- After NESO receives the bids/offers, it would run the SCUC to produce a firm DA schedule.<sup>193</sup> This means that the virtual IC capacity holders would not have the option to 'not nominate' flows that NESO has scheduled in the GB DAM.
- The firm DA schedule identifies which IC capacity holders have or have not been cleared in the GB DAM (and hence defines the direction of IC flows).<sup>194</sup> NESO, in clearing the market, does not form any expectations of the connected countries' wholesale energy prices (as these expectations are directly embedded in market participants' bids).
- NESO can either schedule ICs in the SCUC based on the GB shadow nodal prices (Option 1) or GB national unconstrained price (Option 2). We discuss this further below from ¶15.27 onwards.

5.26. Under **Stage 3** (SDAC clearing):

- Once NESO determines the DA central schedule, the virtual IC capacity holders that are scheduled and other market participants would not be able to change their positions until RT (unless instructed to do so by the NESO) as no IDM is assumed to exist under N3. The described arrangement implies that the EU would be willing to accept that scheduled flows on the ICs are entirely determined by the GB SCUC based on forecasted DA prices of the connecting markets, independent of the eventual realised prices in the same markets.
- Virtual IC capacity holders that have been cleared in the GB DAM are, subsequently, required to submit PTOs into the SDAC in line with the IC capacity they hold and that has been cleared in the GB DAM. This implies that an IC capacity holder that is scheduled in the GB DAM to export/import from GB to a connected SDAC market would have offer to sell/buy electricity at the price floor/ceiling in the SDAC (rather than IC capacity holders bidding in the basis of the expected price).<sup>195</sup>
- Bids/offers from the virtual IC capacity holders and order books from participating NEMOs would be fed into EUPHEMIA, which would clear the SDAC.

## 5.27. As explained above, NESO can either schedule ICs based on GB shadow nodal prices (Option 1) or GB national unconstrained price (Option 2).

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<sup>193</sup> As explained in ¶15.2, the SCUC outputs a least-cost GB schedule that respects the relevant physical and security constraints.

<sup>194</sup> Depending on market participants' bids, it is possible that both directions of flows clear with positive volumes and prices in the auction. In that case, the net flow is scheduled on the IC.

<sup>195</sup> This is a significant difference from existing arrangements where IC capacity holders can choose to 'not nominate' the capacity they hold. Under central scheduling, the position is mandatory because if IC capacity holder that are scheduled in the GB SCUC (preceding the SDAC) would not be scheduled in the SDAC, the GB SCUC would need to be re-ran.

## 5. N3: Central scheduling with national wholesale pricing

- 5.28. **Option 1** ensures that the IC scheduled flows respect the price difference between the shadow nodal price in GB and the (forecasted) price of the connected market, but the direction of scheduled flow on the IC would no longer be necessarily aligned with the commercial price differential. This implies that ICs can intentionally being scheduled counterintuitively, e.g. scheduled to flowing against the commercial price difference. This is departure from N0 Status Quo, where counterintuitive flows primarily arise due to forecast error (see ¶12.12).
- 5.29. Under **Option 2**, scheduling ICs based on the unconstrained GB price is likely to limit the potential reduction in redispatch costs associated with central scheduling. Given that this is one of the key advantages of central scheduling as highlighted by NESO,<sup>196</sup> this seems to us not to align with the other design principles of N3 and therefore do not consider it further. If central scheduling was introduced for other reasons (e.g. to ensure co-optimisation) or the redispatch costs originating from counterintuitive IC flows were mitigated in other ways, this option may warrant further consideration.<sup>197</sup>
- 5.30. As discussed above in ¶15.5, under **Option 1** NESO would likely need to implement transfer payments for negative congestion rents and foregone revenues to ensure IC capacity holders earn the same revenues that they would have earned if they were instead scheduled based on the commercial price differential (that is, Option 2).
- 5.31. With these transfer payments, virtual IC capacity holders' bids into the DA IC capacity auction would continue to be based on their expectation of the commercial price differential (rather than the shadow nodal scheduling price differential which are arguably harder to forecast). Their subsequent bids into the GB SCUC would then reflect their expectation of the price in the connected country (similar to N0 Status Quo).<sup>198</sup> Since the value of IC capacity rights are expected to remain a function of the commercial price differential (akin to the current market arrangements), we do not expect any significant changes to the functioning of DA IC capacity auctions.

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<sup>196</sup> 'Scheduling and Dispatch Options Webinar', NESO, 2024 ([link](#)).

<sup>197</sup> For example, zonal pricing reduces the redispatch cost impact from IC scheduled in a way that aggravated intra-GB congestion, thus making Option 1 a viable option for the Z3 model discussed in Chapter 6.

<sup>198</sup> One nuance would be that the price of the connecting country will be indirectly impacted by how ICs are scheduled in GB (based on shadow nodal prices). This impact might not be material in countries with large bidding zones and relatively limited IC capacity with GB (e.g. Germany) but potentially more important for countries represented by a smaller bidding zone and a relatively large IC capacity with GB (e.g. DK1).

5. N3: Central scheduling with national wholesale pricing

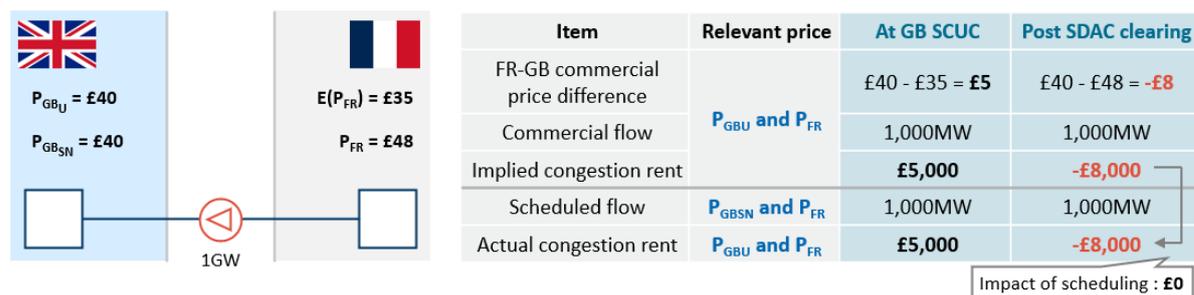
- 5.32. Notwithstanding, there are two scenarios in which the allocation of risk between NESO and traders is complex. Additional consideration would need to be made of the appropriate transfer payments in these scenarios such that there is a balance between: (i) providing market participants with incentives to forecast prices accurately; and (ii) ensuring that market participants bear risks that they can efficiently manage themselves.
- 5.33. In **Scenario 1**, the IC capacity holder’s negative congestion rents are a result of its own forecast error rather than NESO’s choice of scheduling price (see Box 5-3 below).

**Box 5-3: Scenario 1 – Negative congestion rents due to forecast error**

Suppose that a France to GB IC capacity holder expects the French price ( $P_{FR}$ ) to be £35/MWh, and as such bids into the GB SCUC to sell power at £35/MWh. The outturn GB unconstrained price ( $P_{GB\_U}$ ) and the shadow nodal price at the IC’s landing point in GB ( $P_{GB\_SN}$ ) are both £40/MWh.

As the GB shadow nodal price is higher than the expected French price, the IC capacity holder is scheduled to flow 1,000MW from France to GB. This is in line with the commercial price difference, which would also lead to a scheduled flow from France to GB. At the conclusion of the GB SCUC, the IC capacity holder would expect to earn £5,000 based on its forecasted price difference.

As the IC capacity holder’s offer is cleared in the GB SCUC, the IC capacity holder must submit a price taking offer in the French price zone via the SDAC. However, the  $P_{FR}$  ends up clearing at £48/MWh, which is £13/MWh higher than the IC capacity holders’ forecast. Due to flows on ICs being firm, there is no opportunity for the IC capacity holders to update their flow positions after the conclusion of the SDAC, which is a significant difference from existing arrangements where IC capacity holders can choose to ‘not nominate’ the capacity they hold.



As a result, both the commercial and scheduled flows (implied by the IC capacity holder’s bid at GB SCUC) go against the outturn commercial price difference, which in turn leads to both the actual and implied congestion rents to be -£8,000, meaning that the IC capacity holder is in the same position as if flows were scheduled according to unconstrained prices.

In other words, the negative congestion rent is not a consequence of NESO scheduling ICs based on shadow nodal GB prices, but due to the IC capacity holder’s forecast error.

## 5. N3: Central scheduling with national wholesale pricing

5.34. In the above scenario, NESO could choose to not compensate or limit the compensation for the IC capacity holder for the negative congestion rents. However, this would not reflect the additional downside risk that the IC capacity holder faces under N3 relative to N0, in particular:

- Under N0, the IC capacity holder could have chosen not to nominate its flows when it realises its forecast error, and lose only the amount it paid for the IC capacity rights. The IC capacity holder can then unwind its positions in GB and the connected market in the IDM.
- Under central scheduling, however, the IC capacity holder is required to take a position in the connected market after the GB DA central schedule has been determined (even if it realises its forecast error), which creates an uncapped liability risk that requires further consideration.

5.35. In **Scenario 2**, the IC capacity holder earns positive congestion rents only because it was scheduled based on shadow nodal prices – that is, it would have not been scheduled if it had instead been scheduled based on the unconstrained price (see Box 5-4 below). In this scenario, the question arises as to whether the IC capacity holder would have to return the “unintended revenues”.

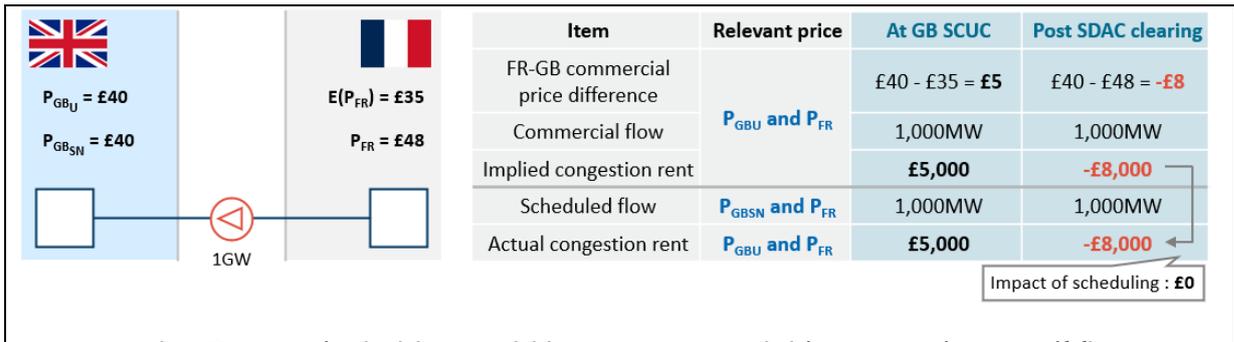
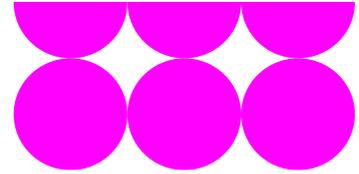
#### Box 5-4: Scenario 2 – Positive congestion rents only because IC was scheduled based on shadow nodal prices

Suppose that a France to GB IC capacity holder expects  $P_{FR}$  to be £43/MWh, and as such bids into the GB SCUC to sell power at £43/MWh. Subsequently,  $P_{GB\_U}$  clears at £40/MWh, while the shadow nodal price at the  $P_{GB\_SN}$  is set at £50/MWh.

As the GB shadow nodal price is higher than the IC capacity holder’s offer, the IC capacity holder is scheduled to flow 1,000MW from France to GB, even though considering the commercial price difference – e.g. the difference between  $P_{GB\_U}$  and the  $E(P_{FR})$  – the IC capacity holder would not have been scheduled. As such, at the conclusion of the GB SCUC, the IC capacity holder would expect to receive £3,000 worth of transfer payments from NESO, to be returned to a net revenue of £0.

As the IC capacity holder’s offer is cleared in the GB SCUC, the IC capacity holder must submit a price taking offer in the French DAM via the SDAC. However,  $P_{FR}$  ends up clearing at £31/MWh in the SDAC (which is £12/MWh lower than the IC capacity holder’s forecast), meaning that the IC capacity holder earns £9,000 of congestion rent, as the outturn commercial price difference ends up being in the same direction as the flow is scheduled (based on the price difference between  $P_{GB\_SN}$  and  $P_{FR}$ ).

5. N3: Central scheduling with national wholesale pricing



However, the IC capacity holder would have not earned this congestion rent if flows were scheduled according to the unconstrained price difference in the GB SCUC. Scheduling based on the shadow nodal price mitigated the impact of the forecast error. Further consideration is required whether in this case the IC capacity holder would be required to return (part of) the earned congestion rent.

5.36. One potential issue that we have considered is how the bidding of IC capacity rights in the opposite direction of the expected commercial price differential would function under N3 Status Quo.<sup>199</sup> It is important under N3 Status Quo that market participants take a position in this direction, as it might be the flow direction indicated by the scheduling price differential.

5.37. Under N0 Status Quo, these rights provide the IC capacity holder with an ‘option value’, which materialises when actual flows are in the opposite direction than initially expected based on the commercial price differences (due to forecast errors or market developments between the IC capacity auction and GB DAM/SDAC). There is limited downside risk as market participants have several opportunities on the DAM and IDM to unwind positions in case their forecast was inaccurate for the connecting market. Under the current market arrangements, the auctions for these IC capacity rights often clear at very low prices which indicates a low valuation of this option value.<sup>200</sup>

<sup>199</sup> Alternatively, when the price difference is not expected to be sufficient to cover losses.

<sup>200</sup> For example, IFA 1 capacity rights from GB to France cleared at €0/MWh in nearly 70% of hours on the first day of the month over the past year, with an average price of €0.15/MWh, weighted by allocated capacity. JAO, ([link](#)). See also ‘Valuation of Interconnector Transmission Rights – Do Auction Prices Reflect Option Values?’, McInerney, C. (2012) ([link](#)).

## 5. N3: Central scheduling with national wholesale pricing

5.38. However, under the N3 Status Quo arrangements, there is the same option value as under N0 Status Quo, but the downside risk is higher due to the lack of an IDM, which means that unwinding a position after the DAM is not possible and the likelihood of incurring losses by inaccurate forecast errors increases. Therefore, there is a risk that no market participants would be willing to take a position opposite to the expected commercial price differential, which would lead to a potential inefficiency in the utilisation of the IC (at times when the scheduling price differential ends up having the opposite sign of the anticipated commercial price differential).

5.39. To mitigate this risk, IC owners could be required to:

- **Bundle rights in both directions into a single product.** Such a bundling would ensure that both parts of the compensation would go to the same IC capacity holder, avoiding most of the cases where the trading costs and risk associated with IC capacity rights might outweigh the forecasted value. While this appears to be a significant change, it appears to be compatible with the philosophy of central scheduling, where it is the central market operator who determines the optimal scheduling of assets (in lieu of market participants);<sup>201</sup>
- **Allow negative bids in the IC capacity auctions** to incentivise participation in auctions for these rights, even in periods when the expected revenue from such rights is lower than the risk for losses from taking a position.

5.40. This additional risk for traders created by combining explicit IC capacity auctions with N3 will likely lead to a commercial loss for the IC owners that might need to be compensated for.

### *Implicit arrangements on NSL and GB-Irish ICs*

5.41. For Norway to remain coupled at DA stage between GB and NO2, a single entity would need to jointly define prices in GB and NO2 and associated flows on NSL. Under the current arrangements, this role is played by N2EX. There are two options as to who this single entity might be under a central scheduling design:

- **N2EX could continue to play this role**, but this would require that it receives all information that the SO would have otherwise used to centrally schedule the GB DAM (including transmission network conditions, etc.). This appears impracticable for security reasons.

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<sup>201</sup> One potential exception is when the market participants are forecasting with high confidence that the price difference between the markets will not be sufficient to cover line losses. In these cases, the value of capacity rights in both directions, will be close to €0/MWh.

## 5. N3: Central scheduling with national wholesale pricing

- **NESO could take on the role**, effectively taking over the market operator role of N2EX (noting that central scheduling already displaces the current role of PXs as market operators). There would be new information NESO would require, over and above what it would have otherwise used in the SCUC, relating to bids and offers in NO2. We consider this option to be impracticable as well, due to the challenges associated with the GB SO operating a market and receiving sensitive information for a Norwegian price zone.

5.42. Therefore, given the challenges described above,<sup>202</sup> the central scheduling algorithm would likely require NSL to move to explicit auctions akin to other continental ICs, unless security concerns could be effectively addressed. In discussions with NESO, we have not identified any credible solutions to this issue.

5.43. For the I-SEM to be coupled with GB at DA stage, we envisage similar issues as described for NSL. There are potential further complications in the I-SEM case:

- The I-SEM market may not be sufficiently liquid to sustain two parallel prices (like NO2 does, as discussed earlier); and
- Once Celtic IC comes online, it may no longer be possible to implicitly couple the GB-Irish ICs and NSL at the same time. This is because under EU regulation, all available cross-zonal capacity has to be allocated to the SDAC.<sup>203</sup> However, once France and Ireland are connected via Celtic, Ireland and Norway would be connected via an electrical path that does not go through GB. As such, the implicit GB coupling would have to likely reserve a proportion of the transmission capacity between Ireland and Norway, which would likely lead to inefficiencies. We do not examine this further in this report given the uncertainty on Celtic's arrangements.

5.44. Similarly to NSL, it seems challenging for NESO (or another party) to be able to co-clear the centrally scheduled DAM together with the I-SEM. Therefore, unless alternative approaches are identified, as a fallback solution ICs between GB and I-SEM would likely need to move to explicit auctions as well.

5.45. If the complications discussed above are resolved and implicit trading on NSL and/or GB-Irish ICs turns out to be possible, we assume that they would both earn congestion rents after the SDAC clears (as GB would not have an IDM under the N3 design) based on the relevant commercial price differential.

5.46. We summarise the sequence of events at the DA stage in Figure 5-4 below.

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<sup>202</sup> These challenges are very similar as under N3 Price Coupling and discussed in more depth in that section.

<sup>203</sup> CACM GL, Articles 30, 39 and 46 ([link](#)).

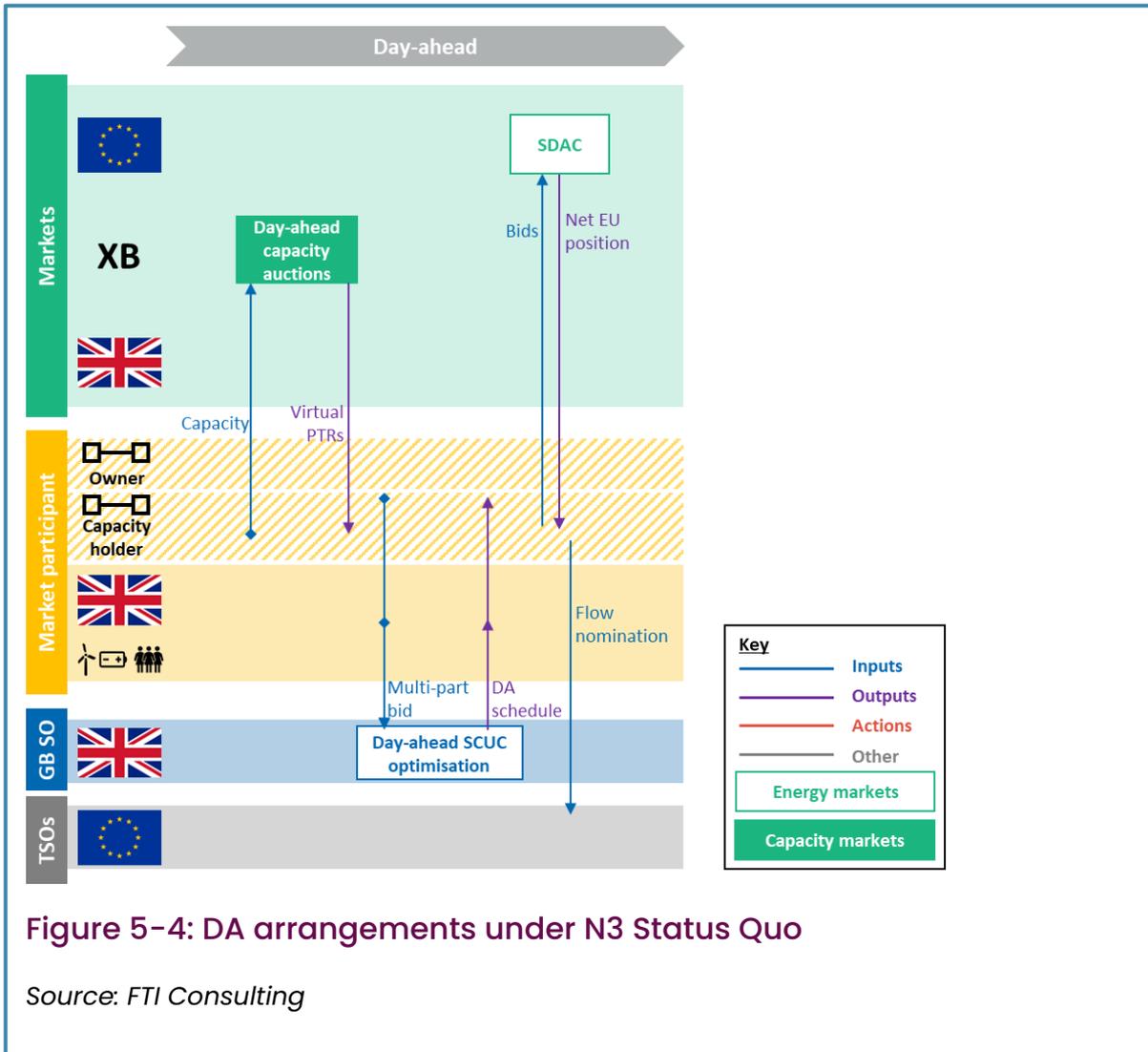
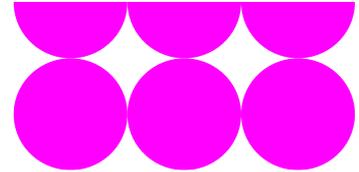


Figure 5-4: DA arrangements under N3 Status Quo

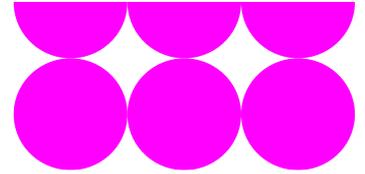
Source: FTI Consulting

### Intraday market

- 5.47. As the N3 market design does not have an IDM, there would no longer be any capacity auctions in GB for the explicitly traded ICs at the ID stage. This is a departure from the N0 Status Quo, in which the NWE ICs operate ID explicit IC auctions. This may, prima facie, result in a loss of revenues to IC owners compared to N0 Status Quo. However, in practice, a proportion of the volumes traded currently on ID explicit IC auctions might reasonably be expected to shift back to the DA explicit IC auctions, particularly given that ICs would be compensated via transfer payments under central scheduling. Overall, the impact on IC revenues would need to be empirically tested.
- 5.48. In Europe, the SIDC would run in the ID timeframe, and (similar to SDAC) would take the DA GB-Europe IC flows determined in the DA stage as given and optimise around them.

## 5. N3: Central scheduling with national wholesale pricing

- 5.49. Given that EU market participants have an opportunity to participate in SIDC (and intra-EU ICs have their positions refined in the SIDC), this is more favourable compared to GB-EU BBZ ICs (that would only be scheduled at DA stage). In the long term, this create an incentive for GB to introduce an IDM (e.g. via several IDAs in line with the existing IDAs in continental Europe), to complement the DAM. It is beyond the scope of this report to examine such a market design change, but we note that this would potentially create an opportunity for further linking of GB and EU cross-border trading arrangements at the ID stage and would reduce the negative impact of forecast inaccuracy in the DA stage (as described in the previous sub-section).
- 5.50. Scheduling ICs at DA stage based on shadow nodal prices could bring potential benefits relative to N0 Status Quo with ICs scheduled based on unconstrained prices. However, the benefits of creating an GB-system-optimal schedule at DA stage will be reduced the greater are forecast errors within the ID timeframe.
- 5.51. The right to nominate the flow on the IC would be transferred from the IC capacity holder to NESO, which could lead to increase risks for IC capacity holders under N3 relative to that under N0. Measures would need to be put in place to mitigate these risks while ensuring that IC traders continue to be incentivised to forecast prices accurately (as discussed in ¶5.32-5.35). Another drawback of explicit trading under N3 compared to N0 is that market participants have no ability to adjust flows on ICs once the GB DA SCUC has concluded. Under N0 Status Quo, there are IDMs (both continuous and IDAs) in both in GB and EU to adjust net positions and renominate flows, if initial price forecasts by market participants were inaccurate.
- 5.52. Under N3, these options would be unavailable for market participants, and only NESO and the connected TSO would have tools to adjust flows in RT. Introducing one or multiple IDAs, e.g. GB ID SCUC(s), could help address several of the highlighted issue by allowing updates to bids and flows based on improved forecasts.
- 5.53. As discussed in Footnote 174, It is possible that as an alternative to an IDM, ID NESO-led procedures would be put in place to reschedule assets in case the necessity of doing so would be known significantly before RT. An example can be a major outage of a GB asset or IC. Not having such ID processes in place could lead to foregoing potential lower cost alternative (relative to the available solutions available in RT) to resolve (forced) deviations from the DA SCUC schedule.



## Real time

- 5.54. After the DAM, GB market participants and IC capacity holders revise their bids and offers for the RT clearing. NESO would run a SCED optimisation to produce a physically binding RT schedule and resolve imbalances (and any resulting minor thermal constraints).<sup>204</sup> This process would differ from the existing BM arrangements, as it is NESO producing the SCED schedule and compensating parties via transfer payments (e.g. there is no need for market participants to provide bids/offers in a pay-as-bid BM-style market).<sup>205</sup>
- 5.55. We assume that NESO would continue to be able to adjust IC flows in RT, if necessary, using SO-SO trades and emergency services (as per N0 Status Quo described in ¶12.19).<sup>206</sup> The IC owner may also need to, unexpectedly, modify the availability of the IC (e.g. unplanned outages). Under N0 Status Quo, if an IC owner curtails their capacity and the capacity has not been nominated yet, the IC owner typically need to reimburse IC capacity holders the original auction price for when the capacity was sold (though variants to this may exist, and the reimbursement may also be related to a 'current' price spread rather than the original auction price).<sup>207</sup>

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<sup>204</sup> A SCUC is used to schedule generation (e.g. determining which units are on or off and their schedules), while SCED takes unit commitment decisions from SCUC is used to determine the most economical dispatch to meet demand.

<sup>205</sup> The transfer payments paid out to compensate for the real-time SCED schedule would be incremental/decremental relative to the transfer payments paid at the DA stage to avoid the double payment of transfer payments.

<sup>206</sup> Similarly, TSOs in connecting countries would not be able to apply NTCs post-DA and the only tool they would have available to modify flows would be as well SO-SO trades or emergency services.

<sup>207</sup> In case the IC owner does not deliver capacity that has been nominated, in addition to the original auction price of the IC capacity, the IC owner may also face imbalance charges. These imbalance charges could be related to the cost of redispatch actions in the connected countries and would be payable by the IC owner to NESO. Under the N3 market design, we envisage a similar regime to be in place. However, since there is no 'nomination' of the IC capacity by the IC capacity holders, we expect that the penalties that IC owners would need to pay for any unavailability would need to be related to the imbalance charges that IC capacity holders are exposed to (which would be typically higher than just reimbursing for the IC capacity auction price). This penalty would also need to be defined in a way that would prevent potential gaming.

## 5. N3: Central scheduling with national wholesale pricing

5.56. We assume that a cross-border BM would need to be developed to be compatible with EU balancing platforms (MARI, PICASSO, TERRE). NESO has previously considered various options for this (see ¶12.20) under the current market design (N0). One option under N3 would be to develop a technical interface to ensure that real-time orders in GB are compatible with the products traded on these platforms.<sup>208</sup>

### N3 MRLVC

5.57. In this section, we set out how the MRLVC design (see N0 MRLVC) could potentially work under the N3 design (“N3 MRLVC”). Effectively, this section seeks to overlay central scheduling, as defined in the N3 design, on the MRLVC cross-border arrangements (albeit with some adjustments where they appear necessary). As explained above, we assume that when implemented, the MRLVC would apply to all GB ICs (including NSL and the GB-Irish ICs).

### Forward market

5.58. The forward market under N3 MRLVC would work in a similar way as in N0 and N3 Status Quo, where ICs can choose to participate in JAO forward auctions and offer capacity for various market timeframes.<sup>209</sup>

5.59. Under the N3 market design, only FTRs would be traded on GB ICs.<sup>210</sup> However, in contrast to N3 Status Quo (explicit), the realised congestion rent in the DA market would be directly paid out to the FTR holder – that is, FTRs are settled based on the difference between the GB DAM price and the DA price in the price zone of the connected market. No longer DA IC capacity auctions (as under N3 Status Quo) takes place as the IC capacity is implicitly allocated in the DA stage through the MRLVC algorithm.

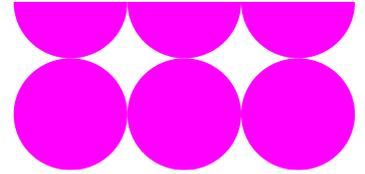
5.60. Market participants would continue to be able to trade bilaterally in the forward market (and the resulting positions would be financial).

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<sup>208</sup> This would not be unprecedented – Article 12(3)(d) of the Electricity Balancing Guideline (“EB GL”) ([link](#)) requires TSOs that use central scheduling to provide “*information regarding how balancing energy bids from specific products or from integrated scheduling process have been converted into balancing energy bids from standard products*”.

<sup>209</sup> Currently, only IFA, IFA2, ElecLink, Nemo Link, Viking Link and BritNed participate in these auctions. In principle, NSL and GB-Irish ICs could also participate.

<sup>210</sup> ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 ([link](#)): page 18.



## Day-Ahead

5.61. Under N3 MRLVC, the calculations of available IC capacity on GB-BBZs, available cross-border transmission capacity on the BBZ-BZZ borders and the BBZ-EU Flow Forecast continue to be performed prior to DA market closure (which occurs simultaneously for both the SDAC and GB DAM). BBZ NEMOs would also continue to combine their received orders and submit order books to the MRLVC algorithm. On the GB side, however, NESO would no longer submit an order book as under N0. There are two potential input options that could be fed into the MRLVC, which affect the choice of prices that can be used to scheduled IC flows:

- market participant's technical details, which due to computational constraints, would require ICs to be scheduled based on the unconstrained GB price; and
- net import/export curves that reflect the cost to the GB power system at the IC landing points of deviating from an estimated central schedule, which would enable ICs to be (approximately) scheduled based on GB shadow nodal prices.

5.62. We discuss these in turn below.

### *Market participants' technical details*

5.63. The market operator (either NESO or potentially one or multiple PX(s)) would aggregate technical details submitted by market participants and input these into the MRLVC algorithm. As this may be computationally complex, the market operator may need to combine and translate the details into a suitable format before submission to the MRLVC operator. There is also some evidence that it is computationally feasible, as EUPHEMIA was designed to be able to accommodate "complex orders" (comprising minimum income conditions orders and load gradient orders, which are similar to the technical details of market participants) from participating countries such as Spain that have unit bidding in place.<sup>211</sup> The algorithm would then need to integrate multi-part bids from GB and price-volume bids from the BBZs to optimise the IC flows.

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<sup>211</sup> 'All NEMOs' proposal for products that can be taken into account by NEMOs in single day-ahead process', ACER, 2017 ([link](#)).

## 5. N3: Central scheduling with national wholesale pricing

5.64. There is also uncertainty around whether intra-GB transmission constraints would or could be included in the MRLVC algorithm. It appears to us that including GB transmission constraints in the MRLVC algorithm is highly unlikely to be a feasible option and we have discarded it due to two reasons:

- It seems computationally challenging for the MRLVC algorithm to be able to simultaneously clear zonal-based prices-volume orders in BBZs with a nodal version of the GB market – particularly given that the time allocated to the MRLVC algorithm to clear is very limited and given that it needs to align with the SDAC timelines.
- ESO may not be willing/able to submit detailed network information to the MRLVC given potential security risks associated with sharing such sensitive information with a third party (as discussed above in ¶15.41).

5.65. To the extent that transmission constraints were excluded from the MRLVC algorithm, this would effectively mean that the firm IC flows, produced by the MRLVC, would be scheduled based on a proxy of the unconstrained GB price. As such, IC flows would often likely be incompatible with the physical GB transmission network (and would potentially require costly scheduling of other assets “around” the MRLVC-determined cross-border flows or adjusting IC flows). While potentially very material under a national pricing regime, this downside could be less severe under a zonal market design (as discussed in the Chapter 6 on the Z3 market design).

### *Net import/export curves*

5.66. Under this approach, NESO would run an initial SCUC to determine a preliminary central schedule prior to the MRLVC, based on market participants’ technical information, transmission network information, forecast prices in each BBZ, and forecasts of flows between BBZs and the rest of Europe.

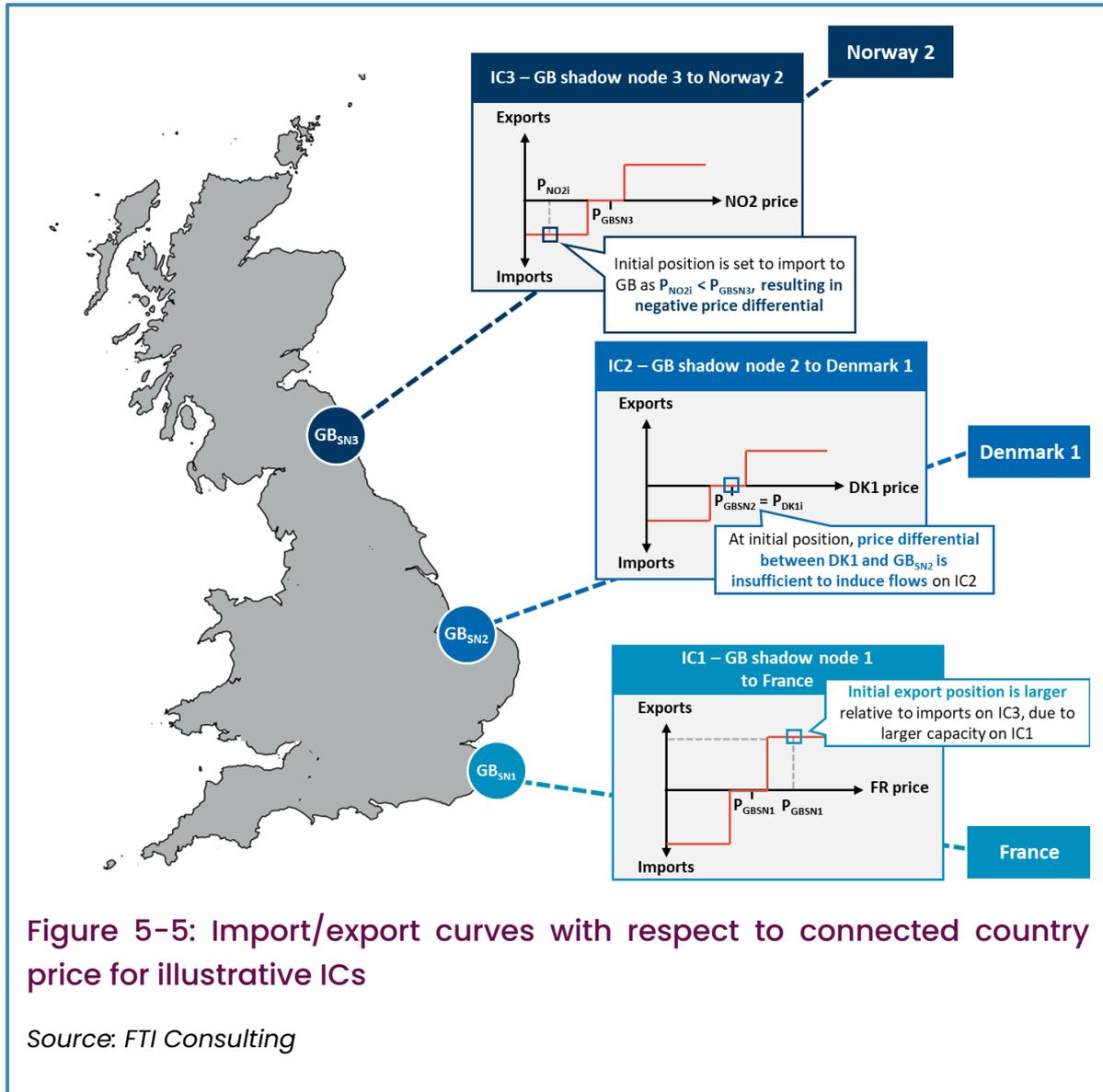
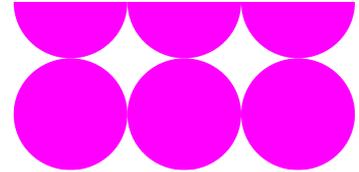
5.67. It would then calculate net import/export curves (as illustrated in Figure 5-5 below) for each GB IC that summarise the schedule of the IC across a range of possible DA prices in the relevant BBZ (assuming that all other BBZ prices remain equal to the initial forecast of the prices for those BBZ).

5.68. The import/export curve would have an initial scheduled position for each IC based on differential between: (i) NESO's expectation of the BBZ price (" $P_{\text{BBZi}}$ "), which is an input to the initial SCUC; (ii) and the shadow nodal price at the IC's connecting node in GB ( $P_{\text{GBSN}}$ ), which is an output of the initial SCUC.<sup>212,213</sup> The purpose of the curve is to enable the MRLVC algorithm to identify the GB-system-optimal direction of scheduled flow per IC for different  $P_{\text{BBZi}}$  levels. Within the MRLVC optimisation, the shadow  $P_{\text{BBZi}}$  will then eventually determine the scheduled flow on the IC (respecting the import/export curves).

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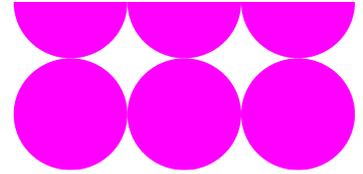
<sup>212</sup> In this paragraph and the subsequent worked example, we describe the simple case, where NESO submits a single curve per IC into the MRLVC process. However, we note that in the case, where flows on one IC impact the shadow nodal price at the landing point of another IC, NESO may want to submit a different curve depending on the flows of the other IC. This can be resolved by NESO submitting multiple set of import/export curves per IC, each of them being conditional on certain set of flows on other ICs. The MRLVC could then rely on the set of curves, which produce scheduled flows on all ICs that are consistent with the conditions of the used import/export curves.

<sup>213</sup>  $P_{\text{GBSN}}$  would vary depending on the IC's flow – for example,  $P_{\text{GBSN}}$  when the IC is scheduled to export would be equal or higher to the  $P_{\text{GBSN}}$  when the IC is not scheduled to flow. This reflects the higher demand in GB when the IC is scheduled to flow from GB to FR.



5.69. Developing the import/export curves displayed in Figure 5-5 follows a two-step process for each IC:

- Developing initial flow assumptions for other ICs:** To construct each GB-BBZ IC's individual import/export curve, the first step is to determine the flows along other GB-BBZ ICs based on: (i) initial assumptions on the prices in BBZs; and (ii) the bids and offers from other GB market participants. The flows on other ICs would then be fixed, to isolate the impact of changing prices in the relevant connected market on the flows of a particular IC.
- Evaluating the impact of changing prices in the connected market:** Using the fixed flow assumptions on other ICs developed in the first step, NESO runs simulations to determine how a deviation from the initial price assumption for the relevant connected market would impact the flows on the IC in question. The results of these simulations allow NESO to produce a curve for each IC, that describes the import/export profile of the IC as a function of  $P_{BBZi}$ .



5.70. Figure 5-5 shows illustrative curves for three example ICs:

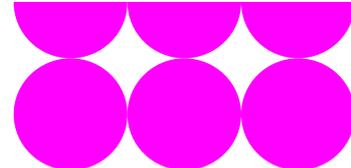
- IC1 between shadow node “GB<sub>SN1</sub>” and the French BBZ: The initial position of IC1 is scheduled to export from GB to FR, as  $P_{FRi} > P_{GBSN1}$ . If  $P_{FR}$  decreases relative to  $P_{FRi}$ , the curve indicates that NESO would gradually not schedule the IC to flow before eventually scheduling the IC to import from FR to GB.
- IC2 between shadow node “GB<sub>SN2</sub>” and the DK1 BBZ: The initial position of IC2 is not to be scheduled (shown as no flow below) as NESO’s expectation of the DK1 price  $P_{DK1i}$  is equal to  $P_{GBSN2}$ . If  $P_{DK1}$  increases relative to  $P_{DK1i}$ , the curve indicates that NESO would schedule IC2 to export from GB to DK1. If  $P_{DK1}$  decreases relative to  $P_{DK1i}$ , the curve indicates that NESO would schedule IC2 to import from DK1 to GB.
- IC3 between shadow node “GBSN3” and the NO2 BBZ: The initial position of IC3 is scheduled to import from NO2 to GB, as  $P_{NO2i} < P_{GBSN1}$ . If  $P_{NO2}$  increases relative to  $P_{NO2i}$ , the curve indicates that NESO would gradually not schedule the IC to flow before eventually scheduling the IC to export from GB to NO2.

5.71. As the import/export curves input into the MRLVC algorithm would be based on GB shadow nodal prices (and forecast European prices) rather than the unconstrained GB price, this could result in MRLVC-optimised flows that are against commercial price differentials and in turn, commercial losses for ICs. As discussed in ¶5.5 and ¶5.30 to 5.35, NESO would likely need to implement transfer payments to compensate ICs for negative congestion rents and foregone revenues that they would otherwise have earned if they were instead scheduled based on the commercial price differential.

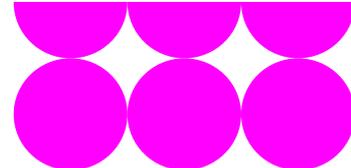
5.72. There is a trade-off between the computational burden (and hence time) and the precision of the import/export curves in mapping the impact of changes in cross-border flows (relative to the initially forecasted flow) on the shadow nodal prices of the IC connection point in GB. A more precise set of import-export curves could lead to MRLVC flows being more likely to be GB-system-optimal, but this could come at a cost of a significantly longer timeframe between market participants submitting their order books and the (final) GB DAM and SDAC prices being published. This would increase the information ‘gap’ between the order books and prices being published, and may not be acceptable to the EU.

5.73. To the extent that the schedule of an IC is highly dependent on other GB-BBZ ICs’ flows, NESO may need to create several import/export curves for each IC (with different assumptions around the schedule of other ICs – see Footnote 212), which could further increase the computational burden of the pre-processing required before submitting the import/export curves to the MRLVC clearing and the MRLVC clearing itself.

5.74. We compare the two potential input options into the MRLVC algorithm in Table below. On balance, we consider net import/export curves (which would require more pre-processing from NESO) to be more appropriate due to the importance of scheduling the ICs based on shadow nodal prices under a central schedule design. We therefore assume that this option would be implemented in the remainder of the section.

**Table 5-1: Comparison of input options to the MRLVC**

	<i>Market technical detail</i>	<i>participants' national</i>	<i>Net Import/export curves</i>
Entity submitting information to MRLVC	GB NESO or GB PX		NESO (after pre-processing)
GB price used to schedule ICs	Unconstrained price	national	Shadow nodal price
Pre-processing requirements	Low, if technical details are directly fed into the MRLVC algorithm Medium, if technical details are translated/simplified before inputting into the MRLVC algorithm		High, as NESO would need to produce an initial central schedule and net import/export curves based on nodal bids
MRLVC computational feasibility	Likely possible, given that EUPHEMIA is able to accommodate complex bids		Likely possible, as information would be pre-processed before submission to MRLVC
Likely level of NESO redispatch required	Higher, as MRLVC would likely produce flows that result in a more costly GB schedule		Lower, as MRLVC-optimisation considers GB transmission constraints
Transfer payments required	None, but likely a more costly GB schedule as GB assets must schedule around IC (or the IC schedules need to be readjusted)		Required if MRLVC-optimised flows are against commercial price differentials
Security risks	Low, as no network information provided to MRLVC operator		Low, as network information is processed by NESO
Changes required from EU	Update to bidding formats, which seems feasible given existing complex bids		MRLVC algorithm would need to be able to accommodate import/export curves, which seems feasible



5.75. A potential middle ground between the two input options could be to treat GB as a zonal market only for the purposes of calculating cross-border flows in the MRLVC – that is, NESO would forward all GB orders and zonal boundaries to the MRLVC algorithm. As such, the IC schedules determined in the MRLVC would be based on zonal shadow prices. The firm flows determined by the MRLVC would then be inputted in the SCUC that schedules all other assets in GB based on shadow nodal prices. This would ensure some degree of transmission constraints are reflected in the MRLVC optimisation, without the need for NESO to pre-process network information to produce net import/export curves. However, this would add another layer of complexity to the N3 market design, and disputes might be raised about the delineation of the zonal boundaries (which could be static or dynamic).<sup>214</sup>

### *MRLVC optimisation process*

5.76. As explained in 5.66 to 5.73, NESO would run an initial SCUC to determine a preliminary central schedule and corresponding net import/export curves per IC. The net import/export curves would then be submitted to the MRLVC to optimise (firm) GB-BBZ flows. Based on these firm flows from the MRLVC, NESO would then run a second SCUC that calculates a final (binding) DA central schedule around the MRLVC-optimised flows. As a result, NESO no longer determines the direction of these flows.

5.77. Given that the purpose of the initial SCUC is to serve as input into the MRLVC algorithm, the schedule is not binding and would not be used to calculate transfer payments. These would instead be calculated based on the difference between the unconstrained schedule (which produces the GB unconstrained price)<sup>215</sup> and the final DA constrained central schedule produced by the second SCUC. The second SCUC take the MRLVC-optimised (and now fixed) flows as given.

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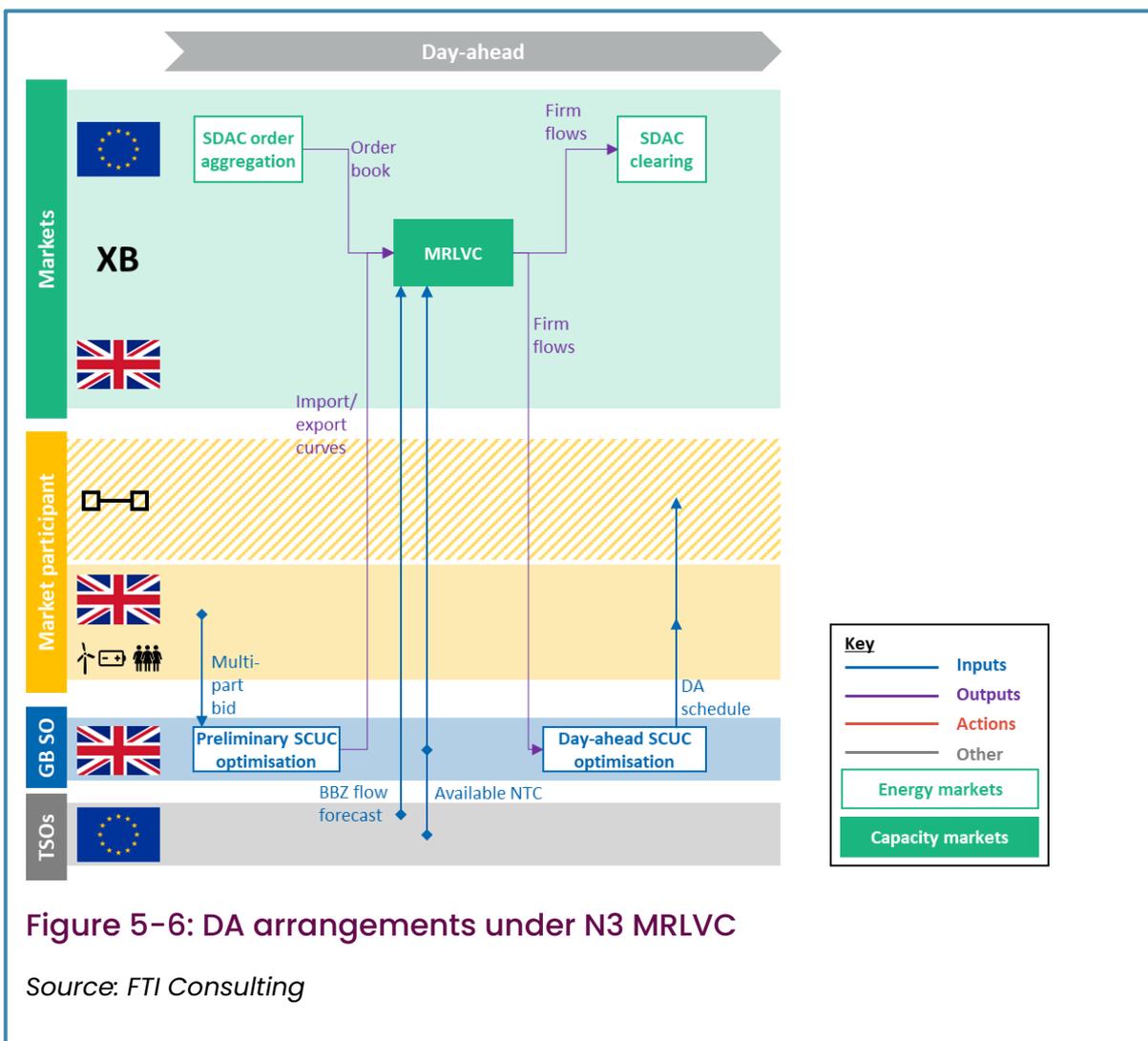
<sup>214</sup> While the delineation of the zonal boundaries for this purpose would have less impact on wholesale prices as under a zonal wholesale market design (Z1 and Z3), the choice of the zonal boundaries could impact the scheduling of the IC which would: (i) directly impact the commercial revenues of the IC owners; and (ii) indirectly impact wholesale prices in GB and the SDAC.

<sup>215</sup> It would be most straightforward to determine the GB unconstrained price with the ICs flows determined by the MRLVC algorithm (based on ICs scheduled based on shadow nodal prices).

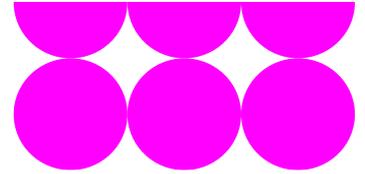
5. N3: Central scheduling with national wholesale pricing

5.78. There is a risk that it may not be possible for NESO to determine a physically feasible DA central schedule with the MRLVC-optimised flows. We do not expect this to be a significant issue as the MRLVC-optimisation would account for GB transmission constraints via the net import/export curves. The frequency and extent of this risk would require empirical testing. In such cases, NESO and European TSOs would need to develop suitable fallback procedures (e.g. similar to the fallbacks when EUPHEMIA fails to clear).<sup>216</sup> NESO would, in that case, need to put in place appropriate mechanisms to enable adjustments to the flows (e.g. potentially a mechanism similar to countertrading, as per current market arrangements).

5.79. We summarise the various steps in the DA stage in Figure 5-6 below.



<sup>216</sup> These are mainly JAO shadow auctions ([link](#)).



## Intraday market

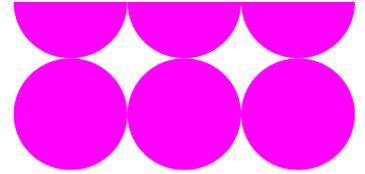
- 5.80. The MRLVC is intended to be a DA trading solution and potential post-Brexit ID trading arrangements have yet to be explored. Given this, and as the N3 market design assumes that there is no IDM in GB, we assume that there would be no ID trading in GB.
- 5.81. In Europe, the SIDC (continuous and IDAs) would continue to run in the ID timeframe. Similar to the ID timeframe for N3 Status Quo described above, the SIDC could either accept the DA MRLVC GB-BBZ flows as fixed and optimise around them, or re-optimize across all ICs and where necessary, pay penalty prices to adjust GB-BBZ flows.<sup>217</sup>
- 5.82. As under N3 Status Quo, not having an ID timeframe in the GB market would create an uneven position for GB-EU ICs, and could drive the introduction of an ID market in the longer run. If so, the DA MRLVC process described above would likely be replicated at the ID stage (except that the volume coupling would take place with one of the SIDC IDAs rather than SDAC). We do not examine this further as it is beyond the scope of this report.
- 5.83. Alternatively ID NESO-led procedures could be introduced as described in ¶15.53.

## Real time

- 5.84. After the DA market, GB market participants would revise their bids and offers for the RT clearing. NESO would run a SCED optimisation to produce a physically binding RT schedule and resolve imbalances (and any resulting minor thermal constraints). This final SCED optimisation would again take the flows determined prior to the RT timeframe as given (that is, either the MRLVC-optimised flows determined at DA, the adjusted flows following NESO/EU TSO intervention pre-gate closure or by the SIDC).
- 5.85. ESO and other European TSOs would continue to be able to adjust IC flows if necessary in real-time. The exact mechanism for doing so would need to be worked out, but we assume that it would require some information exchange between SOs.
- 5.86. Similar to other cross-border arrangements under N3, with respect to the integration of GB into the European balancing platforms (TERRE, MARI and PICASSO), it is likely that GB would need to develop a technical interface that would enable the BM to be compatible with EU balancing platforms (see ¶12.20).

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<sup>217</sup> EU TSOs could also insist on having the unilateral right to redispatch the GB-Europe ICs using the SIDC algorithm, which would heighten commercial risks for IC owners. However, it appears to us unlikely that GB would be willing to accept such an arrangement.



## N3 Price Coupling

5.87. In this section, we set out how Price Coupling (see N0 Price Coupling for design details) could potentially work under the N3 design (“N3 Price Coupling”). Effectively, this section overlays the N3 market design assuming that GB is fully price coupled with the EU. As explained above, we assume that when implemented, Price Coupling would apply to all GB ICs (including NSL and the GB-Irish ICs).

### Forward market

5.88. We assume that the forward market under N3 Price Coupling would function in the same way as N0 Price Coupling described in ¶2.34 to 2.35, and that GB would participate in the same manner as the EU.<sup>218</sup> Under the N3 market design, only FTRs would be traded on GB ICs.<sup>219</sup>

5.89. Market participants would continue to be able to trade bilaterally in the forward market (and the resulting positions would be financial).

### Day-ahead

5.90. To implement Price Coupling in a ‘pure’ sense, GB would effectively need to become part of the SDAC, which would imply that the GB DAM is cleared within EUPHEMIA (that is, akin to pre-Brexit arrangements).

5.91. Under Price Coupling, the question also arises of whether ICs would be scheduled based on shadow nodal prices or the GB unconstrained price, which has an important impact on what information must be forwarded from the GB side to the central Price Coupling algorithm.

5.92. When **scheduling ICs based on shadow nodal prices**, intra-GB transmission constraints would need to be included in the EUPHEMIA algorithm (which would effectively combine a nodal version of the GB market with the existing zonal-based SDAC).

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<sup>218</sup> As per the FCA GL, ICs would likely be required to offer IC capacity in the forward timeframe (unless an exemption is granted)([link](#)).

<sup>219</sup> ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 ([link](#)): page 18.

## 5. N3: Central scheduling with national wholesale pricing

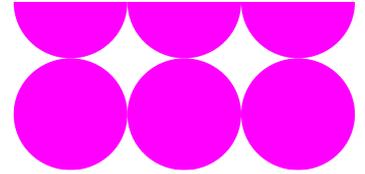
- 5.93. Computationally, and given the security considerations,<sup>220</sup> it appears to us that including GB transmission constraints in EUPHEMIA is highly unlikely to be a credible option in the short to medium term. Even if, in the longer term, it became computationally feasible, this would require significant changes to the EUPHEMIA algorithm which would require significant adjustments / concessions from the EU side.<sup>221</sup> On this basis, we have discarded the option of scheduling ICs based on GB shadow nodal prices under N3 Price Coupling.
- 5.94. When **scheduling ICs based on the unconstrained GB price**, EU NEMOs would continue to feed their order books into SDAC. However, the GB bidding format under central scheduling would be different from the format under self-scheduling – that is, multi-part bids containing market participants’ technical details rather than simple bids. It seems likely that EUPHEMIA would be able to accommodate multi-part bids, as they are similar to the existing “complex orders” from countries such as Spain that have unit bidding (see ¶15.63).
- 5.95. After receiving the EU order books and GB multi-part bids, the EUPHEMIA algorithm would produce an unconstrained GB price and SDAC prices, which would simultaneously be used to schedule ICs.<sup>222</sup>
- 5.96. NESO would take the cross-border volume and direction of flows determined by EUPHEMIA as given (unless physically impossible to clear the GB wholesale market with such flows) and subsequently determine a final (second) binding central DA schedule by running a SCUC optimisation. This means that the GB central schedule would be created by optimising “around” the flows determined by the combined EU + GB EUPHEMIA algorithm, likely leading to a more costly GB schedule compared to having the ICs scheduled based on shadow nodal prices.
- 5.97. The GB price as computed by EUPHEMIA would serve as the GB unconstrained price, e.g. deviations in the schedule of assets when comparing the GB DA SCUC to the GB DA schedule determined by EUPHEMIA will be paid transfer payments (relative to the GB unconstrained price). As ICs are scheduled based on the unconstrained GB price, no transfer payments for ICs will be required. We consider this option practically feasible, as a similar approach is already in place for Italy (albeit it has seven bidding zones in place).

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<sup>220</sup> As discussed earlier, neither GB nor EU side would likely be able to share access to detailed EU order books and GB market data that includes transmission network information (e.g. live information across all nodes on demand/supply and physical availability of transmission capacity).

<sup>221</sup> Such required changes could include a simplification of bidding formats on the EU-side and/or transitioning from the currently linear pricing rule to non-linear pricing (including uplifts) such as in US ISO systems.

<sup>222</sup> The unconstrained price from EUPHEMIA would be used to calibrate the transfer payments.

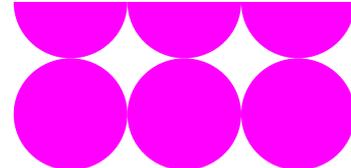


## Intraday market

- 5.98. Assuming there is no IDM under N3, GB would not participate in the SIDC (continuous and IDAs). The operation of SIDC in the EU has two options:
- Take the scheduled GB-Europe IC flows (defined at the DA stage) as a given and optimise the flows of other ICs around it; or
  - Re-optimize the schedules of the flows on all ICs. If the ID flows determined by the EU SIDC on GB ICs are different from those determined at the DA stage, the SO in the relevant EU country would have to pay a penalty price to compensate: (i) the IC for the lost congestion rents; and (ii) NESO for the cost of redispatch incurred to resolve the constraint imposed on the GB system. The latter cost would have to be determined by a re-run of the GB SCUC.
- 5.99. There is also a possibility that European TSOs would not accept either of the two options above, and would instead require that they have a unilateral right to redispatch the GB-Europe ICs using the SIDC algorithm which would create severe complications. This is unlikely to be attractive to GB.
- 5.100. As with the N3 Status Quo, not having an ID timeframe in the GB market would create an uneven position for GB-EU ICs, and could drive the introduction of an ID market in GB in the longer run. If so, the DA Price Coupling described above would likely be replicated at the ID stage (except that the Price Coupling would take place as part of one of the SIDC IDAs rather than SDAC). We do not examine this further in this report.
- 5.101. Alternatively ID NESO-led procedures could be introduced as described in ¶15.53.

## Real time

- 5.102. After the DA market, market participants revise their bids and offers for the RT clearing. NESO would run a SCED to produce a physically binding RT schedule and resolve imbalances (and any resulting minor thermal constraints) via the activation of response and reserves.
- 5.103. SOs may modify availability or flows for specific reasons such as emergency assistance or unexpected intra-country congestion. There would need to be specific arrangements to compensate IC owners and other parties – broadly in line with existing precedent.
- 5.104. The IC owner may also need to modify the availability of the IC (e.g. unplanned outages). If so, it would need to pay a penalty (most likely related to the cost of redispatch actions in both connected countries).
- 5.105. Similar to other cross-border arrangements under N0, with respect to the integration of GB into the European balancing platforms (TERRE, MARI and PICASSO), it is likely that GB would need to develop a technical interface that would enable the BM to be compatible with EU balancing platforms (see ¶12.20).



## N3 Conclusions

5.106. In our discussion above, we have assessed the potential feasibility of combining three selected cross-border arrangements (Status Quo, MRLVC and Price Coupling) with the N3 market design. In doing so, we have not sought to comment on the preferred option(s) for cross-border trading arrangements nor on the desirability of the N3 design itself. Rather, we have taken the N3 market design as given and examined how different cross-border trading arrangements could be developed or adapted in order to be compatible with the N3 market design.

5.107. We find that, with suitable adaptations, N3 market design can be made compatible with Status Quo, MRLVC and/or Price Coupling, although significant trade-offs arise under all three cross-border arrangement options.<sup>223</sup> We summarise our conclusions below:

- (i) Other things being equal, it is preferable from a GB perspective to schedule ICs based on GB shadow nodal prices than the unconstrained GB price, but this would require transfer payments to 'make-whole' ICs. However, if ICs were continued to be scheduled based on unconstrained GB prices, then the benefits case of moving to central scheduling becomes less clear.
- (ii) It is possible to schedule ICs based on shadow nodal prices under N3 explicit cross-border trading arrangements. However, the effectiveness of this arrangement is dependent on the quality of market participants' forecasts of prices in the connecting country (which is also the case under N0). In addition, appropriate measures would need to be developed to allocate risks efficiently among relevant parties. This would likely be cumbersome to implement and could have potential unintended consequences. It is also possible to schedule ICs based on unconstrained GB price, which would likely result in a more costly GB DA schedule and potentially would require to readjust IC schedules after the GB DAM.
- (iii) It is also possible to schedule ICs based on shadow nodal prices under N3 MRLVC. This would require bids to be pre-processed and converted into net import/export curves that are submitted to the MRLVC algorithm. There is a trade-off between the computational burden and the accuracy of the information fed into the MRLVC algorithm. It is also possible to schedule ICs based on unconstrained GB prices, with similar drawbacks as under N3 combined with explicit cross-border arrangements.

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<sup>223</sup> Many of these inherent trade-offs and challenges could be mitigated by introducing a zonal design. This is examined in Chapters 4 and 6 of this report (in relation to Z1 and Z3 market designs).

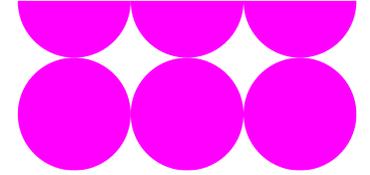
5. N3: Central scheduling with national wholesale pricing

- (iv) Scheduling ICs based on shadow nodal prices is not feasible under N3 Price Coupling. ICs can only be scheduled based on the unconstrained GB national price which would likely be costly<sup>224</sup> – one potential solution, if Price Coupling is a priority, would be to introduce zonal pricing (discussed under Z1 and Z3 in Chapters 4 and 6, respectively).
- (v) As scheduling ICs based on shadow nodal prices is feasible under explicit capacity trading but not under Price Coupling, it follows that under N3 Status Quo, either: (i) different GB ICs would be scheduled based on different (and potentially conflicting) GB price signals; (ii) all ICs would need to be scheduled based on unconstrained prices; or (iii) NSL and GB-Irish ICs would need to revert to an explicit cross-border trading arrangement.

5.108. We compare our the various N3 cross border arrangements in Table and discuss these in turn below.

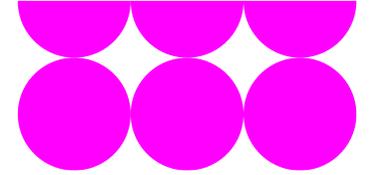
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<sup>224</sup> Relative to N0 combined with Price Coupling, central scheduling with ICs being scheduled on unconstrained prices would likely have a limited impact on market outcomes (from the cross-border perspective), though there would be other benefits in terms of central scheduling (e.g. visibility to SO, market monitoring, scheduling of other two-way assets, e.g. storage).



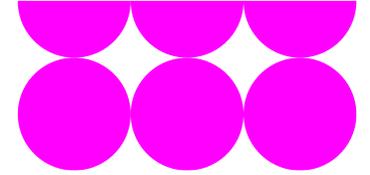
**Table 5-2: Comparison of N3 cross-border arrangements**

Model	Status Quo, considering all ICs explicit		MRLVC		Price Coupling (implicit)	
	Shadow nodal prices	Unconstrained price	Shadow nodal prices	Unconstrained price	Shadow nodal prices	Unconstrained price
ICs scheduled based on						
ICs scheduled in a manner that is GB system optimal	Yes, but potentially some sub-optimal flows will result due to forecast errors of traders	No, disregarding intra-GB constraints can lead to ICs not scheduled optimally from a GB perspective likely leading to a costlier GB schedule compared to when scheduling ICs based on shadow nodal prices	Yes, but potentially some sub-optimal flows will result due to simplifications in the pre-processing of net import-export curves	No, disregarding intra-GB constraints can lead to ICs not scheduled optimally from a GB perspective likely leading to a costlier GB schedule compared to when scheduling ICs based on shadow nodal prices	Yes, perfectly optimal scheduling	No, disregarding intra-GB constraints can lead to ICs not scheduled optimally from a GB perspective likely leading to a costlier GB schedule compared to when scheduling ICs based on shadow nodal prices
Redispatch of ICs (for Tx reasons)	Limited, depends on level of forecast errors between DA and RT.	Potentially redispatch in addition to redispatch due to forecast errors at the DA stage	Limited, depends on level of forecast errors between DA and RT.	Potentially redispatch in addition to redispatch due to forecast errors at the DA stage	Limited, depends on level of forecast errors between DA and RT.	Potentially redispatch in addition to redispatch due to forecast errors at the DA stage



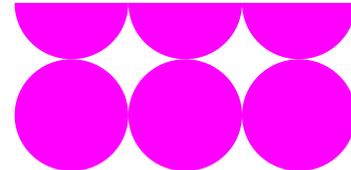
5. N3: Central scheduling with national wholesale pricing

<b>Model</b>	<b>Status Quo, considering all ICs explicit</b>		<b>MRLVC</b>		<b>Price Coupling (implicit)</b>	
	<i>Shadow nodal prices</i>	<i>Unconstrained price</i>	<i>Shadow nodal prices</i>	<i>Unconstrained price</i>	<i>Shadow nodal prices</i>	<i>Unconstrained price</i>
<i>ICs scheduled based on</i>						
Costs to consumers	Transfer payments by consumers needed (likely lower than GB schedule cost impact from scheduling ICs on unconstrained GB price)	High scheduling and/or IC redispatching costs for consumers	Transfer payments by consumers needed (likely lower than GB schedule cost impact from scheduling ICs on unconstrained GB price)	High scheduling and/or IC redispatching costs for consumers	Transfer payments by consumers needed (likely lower than GB schedule cost impact from scheduling ICs on unconstrained GB price)	High scheduling and/or IC redispatching costs for consumers
Feasibility (computational, security)	Not very different from Status Quo	Similar as Not very different from Status Quo	MRLVC feasibility recently questioned by TSOs and more complexity due to pre-processing requirements for NESO, including BBZ price forecast	MRLVC feasibility recently questioned by TSOs	Highly likely unfeasible for security reasons; and (in the short to medium term) for computational reasons	Similar arrangements as pre-Brexit (other than bidding formats)



5. N3: Central scheduling with national wholesale pricing

<b>Model</b>	<b>Status Quo, considering all ICs explicit</b>		<b>MRLVC</b>		<b>Price Coupling (implicit)</b>	
	<i>ICs scheduled based on</i>	<i>Shadow nodal prices</i>	<i>Unconstrained price</i>	<i>Shadow nodal prices</i>	<i>Unconstrained price</i>	<i>Shadow nodal prices</i>
Feasibility (e.g. Europe concessions)	Some concessions required, e.g. scheduled IC flows are firm after GB SCUC and impacts flows compared to Status Quo	Some concessions required, e.g. scheduled IC flows are firm after GB SCUC but limited impact on flows compared to Status Quo	Some concessions required, e.g. MRLVC must be compatible with import-export curves and impact flows compared to Status Quo	Central dispatch overlay does not seem to pose specific additional hurdles	Major changes to the SDAC algorithm would be required which EU may not accommodate	Very limited
Feasibility (gaming potential)	Tailored measures need to be introduced to ensure appropriate incentives and limit risk exposure for IC capacity holders	Similar as Status Quo	No direct issues detected to date, but further investigation required	Similar as Status Quo	No direct issues detected to date, but further investigation required	Similar as Status Quo
Commercial impacts (Congestion rents)	Limited if made whole via transfer payments. Additional risk for traders potentially impacting IC auction prices	Limited for ICs (similar to Status Quo)	Limited for ICs if made whole via transfer payments	Limited for ICs (similar to Status Quo)	Limited for ICs if made whole via transfer payments	Limited for ICs (similar to Status Quo)



### N3 – Scheduling based on shadow nodal or unconstrained price

- 5.109. As discussed in ¶5.6, it is preferable to schedule ICs based on GB shadow nodal prices rather than the GB unconstrained price. This is because scheduling ICs based on shadow nodal prices would enable NESO to create a least-cost schedule across all assets in GB (e.g. including intra-GB and cross-border assets) that respect the physical constraints on the GB network, to the extent these are known at the DA stage.
- 5.110. However, ICs would be exposed to greater commercial risk as they could be scheduled to flow against the commercial price differential (as these would be on the basis of wholesale price differentials). To mitigate this risk and prevent disorderly bidding, NESO would need to introduce transfer payments to ‘make-whole’ ICs (IC capacity holders under explicit, and IC owners under Price Coupling and MRLVC) for negative congestion rents and foregone revenues. These transfer payments are a cost to consumers, and would be calculated based on the difference in their positions if they were instead scheduled based on the unconstrained GB price.
- 5.111. If ICs were instead scheduled based on unconstrained wholesale prices, we expect that this would lead to a GB schedule that is suboptimal from a GB system perspective, as GB assets would need to be scheduled around imperfect IC flows. It is possible that some low-cost GB assets might not be scheduled due to intra-GB physical constraints that arise due to these sub-optimal IC flows. As well, this could potentially lead to an infeasible schedule that requires NESO to reschedule ICs and/or other assets after the DA SCUC.<sup>225</sup> The extent to which the additional costs of a suboptimal GB schedule, if ICs were scheduled based unconstrained national prices, could outweigh the cost of transfer payments (required if ICs were instead scheduled based on shadow nodal prices), would need to be empirically tested.
- 5.112. We note that a direct consequence of scheduling ICs based on shadow nodal prices is that IC schedules would be expected to be different to current market arrangements (N0 Status Quo), which would impact SDAC prices. We expect that more electricity would be imported from Central-West Europe (leading to higher prices in those countries), whereas more power would be exported to Norway (leading to lower prices in Norway).

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<sup>225</sup> Rescheduling ICs after the GB DA SCUC would likely be very costly as it would require paying for the rescheduling of assets in the relevant BBZ to make changes to the IC schedule possible.

## 5. N3: Central scheduling with national wholesale pricing

- 5.113. We are not aware of any precedent where national wholesale pricing would be combined with central scheduling where ICs are scheduled using shadow nodal prices.<sup>226</sup>

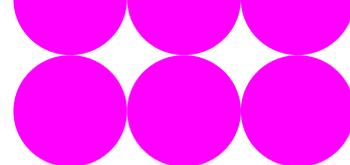
**Conclusion 1:** Other things being equal, it is preferable from a GB perspective to schedule ICs based on GB shadow nodal prices than the unconstrained GB price, but this would require transfer payments to ‘make-whole’ ICs. However, if ICs were continued to be scheduled based on unconstrained GB prices, then the benefits case of moving to central scheduling becomes less clear.

### N3 – Explicit cross-border trading arrangements

- 5.114. We find that it is feasible to schedule ICs based on shadow nodal prices under N3 market design and explicit cross-border trading arrangements. However, various measures would need to be developed to maintain appropriate incentives for IC capacity holders and limit their risk exposure. This would likely be cumbersome to implement and could have potential unintended consequences.
- 5.115. Scheduling ICs based on shadow nodal prices would require the introduction of “virtual IC capacity rights” at the DA IC capacity auctions, which share similarities with both FTRs and PTRs – holders are not able to nominate flows (like FTRs) but are required to take a position in the GB DAM or lose the right to the congestion revenue (like PTRs).

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<sup>226</sup> A practice that would come closest to the described approach would be the near real-time coordination of the scheduling of interties, e.g. transmission lines between North American ISOs that have nodal wholesale pricing in place. In that context, within an ISO’s scheduling algorithm nodal prices are calculated in the neighbouring ISO market based on approximations of where generation would be increased or decreased in the neighbouring ISO’s balancing area (so-called “proxy buses”). Prices at the proxy-buses are calculated to support exports or allow imports and are iteratively exchanged between the ISOs to schedule the intertie (referred to as a “coordinated transaction scheduling”). Such approach could be considered to a very limited extent like MRLVC as interties are scheduled based on prices that are estimated by ISOs rather than the actual outturn wholesale prices from the RT market clearing. However, among many differences, the process is more dynamic and nodal wholesale prices are in place on both sides of the intertie. The original design of the mechanism in place between most US ISOs is described in ‘Coordinating congestion relief across multiple regions’ by Cadwalader, Harvey, Hogan and Pope ([link](#)).



5. N3: Central scheduling with national wholesale pricing

5.116. Virtual IC capacity holders that are scheduled in the GB DAM are required to take a position in the relevant SDAC market to ensure that the IC flows are consistent with that scheduled by the GB SCUC. As explained above, the relevant IC capacity holders would be compensated via transfer payments for negative congestion rents and foregone congestion revenues.

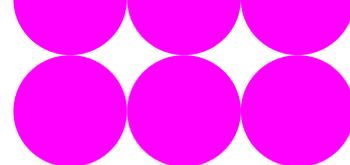
5.117. We have identified five challenges under N3 market design and explicit cross-border arrangements which would need to be overcome:

- First, the extent that IC scheduling is optimal from a GB system perspective would be dependent on the quality of traders' forecasts of the wholesale prices of the connected markets (which is also true under N0 explicit).
- Second (and related), scheduling ICs based on shadow nodal prices in GB would indirectly impact the prices in connected markets. This could make it more difficult to forecast these prices, especially in bidding zones with a low generation/demand relative to the size of the IC(s). The materiality of this impact would need to be empirically tested.
- Third, the SDAC would have to accept that the GB SCUC flows, which would be based on shadow nodal prices and forecast prices in connected markets, are firm and independent of the outturn prices in the relevant European bidding zones.
- Four, additional consideration would need to be made of the appropriate transfer payments made to (or by) the market participants in scenarios where due to forecast errors market participants face negative congestion rents or earn "unintended" congestion revenues. These mechanisms would need to: (i) ensure that market participants retain the incentive to forecast prices accurately; while (ii) ensuring that they bear risks that they can efficiently manage themselves.
- Five, there are potentially increased risks for IC capacity holders under N3 relative to N0, as they do not have access to an ID market to unwind positions in the event of forecast error. This increased risk could lead to no market participants would be willing to take a position opposite to the expected commercial price differential, which would lead to a potential inefficiency in the utilisation of the IC (at times when the scheduling price differential ends up having the opposite sign of the anticipated commercial price differential). This will likely have commercial impacts for IC owners (and may need to be reflected in the transfer payment mechanism described above).

**Conclusion 2:** It is possible to schedule ICs based on shadow nodal prices under N3 explicit cross-border trading arrangements. However, the effectiveness of this arrangement is dependent on the quality of market participants' forecasts of prices in the connecting country (which is also the case under N0). In addition, appropriate measures would need to be developed to allocate risks efficiently among relevant parties. This would likely be cumbersome to implement and could have potential unintended consequences. It is also possible to schedule ICs based on the unconstrained GB price, which would likely result in a more costly GB DA schedule and potentially would require to readjust IC schedules after the GB DAM.

### N3 – MRLVC

- 5.118. It appears that it is feasible to schedule ICs based on shadow nodal prices under N3 MRLVC. NESO would need to pre-process bids submitted to the GB DAM and create net import/export curves for each IC that would be submitted to the MRLVC operator. A net import/export curve summarises the schedule of the IC across a range of prices in the relevant connected BBZ (assuming that the wholesale prices in the other BBZs remain constant), and reflects the impact of changing the scheduled IC flows on the GB shadow nodal price at the IC's landing point. The MRLVC algorithm would then jointly clear the net import/export curves with the EU BBZ order books.
- 5.119. As under N0 MRLVC, the extent that actual flows are intuitive – and also GB-system-optimal – is impacted by a trade-off between accuracy and computational complexity, as explained in ¶15.72. In particular, for N3 MRLVC with net import/export curves, if the optimal schedule of an IC is highly dependent on the flow on other GB-EU ICs, it would be more accurate to have multiple import/export curves for each IC based on different assumptions around the schedule of the other ICs. However, this would increase the computational burden of pre-processing and the time taken for the MRLVC algorithm to clear, resulting in longer timeframes between order book submission and of publishing of GB DAM and SDAC prices. On the other hand, simplifications in the calculation of the net import/export curves could result in a failure to clear the market (and potential market decoupling) if there is insufficient time to find an optimal solution.
- 5.120. Finally, when scheduling ICs based on shadow nodal prices, transfer payments for negative and foregone congestion rents due to flows against price differentials would likely be made to ICs. These would be the result of central scheduling rather than MRLVC, because as explained in ¶15.71, the compensation payments are calculated based on the difference between the unconstrained schedule and final DA constrained schedule, which both take the MRLVC-optimised flows as given.



**Conclusion 3:** It is possible to schedule ICs based on shadow nodal prices under N3 MRLVC. This would require bids to be pre-processed and converted into net import/export curves that are submitted to the MRLVC algorithm. There is a trade-off between the computational burden and the accuracy of the information fed into the MRLVC algorithm. It is also possible to schedule ICs based on unconstrained GB prices, with similar drawbacks as under N3 explicit.

## N3 – Price Coupling

5.121. We do not consider IC scheduling based on shadow nodal prices to be feasible under N3 Price Coupling. For there to be Price Coupling, the GB DA and (EU) SDAC would, by definition, simultaneously clear within a single algorithm. Under N3, this implies the GB central schedule would be an output of the EU+GB clearing algorithm, which appears to be highly unlikely:

- First, this would require GB network information (physical parameters of all intra-GB transmission lines) to be shared with the European MCO, e.g. the entity running the Price Coupling algorithm. We understand from NESO that this would not be possible from a security perspective;
- Second, it does not seem computationally feasible for the Price Coupling algorithm to be able to simultaneously clear the SDAC (which is zonal-based) with a nodal version of the GB market – particularly given that EUPHEMIA already has difficulties related to running times. This may be a transitional issue, and could potentially change in the medium to longer term as computing power continues to improve;
- Third, even if it were technically possible, Price Coupling under N3 would require an overhaul of the current SDAC clearing algorithm and would increase running times. On the face of it there seems limited incentive for EU participants to incur the disruption and cost of accepting the necessary changes in the short term. In this report we, in agreement with NESO, prioritise solutions that require only minimal accommodations made by the EU.

5.122. We therefore consider that Price Coupling under N3 would only be possible if ICs were scheduled based on GB unconstrained prices, which as discussed in ¶5.10, would result in a GB schedule that is suboptimal from a GB system perspective. One potential solution would be to introduce zonal pricing which could, to an extent, mitigate the extent of suboptimal flows. This is because relative to GB unconstrained national prices, GB unconstrained zonal prices would be better aligned with GB shadow nodal prices. Scheduling ICs based on unconstrained zonal prices would therefore be more similar to that based on GB shadow nodal prices. We discuss this option in greater detail in Chapter 6 (Z3 market design).

**Conclusion 4:** Scheduling ICs based on shadow nodal prices is not feasible under N3 Price Coupling. ICs could only be scheduled based on the unconstrained GB national price which would likely be costly – one potential solution, if Price Coupling is a priority, would be to introduce zonal pricing (discussed under Z1 and Z3 in Chapters 4 and 6, respectively).

### N3 – Existing implicit cross-border trading arrangements

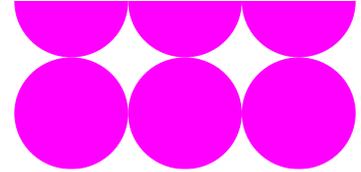
5.123. It is, in theory, possible to have both explicit and implicit trading arrangements under N3. However, there are limitations as to how ICs could be scheduled under different cross-border arrangements. As discussed above, we consider it feasible under N3 to schedule ICs based on GB shadow nodal prices under explicit trading but not implicit trading. Under the N3 Status Quo arrangement there are, therefore, three potential options:

- Different cross-border trading arrangements for different ICs, which would imply that potentially not all ICs would be scheduled based on the same types of price signals, which would be a concern.
- All ICs are scheduled using the same cross-border trading arrangements as they currently are. This would imply that the scheduling of the ICs would be based on the GB unconstrained price, which would mean missing out on the opportunity for ICs under an explicit cross-border arrangement to be scheduled based on shadow nodal prices.
- Reverting NSL and GB-Irish ICs to an explicit cross-border trading arrangement, which would allow all ICs under N3 Status Quo to be scheduled based on shadow nodal prices.

**Conclusion 5:** As scheduling ICs based on shadow nodal prices is feasible under explicit capacity trading but not under Price Coupling, it follows that under N3 Status Quo, either: (i) different GB ICs would be scheduled based on different (and potentially conflicting) GB price signals; (ii) all ICs would need to be scheduled based on unconstrained prices; or (iii) NSL and GB-Irish ICs would need to revert to an explicit cross-border trading arrangement.

# 6. Z3: Central scheduling with zonal wholesale pricing

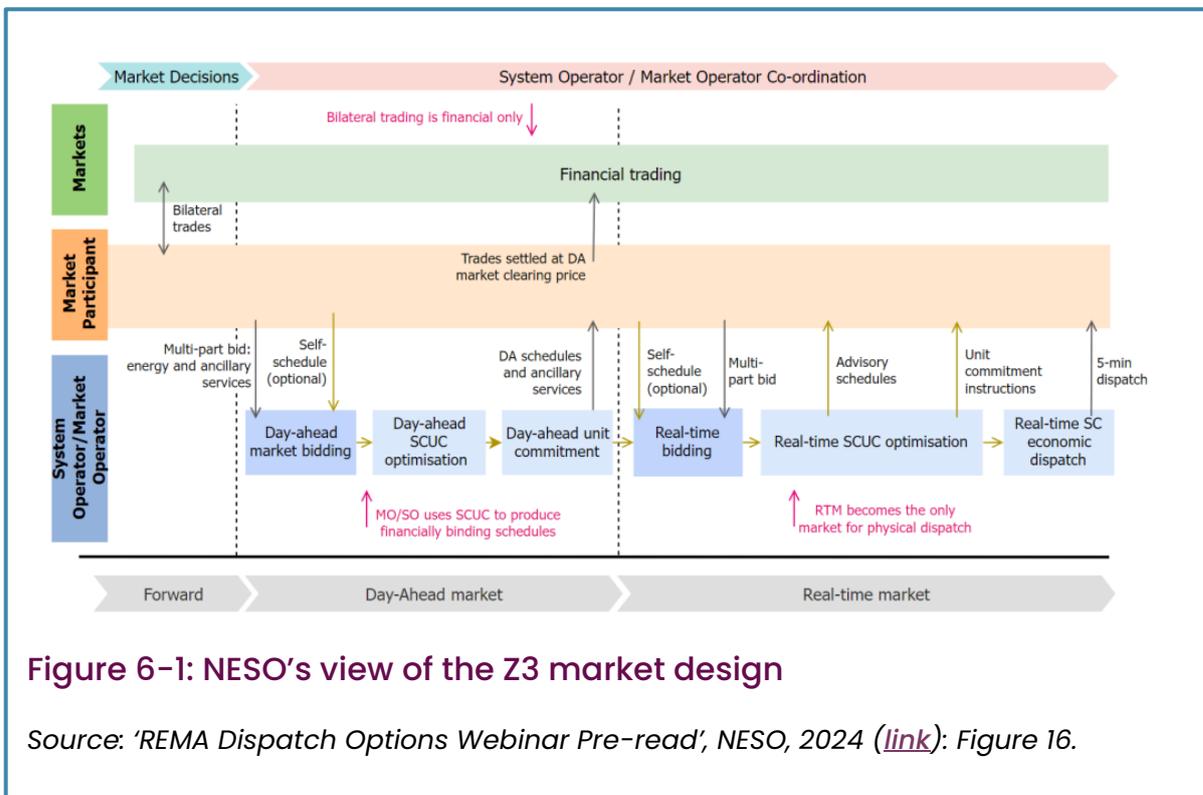




In this chapter, we discuss how the Status Quo cross-border arrangements, MRLVC and Price Coupling could potentially work under the Z3 market design, in which GB moves to zonal wholesale pricing and central scheduling. We start with a section introducing the key market design assumptions and a section describing the different prices that can be used to schedule IC flows under Z3.

### Key market design assumptions

6.1. NESO’s view of the Z3 strawman dispatch model is set out in Figure 6-1 below. This is identical to the N3 strawman dispatch set out in Figure 5-1 except that trades are settled at the zonal wholesale market clearing price rather than the national wholesale market clearing price.



**Figure 6-1: NESO’s view of the Z3 market design**

Source: ‘REMA Dispatch Options Webinar Pre-read’, NESO, 2024 ([link](#)): Figure 16.

6.2. The key market design assumptions under the Z3 market design are the same as the N3 market design described in 15.2. The only exception is that in Z3, alongside shadow nodal prices, unconstrained zonal (rather than national) prices would be produced for commercial settlement purposes of load and generation.<sup>227</sup>

<sup>227</sup> An exception being when ICs are scheduled based on unconstrained zonal prices. In this case, the unconstrained prices also have a scheduling purpose.

## 6. Z3: Central scheduling with zonal pricing

- 6.3. A key assumption underpinning this market design is that resources would be centrally scheduled using shadow nodal prices<sup>228</sup> (e.g. taking into account transmission network capabilities), but resources would be compensated using unconstrained zonal prices (effectively approximating the zonal prices that they would have been exposed under a hypothetical zonal self-scheduling design).
- 6.4. To achieve this, NESO would need to develop a methodology to determine the counterfactual unconstrained zonal schedule and associated prices. Such methodology would require NESO to determine the commercial cross-zonal transmission capacity that can be allocated in this counterfactual “unconstrained” zonal GB DAM clearing. For the purposes of this report, we assume that like Z1, the zones within GB would be price coupled in the zonal GB DAM clearing. NESO’s approach to determining available cross-zonal transmission capacity can either be based on the NTC or flow-based methodology.<sup>229</sup> The unconstrained zonal price would also be an output of the zonal GB DAM clearing.
- 6.5. Similar as under N3, we assume that market participants are compensated via transfer payments under Z3. There are two potential forms of transfer payments that units can receive:
- Assets that are scheduled to operate but are loss-making when receiving the “unconstrained” zonal price are assumed to be paid a top-up to make them whole. This is an essential feature of centrally scheduled markets without nodal pricing in place as otherwise the SO would be, potentially, committing market participants to operate below-cost, which would induce inefficient exit from the market;
  - Similarly, assets that are not scheduled to operate but would have been scheduled in a hypothetical “unconstrained” schedule are compensated for the foregone revenues. Unlike the point immediately above, this feature is a design choice. Alternative approaches are possible where such a compensation is not made (although we would note that these might lead to perverse incentives on the market participants’ bidding behaviour).<sup>230</sup>

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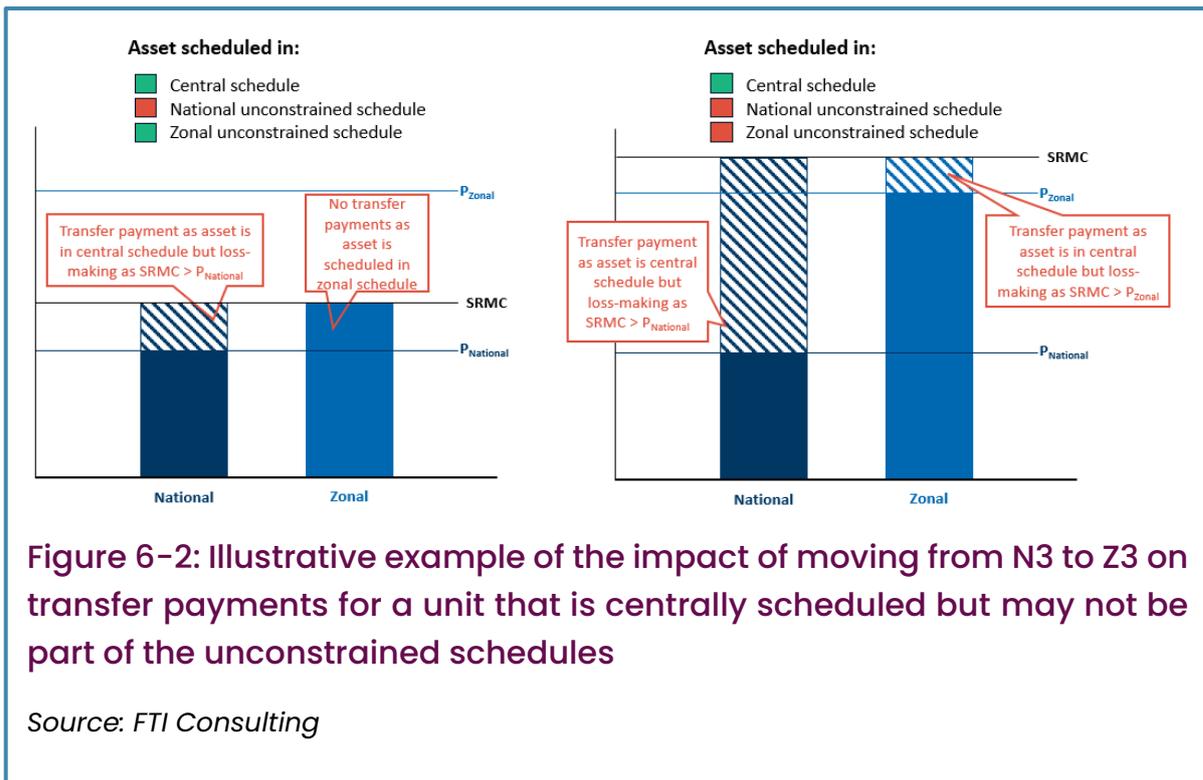
<sup>228</sup> We discuss below the rules that would apply specifically to ICs which may diverge from this assumption.

<sup>229</sup> There are also other alternatives for the determination of cross-zonal transmission capacity, for example NESO could alternatively fix the cross-zonal capacity to the inter-zonal flows from the central schedule and clear the counterfactual GB DAM around those inter-zonal flows. We recognise that the choice of determination of the counterfactual zonal prices and schedules could have important impacts on the quantum of transfer payments, which would need to be empirically tested. However, we do not explore the details and implications of each alternative in this report.

<sup>230</sup> These transfer payments ensure that market participants that expect to not be centrally scheduled do not have the incentive to self-schedule. For example, an asset that would expect not to be centrally scheduled but has a lower marginal cost than the unconstrained zonal price would have an incentive to self-schedule. As such, that asset would receive the zonal wholesale price and make a profit. However,

6. Z3: Central scheduling with zonal pricing

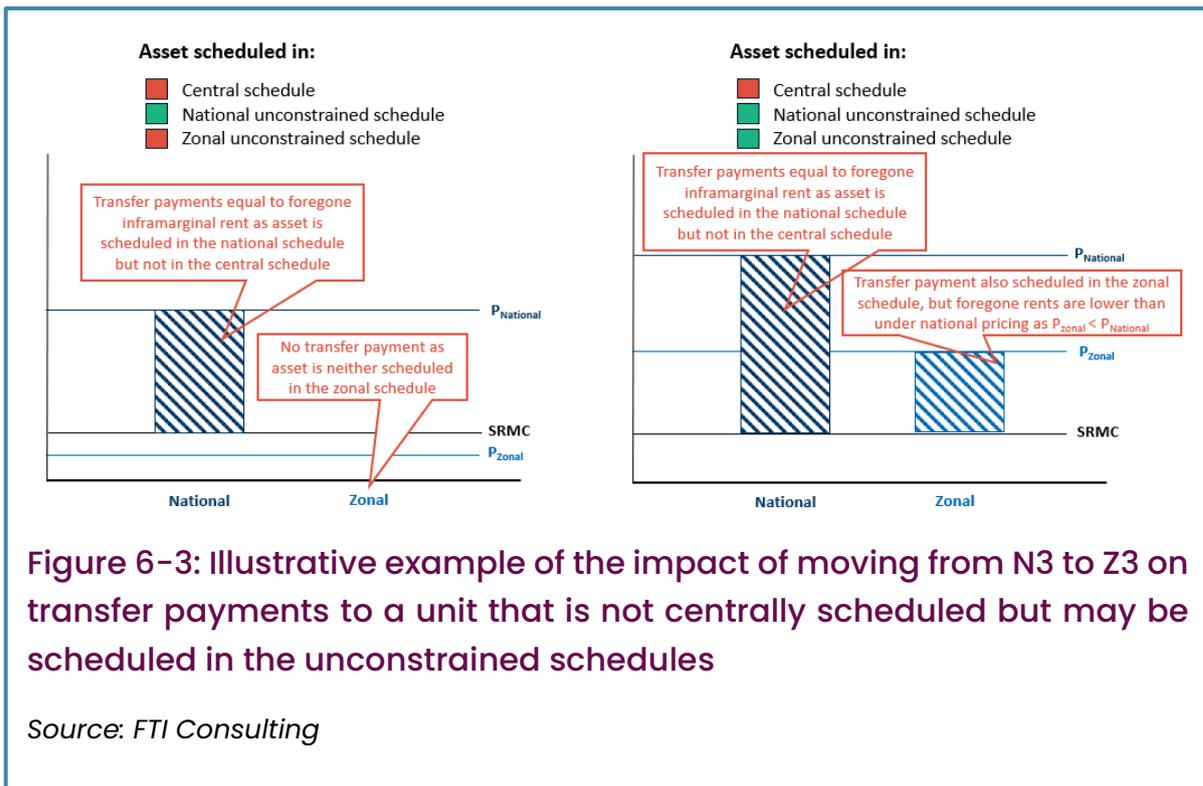
6.6. Compared to N3, the required transfer payments for assets under Z3 are expected to be lower because of volume and price effects. Units that are centrally scheduled but loss-making under N3 (e.g. thermal generation constrained on in the South) would, under Z3, tend to receive higher wholesale (zonal) electricity price compared to N3. As such, they are more likely to be scheduled in the unconstrained zonal schedule and, even if they continue not to be scheduled, they typically will receive a higher zonal than national unconstrained price. Hence, as illustrated in Figure 6-2 below, the required top-up (or transfer payment) would be lower under Z3 compared to N3.



this self-scheduling action would lead to a sub-optimal central schedule. In case a transfer payment is provided to this asset, the incentive to self-schedule would not be there anymore. Restricting market participants from self-scheduling in such scenario would not avoid the need for transfer payments due to issues with disorderly bidding, e.g. market participants would bid below their short-run marginal costs to ensure being scheduled which can potentially lead to a sub-optimal schedule.

6. Z3: Central scheduling with zonal pricing

6.7. Units that would have been scheduled in a hypothetical unconstrained national schedule but not in the central schedule (e.g. renewable generation constrained off in the North) are less likely to be scheduled in the hypothetical unconstrained zonal schedule. Again, even if they were scheduled in the hypothetical unconstrained zonal schedule, they would have to be paid typically a lower transfer payment because the foregone inframarginal rent would be calculate using the relevant unconstrained zonal price rather than the unconstrained national price.<sup>231</sup> Hence, as illustrated in Figure 6-3 below, the required top-up (or transfer payment) would be lower under Z3 compared to N3.



<sup>231</sup> Because the zones where that would occur are typically renewable-rich zones with zonal prices that are lower than an alternative national price (e.g. zones in Scotland).

## 6. Z3: Central scheduling with zonal pricing

- 6.8. A direct consequence of: (i) scheduling all GB assets on shadow nodal prices via an SCUC (including or not ICs, as discussed below); and (ii) having load paying an “unconstrained” zonal price and generators receiving an “unconstrained” zonal price, is that intra-GB congestion rents would typically be lower than under Z1 (they can occasionally even be negative).<sup>232</sup> This implies that transfer payments for intra-GB transmission would need to be introduced to make the transmission owners whole relative to the congestion rents they would have received under an unconstrained zonal schedule.<sup>233</sup> Conceptually, these transfer payments are similar as for ICs when being scheduled based on shadow nodal prices as discussed under N3 (and in more detail as well for Z3 below).
- 6.9. In addition to the market design elements of N3, under Z3 NESO would need to overlay some assumptions that relate to the Z1 market design described in ¶4.2, as well. These are:
- market participants only have firm access to the transmission network within their zone, but not outside their zone;
  - forward energy contracts can be settled based on zonal unconstrained wholesale prices or hub prices (e.g. average load-weighted zonal price). However, different than under Z1, all forward energy contracts, whether traded via an exchange or OTC, would only be financial and not physical;
  - forward GB cross-zonal transmission rights would be implemented in GB to enable market participants to hedge prices across GB zones. However, different than under Z1, these GB cross-zonal rights can only be FTRs.

## Prices used to schedule IC flows

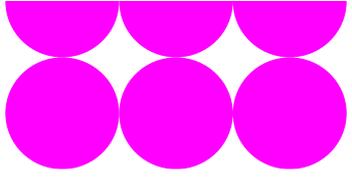
- 6.10. Similar to N3, under each Z3 cross-border trading arrangement, there are two potential options that NESO could use to schedule ICs:
- **Option 1:** Based on the price difference between the GB shadow nodal price at their landing point and the wholesale price in the connected market.
  - **Option 2:** Based on the price difference between GB zonal unconstrained price in the ICs connecting zone and the price in the connected market, which is conceptually consistent with how the IC capacity holders currently earn congestion rents (albeit relative to national GB wholesale prices).

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<sup>232</sup> Intra-GB congestion rents are calculated by multiplying the unconstrained zonal price difference with the scheduled flow across the relevant zonal boundary. Alternatively, intra-GB congestion rents can be calculated as the difference between the total payments collected from GB load and the total payments made to GB generators corrected for imports and exports via ICs.

<sup>233</sup> In practice, the transfer payments would not impact regulated TOs that earn regulated returns on their transmission assets as the transfer payments (which are financed by consumers) would ultimately be returned to consumers. However, the transfer payments could impact Competitively Appointed Transmission Owners (“CATOs”). We do not examine the implications for CATOs further in this report.

## 6. Z3: Central scheduling with zonal pricing

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- 6.11. For Option 1, the end-to-end process for each cross-border arrangement under Z3 would be virtually identical to that under N3. The IC transfer payments are expected to be lower under Z3 compared to N3 as the “scheduling prices” in GB, e.g. shadow nodal GB prices, are expected to be closer to the “commercial prices” under Z3, e.g. unconstrained zonal prices, than to the commercial prices under N3, e.g. unconstrained national prices.
- 6.12. With regards to Option 2, we explain in N3 that scheduling ICs based on the unconstrained GB national price is likely to limit the potential reduction in redispatch costs associated with central scheduling, as IC flows would often likely be incompatible with the physical GB transmission network and leading to a more costly GB schedule. We did not consider this option further as it seemed to us not to align with other design principles of N3.
- 6.13. However, under Z3, assuming that the zonal boundaries align reasonably well with transmission bottlenecks, we expect unconstrained zonal prices to better reflect system constraints than the unconstrained national price. Given this, we expect that the downsides of scheduling IC flows based on zonal unconstrained prices under Z3 to be less severe than under N3 and therefore there are merits for this option to be explored in more depth.
- 6.14. Under Option 2, the end-to-end process of the market would be the same as N3, but the cross-border arrangements would be more similar to Z1. In particular, scheduling ICs based on unconstrained zonal prices would imply that there would be no need for IC transfer payments. This is because the prices used to schedule the ICs are the same prices as those that they are commercially exposed to.
- 6.15. While the GB schedule can be expected to be less system-optimal under Option 2 compared to Option 1, Option 2 can lead to fewer complexities in IC scheduling (as described in more depth when discussing the different cross-border arrangements). At the same time, compared to Z1, such an IC scheduling approach would still allow for leveraging other potential benefits of central scheduling: earlier resolving of transmission constraints, and/or potential to implement the co-optimisation of energy and AS scheduling, and/or more transparency for NESO in managing the system.

## Z3 – Status Quo

- 6.16. In this section, we set out how the Status Quo cross-border trading arrangements in GB (that is, explicit trading for NWE ICs and implicit trading on NSL and GB-Irish ICs) would work under the Z3 market design (“Z3 Status Quo”). We find that the end-to-end process of Z3 Status Quo is virtually identical to that for N3 Status Quo. In this subsection, we therefore focus on: (i) how the challenges and compatibility issues may differ between Z3 and N3 with ICs scheduled based on shadow nodal prices; and (ii) how IC scheduling based on unconstrained zonal prices would be different from scheduling ICs based on shadow nodal prices under Z3.

## 6. Z3: Central scheduling with zonal pricing

6.17. As with N3, a major challenge in integrating the Status Quo cross-border trading arrangements is that Z3 does not have an IDM, which is incompatible with the current ID implicit trading arrangements for the GB-Irish ICs.<sup>234</sup> We therefore make the same assumptions as in N3 that it would be possible to couple the I-SEM and GB at DA instead of at ID (that is, aligned with cross-border arrangements between GB and NO2 via NSL).

## Forward market

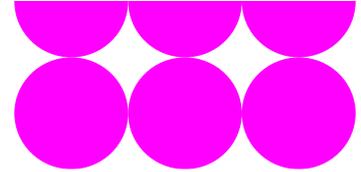
6.18. Independent of whether ICs are scheduled based on shadow nodal prices or unconstrained zonal prices, the forward market under Z3 Status Quo would work in a similar to N3 status quo explained in ¶5.15. As per N3 Status Quo:

- NESO and the relevant European TSOs would calculate the available capacity on the explicitly traded NWE ICs. The determined IC capacity would be made available in the various forward market timeframes through JAO or alike.
- Forward trading is purely financial, such that only FTRs would be traded in the forward market. The volume of these FTRs would be limited by the expected physically available IC capacity to ensure that forward contracts can be settled from the revenues of the DA IC capacity auction.
- Holders of FTRs from the forward market can choose to: (i) sell their FTRs back in the DA IC capacity auction and receive the clearing price of the DA IC capacity auction; or (ii) convert their FTRs into “virtual IC capacity rights” so as to hedge against the difference between DA wholesale price in the connecting IC zone and the DA wholesale price in the connected market. Unlike N3 (and similar to Z1) however, market participants may choose to acquire additional GB cross-zonal transmission rights to hedge price risk between the GB IC zone and other GB zones and/or a GB hub.
- We assume that NSL and the GB-Irish ICs would continue not to offer these products.
- Market participants and IC capacity holders (but not IC owners) would continue to be able to trade bilaterally in the forward market (and the resulting positions would be financial).

6.19. The unconstrained zonal wholesale prices in the GB IC zones could potentially become more volatile (in some zones during some periods) than under a national wholesale price (as under N0/N1/N3). The extent to which increased wholesale price volatility would materialise under zonal pricing could affect the valuation of cross-border transmission rights. This could be either a positive impact (if the increased volatility led to wider price spreads between the GB IC zone and the connected European zone), or a negative impact (if the increased volatility discouraged trading). The balance of these two impacts would need to be further assessed empirically.

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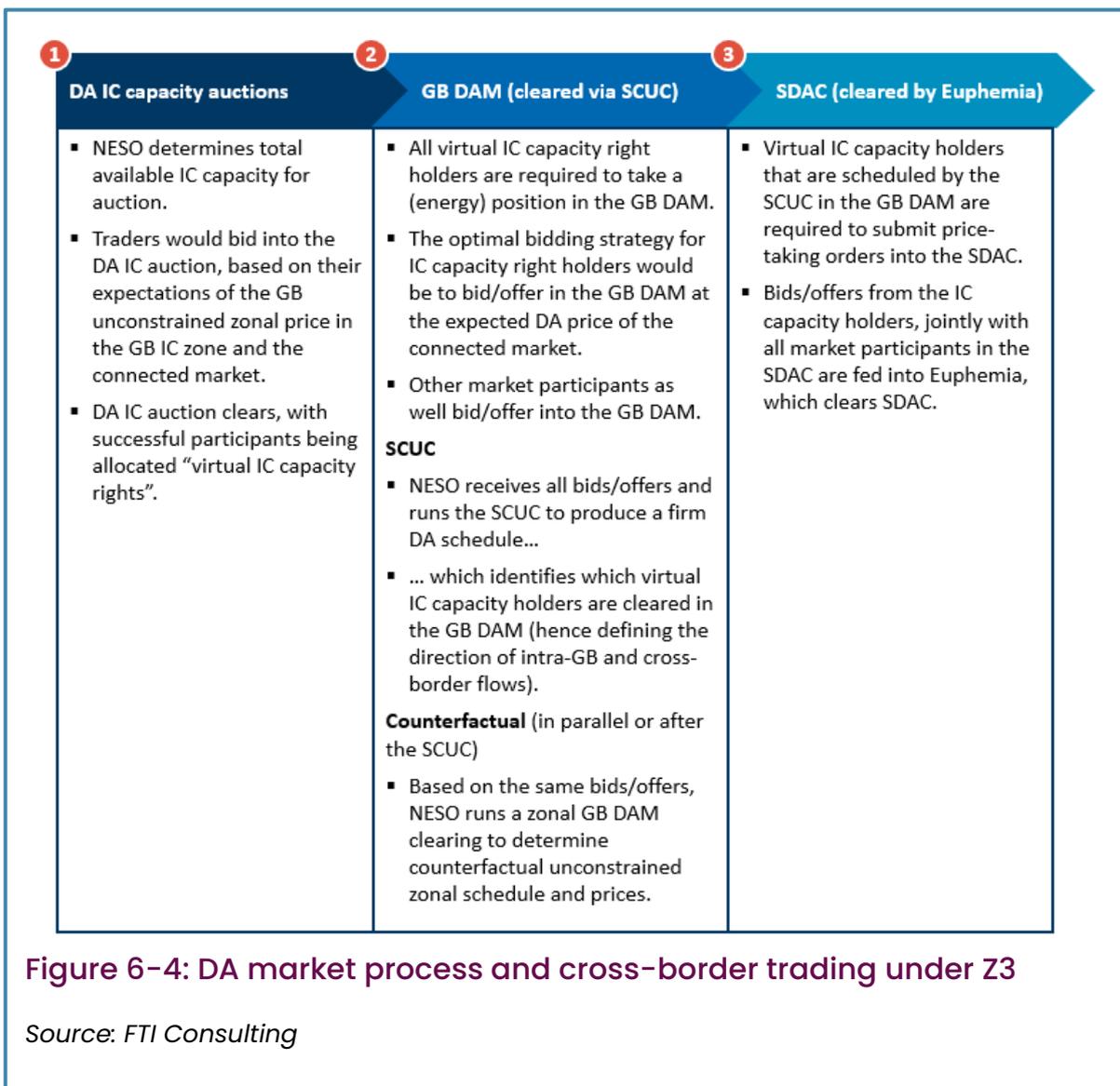
<sup>234</sup> This would no longer be an issue if, as explained in ¶5.82, an IDM is introduced in the future under the market design with central scheduling (N3/Z3).



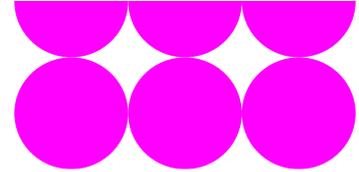
## Day-Ahead market

### Northwest Europe ICs

- 6.20. As per N3, we assume that the IC capacity for NWE ICs would continue to be explicitly traded on separate DA IC auctions. This takes place before the GB DAM (during which NESO runs a SCUC to produce a GB central schedule), which in turn runs before the SDAC (cleared via the EUPHEMIA algorithm).
- 6.21. The overview of the process of the DAM auctions under Z3 is the same as N3 described in ¶5.22 to 5.26, albeit there are some differences in how the counterfactual schedule and unconstrained prices are determined. We summarise this in Figure 6-4 below.



- 6.22. As explained above, NESO can either schedule ICs based on GB shadow nodal prices (Option 1) or GB zonal unconstrained price (Option 2).



### *ICs scheduled based on shadow nodal prices*

- 6.23. Scheduling IC flows based on shadow nodal prices means that the direction of the scheduled flow on the IC is not necessarily aligned with the commercial price differential, which can lead to the introduction of intentionally counterintuitively scheduled flows.
- 6.24. In Section 5 we identified several potential issues if NESO chooses to schedule ICs based on shadow nodal prices under N3, in particular: (i) need for a transfer payment mechanism to 'make-whole' IC capacity holders; (ii) risk of scheduled flows that are misaligned with the scheduling prices; and (iii) risk of lack of participation in the bidding of IC capacity rights in the opposite direction. We find that the same issues are relevant under Z3, albeit to a lesser extent as the commercial price differential (based on unconstrained zonal prices) is more likely to be aligned with the scheduling price differential (based on shadow nodal prices).
- 6.25. Similar to N3, NESO would need to implement a transfer payment mechanism under Z3 to compensate IC capacity holders for negative congestion rents and foregone revenues to ensure that they earn the same revenues to that if they were instead scheduled based on the commercial price differential. However, as we expect the divergence between unconstrained prices and shadow nodal prices to be much smaller under Z3 relative to N3, we would therefore expect the level of transfer payments required to maintain the appropriate balance of incentives and risk for market participants to be lower.<sup>235</sup>
- 6.26. Bidding for IC capacity rights in the opposite direction of the expected price differential under Z3 Status Quo would function in the same way as N3 Status Quo. These rights provide the IC capacity holder with an 'option value', which materialises when actual flows are in the opposite direction than initially expected based on the commercial price differences.
- 6.27. As Z3 does not have an IDM, IC capacity right holders are not able to unwind their positions after the DAM and therefore face additional downside risk and higher likelihood of incurring losses. Therefore, there is a risk that no market participants would be willing to take a position opposite to the expected commercial price differential, which would lead to a potential underutilisation of the IC (at times when the scheduling price differential ends up having the opposite sign of the anticipated commercial price differential). We expect the level of risk under Z3 to be lower than under N3 as the scheduling price differential is less likely to have the opposite sign to the anticipated commercial price differential.

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<sup>235</sup> For example (as explained in ¶15.30 to ¶15.35) when IC capacity holders earn negative congestion rents due to their own forecast error or if they earn positive congestion rents only because the IC was scheduled based on shadow nodal prices.

## 6. Z3: Central scheduling with zonal pricing

6.28. In parallel with or directly after the GB DA SCUC, the “counterfactual” unconstrained GB zonal DAM clearing can be done to determine the unconstrained zonal DAM prices and unconstrained zonal DAM schedule. The same information that served as an input for the GB DA SCUC can be used, including the bids/offers from the DA IC capacity holders. Alternatively, the ICs as scheduled in the GB SCUCs can be used as an exogenous input in the unconstrained GB zonal DAM clearing. In that case, unconstrained GB zonal market clearing would come after the GB DA SCUC. The difference between the GB zonal DA clearing and the GB DA SCUC is that in the GB zonal clearing not all network constraints would be reflected but only NTCs or flow-based constraints between GB bidding zones.

*ICs scheduled based on unconstrained zonal prices*

6.29. NESO can alternatively choose to schedule ICs based on zonal unconstrained prices. If so, the price used to schedule ICs is always aligned with the commercial price, such that there would be no need for IC transfer payments and the issues described above would no longer be relevant. Counterintuitive flows are still possible. However unlike when scheduling ICs based on shadow nodal prices, the counterintuitive flows would always be unintentional (e.g. due forecast errors from IC capacity holders).

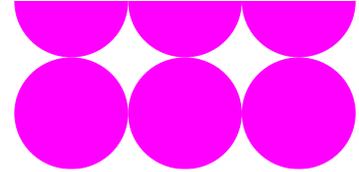
6.30. The unconstrained GB zonal DAM clearing would need to be performed before the SCUC to determine the schedule of ICs. This is unlike if ICs were scheduled based on shadow nodal prices, where the unconstrained GB zonal DAM clearing can take place in parallel or after the SCUC (see ¶6.28 above).

6.31. The same clearing would produce the unconstrained zonal DAM schedule and zonal prices. After, the GB DA SCUC schedule is run,<sup>236</sup> in which all GB assets are scheduled nodally “around” the ICs schedules as determined in the unconstrained GB zonal DAM clearing. As described in the beginning of this chapter, the GB central schedule can be expected to be less optimal compared to when scheduling ICs based on shadow nodal prices. However, there are also potential benefits (e.g. fewer complexities in IC scheduling and no need for IC transfer payments).

6.32. Under both types of scheduling prices, the IC schedules as determined in the GB DA SCUC or the unconstrained GB zonal DAM clearing will be an exogenous input into the European SDAC (which is cleared after).

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<sup>236</sup> Optionally there would be the opportunity to allow for a revision by GB market participants (except for DA IC capacity holders) of bids/offers submitted to the GB zonal DAM clearing before the GB DA SCUC.



### *NSL and GB-Irish ICs*

6.33. We expect that NSL and GB-Irish ICs would likely need to move to explicit auctions, regardless of whether they are scheduled based on shadow nodal prices or unconstrained zonal prices.

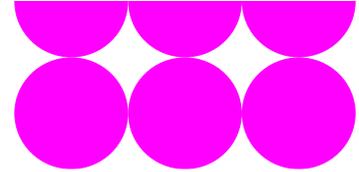
### *ICs scheduled based on shadow nodal prices*

6.34. We expect the issues identified under N3 with regards to NSL and the GB-Irish ICs to be similar under Z3, such that they would likely need to move to explicit auctions:

- As explained in ¶15.41, for Norway to remain coupled at DA stage between GB and NO2, a single entity would need to jointly define prices in GB and NO2 and associated flows on NSL. There are two options for the single entity – N2EX or NESO – but both options appear impracticable for security reasons.<sup>237</sup> Unless these can be effectively addressed, we expect that the NSL may need to move to explicit arrangements; and
- Similar issues would apply to the GB-Irish ICs, with the added complications that: (i) unlike NO2, the I-SEM market may not be sufficiently liquid to sustain two parallel prices (one for the GB-Ireland coupled market clearing and one for the separate I-SEM market clearing); and/or (ii) it may not be possible to implicitly couple the GB-Irish ICs and NSL at the same time once Celtic comes online. Ireland and Norway would then be connected via an extended electrical path (e.g. via North-Western EU countries) that does not go through GB, such that the implicit GB coupling would have an impact on the capacity between Ireland and Norway (which would likely lead to important inefficiencies).

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<sup>237</sup> If the role was played by N2EX, it would need to receive all information that the SO would have otherwise used to centrally schedule the GB DAM, which is unlikely to be acceptable to GB. If it was instead played by NESO, NESO would need to receive sensitive information on the bids and offers in NO2, which is unlikely to be accepted to Norway.



### ICs scheduled based on unconstrained zonal prices

6.35. We expect the issues identified under Z1 with regards to NSL and the GB-Irish ICs to be similar under Z3. In case those issues would not be able to overcome, the fallback solution would be to move the cross-border arrangement on NSL and the GB-Irish ICs to explicit auctions:

- While we deem for NSL the option to keep the Price Coupling process between NO2 and the relevant GB zone separate from the intra-GB Price Coupling process<sup>238</sup>, at least in principle, workable, we do not consider it future proof to new ICs between Norway and GB that connect to different GB/NO zones than NSL. This is because transmission capacity on the relevant bidding zone borders within GB and/or within Norway would need to be reserved for the separate market coupling process between GB and Norway, which is likely to be inefficient.
- Trade-offs for keeping the coupling between I-SEM and GB separate from the intra-GB Price Coupling process mirror the ones for NSL, with the added complexity of already having multiple ICs between GB and I-SEM potentially connecting to different GB zones. The concurrent clearing of I-SEM with several GB zones via the GB-Ireland coupling would imply that the determination of flows on bidding zone borders within GB determined by the GB-Ireland clearing would interact with the intra-GB Price Coupling process, which takes place separately. In practice this could imply having to reserve cross-zonal capacity within GB for the GB-Ireland clearing, which is highly likely to be complex and, more importantly, inefficient.

### Intraday market

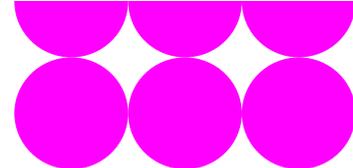
6.36. The ID timeframe for Z3 Status Quo would work in the same way as N3 Status Quo. As the Z3 market design does not have an IDM, there would no longer be any IC capacity auctions in GB for the explicitly traded ICs at the ID stage. In Europe, the SIDC would take the DA GB-Europe IC flows determined in the DA stage as given and optimise around them.

6.37. As described in ¶15.49, this is more favourable to EU market participants and intra-EU ICs (as they can refine their positions in the SIDC) compared to GB-EU ICs and could create an incentive for GB to introduce an ID market to complement the DAM in the long run.

6.38. It is possible that as an alternative to an IDM, ID NESO-led procedures would be put in place to reschedule assets in case the necessity of doing so would be known significantly before real-time. An example can be a major outage of a GB asset or IC. Not having such ID processes in place could lead to foregoing potential lower cost alternative (relative to the available solutions available in RT) to resolve (forced) deviations from the DA SCUC schedule.

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<sup>238</sup> In this case, N2EX would be responsible for the market clearing of only the relevant GB price zone where NSL connects (“GB NSL zone”), NO2 and the flows on NSL.



## Real time

- 6.39. The RT stage for Z3 Status Quo would work in the same way as N3 Status Quo. After the DA market, GB market participants would revise their bids and offers for the RT clearing. NESO would re-run the SCUC optimisation to produce a physically binding RT schedule and resolve imbalances (and any resulting minor thermal constraints). Default the IC flows would be fixed to their positions at DA.
- 6.40. If necessary, we assume that NESO would continue to be able to adjust IC flows in RT using SO-SO trades and emergency services.

## Z3 – MRLVC

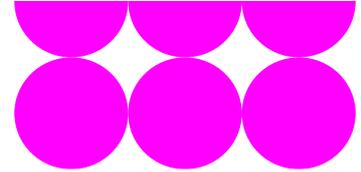
- 6.41. In this subsection, we set out how the MRLVC design would work under the Z3 market design (“Z3 MRLVC”). We find that the end-to-end process of Z3 MRLVC is virtually identical to that for N3 MRLVC. In this subsection, we therefore focus on: (i) any differences between the market designs; and (ii) how the challenges and compatibility issues may differ between Z3 and N3. As per the other market designs, we assume that when implemented, the MRLVC would apply to all GB ICs (including NSL and GB-Irish ICs).

## Forward market

- 6.42. The forward market under Z3 MRLVC would work in a similar way as in N3 MRLVC:
- ICs can choose to participate in JAO forward auctions and offer capacity for various market timeframes;<sup>239</sup>
  - Only FTRs would be traded on GB ICs. These would be settled based on the difference between the DA prices in the GB IC zone and the bidding zone of the connected market. Unlike N3 (and similar to Z1) however, market participants may choose to acquire additional GB cross-zonal transmission rights to hedge price risk between the GB IC zone and other GB zones and/or a GB hub; and,
  - Market participants would continue to be able to trade bilaterally in the forward market (and the resulting positions would be financial).

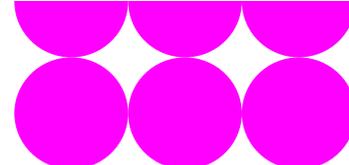
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<sup>239</sup> Currently, only IFA, IFA2, ElecLink, Nemo Link, Viking Link and BritNed participate in these auctions. In principle, NSL and GB-Irish ICs could also participate.



## Day-Ahead

- 6.43. Under Z3 MRLVC, the calculations of available capacity and the BBZ-EU Flow Forecast continue to be performed prior to DA market closure, which occurs simultaneously for both the SDAC and GB DAM. BBZ NEMOs would also continue to combine their received orders and submit order books to the MRLVC algorithm. On the GB side, however, NESO would no longer submit an order book as under N0. There are two potential input options that could be fed into the MRLVC, which affect the choice of prices that can be used to schedule IC flows:
- market participants' technical details, which due to computational constraints, would require ICs to be scheduled based on the unconstrained GB zonal price; and
  - net import/export curves that reflect the cost to the GB power system at the IC landing points of deviating from an estimated central schedule, which would enable ICs to be scheduled based on GB shadow nodal prices.
- 6.44. We compare the two potential input options into the MRLVC algorithm in Table 6-1 below. We highlight in grey areas of differences relative to N3 MRLVC. In all other aspects, the Z3 and N3 MRLVC designs are identical.



**Table 6-1: Comparison of input options to the MRLVC (differences compared to N3 are highlighted in grey)**

	Market participants' technical detail	Net Import/Export curves
Entity submitting information to MRLVC	GB NESO or GB PX	NESO (after pre-processing)
GB price used to schedule ICs	Unconstrained zonal price	Shadow nodal price
Pre-processing requirements	Low, if technical details are directly fed into the MRLVC algorithm Medium, if technical details are translated/simplified before inputting into the MRLVC algorithm	High, as NESO would need to produce an initial central schedule and net import/export curves based on nodal bids. These would be zone-specific.
MRLVC computational feasibility	Likely possible, given that EUPHEMIA is able to accommodate complex bids	Likely possible, as information would be pre-processed before submission to MRLVC
Likely level of NESO redispatch required	Higher but not significantly so, as MRLVC-optimisation would be based on zonal prices that reflect major transmission constraints	Lower, as MRLVC-optimisation based on shadow nodal prices that fully reflect GB transmission constraints
Transfer payments required	None, but likely a slightly more costly GB schedule as GB assets must schedule around IC (or the IC schedules may need to be readjusted). The zonal GB schedule in Z3 is likely to be somewhat inefficient, but less so than under N3.	Required if MRLVC-optimised flows are against commercial price differentials. Lower transfer payments expected under Z3 compared to N3.
Security risks	Low, as no network information provided to MRLVC operator	Low, as network information is processed by NESO
Changes required from EU	Update to bidding formats, which seems feasible given existing complex bids	MRLVC algorithm would need to be able to accommodate import/export curves, which seems feasible

## 6. Z3: Central scheduling with zonal pricing

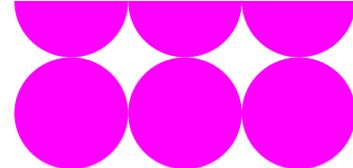
- 6.45. Under N3 MRLVC, we considered the option with net import/export curves (which have higher pre-processing requirements) to be more appropriate due to significant downsides to scheduling ICs based on the unconstrained national price under central scheduling (that is, a more costly GB schedule with high volumes of redispatch). Under Z3 however, we consider that the option with inputting market participants' technical details would be the preferred option as: (i) the downsides are smaller compared to that under N3 MRLVC; (ii) it has lower pre-processing requirements than the import/export curves; and (iii) is likely to be feasible (both computationally and in terms of the degree of accommodations required by the EU).
- 6.46. Given this, we assume market participants' technical details would be an input into the MRLVC in the remainder of the section. The market operator would aggregate the technical details submitted by market participants (and potentially convert them into a suitable format) before inputting these into the MRLVC algorithm to optimise (firm) GB-BBZ flows. Based on these firm flows from the MRLVC, NESO would then run a second SCUC that calculates a final (binding) DA central (zonal) schedule *around* the MRLVC-optimised flows. As a result, NESO does not play a role in determining the direction of these flows.
- 6.47. As ICs are scheduled based on unconstrained zonal prices, transfer payments would not be required. There is a risk that it may not be possible for NESO to determine a physically feasible DA central schedule with the MRLVC-optimised flows. We do not expect this to be a significant issue as the MRLVC-optimisation would take into account the major GB transmission constraints. The frequency and extent of this risk would require empirical testing. In such cases, NESO and European TSOs would need to develop suitable fallback procedures (similar to that described in ¶15.78 for N3 MRLVC).
- 6.48. If net import/export curves were used instead, the MRLVC optimisation would follow the same process as that described in ¶15.76 to 5.77 .

### Intraday market

- 6.49. The MRLVC is intended to be a DA trading solution and potential post-Brexit ID trading arrangements are yet to be explored. Given this, and in line with the Z3 market design, we assume that there would be no ID trading in GB. The ID arrangements in Europe would remain the same as that described for N3 MRLVC.
- 6.50. As described in Z3 Status Quo ID NESO-led procedures, instead of an IDM, could be put in place to reschedule assets in case the necessity of doing so would be known significantly before real-time.

### Real time

- 6.51. The RT stage for Z3 MRLVC would work in the same way as Z3/N3 Status Quo and N3 MRLVC.



## Z3 Price Coupling

6.52. In this section, we set out how Price Coupling could potentially work under the Z3 design (“Z3 Price Coupling”). Effectively, this section overlays the Z3 market design assuming that GB is fully price coupled with the EU. As explained above, we assume that when implemented, Price Coupling would apply to all GB ICs (including NSL and the GB-Irish ICs).

### Forward market

6.53. We assume that the forward market under Z3 Price Coupling would function in the same way as N3 Price Coupling described in ¶15.88 to ¶15.89.

### Day-ahead

6.54. To implement Price Coupling in a ‘pure’ sense, GB would effectively need to become part of the SDAC, which would imply that the GB DAM is cleared within EUPHEMIA (that is, akin to pre-Brexit arrangements). In N3 Price Coupling, we assessed that it would not be feasible from a computational or security perspective to schedule ICs based on shadow nodal prices. The same considerations apply under Z3 Price Coupling and we have discarded this option.

6.55. Should GB return to Price Coupling with the EU (although we do not comment on the likelihood or timelines for this possibility), we assessed that it was feasible to schedule ICs based on the unconstrained (national) GB price under N3 Price Coupling. It would similarly be feasible under Z3, using unconstrained zonal GB prices:

- EU NEMOs and NESO would feed in EU order books and GB multi-part bids respectively, following which the EUPHEMIA algorithm would produce unconstrained GB zonal prices and SDAC prices, which would simultaneously be used to schedule ICs.<sup>240</sup>
- NESO would take the cross-zonal volumes, cross-border volume and direction of flows determined by EUPHEMIA as given (unless physically impossible to clear the GB wholesale market with such flows) and subsequently determine a final (second) binding central DA schedule by running a SCUC optimisation. This means that the GB central schedule would be created by optimising “around” the flows determined by the combined EU+GB EUPHEMIA algorithm. This would likely lead to a costlier GB schedule compared to having the ICs scheduled based on shadow nodal prices. However, we expect the cost difference to be significantly smaller under Z3 Price Coupling compared to N3 Price Coupling.

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<sup>240</sup> The unconstrained price from EUPHEMIA would be used to calibrate the transfer payments.

## 6. Z3: Central scheduling with zonal pricing

- The GB zonal prices as computed by EUPHEMIA would serve as the GB unconstrained zonal prices. As ICs are scheduled based on the unconstrained GB price, no transfer payments for ICs are required.<sup>241</sup>

## Intraday market

6.56. Assuming there is no IDM under Z3, GB would not participate in the SIDC (continuous and ID auctions). Similar to N3, the operation of SIDC in the EU has two options:

- Take the GB-Europe cross-border flows (defined at the DA stage) as a given and optimise the flows of other EU ICs around it; or
- Re-optimize the flows on all GB-EU ICs and intra-GB cross-zonal flows. If the ID flows determined by the EU SIDC on GB ICs are different from those determined at the DA stage, the SO in the relevant EU country may have to pay a penalty price to compensate: (i) the IC for the lost congestion rents; and (ii) NESO for the cost of redispatch incurred to resolve the constraint imposed on the GB system. The latter cost would have to be determined by a re-run of the GB SCUC.

6.57. There is also a possibility that European TSOs would not accept either of the two options above, and would instead require that they have a unilateral right to redispatch the GB-Europe ICs using the SIDC algorithm which would create severe complications. This is unlikely to be attractive to GB.

6.58. As described in Z3 Status Quo, ID NESO-led procedures (instead of an IDM) could be put in place to reschedule assets in case the necessity of doing so would be known significantly before RT.

## Real time

6.59. The RT stage for Z3 Price Coupling would work in the same way as N3 Price Coupling.

## Conclusions

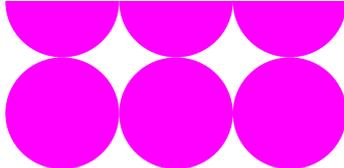
6.60. In our discussion above, we have assessed the potential feasibility of combining three cross-border arrangements (Status Quo, MRLVC and Price Coupling) with the Z3 market design. In doing so, we have not sought to comment on the preferred option(s) for cross-border trading arrangements nor on the desirability of the Z3 design itself. Rather, we have taken the Z3 market design as given and examined how different cross-border trading arrangements could be developed or adapted to be compatible with the Z3 market design.

6.61. We find that, with suitable adaptations, Z3 market design can be made compatible with Status Quo, MRLVC and/or Price Coupling. We summarise our conclusions below:

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<sup>241</sup> This is akin to the approach in place for Italy, which uses central scheduling with zonal pricing.

## 6. Z3: Central scheduling with zonal pricing

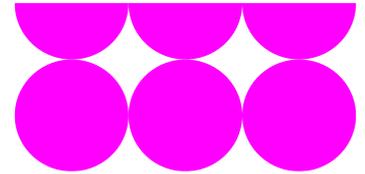
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- (i) Of the various market design options, implementing Z3 would require the most change relative to N0 as GB would need to move to central scheduling while overlaying a zonal market design to determine the unconstrained GB schedule and zonal prices.
  - (ii) Similar to N3, it is feasible to schedule ICs based on shadow nodal prices under Z3 Status Quo (explicit trading) and Z3 MRLVC, but not under Z3 Price Coupling. The issues identified in N3 (that arise due to the divergence between the scheduling and commercial price differentials) continue to apply to Z3, however, they are likely to be less significant as the IC scheduling and commercial price differentials are more likely to be aligned under Z3.
  - (iii) Other things being equal, it is more efficient from a GB system perspective to schedule ICs based on GB shadow nodal prices than the unconstrained GB price, but this would require transfer payments to 'make-whole' ICs and is more complex. Scheduling ICs based on unconstrained zonal prices would make cross-border arrangements significantly simpler under explicit trading and MRLVC. Importantly, scheduling ICs based on unconstrained zonal prices is feasible with Price Coupling (making Z3 and Z1 the only options we have identified that are compatible with Price Coupling).<sup>242</sup>
  - (iv) It would need to be empirically tested how: (i) the gains in simplifying cross-border arrangements when scheduling ICs based on unconstrained prices, compare against; and (ii) the efficiency losses from not scheduling ICs based on shadow nodal prices. Relative to Z1, Z3 combined with ICs scheduled based on unconstrained prices would still allow for leveraging the potential benefits of central scheduling: earlier resolving of transmission constraints, potential for the co-optimisation of energy and AS scheduling and more transparency for NESO in managing the system.
  - (v) Under Z3 Status Quo, continuing the implicit trading arrangements on NSL and the GB-Irish ICs would be challenging regardless of whether ICs are scheduled using shadow nodal prices or unconstrained GB zonal prices. If those challenges are not overcome, those cross-border trading arrangements might need to revert to explicit trading as a fallback option.

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<sup>242</sup> Price Coupling is also feasible under N0 and N3 but not recommendable due to likely significant volume of scheduled IC flows that would aggravate rather than relief intra-GB congestion.

# 7. Interactions with other market reforms





The previous chapters of this report examined the interactions between market designs and cross-border arrangements. In doing so, we implicitly assumed that the wider market arrangements remained unchanged. In this chapter, we relax that assumption and discuss the interactions between cross-border arrangements and market designs with a selection of potential market reforms that could impact cross-border trading arrangements.

## Introduction

7.1. We have been asked to consider four potential market reforms:

- **OHA:** The development of OHAs could have implications for the feasibility and/or efficiency of the cross-border arrangements we discussed earlier. Two potential designs for OHA market arrangements are currently under consideration in Europe and GB: HMs and OBZs;
- **Settlement periods and MTU:** GB is considering shortening the settlement period from 30 minutes to 15 or 5 minutes, while the EU will be moving from the current 1-hour MTUs to a 15-minute MTU in the SDAC.<sup>243</sup> We assume that shortening the settlement period in GB would involve an equivalent reduction in MTUs in the DAM and IDM;
- **GCT:** As discussed in Chapter 2, GB is considering extending its wholesale GCT (currently 1 hour). In contrast, the EU is shortening its IDCZGCT from 1 hour to 30 minutes from the 1st of January 2026<sup>244</sup>; and
- **Bidding zone splits in the EU:** European TSOs are conducting a Bidding Zone Review, in which alternative bidding zone configurations (e.g. splitting Netherlands and Germany into multiple bidding zones) are under consideration. As already discussed in Chapter 4 and Chapter 6, a potential shift to a zonal market design in GB is also under consideration.<sup>245</sup>

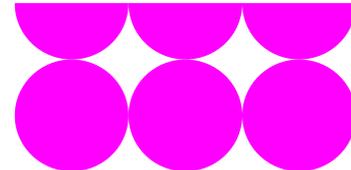
7.2. In the following subsections, we discuss each of these four market reforms in turn.

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<sup>243</sup> A 15-minute MTU is already being rolled out in the SIDC ([link](#)). The go-live of 15 minutes MTUs in the SDAC is planned on the 11<sup>th</sup> of June 2025 ([link](#)).

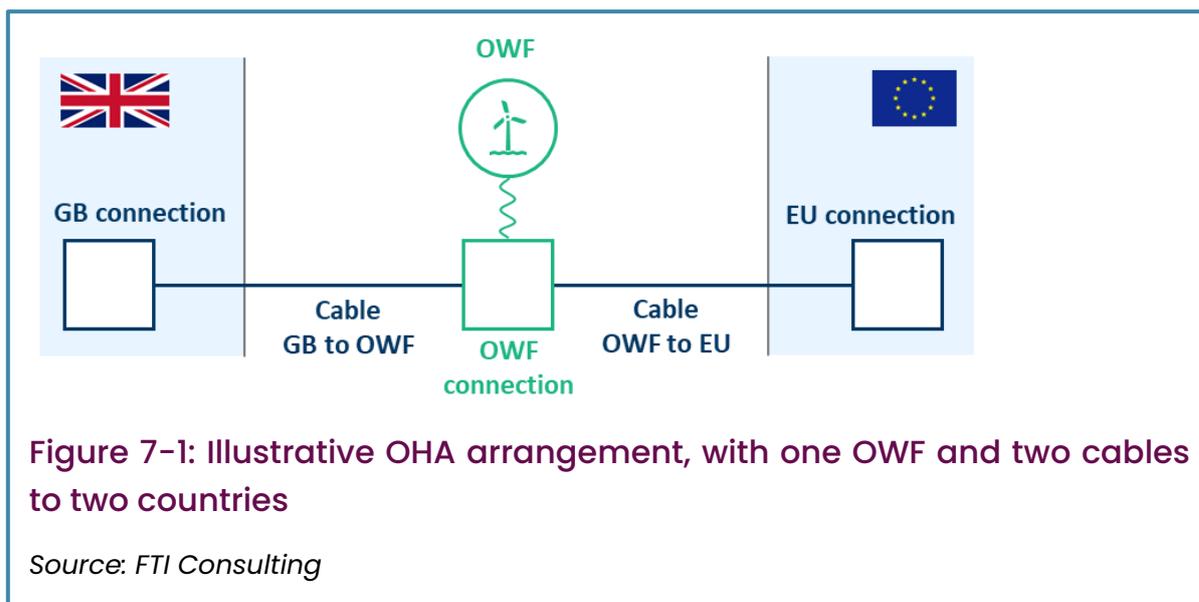
<sup>244</sup> See Art. 5(1) of Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design ([link](#)).

<sup>245</sup> As required as part of the implementation of 'Bidding Zone Review', ENTSO-E ([link](#)). The ongoing bidding zone review is not a one-time exercise and can be triggered in various ways as described in Art. 14 of Commission Regulation (EU) 2019/943.



## Offshore hybrid assets

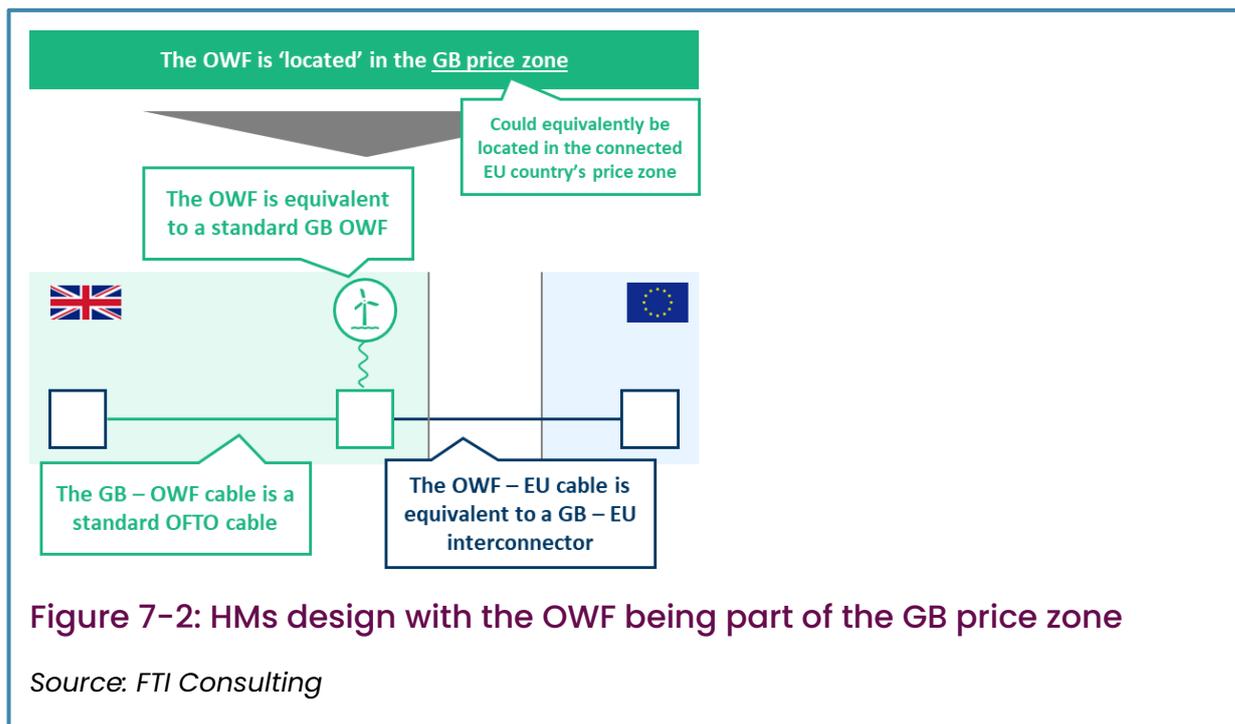
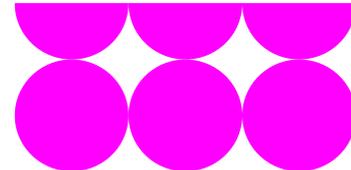
7.3. OHAs are integrated projects, which as illustrated in Figure 7-1 below, typically combine OWFs and ICs<sup>246</sup> to allow OWFs to directly connect to multiple price zones. This is different compared to the traditional 'radial' connection, which links OWFs to a single price zone. Depending on the configuration, OHAs offer the possibility of more efficient use of transmission assets. Unlike radial assets, the transmission can potentially be used to flow power between (onshore) price zones in hours when the offshore wind output is low.



7.4. As explained above, two potential designs for OHA market arrangements are currently under consideration in Europe and GB:

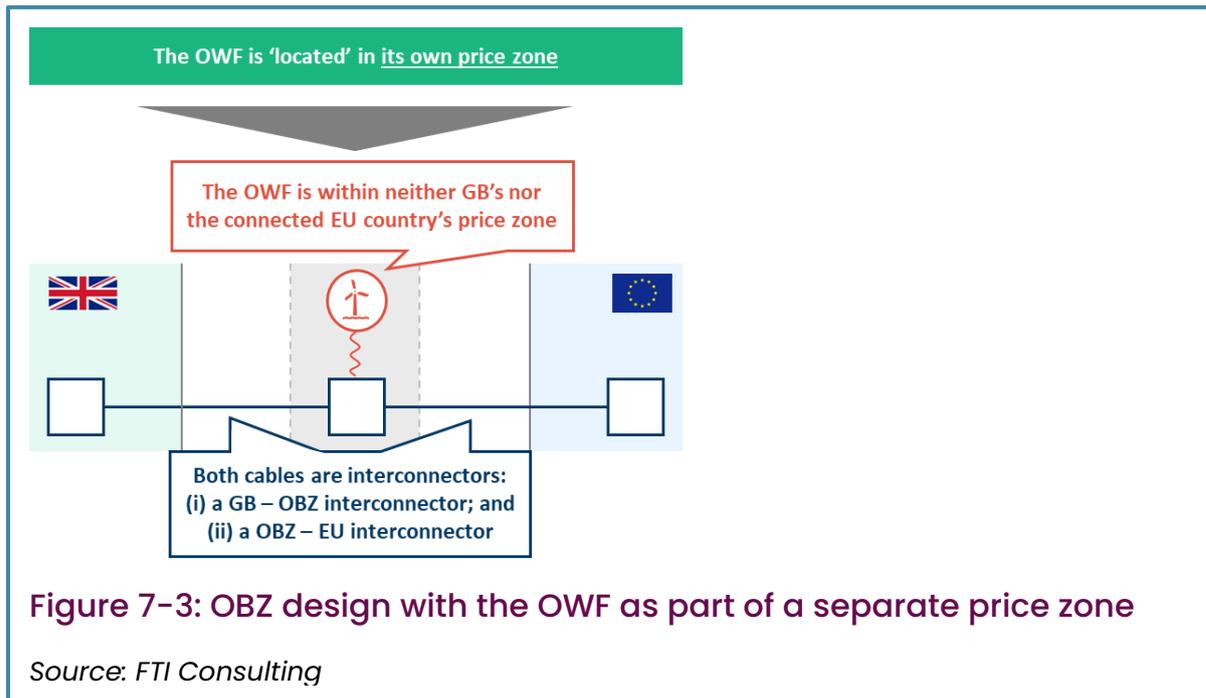
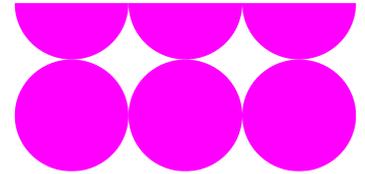
- **HMs:** The OWF is treated as being sited in the price zone of one of the connected countries (the 'HM, illustrated in Figure 7-2), such that the transmission line between the OWF and the HM is considered an internal transmission asset. Under this arrangement, the OWF has priority access to the transmission line over cross-border flows, and always bids into and receives the price in the HM regardless of the direction of flows;

<sup>246</sup> They may also integrate other assets, e.g. offshore sources of demand. In this report we focus on the simplest forms of OHAs which only include OWF and transmission assets.



- OBZ:** The OWF is considered to be sited in its own price zone, such that both the transmission lines connecting to the OWF are considered cross-border assets (illustrated in Figure 7-3). The OWF does not have priority access to cable capacity, and therefore must compete with bids and offers from other market participants in its connected onshore bidding zones. Under implicit trading, the OWF generally receives the lowest price of its two connected onshore bidding zones.<sup>247</sup>

<sup>247</sup> 'Consultation on the Regulatory Framework, including Market Arrangements, for Offshore Hybrid Assets: Multi-Purpose ICs and Non-Standard ICs', 2 June 2023, ([link](#)). There are some scenarios in which the OBZ price formation does not follow this general principle. For example, when the OWF is not generating, the OBZ price can clear at any value between the two connected onshore price zones. Also, when there is not enough transmission capacity to export the OWF generation the price in the OBZ will be zero, e.g. the assumed marginal cost of the OWF.



- 7.5. No conclusive decisions have been made on the OHA market arrangements in either Europe or the UK. However, on the European side ENTSO-E, ACER and the European Commission have all signalled their preference for OBZs.<sup>248,249,250</sup> On the GB side, Ofgem have indicated that there is consensus among stakeholders that OBZ arrangements would be more preferable under an implicit cross-border arrangement, while HMs would be a “fallback arrangement” if the status quo explicit cross-border arrangements remain in place.<sup>251</sup>

<sup>248</sup> ‘ENTSO-E Position on Offshore Development Summary of Recommendations’, November 2022, ENTSO-E ([link](#)).

<sup>249</sup> ‘Reflection on the EU Strategy to harness the potential of offshore renewable energy for climate neutral climate future’, 11 April 2022, ACER and CEER ([link](#)).

<sup>250</sup> ‘An EU strategy to harness the potential of offshore renewable energy for a climate neutral future’, 19 November 2020, ([link](#)).

<sup>251</sup> ‘Consultation on the Regulatory Framework, including Market Arrangements, for Offshore Hybrid Assets: Multi-Purpose ICs and Non-Standard ICs’, 2 June 2023, ([link](#)).

## 7. Interactions with other market reforms

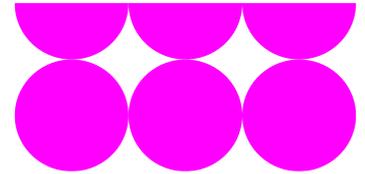
7.6. The interaction between OHAs and cross-border arrangements is largely driven by the choice of the market arrangements. If the OWF is part of the GB HM,<sup>252</sup> we find that there is limited interaction with the choice of cross-border arrangements and do not discuss it further in the rest of this section. The OWF is treated as if it was part of the GB wholesale market (in terms of access and revenues earned). Under all cross-border arrangements, NESO would prioritise flows from the OWF to mainland GB and thus 'reserve' the available capacity on the GB-OWF line based on the forecast production of the GB OWF. Any remaining capacity on the GB-OWF line can be used to accommodate cross-border trade in the same way that any other intra-GB transmission line (e.g. onshore) would be used. Hence for the remainder of this section, we do not focus on the HM solution. Therefore, in what follows we will cover the case when an OWF is: (i) located in an OBZ that is part of GB's jurisdiction ("GB OBZ"); and (ii) located in an OBZ under EU jurisdiction, which is assumed to be part of the IEM.

### Interactions with feasibility of various combinations of market designs and cross-border arrangements

- 7.7. In this section we discuss the feasibility of the different cross-border arrangements; the implications of the different trading arrangements on OHA capacity valuation and/or commercial utilisation are discussed in the next section.
- 7.8. As long as the total number of OBZs remains relatively modest compared to the number of GB and EU zones (such that there are no computational issues incorporating them into the GB or EU markets), we do not anticipate there to be material implications for the feasibility of the various market designs and cross-border trading arrangements other than as discussed below.
- 7.9. When an OWF is located in an OBZ that is part of GB's jurisdiction, the GB OBZ would become a new zone for GB. Given this, it appears to us straightforward to incorporate the additional OBZ zone under zonal market designs (Z1 and Z3). However, incorporating the new OBZ zone under N0/N1/N3 would effectively convert them into Z1/Z3 variants with two zones – a large onshore zone for GB and a small OBZ. In other words, the feasibility assessment of the OHA with N0/N1/N3 becomes the same as the feasibility assessment of the OHA with a zonal design (Z1/Z3).
- 7.10. When an OWF is located in an OBZ that is part of EU's jurisdiction ("EU OBZ"), the OBZ would become a new zone in the IEM that would need to be incorporated into the clearing algorithms for SDAC and SIDC. There would be no material change on the GB side.

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<sup>252</sup> National market under N1 and N3 and the connected GB zone under Z1 and Z3. We do not examine the case in which the OWF is located in the EU HM, as the GB-OBZ line would be akin to a point-to-point IC.



## 7.11. For an EU OBZ (with national pricing in place in GB):

- N0 is feasible for all three cross-border arrangements. Similarly, N3 is feasible for all three cross-border arrangements when scheduling ICs based on unconstrained zonal wholesale prices.
- N3 is feasible for explicit cross-border trading arrangements and MRLVC when scheduling ICs is based on shadow nodal prices. Price Coupling is only feasible when unconstrained national prices are used to schedule ICs.
- N1 is feasible for all the Status Quo arrangement and MRLVC but not for Price Coupling for reasons discussed in Chapter 3 (driven by the mutual incompatibility of the GCT in GB and in the IEM).

7.12. For an EU (with zonal pricing in place in GB) and a GB OBZ (with national<sup>253</sup> or zonal pricing in place in GB):

- Z1 is feasible for all three cross-border arrangements. Similarly, Z3 is feasible for all three cross-border arrangements when scheduling ICs based on unconstrained zonal wholesale prices. As discussed in Chapters 4 and 6, it seems likely that the implicit arrangements for NSL at the DA-stage and for the I-SEM in the ID-stage that are currently in place would have to be turned into explicit arrangements. With regards to MRLVC, the preferred option would be for the order books that are submitted by the PX to the MRLVC algorithm to cover all GB bidding zones (which would now include the OBZ with a GB OWF).
- Z3 is feasible for explicit cross-border arrangements and MRLVC when scheduling ICs based on shadow nodal prices but not for Price Coupling. With regards to MRLVC, the preferred option would be for the order books that are submitted by the PX to the MRLVC algorithm to cover all GB bidding zones.

## Interactions with OHA capacity valuation and/or commercial utilisation of various combinations of market designs and cross-border arrangements

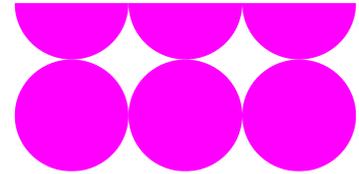
7.13. In this subsection, we discuss how the interaction with OHAs under the GB OBZ and EU OBZ scenarios affects the OHA capacity valuation and/or utilisation of the trading arrangements under Status Quo explicit trading,<sup>254</sup> MRLVC and Price Coupling. We define commercial utilisation as the extent to which the OHA is scheduled relative to the outturn GB/OBZ/connecting market wholesale prices (as different from outturn utilisation of the asset which includes any potential redispatch actions on the OHA).<sup>255</sup>

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<sup>253</sup> As described in ¶17.9, for a GB OBZ the feasibility assessment of the OHA with N0/N1/N3 becomes the same as the feasibility assessment of the OHA with a zonal design (Z1/Z3).

<sup>254</sup> The interactions of OHAs with Status Quo implicit trading are the same as that under Price Coupling.

<sup>255</sup> This implies that by definition under Price Coupling OHAs are optimally commercially used.



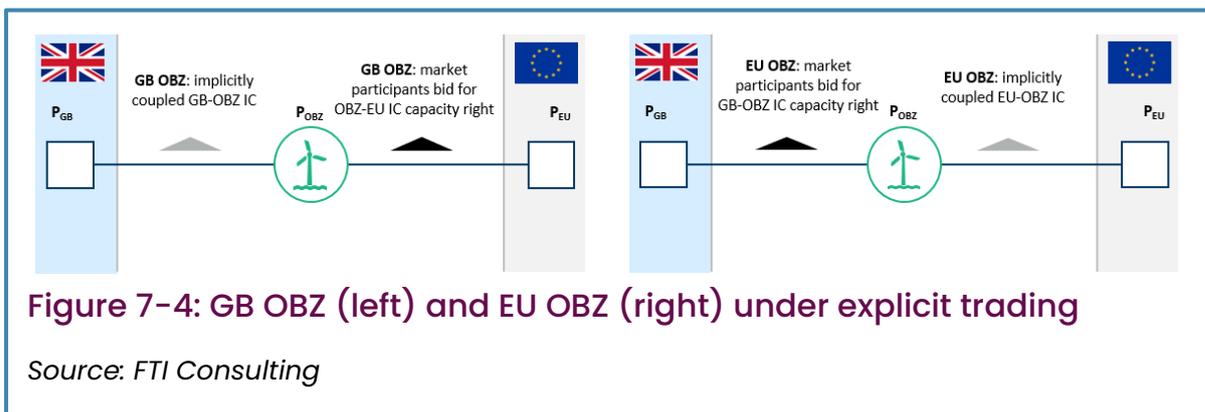
7.14. For each cross-border arrangement, we first discuss general comments that apply to all market designs, before examining the potential further differences in the interactions under: (i) central scheduling (N3 and Z3) versus self-scheduling (N0/N1 and Z1); and (ii) zonal market design (Z1 and Z3) versus national market design (N0/N1 and N3).<sup>256</sup>

7.15. We provide a summary for GB and EU OBZs in Table 7-1 and Table 7-2, respectively, at the end of this subsection.

**Explicit trading**

7.16. We assume that only part of the line would be explicitly traded, depending on whether the OWF is in a GB OBZ or EU OBZ. As illustrated in Figure 7-4 the OWF is in a:

- GB OBZ, we assume that the GB-OBZ line is implicitly coupled with GB mainland (and any other OBZs that may exist)<sup>257</sup>; and
- EU OBZ, we assume that the EU-OBZ line is implicitly coupled with the EU (and any other OBZs that may exist).



7.17. When buying DA IC capacity rights under explicit trading, depending on whether the OWF is in a GB OBZ or EU OBZ, traders would need to forecast the OBZ price and the price in the connecting market or the OBZ price and the GB wholesale market price, respectively.

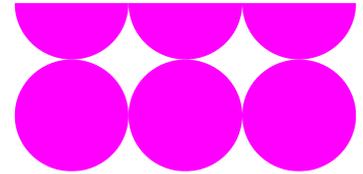
<sup>256</sup> Here we do not discuss in depth the implications for the GB system costs. Everything else equal, central scheduling market designs with OHAs scheduled based on shadow nodal prices will likely result in lower GB system costs than self-scheduling market designs. Similarly, zonal market designs will likely result in lower GB system costs than national market designs.

<sup>257</sup> Traders would not need to buy a LTRR of the implicitly allocated line of the OHA to ensure the ability to schedule flows on the explicitly allocated line of the OHA. However, they can buy such LTRR to hedge between the GB national/zonal mainland wholesale price and OBZ price.

- 7.18. Relative to national/zonal prices in GB, the OBZ price formation dynamics is significantly affected by the wind output and the connected transmission's flows. Unlike larger onshore bidding zones, in which prices change relatively linearly, the prices at an OBZ would typically change in a discrete fashion – as described in Footnote 247, the OBZ price generally falls to the lower of the prices in its connected markets.
- 7.19. Given the challenges in predicting offshore wind output at the OBZ significantly in advance (e.g. DA), this could impact:
- the ability to calculate the optimal transmission capacity that can be traded both on the IC for which capacity is implicitly allocated (EU-OBZ IC for a GB OBZ and the GB-OBZ IC for an EU OBZ) and the IC for which capacity is explicitly allocated (EU-OBZ IC for a GB OBZ and the GB-OBZ IC for an EU OBZ).<sup>258</sup> The allocated capacity would be based on the forecasted volume of the offshore wind and the expected price difference between the GB national/zonal price and the connecting zone. Both forecasts are prone to forecast errors. Hence, there is a significant risk that IC capacity is sub-optimally allocated. We provide an example in Box 7-1.
  - the valuation of the DA IC capacity rights for the IC for which DA IC capacity rights are auctioned off. When buying DA IC capacity rights for a GB or EU OBZ under explicit trading, traders would need to forecast prices in the OBZ price and the price in the connecting or GB wholesale market, respectively. As the OBZ price moves in a discrete fashion, traders would be exposed to a significant risk that a forecast error would result in holding capacity in counterintuitive direction relative to wholesale prices;
  - the utilisation of the OHA transmission capacity for EU OBZs because under an EU OBZ a trader that acquired an IC right must forecast the OBZ price when positioning itself in the GB DAM. The 'discrete' nature of the OBZ price changes based on outturn wind conditions would add to a sub-optimal commercial utilisation of the OHA transmission capacity (e.g. possibly accidentally being under-utilised or utilised in a counterintuitive direction).

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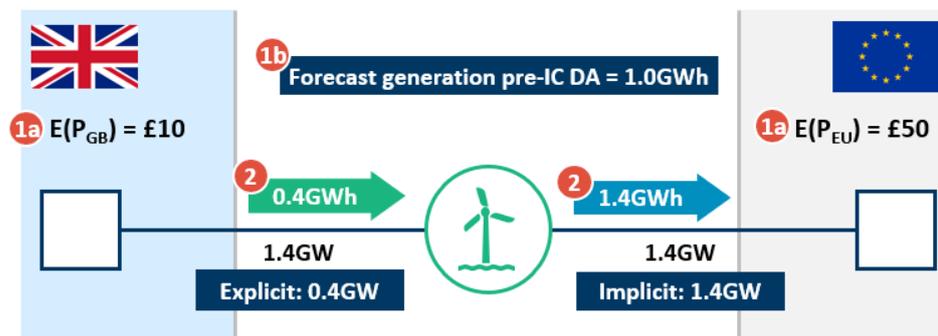
<sup>258</sup> Final outcome of the Task Force Princess Elisabeth Zone, Elia ([link](#)), page 134.



**Box 7-1: Calculation of IC capacity for an OHA under explicit trading**

The figure below shows how the available capacity on the GB-OBZ IC and the EU-OBZ IC for an EU OBZ can potentially be calculated.<sup>259</sup> The OWF is connected with a 1.4 GW to both GB mainland and the European mainland. We describe the different steps below:

- In step 1a the relevant SO must forecast the GB national/zonal price and the price in the connecting European zone.<sup>260</sup> The price differential indicates in what direction the OWF’s generation will flow. In this example, the GB price (£10/MWh) is expected to be lower than the price in the connecting zone (£50/MWh) implying that the OWF generation will flow in the direction of the connecting market. In parallel, in step 1b the generation of the OWF must be forecasted. In this example the generation is expected to be 1.0 GWh.
- In step 2, based on the forecast of the OWF generation and the direction of its flow (1.0 GWh in the direction of the connecting market), the relevant SO calculated that only 0.4 GWh (1.4 GWh-1.0 GWh) can be made available on the EU-OBZ IC to carry power from GB to the connecting market via the OBZ. As such, 0.4 GWh is allocated explicitly on the GB-OBZ IC.<sup>261</sup> We assume that the entire capacity on the EU-OBZ IC is implicitly allocated in the SDAC.



The concern with the process above is that the calculation of how much IC capacity that can be allocated explicitly and implicitly is conditional upon estimations of the wholesale prices in GB and the connecting market and also on the estimated OWF generation. Any forecast error can lead to sub-optimal allocation of the cross-border capacity.

**Central vs self-scheduling market design**

7.20. As discussed in footnote 198, the scheduled flow and direction of an IC has an impact on the wholesale price of the connecting EU bidding zone – an IC scheduled to export from GB would imply additional supply in the connecting EU bidding zone, which has a downward impact on EU wholesale prices. This impact may not be material for large bidding zones and relatively limited interconnection with GB (e.g. Germany) but could potentially be more important for smaller bidding zones that are well interconnected with GB (e.g. DK1 or I-SEM).

## 7. Interactions with other market reforms

- 7.21. Generally, GB shadow nodal prices can be more volatile than national/zonal wholesale prices. Increased volatility can make it harder to anticipate the IC scheduling under central scheduling based on shadow nodal prices compared to central scheduling with (unconstrained) zonal/national wholesale prices or self-scheduling.<sup>262</sup> Given this, it could potentially become more challenging to forecast the relevant EU wholesale prices and the OBZ price insofar as they both could depend, in part, on the GB shadow nodal price.
- 7.22. We therefore expect that under central scheduling, when scheduling ICs based on shadow nodal prices, the valuation of the OHA capacity rights, and their commercial utilisation would more likely be negatively impacted compared to if ICs were scheduled based on unconstrained prices.

### National vs zonal market design

- 7.23. As discussed in Chapter 4, GB prices under zonal market design are likely to be more volatile than under national market design. This could increase the volatility of OBZ prices (as they generally fall to the lower of the prices in the two connected markets) and could affect the valuation of OHA capacity rights and OHA commercial utilisation under Z1/Z3 relative to N0/N1/N3. The overall direction of the impact on the valuation is unclear. As discussed earlier in Chapter 4 this is because the increased volatility could increase the price spreads (giving rise to higher congestion rents); but the increased volatility could also reduce the attractiveness of purchasing capacity under explicit trading. Increased price volatility under zonal pricing could have a minor negative impact on the OHA commercial utilisation.

### MRLVC

- 7.24. As with explicit trading, MRLVC relies on forecasts (for example, of the expected EU BBZ-EU flows). As described in ¶7.19, forecast errors could lead to inefficient allocation of OHA capacity and OHA utilisation.

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<sup>259</sup> Alternative approaches might be introduced but the inefficiencies arising from having to forecast the wind generation and price differential across wholesale markets when calculating the capacity that can be explicitly allocated on the EU-OBZ or GB-OBZ IC seem unavoidable.

<sup>260</sup> We assume both NESO and the connecting TSO would go through this process and the least capacity projected by both would be explicitly allocated.

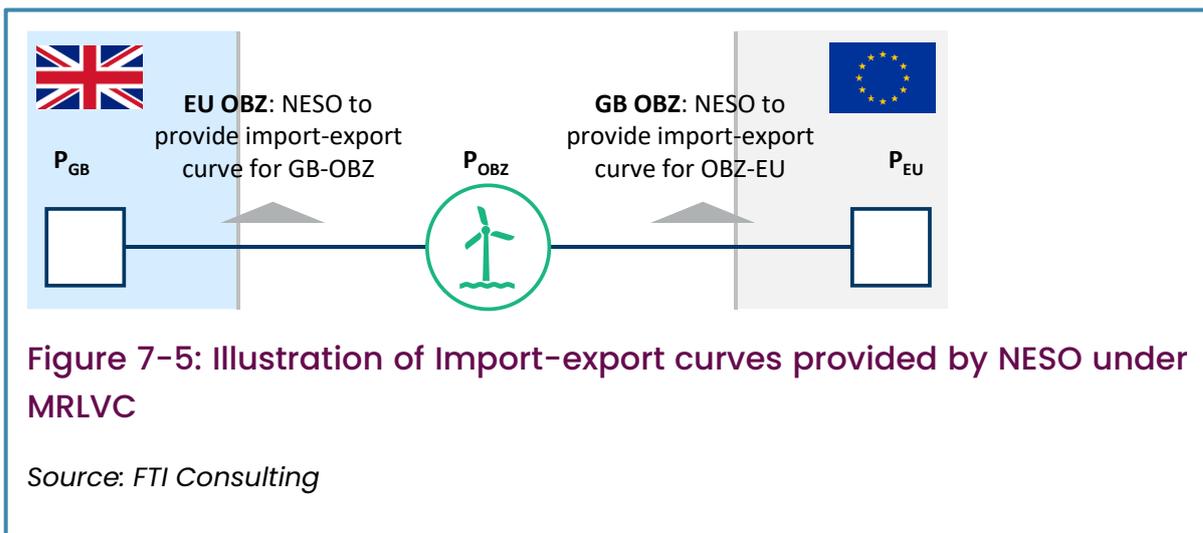
<sup>261</sup> Here we assume that the relevant SO can restrict the NTC ex-ante of the wholesale market which might not necessarily be the case.

<sup>262</sup> We assume NESO would publish historical shadow nodal prices. Anticipating IC scheduling would be further complicated without visibility of historical shadow nodal prices.

- 7.25. Under MRLVC forecast errors might be less of an issue than under the Status Quo explicit trading arrangements, as the time lag between the clearing of the MRLVC algorithm and the GB DAM is expected to be shorter than that between the clearing of the DA IC capacity auction and the GB DAM.

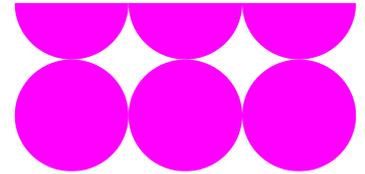
### Central vs self-scheduling market design

- 7.26. As discussed above, relative to self-scheduling or central scheduling based on unconstrained prices, the MRLVC algorithm can be expected to be more complex under central scheduling based on shadow nodal GB prices.
- 7.27. This aside, we do not expect the introduction of OHAs to significantly alter the process of cross-border trading under MRLVC. As illustrated in Figure 7-5 below, if the OHA includes a GB OBZ, NESO would provide import-export curves (which in this case show how changes in the anticipated EU price impact the optimal scheduling of the OBZ-EU line). If the OHA includes an EU OBZ, NESO would provide import-export curves (which in this case indicate how changes in the anticipated OBZ price impact optimal scheduling of the OBZ-GB line).



### National vs zonal market design market design

- 7.28. As discussed in Chapter 4, GB prices under zonal market design are likely to be more volatile than under national market design. This could have an impact on OHA commercial utilisation under Z1/Z3 relative to N0/N1/N3, but the direction of the impact is not clear.
- 7.29. In addition, the information required under the zonal market designs that must be submitted to the MRLVC algorithm is more extensive compared to under national pricing, which would increase computational run-times.

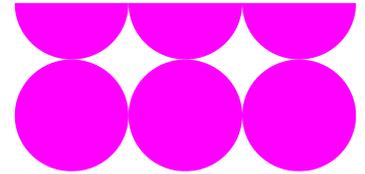


### Price Coupling

- 7.30. There appears to be a consensus that implicit trading (e.g. Price Coupling) is the most effective approach to integrate OBZs into the European and GB markets. When allocating the IC capacity under Price Coupling no expectations need to be formed about the generation of the OWF and other parameters, such as price differentials (under explicit) or EU BBZ-EU flows (under MRLVC). The OBZ price formation and OHA utilisation are therefore not impacted by forecast errors that might otherwise occur (e.g. under explicit or MRLVC arrangements).
- 7.31. OHAs with either EU or GB OBZs would be straightforward to incorporate under Price Coupling, as they could be included in the central clearing algorithm along with all other GB and EU price zones. Given that, in the short- to medium-term, only a relatively small number of OBZs between GB and EU are likely to be introduced (e.g. fewer than 10), these OBZs could likely be incorporated into the EUPHEMIA algorithm without significant computational challenges (though perhaps with some increase in the computational time required to clear the SDAC).

### Central vs self-scheduling market designs

- 7.32. As described Chapters 5 and 6, Price Coupling (on both ICs and OHAs) is not compatible with central scheduling in which ICs are scheduled based on a GB shadow nodal prices (which is preferable to using the unconstrained prices, especially under national pricing (N3)).
- 7.33. Price Coupling on OHAs is compatible with centrally scheduling ICs based on unconstrained prices, but the same limitations as that discussed in Chapters 5 and 6, apply – under N3, this is expected to lead to a GB schedule that is suboptimal from a GB system perspective. However, it may be less of an issue under Z3, to the extent that the GB zones are aligned with the main transmission constraints of the system, such that unconstrained zonal prices do not diverge significantly from shadow nodal prices.



### National vs zonal market design

- 7.34. OHAs are already expected to increase the computational burden of EUPHEMIA relative to not building any OHAs<sup>263</sup> under Price Coupling. In addition, a zonal market design in GB is expected to increase the computational burden for EUPHEMIA relative to a national market design. It is unclear whether EUPHEMIA would be able to accommodate both OBZs and zonal market design without a material increase in SDAC and/or SIDC run times. However, this may be a transitional issue, and could potentially change in the medium to longer term as computing power continues to improve.
- 7.35. To the extent that there are no concerns with computational complexity when introducing a zonal GB market design jointly with OBZs in EUPHEMIA, the interaction of OHAs with the Price Coupling cross-border trading arrangements is expected to be largely similar under market designs with zonal pricing and national pricing.<sup>264</sup>

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<sup>263</sup> Similarly, an OHA design that uses OBZs would be computationally more intensive compared to a HM design.

<sup>264</sup> Assuming ICs are scheduled based on unconstrained prices under the central scheduling market designs.



**Table 7-1: Summary of feasibility and OHA valuation and/or commercial utilisation under various combinations of cross-border arrangements and market designs for GB OBZs (commercial utilisation refers to the scheduling of the OHA relative to outturn wholesale prices)**

	N0/N1	N3	Z1	Z3
Status Quo Explicit	Inclusion of OBZ effectively converts N0/N1 into Z1	Inclusion of OBZ effectively converts N3 into Z3	<p><b>Feasible</b> but <b>imperfect OHA capacity calculation</b> due to forecast errors in GB and connecting wholesale market prices and, especially, the OWF generation which are likely to negatively impact the valuation and utilisation of the OBZ-EU IC.</p> <p><b>Negative impact expected on the valuation</b> of the OHA capacity rights compared to standard ICs under explicit trading due to forecast errors in the prices of the connecting market and, especially, OBZ prices.</p> <p>As well, likely additional negative impact on the OHA commercial utilisation due forecast errors in the connecting market price.</p>	<p><b>Feasible</b> with <b>shadow nodal prices</b> but implicit arrangements (NSL/GB-Irish ICs) may need to turn explicit.</p> <p>The OHA capacity calculation, valuation of the OHA capacity rights, and their commercial utilisation would likely be more negatively impacted compared to if OHAs were scheduled based on unconstrained prices (Z1). The reason being that GB shadow nodal prices are likely more volatile than national/zonal GB wholesale prices (impacting indirectly OBZ prices and prices in the connecting market). However, potential positive impact on GB system costs compared to Z1.</p>
MRLVC			<p><b>Feasible</b>, preference for the order books submitted to the MRLVC to cover all GB zones.</p> <p><b>Likely negative impact on OHA utilisation</b> due to forecast errors compared to standard ICs under MRLVC but <b>likely less impactful than under explicit trading</b> due to relatively short time lag between the clearing of the MRLVC algorithm and the GB DAM.</p>	<p><b>Feasible</b> with shadow nodal prices, preference for the order books submitted to the MRLVC to cover all GB zones.</p> <p><b>More complexity than under Z1</b> potentially leading to an increasing negative impact on the OHA utilisation but <b>potential positive impact on GB system costs</b>.</p>
Price Coupling			<p><b>Feasible</b>, main concerns relate to <b>computational burden</b> for EUPHEMIA.</p>	<p><b>Not feasible</b> with shadow nodal prices; same implications as Z1 if unconstrained prices are used.</p>

**Table 7-2: Summary of feasibility and OHA valuation and/or commercial utilisation under various combinations of cross-border arrangements and market designs for EU OBZs (commercial utilisation refers to the scheduling of the OHA relative to outturn wholesale prices)**

	N0/N1	N3	Z1	Z3
Status Quo Explicit	<b>Feasible</b> but relative to standard ICs negative impact on <b>valuation/commercial utilisation due</b> to forecast errors OWF generation and GB/OBZ/connecting market wholesale prices.	<b>Feasible</b> with <b>shadow nodal prices</b> but implicit arrangements (NSL/GB-Irish ICs) may need to turn explicit. Similar concerns as under N0/N1 with increased complexity but likely significant positive impact on GB system costs (relative to N0/N1).	<b>Feasible</b> but more volatile GB prices compared to N0/N1 with ambiguous impact on the OHA valuation, <b>minor negative impact on utilisation</b> but likely significant positive impact on GB system cost compared to N0/N1. Same concerns as under Z1 for a GB OBZ but higher negative impact on commercial utilisation due to need to forecast OBZ price.	<b>Feasible</b> with <b>shadow nodal prices</b> but implicit arrangements (NSL/GB-Irish ICs) may need to turn explicit. Same concerns as under Z1 but OHA valuation/ commercial utilisation likely more negatively impacted compared to Z1 due to GB shadow nodal prices being more volatile than GB zonal prices. However, potential positive impact on system costs compared to Z1.
MRLVC	<b>Feasible</b> , expected negative impact on commercial utilisation relative to standard ICs due to forecast errors but likely <b>less impactful than under explicit trading</b> .	Feasible with shadow nodal prices. More complex than under self-scheduling (N0/N1/Z1) potentially leading to a negative impact on the OHA commercial utilisation but likely positive impact on GB system costs (relative to self-scheduling).	<b>Feasible</b> , preference for order books submitted to the MRLVC to cover all GB zones. Same concerns/opportunities as under Z1 for a GB OBZ.	<b>Feasible</b> with shadow nodal prices, preference for the order books submitted to the MRLVC to cover all GB zones. Same concerns/opportunities as under Z3 for a GB OBZ
Price Coupling	<b>Feasible under N0. Not feasible under N1</b> due to different GCTs in GB and Europe.	<b>Not feasible</b> with shadow nodal prices; same implications as N0 with unconstrained prices.	Feasible, highly likely positive impact on GB system costs compared to N0/N1, main concern is the computational burden for EUPHEMIA.	<b>Not feasible</b> with shadow nodal prices; same implications as Z1 if unconstrained prices are used.

## Other market design changes in GB and the EU

7.36. As explained in ¶7.1, GB and the EU are currently considering several related reforms to the electricity market: (i) shortening of settlement periods/MTUs; (ii) changes in GCT; and (iii) bidding zone splits. We discuss each type of reform in turn below.

### Settlement periods and MTUs

7.37. REMA is exploring a potential shortening of the GB settlement period from 30 minutes to 5 or 15 minutes. This aims to create a more granular wholesale market temporal signal to incentivise market participants to match supply and demand in shorter timeframes. As a consequence, DESNZ anticipates that the volume of BM actions to resolve energy imbalances would be reduced and therefore balancing and reservation costs would also fall.<sup>265</sup> We assume that shortening the settlement period in GB would involve an equivalent reduction in MTUs.

7.38. The EU is currently transitioning from the current 1-hour MTU to 15-minute MTUs in both SDAC and SIDC, to allow for more precise matching of supply and demand closer to RT.<sup>266</sup>

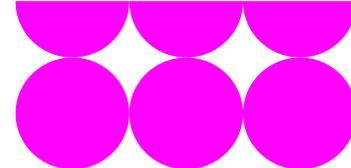
7.39. If both GB and EU were to move to shorter MTUs, cross-border trading on ICs could take place at the least granular period of the connected markets (e.g. if GB were to move to a 5-minute MTU period, cross-border trade would be based on EU's 15-minute MTU). A shorter MTU would likely have implications for the computational intensity of all cross-border trading arrangements, including explicit auctions, MRLVC and Price Coupling.

7.40. The additional computational burden arising under a shorter MTU in the EU could also potentially interfere with zonal GB pricing being feasible under Price Coupling: for example, if the computational feasibility constraints were such that either (i) EU could integrate GB zones into the SDAC; or (ii) EU shortens its MTUs, but (iii) both reforms were not simultaneously achievable, then there is a risk that the EU would prioritise reducing the MTU over the integration of GB zones.

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<sup>265</sup> Review of Electricity Market Arrangements Options Assessment, DESNZ, March 2024 ([link](#)), 3.270.

<sup>266</sup> To date, a 15-min MTU in the SIDC has been launched on the Croatian, Slovenian and Hungarian borders. The go-live for other SIDC and SDAC is planned for 2025 ([link](#)).



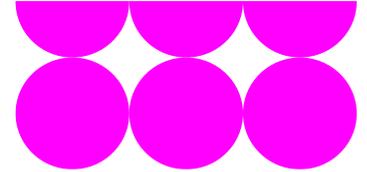
## Changes to gate closure times

- 7.41. In this section we discuss the potential impact of shortening the EU wholesale GCT only (there is currently no discussion that we are aware of to extend gate closure in the EU). We have previously discussed the potential for extending GB GCT in Chapter 3 on market design NI and we do not discuss shorter GCT in GB since REMA has concluded that a shorter GCT “is not something that could be implemented in the short-to medium-term”.<sup>267</sup> In the remainder we will only discuss the case that that the IDCZGCT moves to 30-minutes. This implies that we do not consider a case where the GCT in GB would occur after the GCT in the connecting European market.
- 7.42. We do not expect that a transition to a 30-minute IDCZGCT would have major impacts under Status Quo arrangements or under MRLVC, as we assume that under those cross-border arrangements GB market rules would not be driven by EU regulations. However, having a 30-minute IDCZGCT while keeping the GB wholesale GCT equal to 1 hour would have qualitative similar impacts as discussed in Chapter 3 where we assumed an extended GB wholesale GCT and an IDCZGCT of 1 hour).<sup>268</sup> As discussed in Chapter 3, an increased gap between the European and GB wholesale GCT could negatively impact the valuation of ID IC rights. The extent to which ICs are utilised (under explicit) or allocated (under implicit) in line with ID market prices closest to delivery could also be negatively impacted.
- 7.43. Under the Status Quo cross-border trading arrangement and MRLVC, having a different GCT between GB and the EU implies that cross-border trade on the IC by market participants is only possible up to the GCT on either side that is furthest ahead of delivery.
- 7.44. Having a different GCT also has an impact on the timing of SO-SO trades on ICs. Two scenarios can be thought of: (i) SO-SO trades are done while the GB ID market is closed but the SIDC is still open, or (ii) SO-SO trade is only possible after the IDCZGCT.
- 7.45. Under the first scenario, the potential issue is that SO-SO trades could be unwound on the European side by ID trades in the SIDC.

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<sup>267</sup> Review of Electricity Market Arrangements Second Consultation Document, DESNZ, March 2024 ([link](#)), page 103.

<sup>268</sup> Having a different wholesale GCT between a GB and a European connecting zone is not something new. While the IDCZGT of the SIDC is currently 1-hour (other than on the Finnish-Estonian border), the GCT of GB and the national IDM in connected countries can be different (e.g. the GCT of the national IDM in Belgium is 5 minutes before delivery).



- 7.46. Under the second scenario, NESO would have to anticipate the possibility and costs of SO-SO trades closer to delivery when it can already redispatch other assets to resolve internal congestion. Connecting TSOs need to approve SO-SO trades closer to delivery (and if yes, the cost of redispatching ICs) while in the meantime other assets can be used in GB to resolve internal congestion. This uncertainty might lead NESO to (potentially inefficiently) avoid reliance on SO-SO trades, which could mean that potentially more expensive (intra-GB) redispatch actions would have to be relied on to relieve internal GB congestion.
- 7.47. Under the second scenario an alternative would be to have EU-only countertrading. NESO would trade with IC capacity holders who can still adapt their position in the relevant connecting European market after the GB wholesale GCT. From the European perspective this might be problematic as European TSOs would no longer be able to countertrade in the GB market. Instead, the European TSOs would need to revert to SO-SO actions.
- 7.48. Under Price Coupling and the assumption that GB would have to follow the relevant EU IEM Regulations, GB would have to shorten its GCT as well to 30 minutes to align with the timings in the EU. A shorter GCT might lead to difficulties for NESO as it would have less time to resolve intra-GB transmission constraints. As such, we consider this reform to be more compatible with zonal pricing (Z1 and Z3) and the market N3 design variant where ICs are scheduled based on shadow nodal prices, under which we expect constraints volumes to reduce relative the N0. However, insofar as Price Coupling would require GB gate closure to be shortened, this would not appear to be consistent with REMA's previous conclusion ("[a shorter GCT] is not something that could be implemented in the short-to medium-term").<sup>269</sup>

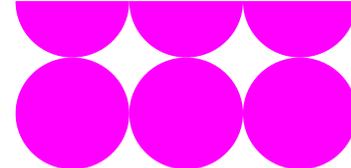
### Bidding zone splits

- 7.49. The latest iteration of the EU bidding zone review is currently in progress and is exploring the option of multiple bidding zones in Germany, France, the Netherlands, as well as changes to the existing bidding zone configuration in Italy and Sweden.<sup>270</sup> This may have implications on the computational burden of EUPHEMIA and the volatility of wholesale prices in connected markets.

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<sup>269</sup> Review of Electricity Market Arrangements Second Consultation Document, DESNZ, March 2024 ([link](#)), page 103.

<sup>270</sup> See ACER's decision on alternative BZ configurations as described in 'Bidding Zone Review', ENTSO-E ([link](#)).



### *Explicit cross-border trading arrangement*

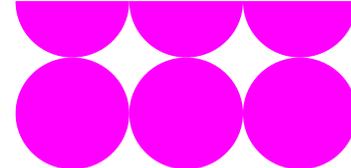
- 7.50. If some of the price zones that GB ICs connect to in Europe (e.g. France, Netherlands, or Germany, once NeuConnect becomes operational) were to be divided in multiple bidding zones, wholesale prices in these smaller price zones would potentially become more volatile than before.
- 7.51. If this was the case, this could affect the commercial utilisation of the relevant ICs and their valuation under explicit trading. The impact on the commercial utilisation of IC rights is likely slightly negative (due to a higher likelihood of unintentional non-intuitive flows) while the impact on the valuation of IC rights is ambiguous. It can be positive if the increased volatility resulted in higher expected congestion rents on ICs between GB and the relevant EU zone or negative if the increased volatility discouraged trading and therefore led to under-utilisation of ICs. The balance and magnitude of the impact would need to be empirically evaluated.

### *MRLVC*

- 7.52. Since only connected zones' bids and offers are fed into the MRLVC algorithm, any bidding zone review that impacts the connected zones would have a subsequent impact on the data shared with the MRLVC. Depending on the way European bidding zones would be reconfigured, this could impact the computational complexity and/or the effectiveness of MRLVC.
- 7.53. Splitting European bidding zones could lead to having more EU BBZs, i.e. European bidding zones that are connected to GB, which could lead to: (i) more EU BBZ to EU BBZ borders that would need to be optimised in the MRLVC algorithm; and/or (ii) more borders between EU BBZs and other EU bidding zones that are not connected with GB, for which the flows would have to be forecasted. The former would increase the computational complexity of the MRLVC algorithm, while the latter would likely negatively impact the effectiveness of MRLVC.<sup>271</sup> At the same time, the size of the order books submitted to the MRLVC algorithm could be smaller, which would reduce the computational complexity of the MRLVC algorithm (e.g. if Germany were split into multiple zones, only the order books of the German Northern zones would likely need to be submitted to the MRLVC algorithm rather than the entire German order book).

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<sup>271</sup> The EU BBZ-EU flows would likely become harder to forecast if the EU BBZs became significantly smaller. A potential remedy would be to not only optimise EU BBZ-EU BBZ borders in the MRLVC algorithm but to also increase its geographical coverage (similar as that proposed for GB when GB would implement a zonal wholesale market, see Z1 MRLVC). However, increasing the geographical coverage of the MRLVC algorithm would increase its computational burden.



### Price Coupling

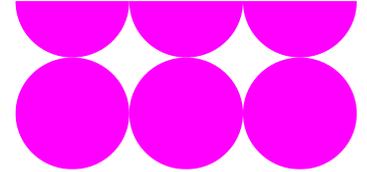
- 7.54. Adding more bidding zones on the EU side due to bidding zone splits does not impact the effectiveness of Price Coupling under all market designs but could potentially increase the computational time required to clear the SDAC. This could affect the feasibility of implementing Price Coupling if GB were to adopt zonal market arrangements (Z1 or Z3). This could be the case if the EU had to choose between introducing additional bidding zones within the EU relative to accommodating GB zones: if both were simultaneously deemed not possible, then there is a risk that the EU may choose to prioritise integrating the EU bidding zones into EUPHEMIA rather than accommodating GB zones.
- 7.55. We do not expect it to affect the feasibility of implementing Price Coupling under N3/Z3 if ICs were scheduled based on the unconstrained national price.<sup>272</sup>

### Conclusions

- 7.56. In our discussion above, we have assessed how the three cross-border arrangements (Status Quo, MRLVC and Price Coupling) and the four different market design arrangements (N1, Z1, N3 and Z3) interact with a selection of potential market reforms. In doing so, we have not sought to comment on the preferred option(s) for cross-border trading arrangements, specific market design arrangements nor the potential market reforms themselves. We have taken the potential market design changes as given and examined how different of cross-border trading arrangements could be developed or adapted to be compatible with those potential market design changes under the different (wider) market design arrangements.
- 7.57. With regards to OHAs, it is found that:
- (i) As long as the total number of OBZs remains relatively modest compared to the number of GB and EU zones (such that there are no computational issues incorporating them into the GB or EU markets), no material implications for the feasibility of the various market designs and cross-border trading arrangements are anticipated.
  - (ii) The valuation and commercial utilisation of explicitly allocated IC capacity would be impacted by potential forecast errors by market participants. The likelihood of forecast errors is expected to increase as the price formation in the OBZ is more 'discrete' relative to onshore zones. In addition, the OWF generation must be forecast when calculating the IC capacity available for wholesale trade on the OHA.

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<sup>272</sup> We do not discuss the implications for Price Coupling under N3/Z3 if ICs were scheduled based on shadow nodal prices as we concluded it would not be feasible in Chapters 5 and 6.



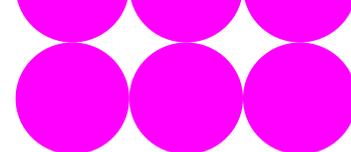
- (iii) Similarly, the commercial utilisation of ICs under MRLVC is impacted by the accuracy of the information fed into the MRLVC algorithm. The likelihood of imperfect information is higher with OHAs for similar reasons as set out above.
- (iv) Considering the additional difficulties and complexities of combining OHAs with explicit trading and MRLVC, it appears to us that as OHAs play a greater role in cross-border trading, this would create additional incentives for GB to move to Price Coupling. In turn, as discussed earlier, a zonal wholesale market design (Z1 or Z3) is the only variant that can be combined with Price Coupling without significant downsides.

7.58. With regards to other market reforms in GB and the EU examined, it is found that:

- (v) A shorter MTU would likely have implications for the computational intensity of all cross-border trading arrangements. The additional computational burden arising under a shorter MTU in the EU could also potentially interfere with zonal GB pricing being computationally feasible under Price Coupling.
- (vi) A reduced GCT to 30 minutes in the EU is expected to create potential complications with countertrading and SO-SO trades under explicit trading arrangements and MRLVC. This could potentially lead to NESO having less means to resolve intra-GB constraints. Under Price Coupling, to the extent that GB is required to follow IEM regulations, this would imply that GB would also need to reduce its GCT. This would imply NESO would have less time to resolve intra-GB constraints. Thus, across all cross-border arrangements, a shorter GCT in the EU may lead to more difficulties for NESO to resolve intra-GB constraints. As such, it is considered that this reform is more compatible with market designs with lower constraint volumes, such a zonal market design (Z1, Z3) and the N3 market design where ICs are scheduled based on shadow nodal pricing.
- (vii) Bidding zone splits on the EU side could potentially lead to more volatile wholesale prices in the smaller price zones. This could increase the likelihood of forecast errors, which would likely have a negative impact on the commercial utilisation and valuation of explicitly traded IC capacity. Likely imperfections in the data shared would have a stronger impact on the MRLVC clearing and, overall, the effectiveness of the MRLVC is expected to decrease. Given this, similar to OHAs (albeit to a lesser extent), bidding zones splits on the EU side would create greater incentives for GB to move to Price Coupling which, in its turn, creates greater incentives to adopt a market design that reduces constraint volumes, such a zonal market design.

# Appendix 1





## Appendix 1: Bidding incentives under explicit IC capacity trading

A1.1 In this Appendix we illustrate the bidding incentives of IC capacity holders for under explicit trading. The worked example described below shows how virtual IC capacity holders are incentivised to bid in their expectation of the connected country's price and to not bid higher or lower.

A1.2 Suppose there is an IC capacity holder that owns the rights to flow 1,000 MW from GB to France in a given hour, and hence must take a buying position of 1,000 MW in the GB DAM. The IC capacity holder has perfect information about the price in France ( $P_{FR}$ ) in that hour to be £50/MWh. However, the IC holder can choose to bid equal, above or below the French price in the GB wholesale market. Below, we consider the possible GB price outcomes and resulting revenues for two different bidding strategies.

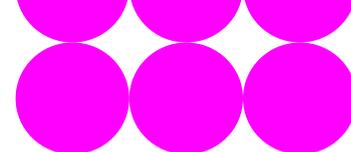
### **Case 1: Bid > $P_{FR}$**

A1.3 In Table A-1, we compare the IC capacity holder's revenues if they bid above the anticipated French price ( $Bid > P_{FR}$ ) to bidding exactly the anticipated price ( $Bid = P_{FR}$ ) under three GB price outcomes (which are uncertain to the IC capacity holder when submitting its bid in the GB DAM):

- $P_{GB}$  represents the outturn GB unconstrained price;
- $P_{FR}$  represents the outturn FR price;
- $Bid_{GB}$  represents the IC capacity holder's bid to buy power in GB;
- **GB to FR flow** indicates whether the GB to France flow would be in merit based on the unconstrained GB price;
- **Revenue** describes the total revenue earned by the capacity holder from congestion rents and compensations.

**Table A-1: Comparison of an IC capacity holder's revenues under different outcomes of the  $P_{GB}$  when bidding higher than  $P_{FR}$  in the GB wholesale market**

Case	Price outcome	$P_{GB}$	$P_{FR}$	Outcomes ( $Bid_{GB} > P_{FR}$ )			Outcomes ( $Bid_{GB} = P_{FR}$ )		
				$Bid_{GB}$	GB to FR flow	Revenue	$Bid_{GB}$	GB to FR flow	Revenue
1a	$Bid_{GB} > P_{GB} > P_{FR}$	£55	£50	£60	In merit	-£5,000	£50	Out of merit	£0
1b	$P_{GB} > Bid_{GB} > P_{FR}$	£65	£50	£60	Out of merit	£0	£50	Out of merit	£0
1c	$Bid_{GB} > P_{FR} > P_{GB}$	£30	£50	£60	In merit	£20,000	£50	In merit	£20,000



A1.4 As shown, under Cases 1b and 1c, the IC capacity holder's revenues are the same under both bidding strategies. However, in Case 1a ( $Bid > P_{GB} > P_{FR}$ ), if the IC capacity holder bids:

- Above  $P_{FR}$ , it would have been in merit and had to purchase 1,000 MW of electricity in GB for £55,000 and sold it in France for £50,000, resulting in a loss of £5,000.<sup>273</sup>
- Equal to  $P_{FR}$ , it would not have been merit and earned zero congestion rents.

A1.5 The IC capacity holder is therefore under all scenarios of the GB price equally well or better off by bidding in the anticipated  $P_{FR}$ .

**Case 2: Bid <  $P_{FR}$**

A1.6 In Table A-2, we compare the IC capacity holder's revenues if they bid below the anticipated French price ( $Bid < P_{FR}$ ) to bidding exactly the anticipated price ( $Bid = P_{FR}$ ) under three GB price outcomes.

**Table A-2: Comparison of an IC capacity holder's revenues under different outcomes of the  $P_{GB}$  when bidding lower than  $P_{FR}$  in the GB wholesale market**

Case	Price outcome	$P_{GB}$	$P_{FR}$	Outcomes ( $Bid_{GB} < P_{FR}$ )			Outcomes ( $Bid_{GB} = P_{FR}$ )		
				$Bid_{GB}$	GB to FR flow	Revenue	$Bid_{GB}$	GB to FR flow	Revenue
2a	$P_{FR} > Bid_{GB} > P_{GB}$	£30	£50	£40	In merit	£20,000	£50	In merit	£20,000
2b	$P_{GB} > P_{FR} > Bid_{GB}$	£60	£50	£40	Out of merit	£0	£50	Out of merit	£0
2c	$P_{FR} > P_{GB} > Bid_{GB}$	£45	£50	£40	Out of merit	£0	£50	In merit	£5,000

A1.7 As shown, in Cases 2a and 2b, the IC capacity holder's revenues are the same under both bidding strategies. However, in Case 2c ( $P_{FR} > P_{GB} > Bid$ ), if the IC capacity holder bids:

- Below  $P_{FR}$ , it would have been out of merit and earned zero congestion rents.
- Equal to  $P_{FR}$ , it would have been merit. It would have purchased 1,000 MW of electricity in GB for £40,000 and sold it in France for £45,000, earning congestion rents of £5,000.

A1.8 Again, the IC capacity holder is therefore under all scenarios of the GB price equally well or better off by bidding in the anticipated  $P_{FR}$ .

<sup>273</sup> Under N3/Z3 and ICs scheduled based on shadow nodal pricing, the negative revenue can be a consequence of earning negative congestion rent or alternatively transfer payments from the IC capacity holder to NESO.

