Making Future

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Future of Interconnectors (FIC)

Phase #2 stakeholder webinar 12th January 2023

ESO & AFRY

Agenda

Part 1.

Introduction → Interconnector challenges & opportunities → Adequacy → Flexibility → Operability

Part 2.

Multi Purpose Interconnectors → Next steps → Q&A

INTRODUCTION

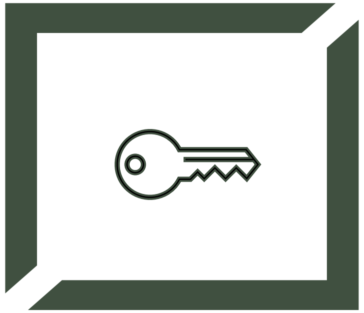
The system is evolving towards net zero and interconnection capacity is scaling up – creating both challenges and opportunities

Net zero creates challenges for the system

- Flexibility
- Operability
- Adequacy

Interconnection capacity expected to increase

- Today: 8.4GW
- Gov. ambition: 18GW by 2030
- FES 2022: 13-25GW by 2035



Interconnectors can play an important role in managing the system

- Generate challenges *and* opportunities
- Potentially important role in transition to net zero, but…
- Dependent on a solid regulatory framework and efficient markets

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SCOPE AND TIMELINE

The project will produce 5 reports

Phase 1
Status quo and future landscape

- Status quo
- Future landscape GB & Europe
- Interviews with ESO experts
- Progress webinar

Phase 2
The future role of interconnection

- Future role of ICs
- Interviews with HVDC experts & IC developers
- Progress webinar

Phase 3
Options for interconnector planning and operation

- Long-list of options
- Long-list 'play-back'
- Final summary report
- Progress webinar

Publish reports

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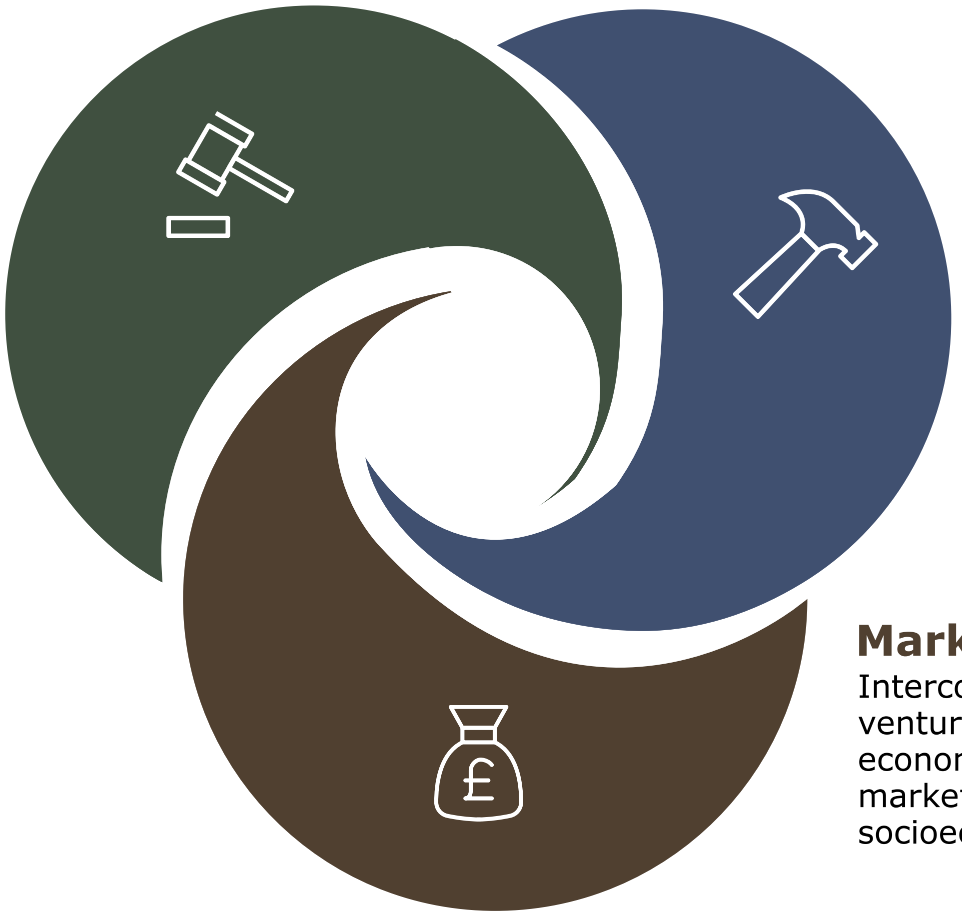
OPPORTUNITIES AND RISKS

Interconnectors themselves face a number of challenges which are inherently linked and tend to overlap

Policy & regulation

Policy & regulatory alignment (or misalignment) between Great Britain and connected markets can severely influence interconnector behaviour in both planning and operational timescales



Physical attributes

Interconnectors' physical characteristics have the potential to alleviate grid issues in GB, yet they may also exacerbate certain challenges

Market & commercial

Interconnectors are commercial ventures and therefore appropriate economic signals across the right markets must exist to maximise socioeconomic welfare

CHALLENGES AND OPPORTUNITIES

GB and the EU are facing similar challenges in the energy transition; close cooperation can help turn policy goals into realities

TSO interaction/relationships

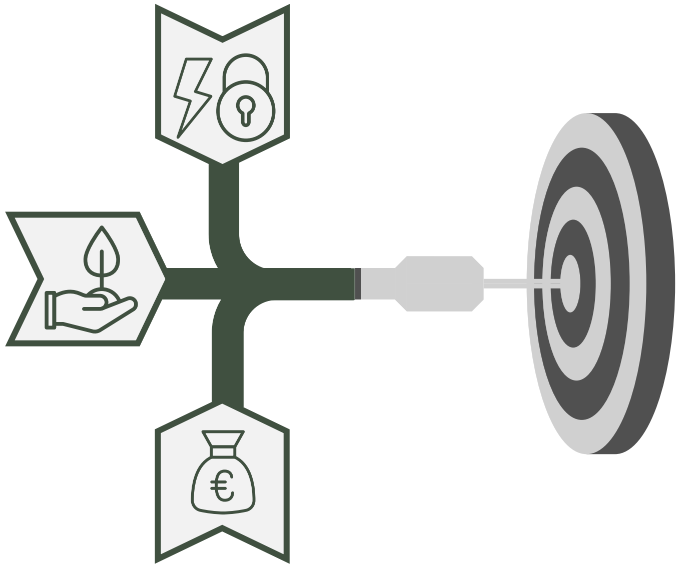
Emergency actions between TSOs are sometimes required to ensure system security. How to understand, quantify the benefits and agree costs for actions with other TSOs is key, at present there are a wide range of bespoke arrangements.

Political sensitivity

Interconnectors change the distribution of benefits & costs between producers/consumers in different connected markets which can be unpopular amongst parties that are perceived to ‘lose out’ from changes to arrangements or deployment of interconnectors.

Regulatory incompatibility

While regulation intends to enable and incentivise initiatives based on domestic politics, incompatible regulations between connected countries can be detrimental to interconnector efficiency.



Policy & regulation | **Physical attributes** | **Market & commercial**

CHALLENGES AND OPPORTUNITIES

The physical attributes of interconnectors can solve issues in the GB grid, but also introduce new challenges to consider

500MW-2000MW

Interconnector capacity size

Each individual interconnector is of a considerable size and has a notable potential physical impact on GB's electricity market and system, as well as system security requirements (system contingencies/largest loss).

Aggregated interconnector capacity

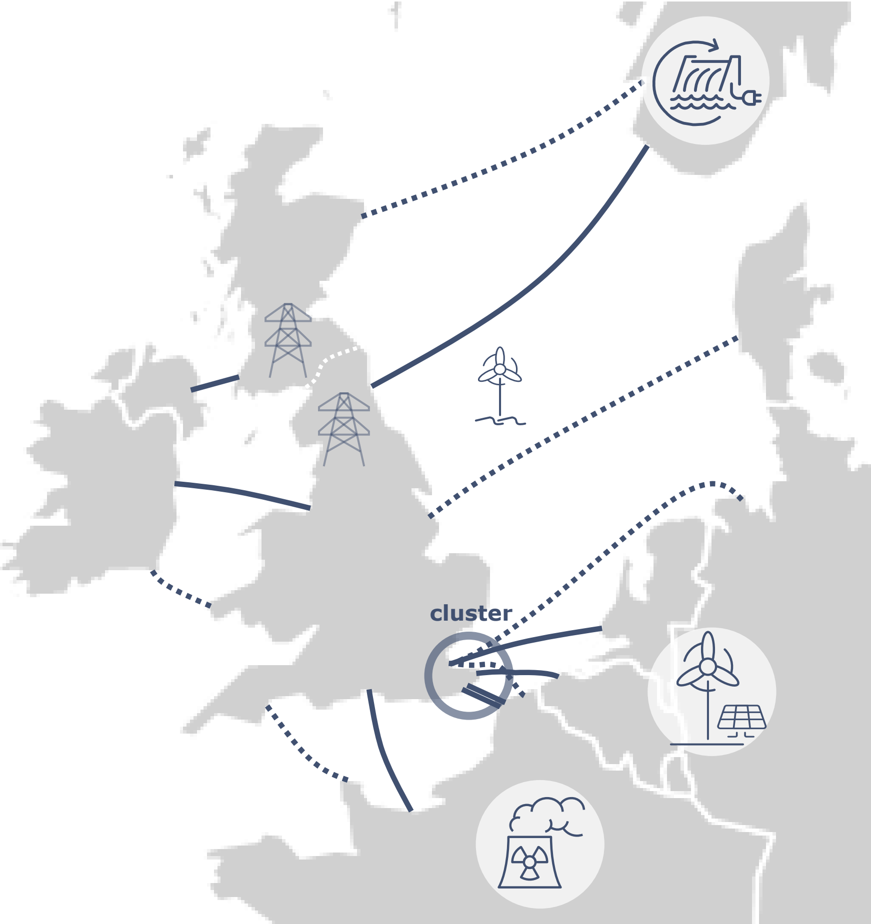
With more than 8GW ICs today and increasing capacity, the aggregated effect of interconnectors is considerable. ICs can support GB's transition towards net zero. However, collective scale amplifies all challenges related to interconnection.

Physical characteristics of connected markets

The physical systems of connected markets will have an impact on IC operation. Sharing of renewable resources and capacity due to imperfect correlations in demand and weather patterns may offer opportunities, but resource adequacy in critical periods can be a challenge.

Location of GB landing points

Location of landing points have an impact on the grid and other grid users. Clustering of interconnectors can have a considerable effect on congestion, stability and voltage in the area.



Notes: Map does not show all proposed/potential interconnectors

Policy & regulation | Physical attributes | Market & commercial

CHALLENGES AND OPPORTUNITIES

Interconnectors can be a valuable resource to support the energy transition, but require efficient markets to optimise socio-economic benefits

Ramping

Whilst ICs present an opportunity as a highly flexible energy resource, the ability for the system to accommodate rapid changes in flow position is governed by system security constraints. This can limit the potential flexibility of interconnectors with consequences for interconnector's commercial cases, and potentially consumers.

Indirect energy source

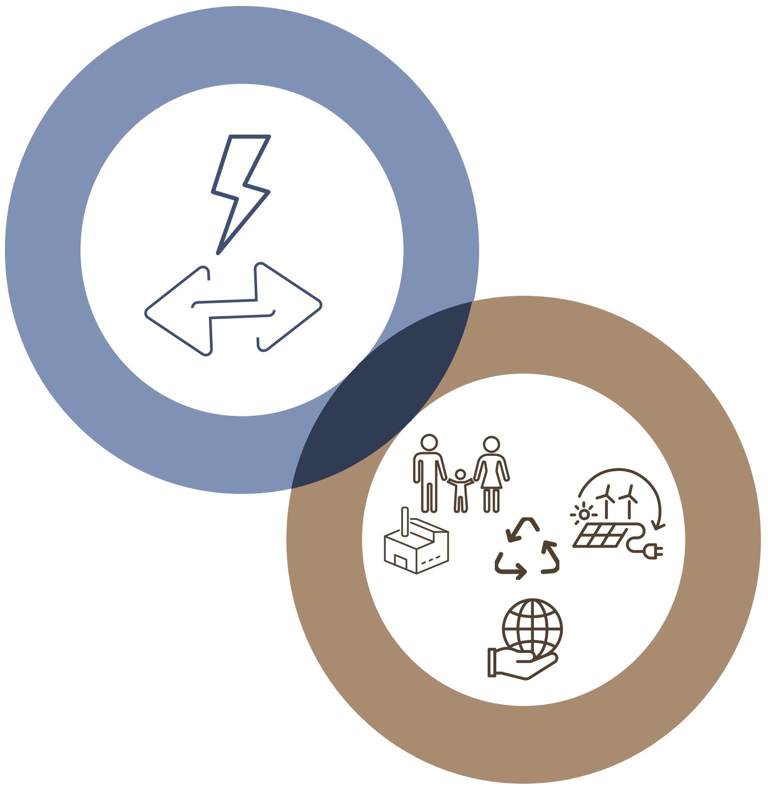
Interconnectors do not generate active power themselves, instead they provide access to third party energy resources. This means they are not tied or limited to a specific fuel or energy source, but their operation depends on the availability and relative economic efficiency of collective energy resources in connected markets.

Market signals

As commercial assets, flows are generally determined by price signals, which should be designed to efficiently distribute socio-economic welfare. This requires an efficient market, both long-term and up to the last minute before delivery. Weak or distorted signals can leave economic value on the table.

Market access

Interconnectors can provide value to the TSO as well as consumers and producers in both connected markets. The facilitation of interconnectors in different markets such as ancillary services could increase benefits to consumers and interconnector owners.



Policy & regulation | Physical attributes | Market & commercial

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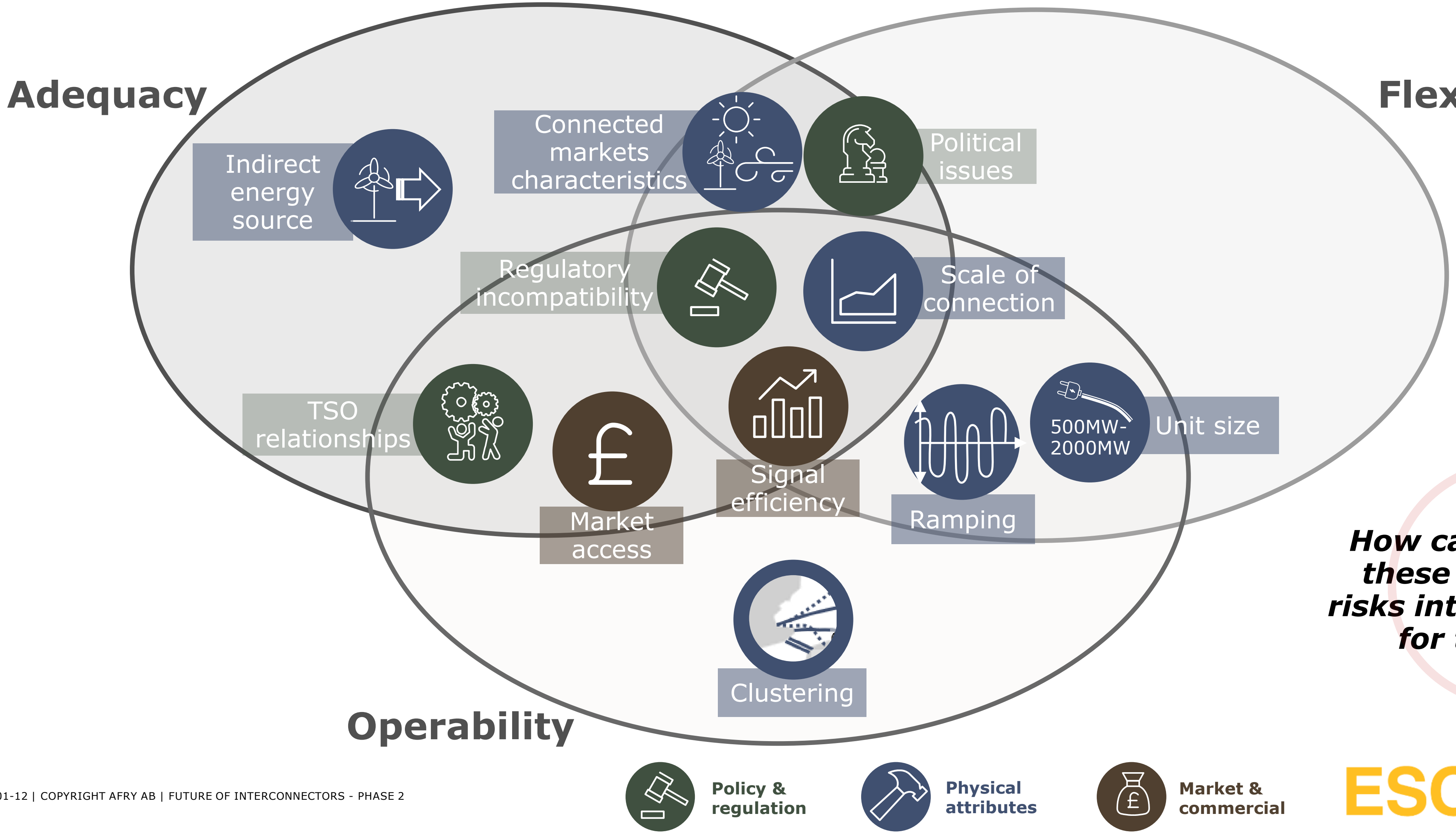
CHALLENGES AND OPPORTUNITIES

Interconnector challenges and opportunities have a significant impact on the future operation of GB's electricity system



How can we manage these risks, or turn risks into opportunities for the future?

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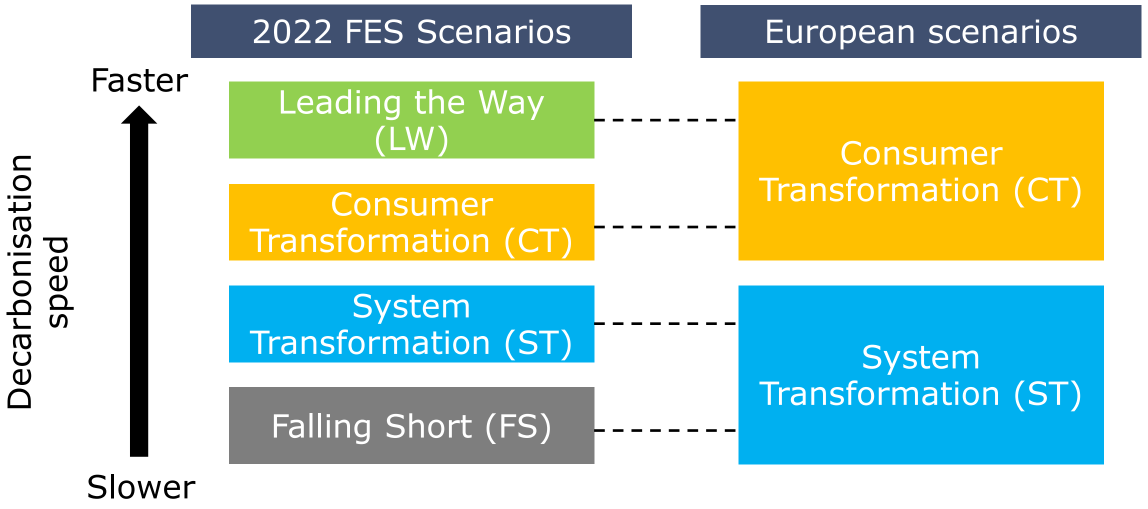
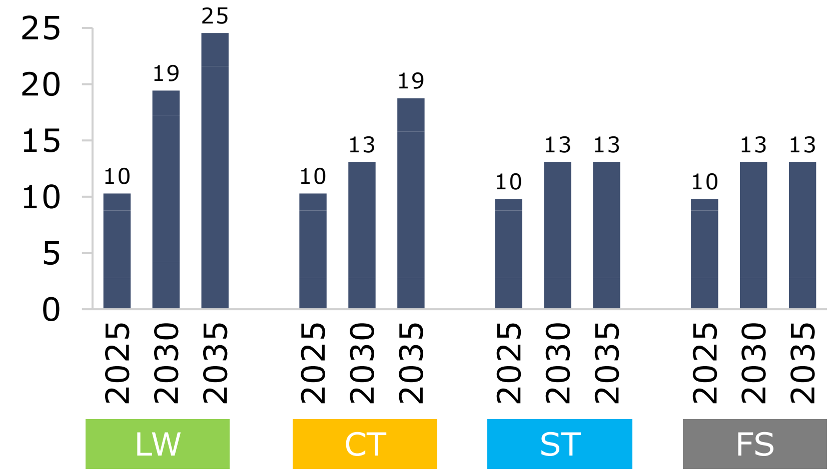
MODELLING REFRESHER

The following quantitative results are based on the modelling of the 4 FES scenarios, providing a range of outcomes for a decarbonised network



TOTAL INTERCONNECTOR CAPACITY TO GB (GW)



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ADEQUACY

Imports into GB during periods of system stress have the potential to increase in the future, particularly on high RES penetration scenarios

Potential contribution

Imports into GB are mostly expected to grow in absolute terms during periods of system stress. Greater imports are seen in scenarios with more RES penetration, as these also see greater growth in IC capacity.

Average imports into GB at peak hours

2025: 3-5 GW or 9-13% of demand | **2035**: 2-13 GW or 6 -37% of demand

Divergence in coincidental net peak demand in interconnected countries

The correlation between coincidental net peak demand (residual demand after accounting for variable RES) in Great Britain and interconnected countries decreases in the future due to increasing penetration of intermittent RES sources.

Share of time that an interconnected country is under stress at the same time as GB

2015: 48-69% | **2025**: 24-40% | **2035**: 10-22%

Seasonal distribution of net peak demand periods

The majority of peak periods in GB are seen in the winter months, in line with higher demand consumption. However, there is a slow shift of periods towards the summer in the future.

Share of peak hours in winter

2025: 93-98% | **2035**: 79-88%

Daily distribution of net peak demand periods

The addition of flexible sources (in both demand and generation) cause peak periods to spread more within all the hours of a day, moving away from current behaviour where peak periods occur in the evening.

Share of peak hours between 17 and 24 hrs

2025: 58-65% | **2035**: 21-64%

Duration of consecutive net peak demand periods

The duration of peak periods can grow in the future as renewables displace conventional dispatchable generation. When RES sources are low, this usually lasts for a prolonged time, thus impacting the duration of consecutive peak periods.

Average duration of consecutive peak hours in winter

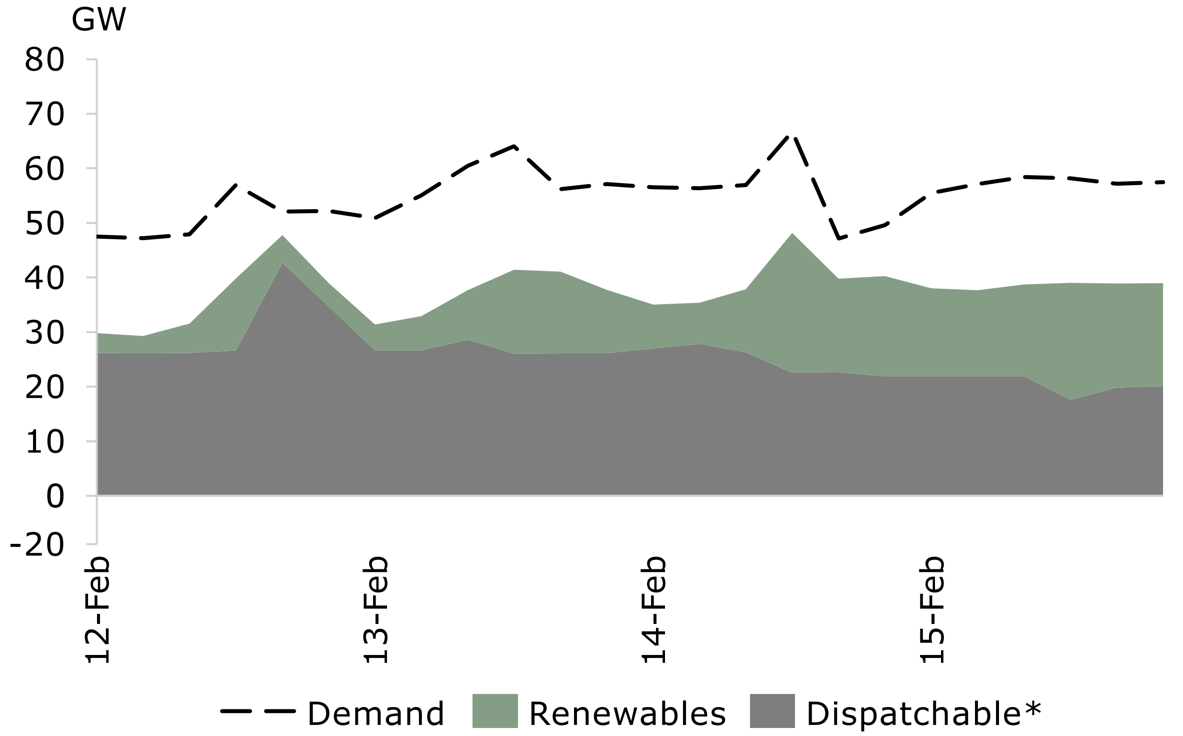
2025: 8-13 hours | **2035**: 11-28 hours

Note: The data presented here covers the system's conditions during the 5% of hours with highest residual demand in GB
The ranges shown here represents ranges across the 4 FES scenarios

ADEQUACY

Interconnector flows are a key source of energy to cover GB’s demand in prolonged periods of peak net demand, when the system is under stress

4-DAY EXAMPLE OF IC CONTRIBUTION TO ADEQUACY IN GREAT BRITAIN



Note: Data shown is for the LW scenario in 2035 for illustrative purposes only
* Includes reservoir hydro and storage

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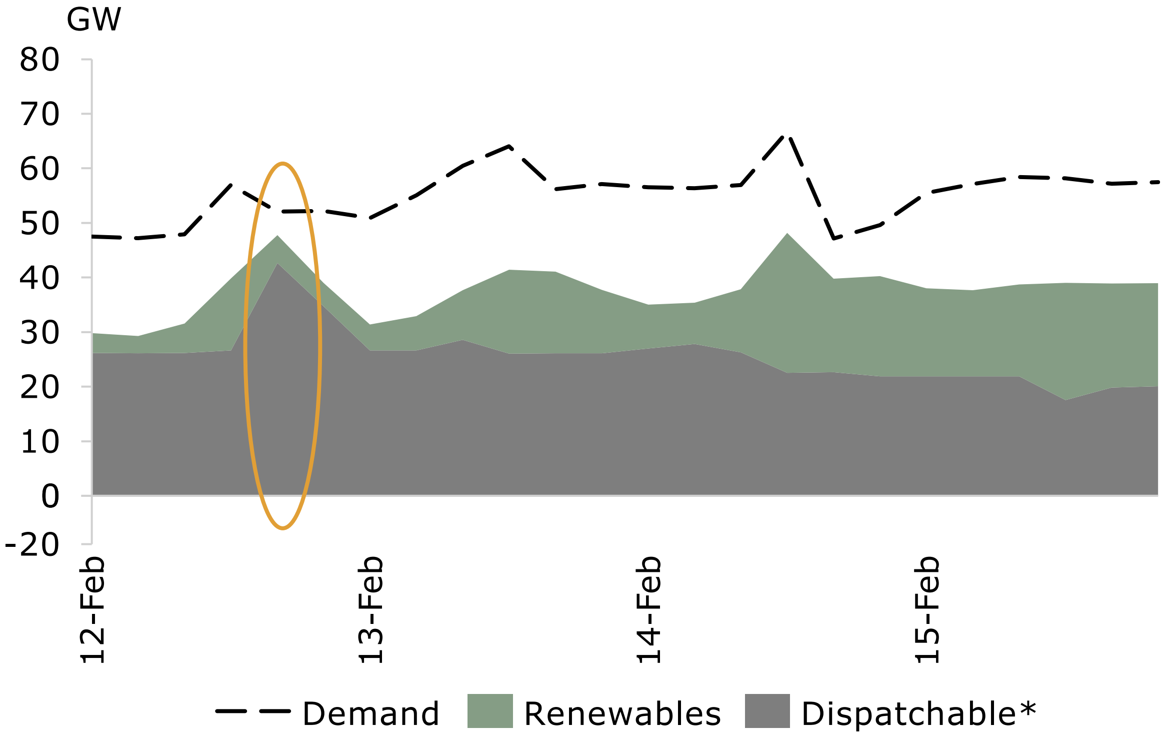
4-DAY EXAMPLE OF IC CONTRIBUTION TO ADEQUACY IN GREAT BRITAIN



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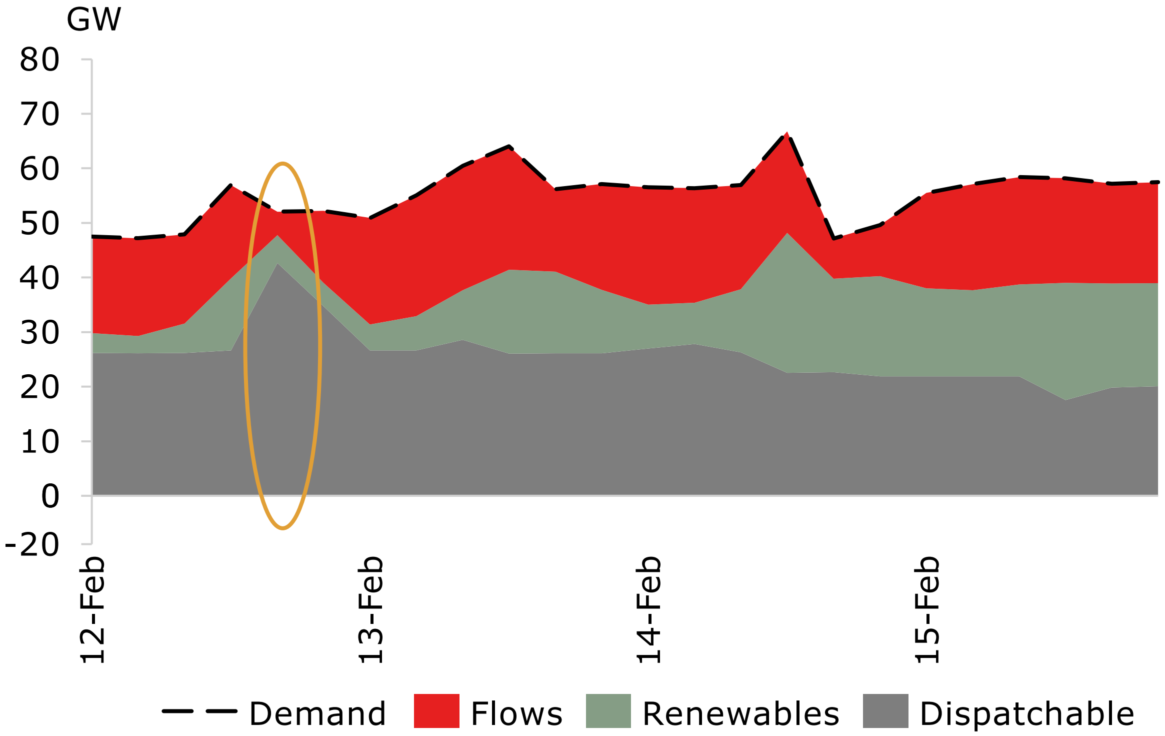

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ADEQUACY

Improving predictability of interconnector behavior during peak periods will enhance overall operation of the system and can increase their value

BARRIERS	ENABLERS
Lengthy development processes potentially delaying projects and preventing GB from achieving government IC capacity ambitions.	Policy makers and regulators can (collectively) **incentivise faster and smoother development** of interconnectors to accelerate construction of new interconnection capacity.
Markets for cross border trading not necessarily reflecting **GB system security interests,** and distorted market signals in critical periods can prevent imports in a loss-of-load event.	To enable markets to achieve **flows that align with the needs** of the system, value of system security should be appropriately reflected in the determination of flows.
Missing clear regulatory and operational framework to deal with conflict of interest in periods of system tightness at both sides of the interconnector.	Define what constitutes coinciding stress events and establish clear and transparent **regulatory and operational framework** that provides a fair allocation.

FLEXIBILITY

Interconnectors are highly flexible sources as they can quickly respond to market signals to balance a dynamic energy system

Change of direction of flow

Interconnectors can change their position (importing/exporting or not flowing) several times a day, helping to balance a dynamic system.

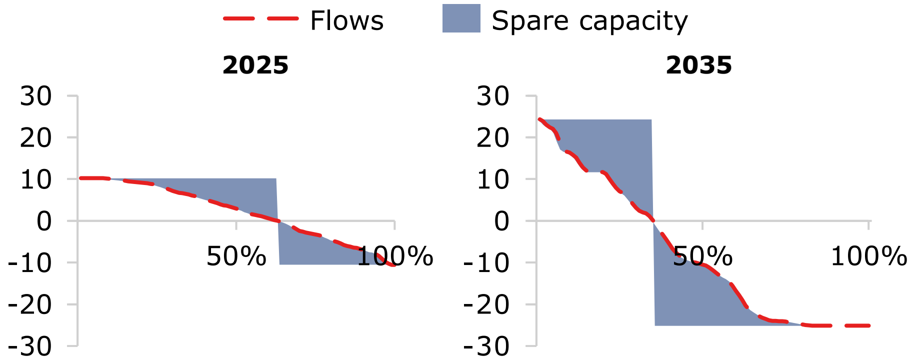
Range of daily changes in flow direction

2-11

Growing interconnector capacity

Interconnectors are a highly flexible resource with extremely fast ramp times. The prevalence of this technology is expected to increase in the future, offering a potentially large pool of highly flexible resource to help manage physical system fluctuations, particularly those that are weather driven.

IC utilisation and flexibility provision (GW)



2025	2035
57% < 5GW	61% < 10GW
43% > 5GW	39% > 10GW

Spare interconnector capacity

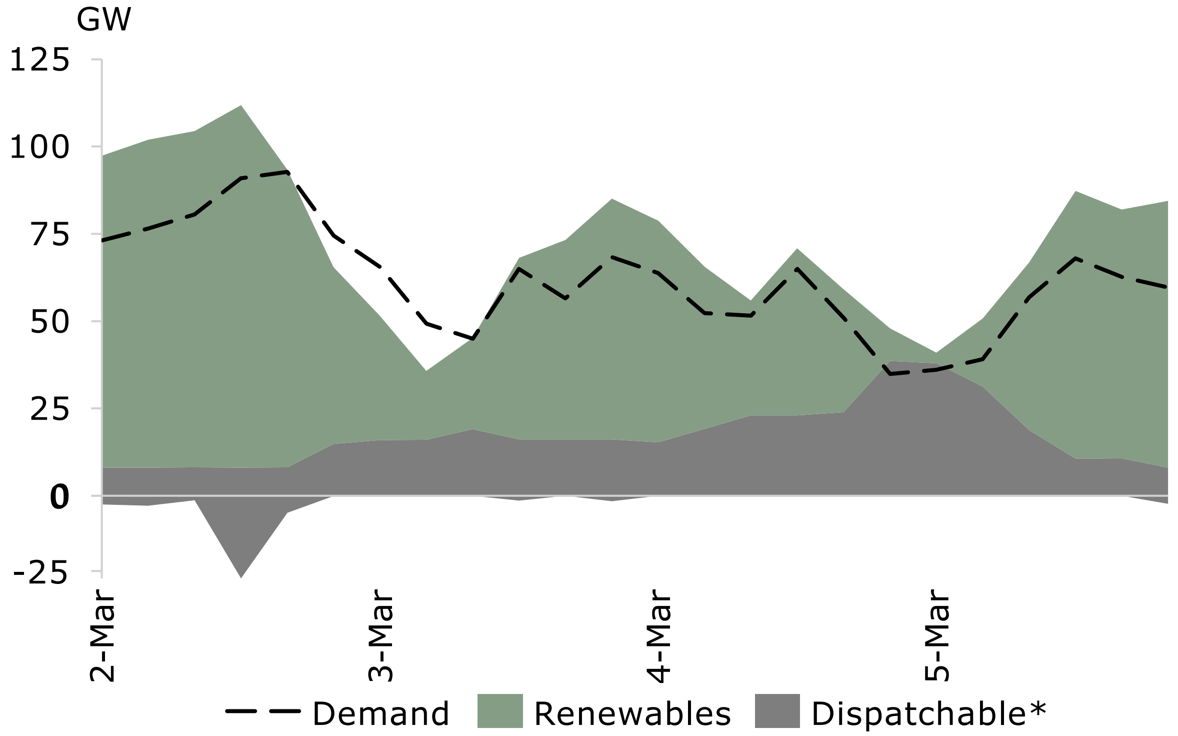
Hours when interconnectors are not fully utilised provide flexibility to the system, as they can modify their position to sudden changes in market conditions.

Note: The chart only highlights flexibility in the same direction as the flows. However, due to reverse flows, IC can provide flexibility on both directions
Data shown is for the LW scenario for illustrative purposes only

FLEXIBILITY

Interconnector flows help balance a highly dynamic system once RES sources displace conventional dispatchable sources

4-DAY EXAMPLE OF IC CONTRIBUTION TO FLEXIBILITY IN GREAT BRITAIN



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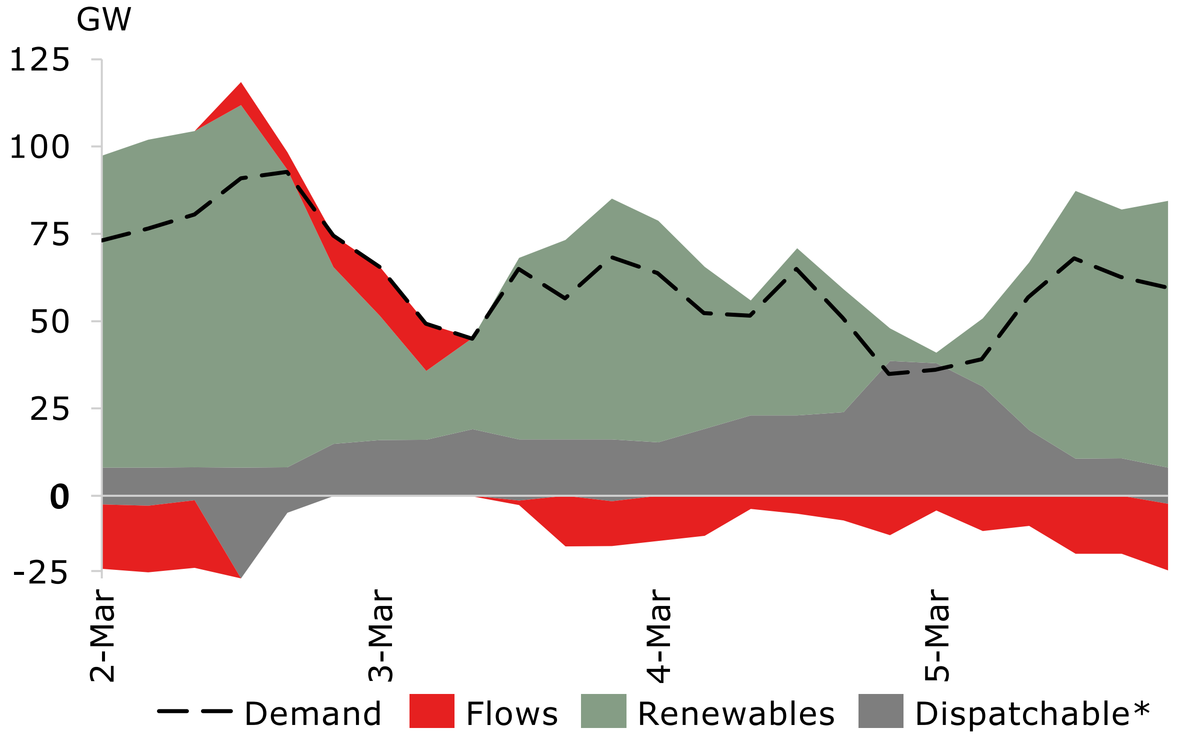

Note: Data shown is for the LW scenario in 2035 for illustrative purposes only
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FLEXIBILITY

Efficient short-term markets are essential to fully utilise the flexibility of interconnectors

BARRIERS	ENABLERS
EU Exit prevents access to the European market coupling initiatives.	Regulations related to trading over GB interconnectors should aim to **couple GB** with rest of Europe as **tightly as possible**, within the boundaries of the TCA agreement.
Currently limited opportunity for trading over interconnectors in the **intraday timeframe**.	Develop more effective **cross border intraday markets** (implicit or explicit) for trading over the interconnectors as close to delivery as operationally possible.
Ramping constraints in the system at each side of the interconnector.	Develop a **framework that optimises ramping restrictions** while respecting operational requirements for ramping limits.

OPERABILITY

Interconnectors equipped with appropriate VSC technology have the capability to effectively provide all ancillary services, however, they may also amplify certain challenges if not managed properly

Frequency	Reserve	Thermal	Voltage	Stability	Restoration
		*ICs **resolve**, but can also **exacerbate** many thermal constraint issues*			

Does not provide the service

Could technically provide the service, but **currently not universally eligible** to participate

Provides the service **today**

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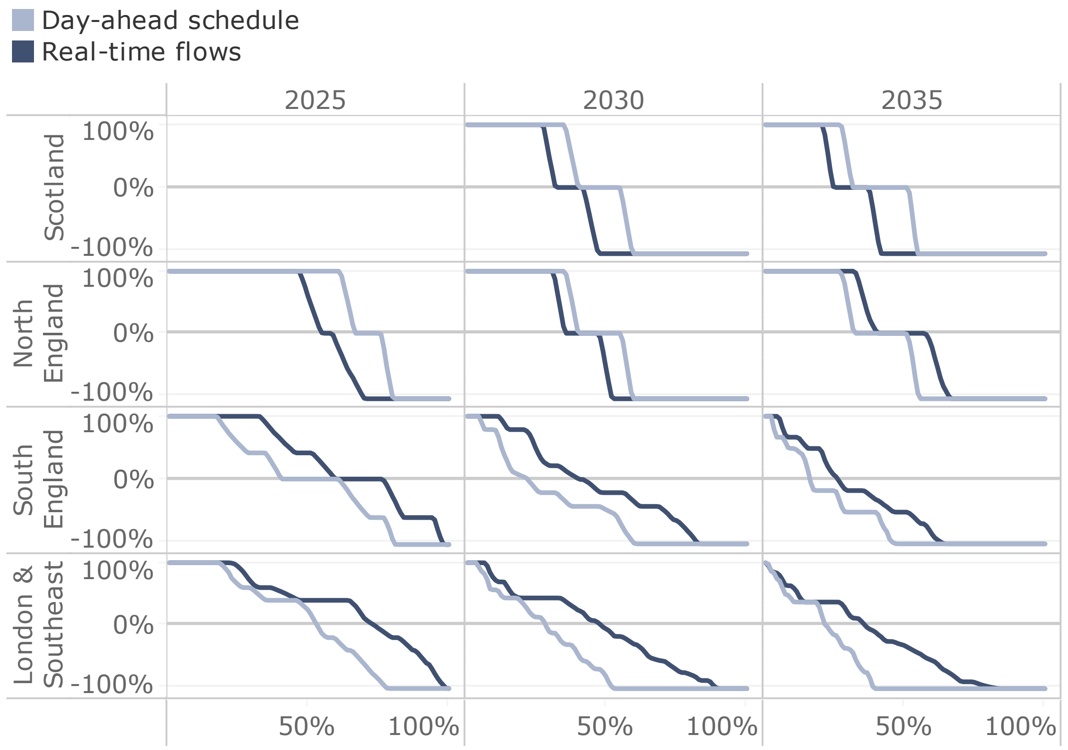
OPERABILITY

Interconnector flows may need to deviate in real time from DA scheduling in order to satisfy the operability constraints on the system

IC UTILISATION BY INTERCONNECTED REGION (%)



COMMENTARY

- Actions need to be taken on interconnector flow in order to make sure that all operating constraints on the system are met
  - As some constraints cause a change in the market behaviour (such as wind curtailed because of inability to be transmitted), interconnectors can adapt to make sure energy is met subject to all technical constraints
- Deviations between DA and real time schedule result in costs faced by ESO (e.g. the BM or trades via IC)
- Only LW scenario is shown for illustrative purposes

Note: positive values represent imports into GB and negative values represent exports to connected regions

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OPERABILITY

Interconnectors can be very capable of supporting system operation, given the right balancing service and investment signals

BARRIERS	ENABLERS
Clustering prevents interconnectors from unlocking their full operability potential and can cause costly TSO interactions.	Enhanced strategy for **incentivising connections** to areas that **benefit system operability** the most, potentially using locational signals.
Sub-optimal scheduling of interconnectors not reflecting local grid issues/constraints.	Consider solutions to **improve interconnectors' initial allocation** reflecting operability challenges.
Ineligibility for certain balancing services prevents access to a potential revenue stream, blocking incentives for investment in enabling technology.	Consider routes to **improve eligibility**/participation potentials. For some services this may also require procuring active energy services in remote markets to deal with energy impacts of interconnector operation.

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Part 2

IMPACT OF MPIs

The main differences in an MPI relative to a conventional IC are part loading and potentially different utilisation, depending on different losses and connected-wind capacity

IC utilisation and MPI configuration

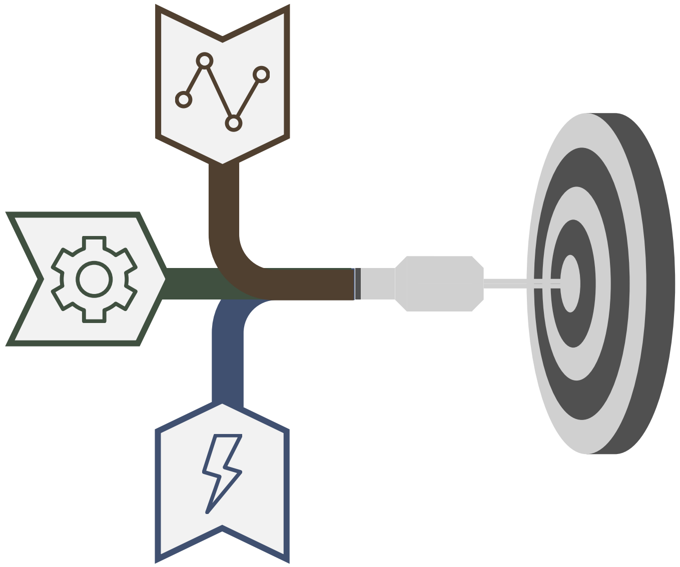
MPIs are almost always at least part-loaded. The total utilisation rate (relative to a conventional IC) depends on IC losses and on whether the connected-wind capacity is equal to or greater than the IC capacity.

Market set-up

No significantly different results are observed across the two set-ups considered, Home Market (HM) and Offshore Bidding Zone (OBZ). Price differentials remain the main driver of flows.

Impact on adequacy, flexibility and operability

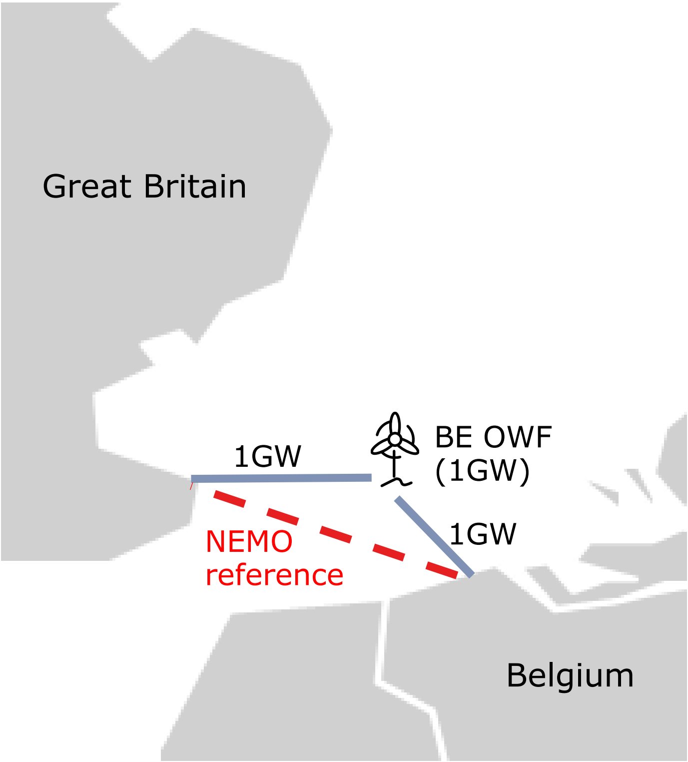
The impact on adequacy is estimated to be minor, given that MPI flows are still at full capacity when the price differential is largest. There might however be implications for flexibility and operability.



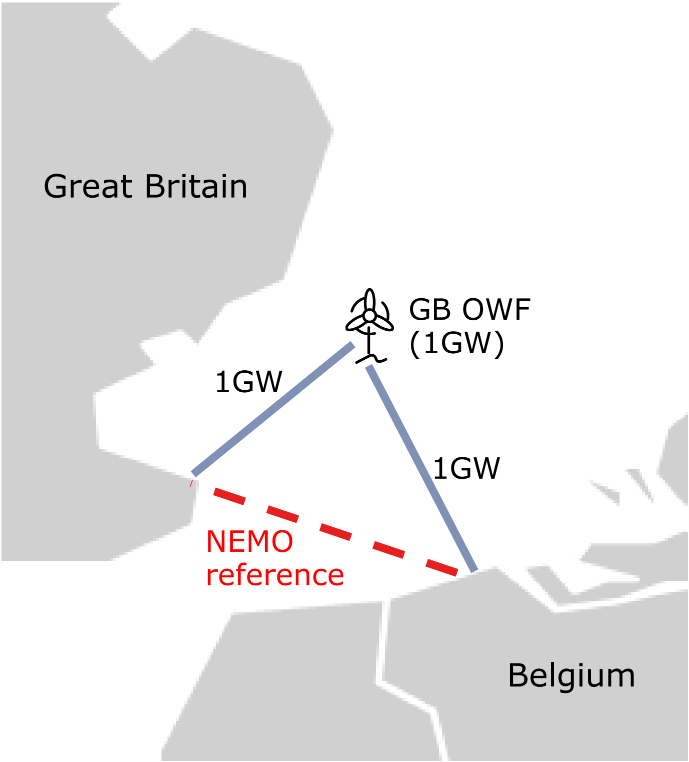
IMPACT OF MPIs

We modelled MPI sensitivities with different configurations (MPI with a BE OWF, a GB OWF, or with both BE and GB OWFs), under 2 set-ups (Home Market or Offshore Bidding Zone), for both the LW and ST scenarios

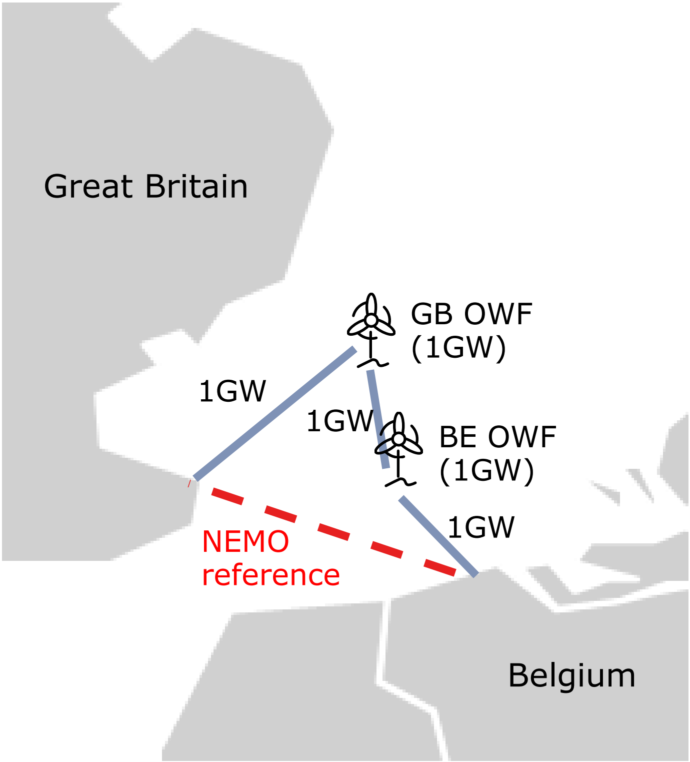
BE OWF



GB OWF



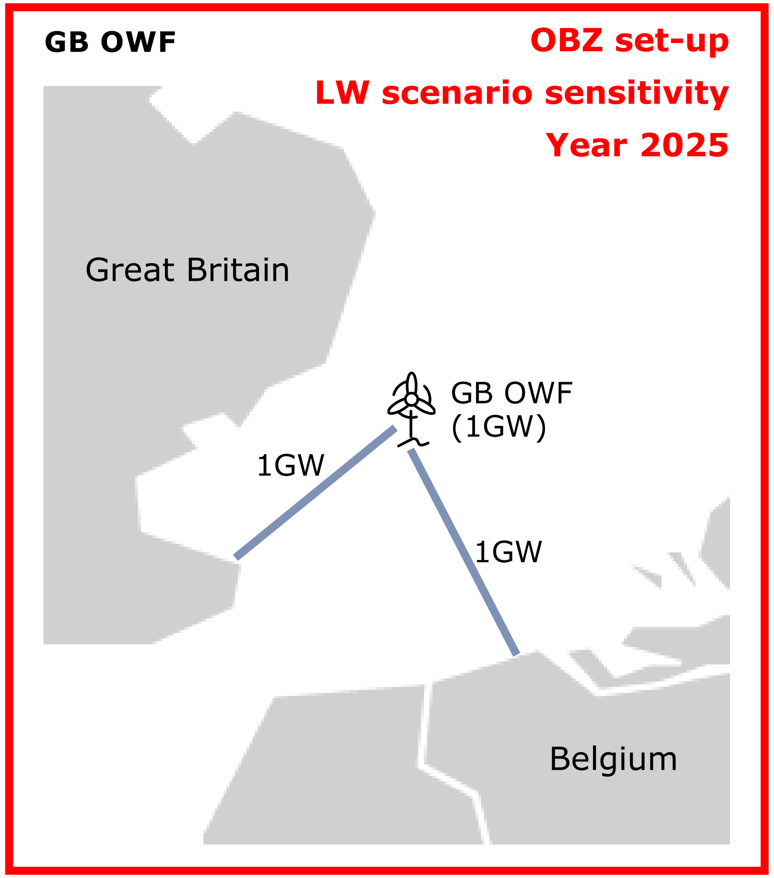
GB AND BE OWF



OWF = Offshore Wind Farm

IMPACT OF MPIs

For this webinar, we will focus on one configuration and examine the MPI impact on IC utilisation – although leading to different outcomes, the same trends apply also to the other configurations



WOULD THE MPI IMPACT HAVE DIFFERED, HAD WE PICKED A DIFFERENT CONFIGURATION OR YEAR?

Configuration:

- **BE OWF sensitivities**
  Flows are more aligned with the standard NEMO IC in the reference scenario, as overall losses are more comparable than in the GB OWF only case.
- **GB+BE OWF sensitivities**
  Given two windfarms connected (a total of 2GW instead of 1GW), full-capacity flows into each market are similar to NEMO IC in the reference scenario, but there are also more hours with some flows into each market.

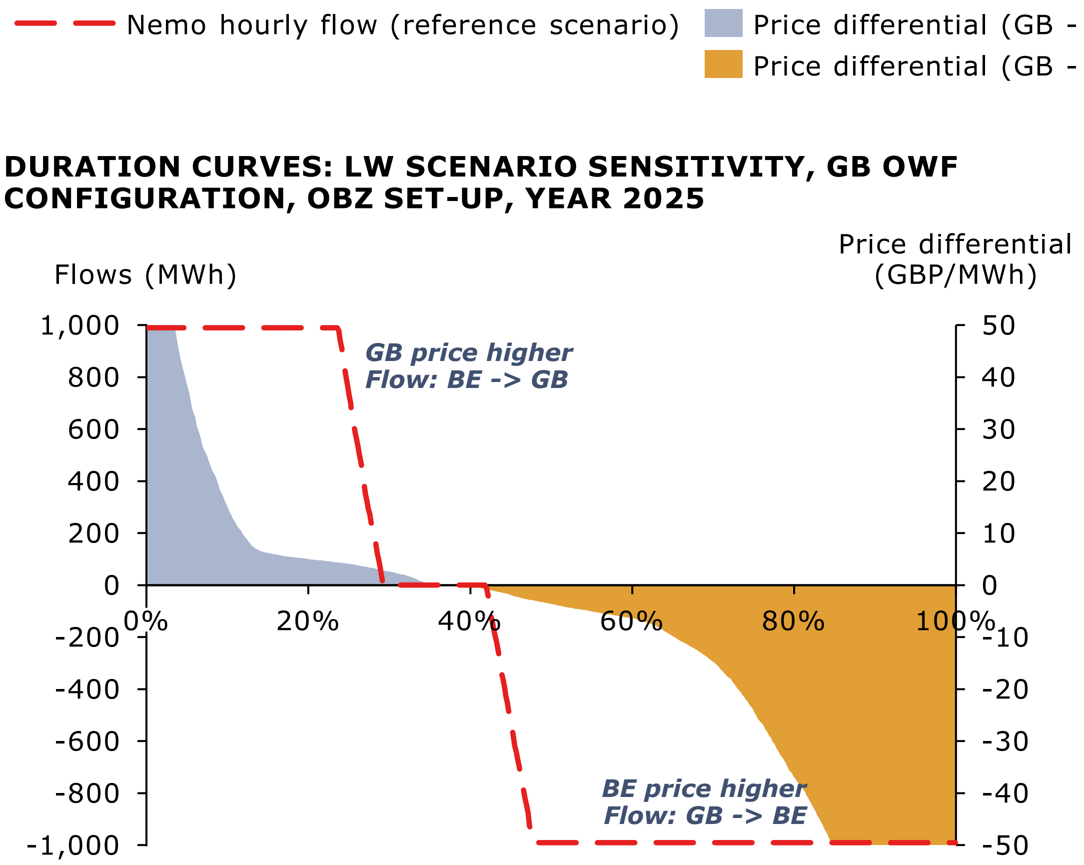
Year selection:

- **Year 2035**
  While the same trends apply, flows are even more heavily in direction GB->BE, based on prevailing price differentials.

IMPACT OF MPIs – LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025

Comparison to conventional IC operation to understand impacts of MPIs – flows across NEMO in reference case provides a benchmark

DURATION CURVES: LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025



COMMENTARY

- NEMO operation under the reference LW scenario (**red dashed** line) follows price differentials.
  - The main direction of flow is GB->BE;
  - But flows serve both markets, with flows at full capacity for about 20% of the time GB->BE and for about 50% of the time BE->GB; and
  - There is a deadband with zero flows for about 10% of the time, where price differential is too low to justify power flows given losses.

Note: duration curves are reflective of the full weather years range considered.

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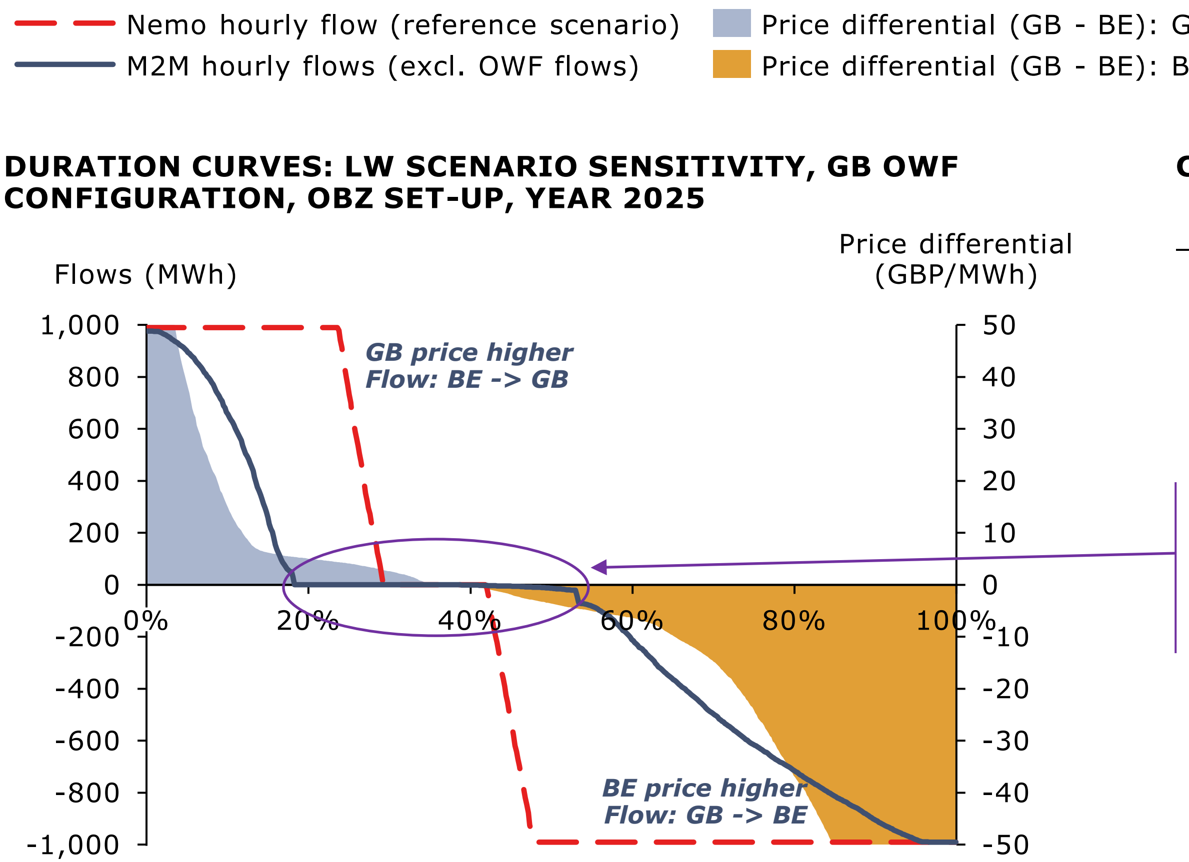
IMPACT OF MPIs – LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025

M2M flows, ignoring flows linked to connected offshore wind output, are lower in magnitude and exhibit a wider deadband relative to NEMO

DURATION CURVES: LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025



COMMENTARY

- **Market to market (M2M) flows on the MPI**, if excluding the offshore wind farm (OWF) flows (in **blue**), still follow price differentials, but are reduced in scale.
  - M2M flows are much **lower** in volume compared to the NEMO IC reference.
  - There is also a broader deadband where M2M flows are zero, due to the price differential being too low to justify flows. This is linked to **greater losses on the MPI given longer overall cable distance** (this is driven by the geography of the case examined, rather than the MPI solution specifically).

Note: duration curves are reflective of the full weather years range considered.

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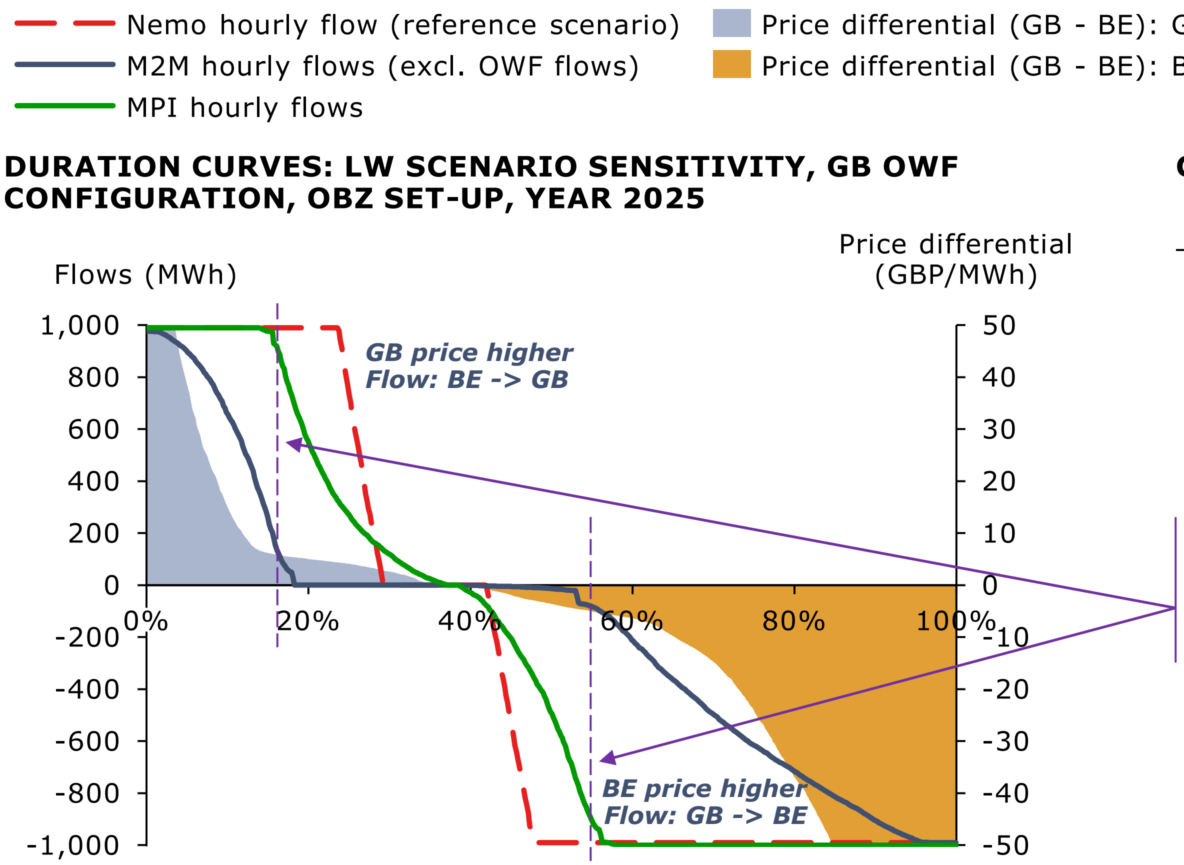
IMPACT OF MPIs – LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025

Combined M2M and connected OWF flows are similar to the conventional IC, but with some notable differences

DURATION CURVES: LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025



COMMENTARY

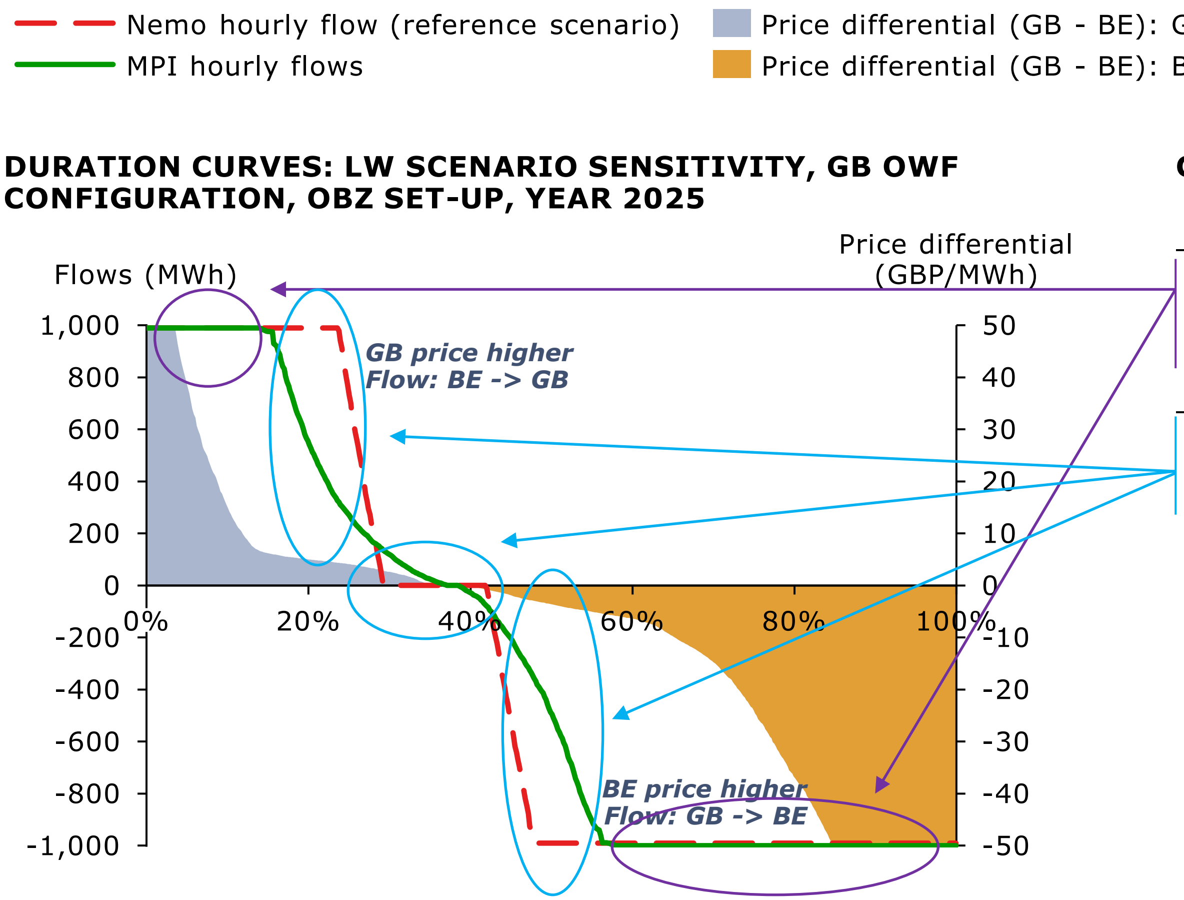
- If OWF flows are included in addition to M2M flows, **total MPI flows** (in **green**), follow price differentials but with some differences compared to NEMO reference.
  - Flows are **almost never zero**, because almost always some wind is being generated in and exported from the OBZ, even at low price differentials.
  - Flows reach **full capacity** (in either direction) roughly **when the M2M flows become greater than zero**. This is when price differentials become large enough to justify standard M2M flows via the OBZ – but **full flows are observed less frequently** than the NEMO reference.
  - Total MPI flows **grow to maximum capacity more slowly than in the NEMO reference**. This is due to the wider M2M-flows deadband, in this case.

Note: duration curves are reflective of the full weather years range considered.

IMPACT OF MPIs – LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025

While adequacy is supported, there might be potential implications for flexibility and operability

DURATION CURVES: LW SCENARIO SENSITIVITY, GB OWF CONFIGURATION, OBZ SET-UP, YEAR 2025



COMMENTARY

- Flows are at maximum capacity in the hours with the largest price differentials, as is the case for the NEMO reference case. This suggests that the impact of MPIs on **adequacy** is minor.
- On the other hand, there are more instances of partial flows and fewer instances of zero flows, with potential implications for **flexibility** and **operability**.

Note: duration curves are reflective of the full weather years range considered.

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Q&A

Contact us

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