4 APRIL 2019

SECURELY CONNECTED: AN ASSESSMENT OF THE CONTRIBUTION OF INTERCONNECTORS TO SECURITY OF SUPPLY IN GREAT BRITAIN

A REPORT ON BEHALF OF NATIONAL GRID VENTURES

4 April 2019

Table of contents

Section

Glossary

Term	Definition
BEIS	Department for Business, Energy, & Industrial Strategy
Call for Evidence	Capacity Market and Emissions Performance Standard Review Call for Evidence
CCGT	Combined Cycle Gas Turbines
CHP	Combined Heat and Power
CM	Capacity Market
CMU	Capacity Market Unit
Consultation	Consultation on proposals for further amendments to the capacity market
DDM	Dynamic Dispatch Model
Delivery Body	Electricity Market Review Delivery Body
DSR	Demand Side Response
EC	European Commission
ECR	Electricity Capacity Report
EFC	Equivalent Firm Capacity
EFIC	Equivalent Firm Interconnector Capacity
EU	European Union
EUR	European Euro
FES	Future Energy Scenarios
FTI	FTI Consulting
GB	Great Britain
GBP	British Pounds
Government	UK Government

HVDC	High-Voltage Direct Current
I-SEM	Integrated Single Electricity Market
NGET	National Grid Electricity Transmission
NGIH	National Grid Interconnector Holdings
NGV	National Grid Ventures
OCGT	Open Cycle Gas Turbines
PTE	Panel of Technical Experts
SO	System Operator
TSO	Transmission System Operator

Summary of key conclusions

Interconnectors bring many benefits to GB consumers, including allowing imports of lower-cost electricity into the GB market (reducing consumer prices) and supporting the decarbonisation agenda. They also contribute greatly to GB security of supply by enabling the import of electricity at times of so-called 'system stress', when GB might have insufficient generation available to meet the country's needs.

The contribution of interconnectors to GB security of supply is reflected in the participation of interconnectors in the 'Capacity Market' ('CM'). In return for financial compensation, capacity providers have an obligation to be available to provide electricity should the operator of the electricity system announce that it has system stress concerns.

The operation of the CM involves a metric known as a de-rating factor which, broadly speaking, reflects the probable availability of each generator class or interconnector at times of system stress. For an interconnector, the probability of it importing electricity to GB at times of high GB system stress is driven predominantly by the market dynamics between GB and the connected country. This is challenging to estimate, not least because there has not been a system stress event in GB for several decades.

In our report, we have looked at how the de-rating factors could be estimated, using 'price' and 'margin' as our key proxies of system stress and analysing the historical coincidence of system stress between GB and connected or potentially connected countries. This is on the basis that electricity is likely to flow from countries with lower stress to those with higher stress at a given moment.

Our results show that when the GB electricity market has been most stressed (i.e., in **conditions that are most relevant to GB security of supply**), the market conditions that drive interconnector flows are **almost always such that flows to GB would be expected**.

For the countries we have looked at, our results show that the probability of interconnectors being available for imports to GB would be **75-95% during relevant periods – i.e., not dissimilar to thermal generators** (other than for Ireland, which is a special case). Therefore, when needed most, **our analysis shows that interconnectors can be relied upon to deliver.**

We have also conducted a review of the current methodology for selecting de-rating factors, which appears to **under-estimate the contribution of interconnectors**. Broadly speaking, an extremely complex modelling methodology is employed, which draws on a large range of input scenarios, to result in a **very large range of de-rating factors for each interconnector**, which informs a decision ultimately made by the Secretary of State.

The way in which scenarios and 'sensitivities' are used in the modelling biases the interconnector de-rating factors downwards. In particular, the use of a single 'downside' sensitivity has a large influence on the results. Providing a more balanced sensitivity analysis would likely result in higher de-rating factors for interconnectors, resulting in considerable savings for GB consumers.

Our overall view is that the current method of selecting de-rating factors is therefore overly conservative, resulting in de-rating factors that are considerably below what the historical analysis would imply. Some commentators have expressed a concern that using historical data to set the de-rating factor would not reflect likely changes in the generation mix in neighbouring countries that are likely to occur over the four-year period between the time the factor is set and the time the capacity must be available. However, in our view, it is not reasonable to discount completely historical performance. After all, whilst generation stock in each country does of course evolve over time, the data suggests that **the change over a four-year time horizon is typically moderate**. There are, therefore, merits to placing greater weight on (less subjective) historical analysis, if that historical analysis properly reflects periods of high system stress in GB (which the 'current' approach to such analysis does not).

For example, one approach could be to use a historical methodology, but with a factor reduction to reflect a **cautious and conservative view of the likely future changes in energy markets**. This approach has the advantage of being transparent in the inherent trade-off between cost and cautiousness: e.g., a higher factor would reflect a more cautious, but more costly, approach.

Alternatively, if policy makers determine that the penalty regime should be strengthened, this could potentially provide appropriate incentives for eligible participants (i.e. interconnectors and all generator classes) to **select their own de-rating factor**. With a revised penalty regime and secondary trading rules, this approach moves the risk-setting role from policy-makers to the participants (who are arguably best placed to understand and manage the risk).

1. Introduction

1.1 Interconnectors are high voltage electricity transmission cables that allow electricity to flow between electricity markets. In the context of Great Britain ("GB"), interconnectors are subsea cables that currently connect the British electricity market with the markets of France, Ireland and the Netherlands. Further interconnection is envisaged - cables to Belgium and Norway (as well as an additional cable to France) are currently under construction. Moreover, many other interconnector projects are in the planning stages – to link GB to the German and Danish markets as well as additional cables to France, Ireland and Norway. Britain's interconnector capacity is likely to expand from its current level of 4GW (gigawatts being a measure of energy transfer per second) to nearly 12GW by the mid-2020s.

1.2 The drivers of this increase in capacity are threefold:

- First, interconnectors allow low cost electricity to be exported to neighbouring markets with higher prices and, in so doing, reduce prices in the importing market. Great Britain generally has higher prices than its neighbours, which means that electricity imports have the potential to reduce GB consumer prices.
- Second, interconnectors support the decarbonisation agenda, allowing for better and more efficient management of intermittent renewable generation, whose output is dependent on prevailing weather conditions. Renewable generation output can be exported when output is greater than required to meet local demand and equally, imports can be used to meet local demand when renewable output is low.
- Third, interconnectors boost the security of supply of a country. Interconnectors provide access to additional generation capacity located in a neighbouring country that can potentially be drawn upon to support the local system in the event of unexpected problems such as generator breakdowns (or outages) or higher than expected demand. This additional resource can therefore be used to reduce the risk of enforced demand shedding and ultimately system wide stress.

1.3 The contribution of interconnectors to Britain's security of supply is the focus of this report.

1.4 In 2015, the value that interconnectors provide in **enhancing GB security of supply** for electricity was reflected through their inclusion in the GB Capacity Market ("CM") by the Department for Business, Energy and Industrial Strategy's ("BEIS").[1] The CM is a market mechanism designed to secure a level of reliable future capacity in the GB electricity market.

BEIS review of the CM

1.5 BEIS has a statutory requirement to review the CM every five years and is conducting the first such review in 2018.[2] The purpose of this five-year review is to assess if the CM is fulfilling its objectives and to establish whether these objectives remain appropriate. In August 2018, BEIS published the *Capacity Market and Emissions Performance Standard Review Call for Evidence* ("Call for Evidence")[3] and subsequently published in March 2019 a consultation on further proposals to the capacity market (the "Consultation").[4]

1.6 BEIS' initial view, as expressed in the Call for Evidence, is that the CM has achieved its initial objectives, is broadly working as intended, and that the CM's objectives continue to remain relevant.[5]

1.7 However, the Call for Evidence noted specific areas where BEIS was minded-to investigate further based on concerns raised by stakeholders to date. One area of concern raised is the interconnector 'de-rating' methodology, which, as described in Section 2 below, is essentially a measure of the reliance that can be placed on a technology to deliver electricity (or reduce demand) at times of system stress in future periods.

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1 BEIS (2015): Announcement of de-rating methodology for interconnectors in the Capacity Market. "*Electricity interconnectors make an important contribution to our security of supply which we will value through their inclusion in the Capacity Market from the T-4 auction in 2015.*"

2 Concurrently, Ofgem is undertaking a separate review of the CM design which relates to the CM rules.

3 BEIS (2018): "Capacity Market and Emissions Performance Standard Review: Call for Evidence."

4 BEIS (2019): "Proposals for further amendments to the capacity market."

5 BEIS (2018): "Capacity Market and Emissions Performance Standard Review: Call for Evidence.", page 3.

1.8 According to BEIS, some stakeholders have argued that the interconnector de-rating methodology is over-compensating interconnectors relative to their expected contribution to the security of supply. Additionally, some stakeholders believe that additional interconnector capacity may produce diminishing benefits to GB security of supply as these new links would be facilitating flow from the "*same limited pool of spare capacity*" into GB.[6]

1.9 In the Consultation of March 2019, BEIS reiterated its view that the Capacity Market is the right mechanism for delivering security of supply. The Consultation focuses on a limited number of 'priority' changes which includes interconnector de-rating factors.[7]

Purpose of this report

1.10 In the context of BEIS' review of the CM, and in particular the concerns expressed about interconnector de-rating factors, National Grid Ventures ("NGV") has asked FTI Consulting ("FTI", or "us") to assess the contribution of interconnectors to GB security of supply and to comment on whether the existing de-rating methodology remains appropriate. This report sets out our findings and suggestions.

1.11 This report is intended to support NGV in its response to the Consultation. However, the opinions expressed in this report are solely those of the authors, and do not necessarily reflect the opinions of NGV or any other stakeholder.

Restrictions and limitations to the scope of our work

1.12 FTI accepts no liability or duty of care to any organization other than NGV for the content of the report and disclaims all responsibility for the consequences of any person other than NGV acting or refraining to act in reliance on the report or for any decisions made or not made which are based upon the report.

1.13 This report contains information obtained or derived from a variety of sources. FTI has not sought to establish the reliability of those sources or verified the information provided.

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6 BEIS (2018): "Capacity Market and Emissions Performance Standard Review: Call for Evidence", page 7.

7 In this regard, BEIS proposes two key changes in the Consultation: the formal removal of the historical floor and improved transparency in the modelling process. The substance of this report is highly relevant to both of these questions, as well as to the original set of wider issues highlighted in the Call for Evidence.

1.14 No representation or warranty of any kind (whether express or implied) is given by FTI to any person (except to NGV under the relevant terms of our engagement) as to the accuracy or completeness of this report.

1.15 This report is based on information available to FTI at the time of writing of the report and does not take into account any new information which becomes known to us after the date of the report. We accept no responsibility for updating the report or informing any recipient of the report of any such new information.

Structure of this report

1.16 The remainder of this report is structured as follows:

- **Section 2** summarises the background to the issues, including the CM itself and the historical calculation of de-rating factors.
- **Section 3** presents our analysis of the security of supply provided by interconnectors. We analysed historical data from GB and neighbouring countries and considered what the implications are for the contribution of interconnectors to GB security of supply.
- **Section 4** critiques the current interconnector de-rating factor methodology.
- **Section 5** proposes some alternatives and refinements to the current interconnector de-rating factor methodology.
- Appendices 1 through 5 provide supporting analysis.

2. Background and context

2.1 Over the past decade, the electricity generation market in GB has been evolving. The ongoing closure of many aging and unprofitable thermal generators has limited the availability of generating capacity able to provide electricity in a controllable (or 'dispatchable') manner and able to respond flexibly to meet peaks and troughs in demand. In turn, these generation resources are being replaced by more intermittent sources that supply electricity in a much less flexible manner, but contribute significantly to the UK's climate targets as set out in the Climate Change Act of 2008.[8] In addition to these supply-side factors, some stakeholders expect electricity demand to increase in the future, as a result of the electrification of transport, for example. The combination of these factors mean that security of supply has become a growing issue for regulators and policymakers.

2.2 In light of the changing dynamics of the energy market, the UK Government ("the Government") concluded that the wholesale markets were not producing sufficiently strong price signals for the investment necessary to meet long-term capacity requirements. In particular, policy-makers identified a 'missing money' problem, referring to the inability of electricity prices to sufficiently increase at times of scarcity to reflect the value that consumers place on security of supply.[9]

2.3 Driven by concerns of insufficient investments in dependable generation, the CM was introduced in 2014 as a mechanism to increase the incentives for energy developers to invest in order to meet future capacity requirements. At its inception, the three key objectives of the CM were:[10]

- **security of supply**: incentivise sufficient investment to ensure security of electricity supply;
- **cost effectiveness**: ensure that the most efficient level of capacity is secured at minimum cost to consumers; and

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8 DECC (2008): "Climate Change Act 2008", Chapter 27.

9 See, for example, DECC (2014): "Electricity Market Reform – Capacity Market, Impact Assessment" which states that capacity providers face 'missing money' due to "*energy prices not adequately rewarding capacity at times of stress.*"

10 DECC (2014): "Electricity Market Reform – Capacity Market, Impact Assessment".

- **avoid unintended consequences**: minimise design risks and complement the decarbonisation agenda.

2.4 The rest of this section provides greater context to our assessment on the contribution of interconnectors to the security of supply. We set out, in turn:

- the background to the CM, its design, and interconnector participation; and
- the objective of de-rating factors and the evolution of the methodologies.

Background to the CM

2.5 The security of Britain's electricity supply has come increasingly under policy makers' focus over the last decade. Driven by the environmental agenda, uncontrollable and intermittent renewable generation (mainly wind and solar technologies), has expanded rapidly whilst, at the same time, older thermal generation, which can be more easily controlled, has been decommissioned and not replaced. While beneficial in the context of meeting environmental obligations, this trend has led policy makers to be concerned that the reduction in controllable, typically thermal, generation increases the risks of a security of supply incident – in which the country finds itself with insufficient available generation capacity to meet its immediate needs, resulting in system stress.

2.6 To mitigate this concern, in 2014 policy makers introduced the CM. Operating alongside the wholesale electricity market, the CM rewards providers of generation capacity for being available to generate (while the wholesale electricity market continues to reward the actual output generated). The CM operates as an auction, in which the overall amount of capacity required is set centrally (essentially by government). Providers of generation capacity (that meet certain criteria) then bid in until the auction clears, with those that are successful receiving the auction clearing price. In return, those providers have an obligation to be available to generate electricity should the operator of the electricity system announce that it has immediate concerns about the security of the system. Policymakers believed that, by creating an additional funding stream, the CM auction would incentivise investment in capacity and, in so doing, ameliorate their concerns regarding GB's security of supply.

De-rating factors ("DRFs")

2.7 In developing the CM, policy makers considered how to reflect the fact that no single source of generation is 100% reliable. As with all forms of machinery, breakdown and outages occur from time-to-time for all generation units. The issue was, therefore, how to set the amount of capacity that would be bought in the auction considering the fact that there is always a degree of uncertainty regarding the actual availability of a generating unit.

2.8 In this regard policy makers faced a trade-off: if they were unduly conservative in the estimate of generator reliability then too much capacity would be procured - the cost of which would fall upon customers. But if there were over optimistic on the assessment of generator reliability then the risk of a security of supply incident would be increased – with consequential costs to customers also.

2.9 Several approaches to take account of the reliability issue were considered, but the chosen measure was the introduction of the so-called 'de-rating factor'. This reduced the volume that a generator could bid into the CM to take account of the risk that a given generator may be experiencing an outage at the time of a security of supply event. The factor was based on the historical availability observed over the previous seven years and varied depending on generator technology – for example, nuclear power stations had a factor of 81.39%, whereas open cycle gas turbines, which have historically been more reliable, had a factor of 93.61%

2.10 Table 2-1 below shows the T-4 de-rating factors for generating technologies in 2014 and 2018.

Table 2-1: T-4 de-rating factors for generators in 2014 and 2018

Technology class	De-rating factor in 2014	De-rating factor in 2018
Oil-fired steam generators	82.10%	89.13%
Open Cycle Gas Turbine ("OCGT")	93.61%	95.14%
Reciprocating engines	82.10% for oil recips[11] 93.61% for gas recips	85.14%
Nuclear	81.39%	84.20%
Hydro	83.61%	90.09%
Pumped Hydro	97.38%	95.52%
Combined Cycle Gas Turbine ("CCGT")	88.00%	90.00%
Combined Heat and Power	90.00%	90.00%
Coal / Biomass / Energy from Waste	87.64%	86.56%

Source: Delivery Body.

Inclusion of interconnectors in the CM

2.11 In the initial CM auction in 2014, interconnectors were not allowed to participate. Instead, the benefit of interconnectors was (somewhat roughly) taken into account in the volume that was procured in the auction. This meant that interconnector owners did not receive payment for the security of supply benefits they provided. Unsurprisingly, they argued that this was unfair as it reduced the revenues that were available to them relative to generators. Equally, policy makers were concerned that it might deter investment in interconnectors, which, as already noted, were identified to be highly beneficial to GB consumers.

11 'Recips' refer to reciprocating engines.

2.12 Therefore, in the subsequent CM auction in 2015, the CM rules were adapted to allow interconnectors to participate. This raised the same question as that which had been raised in the context of generators: how reliable are interconnectors and would they actually deliver electricity if Britain needed them to keep the lights on?

2.13 Uncertainties about the reliability of interconnectors to be able to supply electricity at critical moments arose from two areas:

- first, a cable might be technically unavailable (for example a convertor station fault or the very unlikely event of a cable strike); and
- second, even if the cable was technically available, there was a risk that the connected market might not be able to (or want to) generate sufficient surplus electricity to export electricity to Britain at the critical time.

2.14 Therefore, a de-rating factor was proposed for interconnectors that took into account *both* of these risks. The first risk, that of technical unavailability, was straightforward to evaluate on the basis of historical data on cable outages (reliability is in the order of 95% to 98%).

2.15 The second risk, that of whether the connected market will be able to generate sufficient electricity to export to GB at the critical time of a stress event, is more difficult to evaluate. (We note that other technologies are also dependent on 'market conditions' (e.g., generators using gas fuel are obviously reliant on the gas supplies available). However, interconnectors are the only technology where the de-rating factor methodology considers, explicitly, market conditions.

2.16 This 'market risk' requires an assessment of the probability that the connected market, for example France or Norway, is likely to export electricity to GB at the precise time Britain needs it to prevent system stress. Given that Britain has not experienced a system wide scarcity event for several decades, it is inevitable that this assessment is somewhat subjective.

2.17 Although subjective it is also important. If this risk of non-delivery is judged too conservatively it means that additional capacity will be procured in the CM unnecessarily – with the cost falling upon consumers. If it is too optimistic then there is an increased risk of system stress.

Interconnector de-rating factors

2.18 The CM rules dictate that the interconnector de-rating methodology is set by a so-called 'hybrid' approach. This approach considers both:

- historical interconnector flows when day-ahead wholesale electricity price differentials are positive (or just positive price differentials for new interconnectors); and
- forecast flows from probabilistic energy market forecasting.

2.19 The historical de-rating factor for the interconnector CMU, based on analysis and advice from Pöyry, is determined by considering the periods of 50% highest peak demand during the winter quarter over the preceding seven years (for existing interconnectors).[12] The de-rating factor is calculated over this period as the percentage of time where the day-ahead price differentials between the two regions are positive (and, for existing interconnectors, where actual flows are in the expected direction given price differentials). The expectation was that the historical approach would produce conservative de-rating factors which would act as a floor in the Secretary of State's ultimate determination.[13]

2.20 Interconnectors have been assigned de-rating factors for participation in four T-4 CM auctions for delivery years ranging from 2019/20 to 2022/23 as well as the upcoming T-1 CM auction for the 2019/20 delivery year.[14] Throughout this period, the Secretary of State has published de-rating factors for all interconnectors that are either operational or are expected to be completed by 2020, representing interconnections with five separate countries.[15]

2.21 The associated de-rating parameters used in the T-4 auctions, averaged across the connected country, are demonstrated in Figure 2-1 below.

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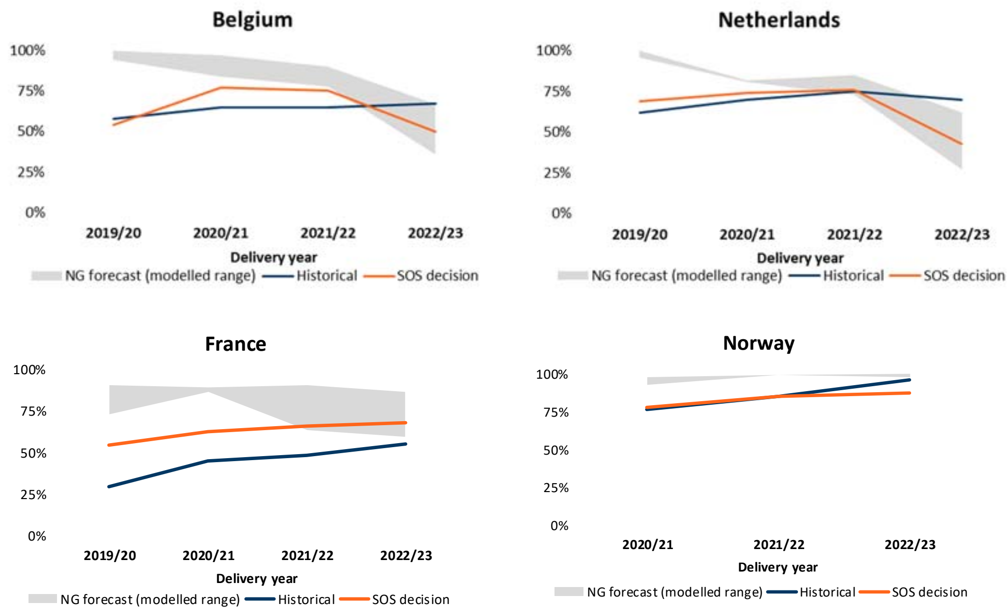
12 This period aligns with the historical approach used for generators.

13 BEIS (2015): "Announcement of De-Rating Methodology for Interconnectors in the Capacity Market."

14 Unlike new generators, all interconnectors are unable to bid for a long-term duration capacity contracts.

15 These interconnectors include IFA, Eleclink, BritNed, Nemolink, Moyle, EWIC, IFA2 and NSL. De-rating factors for IFA2 and NSL were only included in the three most recent auctions.

Figure 2-1: De-rating factor decisions vs. forecasted 'modelled' range



Source: FTI Analysis; Delivery Body.

2.22 For the delivery years 2019/20 to 2021/22, the results of the historical analysis conducted had been a factor in the Secretary of State decisions – as an example, France had a very high (and narrow) modelled range for delivery year 2020/21 but the Secretary of State point estimate was somewhere between this level and the level implied by historical analysis.

2.23 However, for the 2022/23 delivery year, for Belgium, the Netherlands and France, a wider set of input assumptions has led to a **broader range of modelled outcomes**, indicating less certainty in the forecast, and also – notably - a lower range.

2.24 Given that we observe that (i) there are no changes to the operations of the interconnectors; (ii) no new interconnector capacity has come online during this period; and (iii) the interconnected market has not materially changed, the fundamental driver behind these broader and lower forecasts appears to be a change in the forecast modelling approach.[16]

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16 We note that these wider ranges corresponded to the period when the modelling approach was changed from a model outsourced to Baringa to the Delivery Body's in-house model, supported by Pöyry.

2.25 In addition, the Secretary of State decisions appear to have decreased in line with forecasted ranges in Belgium, the Netherlands and Norway. These decisions have fallen **below** the historical averages which were originally intended as the 'floor' in the de-rating calculation. Indeed, the Panel of Technical Experts ("PTE") concluded in 2018 that, due to the potential for significant changes in the European Union ("EU") system beyond 2020, the historical floor should not be included as a data point in the calculation of interconnector de-rating factors.[17]

2.26 Conversely, when forecasted ranges were significantly above historical averages in the earlier years of interconnector CM participation, the Secretary of State decisions do not appear to track the forecasts as closely. This highlights an apparent tendency of decision-makers to favour the more conservative approach (i.e., the approach that leads to lower de-rating factors) – but as noted below, this comes at increased consumer costs, undermining the benefits interconnectors provide.

Scope for reassessment of interconnector de-rating methodology

2.27 Interconnectors have contributed to **reducing costs for consumers**: in the most recent T-4 auction for delivery in 2021/22, new and existing interconnectors provided a combined 9% of the cleared capacity in the GB market for this delivery period and none of the interconnector participants in the CM exited the auction. If there had been, say, 1GW less[18] of interconnector capacity bid into the 2018 T-4 auction (either through lower DRFs or nameplate interconnector capacity), the auction would have cleared at c. £10/kW/year rather than £8.40 kW/year.

2.28 However, the precise contribution of interconnectors to **GB security of supply** is not so easily estimated, since the very event in which such security of supply is required (i.e., a formal System Stress Event) has not occurred since the inception of the CM. However, as we explain in Section 3 below, there is evidence to suggest that, certainly on a historical basis, the contribution is significantly greater than implied by the current de-rating factors.

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17 The PTE have recently considered that the "*historical floor no longer remains relevant"* and "*recommend that the historical estimates should not form a floor when determining the T-4 DRFs".* BEIS (2018): Panel of Technical Experts: Independent Report on National Grid's Electricity Capacity Report 2018.

18 Approximately 6.5 GW of physical interconnector capacity qualified for last year's T-4 auction (delivery year 2021/22). The application of de-rating factors reduced the interconnector capacity able to participate in the auction to 4.6 GW, a reduction of 1.9 GW.

2.29 This five-year CM review presents an opportunity to reassess the fundamental question of how much interconnectors contribute to security of supply in GB during periods of system stress, and, in turn, whether the current methodology for determining de-rating factors for interconnectors adequately reflects this (significant) contribution.

3. Analysis of interconnectors' contribution to GB security of supply

3.1 Security of supply concerns the ability of the GB electricity market to meet demand reliably in each period. Participants that have been awarded Capacity Agreements through the CM auctions, including interconnectors, are called upon to deliver their promised level of capacity when instructed to do so by the SO during a System Stress Event.[19]

3.2 Interconnectors play a key role in providing security of supply as they allow access to additional generation capacity sited in other electricity markets that can be used to import electricity to GB.

3.3 This section considers ways in which interconnectors' contribution to security of supply might be measured. Our analysis is based on empirical evidence to assess the contribution of interconnectors to GB security of supply observed over the last several years.

3.4 Recognising the limitations of historical data, we have undertaken a variety of methodologies, using different metrics and sample ranges to identify the range of outcomes.

3.5 This section sets out:

- the objectives of our assessment;
- our approach to the analysis;
- the key findings from each of our analyses; and
- conclusions on our assessments and potential implications.

[19] Under the current version of the CM Rules, a System Stress Event is defined as a 30-minute period in which there is an "Instigated Demand Control Event" due to insufficient supply to meet demand for at least 15 continuous minutes.

Objectives and challenges

3.6 As discussed in the previous section, de-rating factors are used to estimate the reliable capacity that a specific technology can provide during a System Stress Event. For thermal generators, this is based on observed historical technical availability (although, for completeness, we note that this measurement is not necessarily straightforward, and it has been noted that opportunities for 'gaming' the process exist).[20] 'Technical' availability reflects the physical condition of the plant – for example, thermal generators can break down, or be required to reduce output or shut down completely for maintenance.

3.7 For interconnectors, this technical 'risk' is a factor. However, from a GB security of supply perspective, interconnectors are also subject to market conditions; that is, whether the energy market in the neighbouring country can deliver power to GB during a specific period.[21] De-rating factors for interconnectors therefore also reflect an estimate of the probability of generators in neighbouring countries being unable to deliver in times of system stress in GB.

3.8 Therefore, in principle, de-rating factors should consider the probability of **coincident system stress** where the energy market in a connected country is unable to deliver the required additional power to relieve GB system stress (or, in the worst-case scenario, importing power from the GB energy market during these periods).

3.9 It is in this context that we undertake an empirical analysis on historical evidence to assess the contribution of interconnectors to GB security of supply.

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[20] Ofgem (2016): Statutory consultation on changes to the Capacity Market Rules, pages 55-59. Ofgem "*conducted and reviewed additional quantitative analysis to identify the approximate size of the 'capacity gap' caused by generators potentially overstating their connection capacity.*"

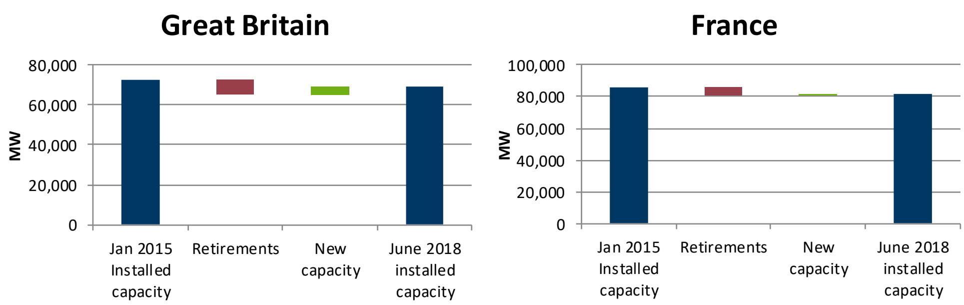
[21] To an extent, generators are also subject to some market conditions, for example due to the availability of gas supply. However, the de-rating methodology for these generators do not consider these market conditions.

3.10 However, since the inception of the CM in 2014, no System Stress Events have occurred, making it difficult to measure the effectiveness of any capacity type in fulfilling their CM obligation.[22] As no System Stress Events have been experienced to date, we have looked at conditions that could be considered to reasonably proxy these events. For example, observed interconnector flows during periods *nearing* system stress might be considered to provide an indication of how interconnectors would perform in *actual* System Stress Events.

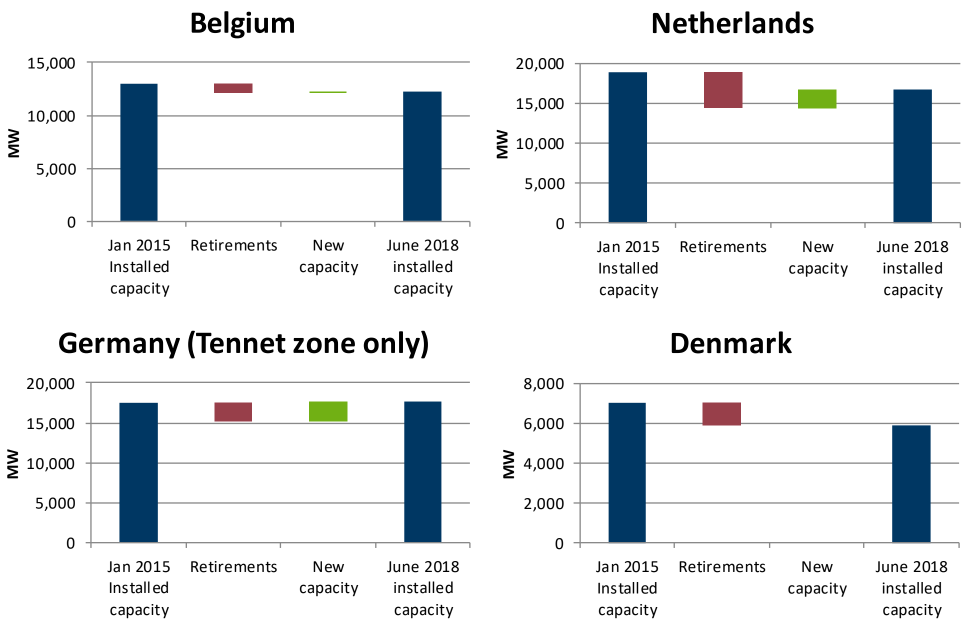
3.11 We are aware that some stakeholders consider that a historical approach might not be reflective of future performance. This is on the grounds that changes in the generation portfolio and/or increases in interconnector capacity may render historical data less reliable for the purposes of estimating future performance.

3.12 Nevertheless, our view is that it would not be reasonable to discount completely historical performance. After all, whilst generation stock in each country does of course evolve over time, the data suggests that the change over a four-year time horizon is typically moderate (and certainly not, in our view, enough to justify the removal of the historical 'floor'). This is clearly illustrated in Figure 3-1 below which shows the change in the generation portfolio for GB and each of the connected countries.

Figure 3-1: Change in the generation portfolio between January 2015 and June 2018



[22] In both October 2016 and November 2016, the SO issues Capacity Market Notices, signalling a coming System Stress Event. However, both were withdrawn before CM participants were asked to deliver promised capacity. These instances were the result of increased pressure on the system from moving off from daylight savings time (generators that were offline for summer had not been fired up) and unexpected power outages.



Source: ENTSO-E FTP.
Notes: Unit-level data used which only includes plants above 100MW (which is a limitation of the analysis given material increases in embedded generation over this period that is typically less than 100MW in capacity). Data available starts from January 2015. The electricity market in Germany is split into the four zones. We consider the zone where the potential future GB-Germany interconnector will connect to.

Our approach to the analysis

3.13 There are two key challenges when assessing the contribution of interconnectors by considering historical data.[23] These are:

- first, which *metrics* to use as a proxy for system stress (or periods nearing system stress); and
- second, which *periods* to focus our analysis on.

3.14 We discuss each of these challenges below as we set out the different analyses and sample ranges.

23 All our analysis is based on historical data available in the public domain at the time of writing this report.

Metrics tested

3.15 We consider the following metrics to proxy the contribution of interconnectors to security of supply in GB.

- **Price:** We use hourly day-ahead energy market prices in euros for our analysis. It is reasonable to assume that when prices are high in GB, the system is potentially nearing or at greater risk of stress, and interconnector flows toward GB would provide security of supply contributions. For this to occur, prices in GB must be higher than prices in Europe; and
- **Margin**: We calculate margin as the difference between hourly available capacity and demand, divided by demand, to measure the amount of excess capacity within an electricity system. It is reasonable to assume that when margin in GB is low, the system is nearing or at greater risk of stress.

3.16 For each of these metrics, we consider correlations between GB and the existing and future connected countries: France, the Netherlands, Belgium, Norway, Ireland, Germany and Denmark (the “non-GB” countries), where data is available.

3.17 Additionally, we undertake additional analyses to identify whether forced generator outages and low wind availability have a high correlation between GB and non-GB countries. This is because some commentators consider that forced generator outages and low wind availability could result in a System Stress Event – and if a coincident event occurs between countries, this will limit the contribution of interconnectors to GB security of supply.

3.18 Therefore, in response to these concerns, in these analyses we:

- evaluate the correlation of forced generator outages between GB and non-GB countries to determine if there is a high probability of coincident outages; and
- evaluate the correlation of wind generation during periods of low wind availability between GB and the non-GB countries in our analysis.

3.19 In Appendix 2, we also detail how levels of GB demand are correlated with the direction of interconnector flow. We find that, for BritNed and for IFA, the two non-Irish operating interconnectors, flows are mostly toward GB (in line with price signals), irrespective of demand; i.e., GB is a net importer of electricity under all GB demand scenarios since the price is consistently higher in GB.

Development of sample ranges

3.20 As in the prevailing historical de-rating factor methodology, our statistical analysis focuses on certain periods where it is expected that GB is more likely to experience system stress. This 'sample range' for each year is defined as the set of hours that are: (i) between 7am to 7pm; (ii) in working days only; and (iii) during the months December, January and February. For each sample range in each year, the hours representing the top 50% of demand are selected, and the analysis of interconnector performance conducted over those hours only. [24]

3.21 The sample range chosen reflects a judgment regarding the trade-offs between:

- a smaller set of hours, that might better proxy for system stress albeit a small sample; and
- a larger set of hours, that might not proxy for system stress as well, but reducing the risk of errors arising from small sample sizes.

3.22 In our view, there is no one sample range judgment that is definitively correct. For example, the sample range used by the historical de-rating factor methodology observes the top 50% of demand during winter weekday peak-periods. However, this selection of periods may not necessarily cover all periods that proxy for system stress, some periods may indeed fall outside the sample range. Alternatively, the sample range may include many periods that do not proxy for system stress, thereby diluting the findings.

3.23 We have, therefore, chosen to run our analysis across four different sample ranges. These sample ranges are:

- **Case 0: Base Case**. This follows the same parameters as the prevailing historical methodology. The 'sample range' for each year is defined as the set of hours that are: (i) between 7am to 7pm; (ii) in working days only; (iii) during the months December, January and February; and (iv) representing the top 50% of demand within those temporal parameters.
- **Case 1: Higher Demand Restriction (winter peak).** This is the same as Case 0, except we apply a narrower definition of peak demand which might better proxy for System Stress Events. The 'sample range' for each year is defined as the set of hours that are: (i) between 7am to 7pm; (ii) in working days only; (iii) during the months December, January and February; and (iv) representing the top 5% of demand within those temporal parameters.

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[24] The historical de-rating factor methodology was used until the recent T-4 auction parameters set in 2018, where it was deemed by the PTE (and applied by the Secretary of State) to be no longer relevant.

- **Case 2: Higher Demand Restriction (all periods)**. This case recognises that system stress may occur outside historical peak periods of demand, such as the two instances where the SO issued Capacity Market Notices in October and November. The 'sample range' for each year is defined as the set of hours that represent the top 5% of demand within each year.
- **Case 3: Restricted Timeframe (2014+)**. This case is the same as the Base Case, but isolates the period after market coupling was introduced in 2014.[25] Therefore, the 'sample range' for each year is defined as the set of hours that are: (i) between 7am to 7pm; (ii) in working days only; (iii) during the months December, January and February; and (iv) representing the top 50% of demand within those temporal parameters, and only years 2014 onwards are used.

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25 Market coupling is a set of arrangements which integrates several electricity markets through implicit auctions for interconnector capacity. These auctions are intended to provide more accurate price signals which enable more efficient allocations of interconnector capacity. As interconnector flows react more accurately to price signals with market coupling, restricting the historical analysis to these periods is likely to provide results that might be more informative when deriving key lessons for the future.

3.24 The criteria for each sample range is summarised in Table 3-1 below.

Table 3-1: Sample ranges for historical data analysis

Sample range	Case 0: Base case (winter peak)	Case 1: Higher Demand Restriction (winter peak)	Case 2: Higher Demand Restriction (all periods)	Case 3: Restricted timeframe (2014+)
Timeframe	1 April 2011 – 31 March 2018	1 April 2011 – 31 March 2018	All data points	1 April 2014 – 31 March 2018
Months	Core winter period (Dec – Feb)	Core winter period (Dec – Feb)	All data points	Core winter period (Dec – Feb)
Days	Working days only	Working days only	All data points	Working days only
Hours	7am – 7pm GMT/BST	7am – 7pm GMT/BST	All data points	7am – 7pm GMT/BST
Demand	Top 50% for hours above each year	Top 5% for hours above each year	Top 5% for each year	Top 50% for each year
Rationale	Replication of current historical de-rating factor methodology	Replication of Base Case with restricted demand criteria	System stress may occur outside of peak demand periods	Replication of Base Case considering only the post-market coupling period
# of observations	2,586	263	3,765	1,476

Note: Numbers of observations are presented based on the theoretical timeframe indicated in the table. However, the available price and demand data began in January 2012, and the available margin and outages data began in January 2015. Therefore, the actual number of observations used in the analyses is lower. Demand criteria is applied on the GB demand (hourly total load), available from ENTSO-E Country Package for 2012-2014 and ENTSO-E FTP for 2015-2018.

3.25 We consider multiple cases to yield a more robust view of any correlation patterns and conclusions about the benefit that interconnectors may provide to the security of supply in GB.

3.26 In practice, each of our analyses yielded very similar results across each country and across each of the sample range cases set out above.

3.27 For presentational purposes, we have elected to use the Base Case and the Netherlands as our 'default' example of results in this section. However, in the few instances where other countries or cases produce significantly different results, we note them for completeness.[26] The remaining results can be found in Appendix 1.

Price analysis

Price analysis:

Objective: Observe the contribution of interconnectors to GB security of supply in periods when wholesale prices are high (indicating a more stressed GB electricity system).

Hypothesis: In periods when prices in GB are high, interconnector flows should predominantly be in the direction towards GB to reflect their contribution to GB security of supply.

Approach: In each sample range, calculate the proportion of periods where the day-ahead prices in GB are higher than the equivalent prices in the connected countries. The proportion of these periods would indicate the level of contribution to GB security of supply.

Findings: When prices are at their highest in GB, prices in connected countries are almost always lower. This means that interconnectors enable cheaper electricity to be imported into GB from connected countries at the most critical periods nearing system stress. Hence, on the basis of price differentials, the historical analysis shows interconnectors are extremely valuable to GB security of supply.

26 This is particularly true of Ireland. As well as some particular operational issues with the Irish interconnectors, the introduction of the I-SEM and market coupling has changed the market dynamics between Northern Ireland and the rest of Europe.

3.28 Our price analysis uses day-ahead prices available from January 2012 onwards. This restricts the timeframe used for the Base Case and Higher Demand Restriction (winter peak) from seven years, as intended, to six years.[27]

3.29 Because the day-ahead prices are the most complete set of price data available for all connected countries, we use day-ahead prices in our analysis.[28]

3.30 For each scenario, we rank hourly price data by the GB price, and group observed prices into intervals of €10/MWh. We then calculate the percentage of observations in which the non-GB price was lower than the GB price within each interval. [29] This would imply that the interconnector flows will be in the GB direction at that time.

3.31 As the analysis to follow demonstrates, we observe a consistent result across **every sample range and every connected country**. When GB prices are high, it is highly likely that GB prices would be higher than the connected country. Therefore, to the extent that a high price in GB might proxy a period of system stress, interconnectors are likely to be beneficial i.e., alleviating potential security of supply concerns.

3.32 The figures below summarise the results from our price analysis. The horizontal axis is sorted into GB price buckets ranging from low prices to high prices. The lighter blue area represents the frequency of observations within each GB price bucket, as referenced on the right vertical axis and the darker blue bars represent the percentage of time that, within each GB price bucket, the GB price was higher than the non-GB price, as referenced on the left vertical axis.

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27 Data is available from ENTSO-E FTP for 2015-2018. Data for 2012-2014 is gathered from BELPEX for Belgium, EPEX for France, EnergyMarketPrice for GB and NL, SMP for Ireland, and Nordpool for Norway. All data is converted to GMT/BST time taking into account daylight savings and averaged to hourly level if given in more granular intervals. All data except GB is given in EUR/MWh. GB data is converted from GBP/MWh to EUR/MWh using daily reference exchange rate from European Central Bank Statistical Warehouse.

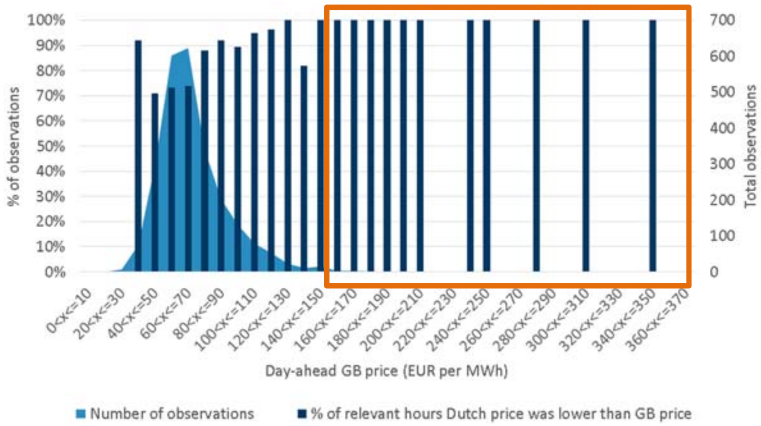
28 We recognise that interconnector flows are not perfectly correlated with day-ahead price differentials, and in practice that interconnector flows are more likely to respond to spot prices. For this reason, we undertook separate analysis in Appendix 2 that shows that day-ahead prices match the direction of interconnector flow in the sense that flow is from the lower-price zone to higher-price zone. This gives us a high degree of confidence that day-ahead prices are reasonable for our purposes.

29 Intervals are used to group data points so that there is sufficient data to compare non-GB and GB prices.

3.33 It should be noted that there are fewer observations for very high prices since periods of near system stress conditions are inherently rare. In the figures below, the gaps between darker blue bars represent buckets for which no observations exist, rather than the non-GB price being higher than the GB price.

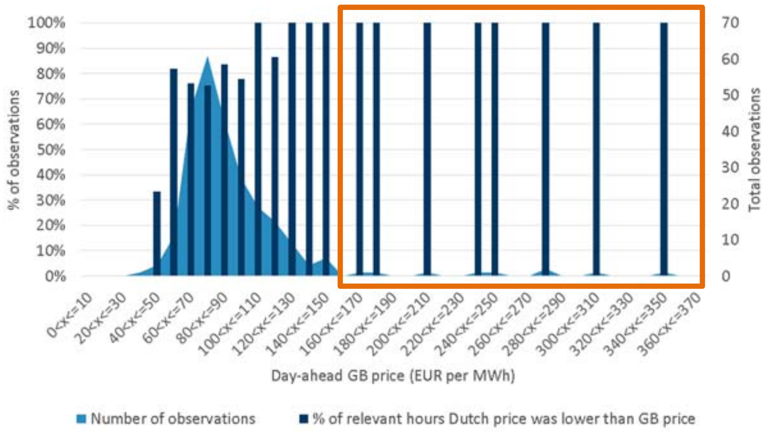
3.34 We present the results for both the Base Case and Higher Demand Restriction (winter peak) scenarios to show that this result also holds for restricted demand criteria. The results for remaining scenarios and countries are presented in Appendix 1.

Figure 3-2: Netherlands price analysis results (Base Case)



Note: The orange box represents periods that are better proxies of system stress. Source: FTI analysis; ENTSO-E FTP for 2015-2018; ENTSO-E Country Package and EnergyMarketPrice for 2012-2014.

Figure 3-3: Netherlands price analysis results (Higher Demand Restriction (winter peak))



Note: The orange box represents periods that are better proxies of system stress. Source: FTI analysis; ENTSO-E FTP for 2015-2018; ENTSO-E Country Package and EnergyMarketPrice for 2012-2014.

3.35 Figure 3-3 above demonstrates that, while the frequency of periods of very high GB prices is low (198 observations above €100 and 17 observations above €150), the price in GB in these instances is always higher than the price in any non-GB connected country. This suggests that, historically at least, interconnectors enable cheaper electricity to be imported into GB from connected countries at the most critical periods nearing system stress.

3.36 The figures above highlight a challenging trade-off, as noted above, between a smaller sample (that is a better proxy for system stress, but potentially less statistically reliable) and a larger sample (that is a worse proxy for system stress, but potentially more statistically reliable).

3.37 We also consider the fact that price spreads are likely to need to exceed a certain hurdle rate in order to make flowing electricity across the interconnector profitable, due to costs associated with technical line losses.[30] For the purposes of our analysis we have used a 3% spread to represent a 'hurdle rate.'[31] Our analysis therefore considers whether higher-than-normal GB prices would still exceed the non-GB price if the GB price had been 3% lower to reflect this.

30 Technical losses are a natural consequence of power dissipating as electricity flows through cables.

31 We understand from NGV that loss factors are 3% for BritNed and 2.313% for IFA.

3.38 The effect of the additional 3% hurdle rate varies by country. For some countries, the frequency of periods for which high GB prices are higher than the non-GB price, including the 3% spread, are identical to the frequency excluding the 3% spread. For other countries, a minor reduction in frequency is experienced, as indicated in the bold highlighting of the table below. This implies that, even with the 3% minimum spread applied, high GB prices still likely result in electricity flow towards GB, and that periods of system stress in GB are indeed met with security of supply from interconnectors.

3.39 The tables below demonstrate these results, first for all GB prices greater than €100 and then for GB prices greater than €150.

3.40 It is important we note that, whilst we use these price levels for the purposes of our analysis (given the requirement for a reasonable number of data points to draw on), we do not consider that they represent prices associated with system stress. Therefore, the percentage factors in the tables below represent, at the most, an extreme lower bound of the historical interconnector contribution in each case.

Table 3-2: Percentage of periods when non-GB price was lower than GB price for periods where GB price exceeded €100 and €150

	When GB price > €100 including 3% spread				When GB price > €150 including 3% spread			
	Base Case	Higher Demand Restriction (winter peak)	Higher Demand Restriction (all periods)	Restricted timeframe (2014+)	Base Case	Higher Demand Restriction (winter peak)	Higher Demand Restriction (all periods)	Restricted timeframe (2014+)
Belgium	85%	82%	87%	81%	88%	78%	93%	92%
Norway	90%	92%	93%	98%	94%	100%	91%	100%
France	81%	80%	84%	78%	88%	78%	93%	92%
Ireland	38%	47%	43%	51%	59%	67%	60%	67%
Netherlands	93%	97%	94%	95%	100%	100%	100%	100%
Germany	93%	90%	96%	95%	94%	89%	98%	100%
Denmark	90%	90%	93%	98%	94%	100%	91%	100%
Average # of observations	*161*	*49*	*324*	*95*	*15*	*8*	*51*	*11*

Note: Sensitivity calculated by decreasing GB price by 3%.
Source: FTI analysis, ENTSO-E FTP for 2015-2018, ENTSO-E Country Package, BELPEX, EPEX, EnergyMarketPrice and NordPool for 2012-2014.

3.41 These results highlight the benefit of interconnectors to the GB electricity market, providing access to lower prices during instances of extreme price spikes and supplying electricity into GB during periods of potential system stress. We note that:

- When the GB price is greater than €150, all countries with the exception of Ireland show prices lower than GB at least 89% of the time across all four scenarios;
- Adding a 3% price hurdle does not change this result for Denmark, the Netherlands, Germany and Norway;
- For Belgium and France, the additional 3% price hurdle has a minor impact on the results. However, the GB price is still higher than the non-GB price at least 78% of the time that the GB price is higher than €150;
- Although Ireland is a clear outlier, the Irish price is still lower than the GB price at least 61% of the time that the GB price is higher than €150 and 59% when a 3% price spread is included;
- When the GB price is greater than €100, all countries, except for Ireland, show prices lower than GB at least 83% of the time across all four scenarios; and
- The results from Denmark/Norway are not affected by applying a 3% price spread when the GB price is greater than €100, and the remaining countries show a slight decrease in the percentage of time that the GB price is higher than the non-GB price.

3.42 In summary, when prices are at their highest in GB, the prices within interconnector countries are almost always lower. Hence, when using price differentials alone to understand whether GB could expect to import, **historical analysis shows interconnectors are highly valuable to GB security of supply.**

Margin analysis

Objective of analysis:
Observe the contribution of interconnectors to GB security of supply in periods when margins are low (indicating a more stressed GB electricity system).

Hypothesis:
(1) In periods when margins in GB are low, interconnector flows should predominantly be in the direction towards GB to reflect their contribution to GB security of supply.

(2) In periods when margins in GB are low, prices in GB should predominantly be higher than prices in the connected countries.

(3) In periods when margins in GB are low, connected countries would have sufficient margins on average to be utilised by additional interconnectors, should they be built.

Approach to analysis:
(1) Calculate the proportion of periods where GB capacity margins (excluding wind generation and interconnector capacity) are lower than the margins in the connected countries. The proportion of these periods would indicate the level of contribution to GB security of supply.

(2) Calculate the proportion of periods where GB prices are higher than non-GB prices during periods of low margins in GB.

(3) Calculate the average capacity margins in connected countries during periods of low margins in GB.

Summary of findings:
(1) When margins are at their lowest in GB, margins in connected countries are almost always higher than GB which indicates potential excess capacity available to be imported into GB.

(2) When margins are at their lowest in GB, prices in GB are almost always higher than connected countries which indicates that flows will be in the direction towards GB.

(3) When margins are at their lowest in GB, there are sufficient margins in connected countries which indicates that new interconnectors would be able to facilitate additional electricity flow into GB during periods of GB system stress.

3.43 Excess capacity, referred to as margin, might also be another suitable proxy for identifying periods near system stress. For the purpose of our analysis, we calculate margin as the difference between available generator capacity and demand, divided by demand. Using this definition, a higher margin means that there is more excess capacity in the system and a lower margin means that there is less excess capacity in the system and that, everything else being equal, there is a greater probability of system stress. Available generator capacity is the difference between total installed capacity and total unavailable capacity, which is the sum of forced and planned outages.

3.44 Available generator capacity is calculated as follows:

- for all generation types provided in ENTSO-E (except wind),[32] it is the difference between total installed capacity and total unavailable capacity, which is the sum of all registered unique outages; and
- for wind, available capacity equals actual generation output, to reflect the fact that marginal cost of running a wind farm is sufficiently low and generator availability is determined by weather conditions.

3.45 The margin analysis is undertaken using two different approaches:

- first, we take all generation types for the calculation of available capacity (as total installed capacity except wind, minus total outages except wind, plus actual wind generation); and
- next, we exclude wind generation in the calculation of available capacity (total installed capacity except wind minus total outages except wind).

3.46 Both datasets focus only on domestic capacity and exclude interconnector contribution to capacity. This is to isolate the contribution of interconnectors from margins in each period which allows a better comparison in margins between the two connected countries. Hence, 'margin' in this context should be taken to mean margins excluding interconnector capacity.

Correlation between margins in connected countries

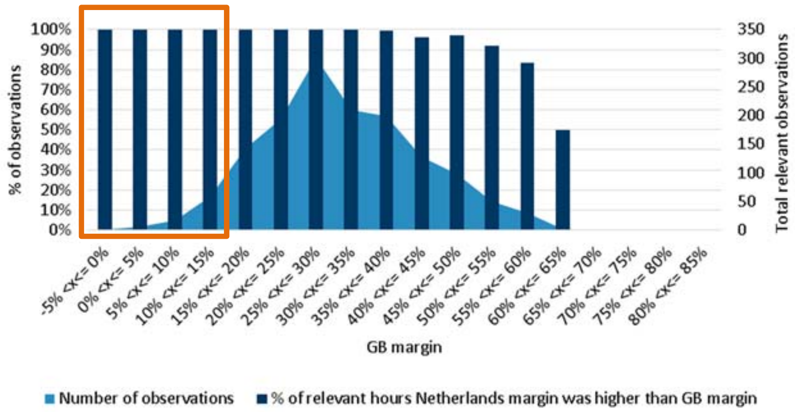
3.47 The margin results, both with and without wind generation, show that when GB margin is low (i.e. there is limited excess capacity in GB generation), the margin is almost always higher in other countries in Europe. In the particular case of France, the GB margin is still most often smaller than the French margin, but to a lesser degree than the other countries analysed.

32 Our estimate of available generator capacity includes large solar generation as recorded in the ENTSO-E dataset.

3.48 The figures below illustrate these results. The horizontal axis is sorted into GB margin buckets ranging from low margin (high probability of stress) to high margin (lower probability of stress). The lighter blue area represents the frequency of observations within each GB margin bucket, as referenced on the right vertical axis and the darker blue bars represent the percentage of time within each GB margin bucket that the non-GB margin was higher than the GB margin, as referenced on the left vertical axis.

3.49 Figure 3-4 below illustrates this result for the Netherlands and France for the Base Case, including wind generation. France is shown as it does not follow the same pattern as the other six countries. Further, we show only the results including wind generation because this is a more accurate representation of true system stress. Full results across all countries and scenarios, both including and excluding wind generation, can be found in Appendix 1.

Figure 3-4: Netherlands margin analysis, including wind generation (Base Case)

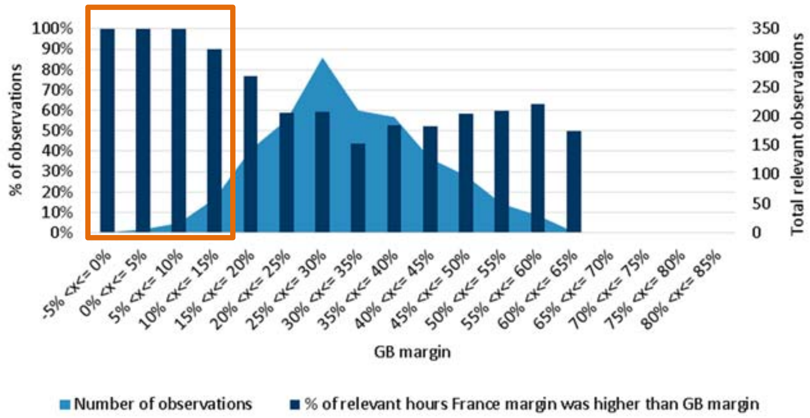


Note: The orange box represents periods that are better proxies of system stress.
Source: FTI analysis; ENTSO-E FTP.

3.50 GB's relationship to France, with respect to margin, is slightly different. As shown below, for some levels of GB margin, the percentage of time that the margin in France is higher than the margin in GB is around 50%. This result is influenced by France's 2016 crisis of concurrent nuclear reactor shutdowns due to safety concerns, resulting in GB being a net exporter of electricity to France in several consecutive months in winter 2016/17, for the first time since the winter of 2009/10.

3.51 However, the results below show that, as the GB margin becomes very low and the system is under high stress, France's margin is almost always higher. This is evidenced by the first four bars on the left-hand side of Figure 3-5 (recognising a limited sample size) which show that the French margin is higher than the GB margin for the vast majority of periods when the GB margin is equal to or less than 15% (and indeed is higher in **all** periods where GB margin is equal to or less than 10%).

Figure 3-5: France margin analysis, including wind generation (Base Case)



Note: This is the same as Restricted timeframe (2014+) as margin data starts in January 2015. The orange box represents periods that are better proxies of system stress.
Source: FTI analysis, ENTSO-E FTP.

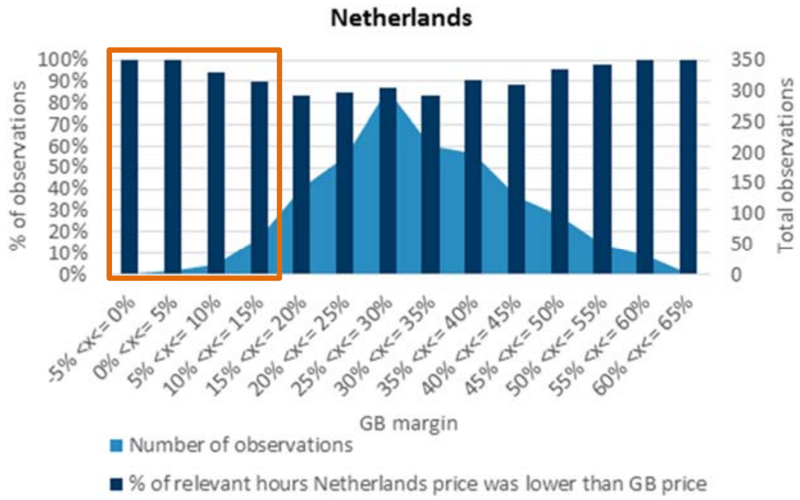
3.52 What this analysis does not show is that interconnectors do not only draw on the margin of the connected country, but also from all electricity markets adjacent to the connected country due to a large degree of European interconnection. For example, if the GB electricity market was to experience a System Stress Event, spare generation from Italy could contribute to GB security of supply by generating electricity to flow into France allowing, in turn, France to export to GB. This is an aspect of interconnector contribution to security of supply which is difficult to capture (even the most complex modelling techniques need to have a geographical boundary which is likely to be less than the entirety of the actual synchronous system) but should be borne in mind when setting de-rating factors and considering scenarios and sensitivities.

Correlation between prices and margins

3.53 In addition to our analysis that considers how GB margin relates to the non-GB margin during periods of low margin in GB, we also consider how GB prices relate to non-GB prices during periods of low margin in GB. The purpose of this analysis is to assess whether periods of low margin in GB are accompanied by market price signals that would indicate interconnector flows toward GB.

3.54 We compare the prices in the Netherlands to prices in GB across various levels of GB margin, as presented in Figure 3-6 below. The remaining scenarios exhibit very similar results and are presented in Appendix 1.

Figure 3-6: Netherlands price vs. margin analysis (Base Case)



Note: The orange box represents periods that are better proxies of system stress. Source: FTI analysis; ENTSO-E FTP for 2015-2018; ENTSO-E Country Package and EnergyMarketPrice for 2012-2014.

3.55 These results show that, when margin is very low in GB, as indicated by the leftmost four dark blue bars, the price in GB is higher than the Netherlands price most of the time.

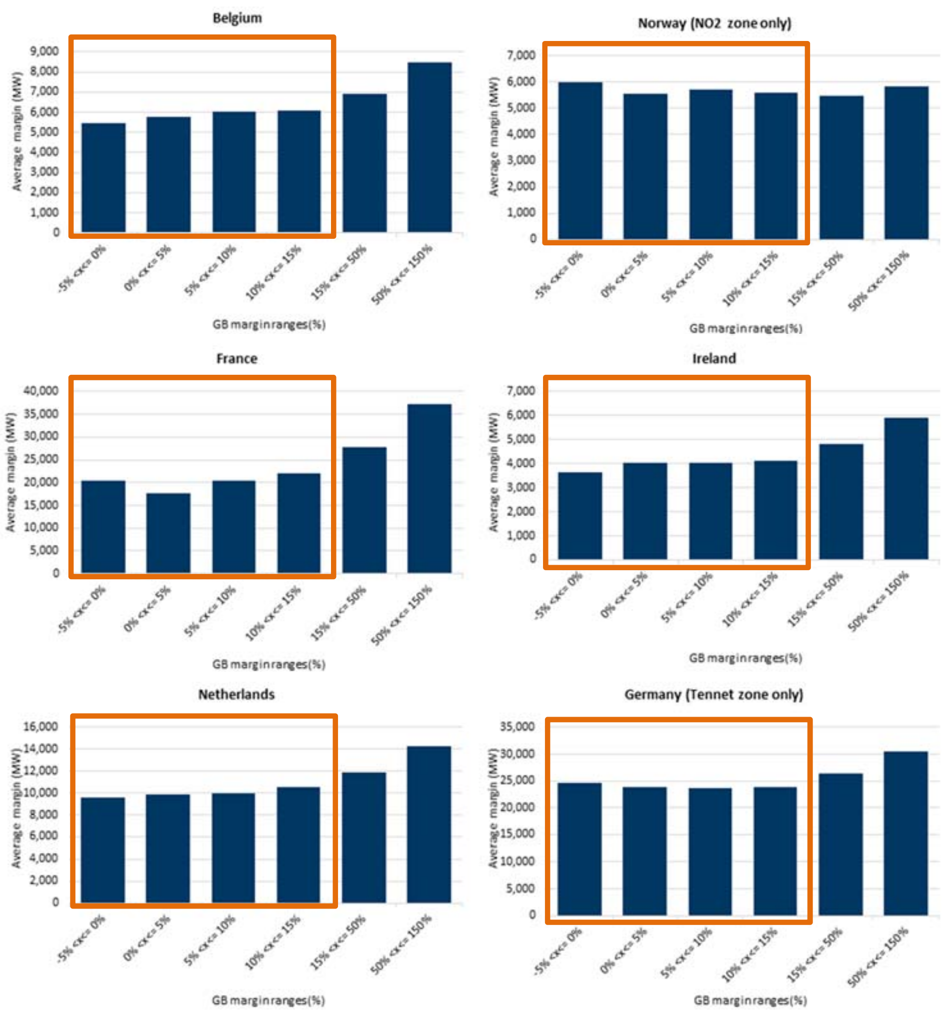
3.56 The set of margin analyses above can be used as a proxy for system stress, demonstrating that, when the GB system is near system stress as represented by very low margins on the left-hand side of the figures above, it is highly likely to be more stressed than the connected country. This means that in a System Stress Event, interconnectors are likely to flow towards GB, providing benefits to security of supply.

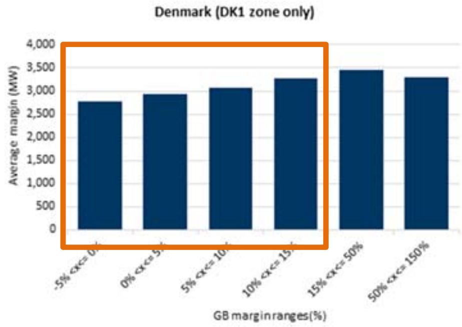
Capacity margins in connected countries when GB margins are low

3.57 We next consider the quantity of margin that is available to be imported into GB during periods of near system stress. As discussed in Section 2, some stakeholders have postulated that, as more interconnectors are developed between GB and the connected countries, the additional interconnector capacity becomes redundant as electricity is exported from a constrained pool of excess capacity.

3.58 Our analysis is presented in Figure 3-7 below. This analysis sets out the average margins of each connected country across the range of GB margins (the vertical axis of each chart shows the non-GB average margin, in MW terms, whereas the horizontal axis shows the GB margin, in percentage terms).

Figure 3-7: Average excess non-GB margin over GB margin





Source: FTI analysis; ENTSO-E FTP.

3.59 These results suggest that, in each connected country, there is a **considerable amount of excess capacity when GB margins are low**, as indicated by the orange boxes. This analysis in effect highlights the 'cushion' in capacity available in connected countries when GB margins are low.

3.60 For example, in France, the results show that excess capacity is available to be imported into GB at all levels of GB margin. The magnitude of the excess capacity in near system stress situations suggests that there is security of supply benefits to building new interconnectors between GB and the countries analysed. In France there is over 15GW of excess capacity during periods of low GB margins and in Germany (in the Tennet zone only) there is over 20GW of excess capacity. This means that **new interconnectors would be able to facilitate substantial additional electricity flows into GB during periods of GB system stress, suggesting that the postulated 'saturation' effect would be limited**.

3.61 Importantly, this analysis does not recognise the benefits of interconnectors from a pan-Continental European perspective. Indeed, while margins in the connected country can contribute to GB security of supply, interconnectors also **facilitate electricity flows to GB from countries neighbouring the connected country, not just the connected country itself, further increasing the capacity available for interconnectors to import into the UK**.

Correlation between supply-side indicators

Objective of analysis:

Observe the likelihood of coincident (1) forced generator outages or (2) low wind generation. If forced outages and low generation are considered to lead to a System Stress Event, a coincident event could potentially limit the contribution of interconnectors to GB security of supply.

Hypothesis

(1) The probability of forced generator outages in each period is predominantly independent in each country. Hence, we do not expect to observe high correlations of forced generator outages.

(2) Low wind availability should not be a key driver to system stress as this would reflect fundamental unaddressed security of system issues with that country. Nevertheless, even if it does, we do not expect to see high correlations of wind generation when there is low wind availability.

Approach to analysis

(1) We measure the correlation of forced generator outages between GB and each connected country.

(2) We measure the correlation of wind generation between GB and each connected country.

We use the 'Base Case' sample range for each analysis. For the wind analysis, instead of observing periods of the top 50% of GB demand, we observe periods of the lowest 15% of GB wind generation in each year.

Summary of findings

(1) There is no high correlation of forced generator outages between GB and each connected country, indicating that there is a low probability of a high coincident force outages.

(2) There is no high correlation of low wind generation between GB and each connected country, indicating that there is a low probability of a high coincident low wind availability.

Both of these factors serve to protect the contribution of interconnectors to GB security of supply.

3.62 In addition to the price and margin analysis above, we also consider it valuable to examine some supply-side factors directly. As some commentators consider that coincident events such as forced generator outages and low wind availability would limit the contribution of interconnectors to GB security of supply, we consider the:

- correlation between forced generator outages; and
- correlation between low wind generation

between GB and each connected country.

Correlation between generator outages

3.63 The benefit of interconnectors is reduced if the two connected countries experience reductions in supply concurrently. Supply reductions (not related to non-dispatchable intermittent supply) are a potential cause of a System Stress Event, where a plant is unexpectedly offline due to technical failure or some other unforeseen circumstance. We do not undertake our analysis on planned generator outages as we assume that generators would not plan an outage over periods where system stress is more likely to occur.[33]

3.64 To assess the likelihood that generator outages in GB and the connected countries occur simultaneously, we calculate correlation coefficients both (i) as an aggregate of generation types and then (ii) separately for a subset of peaking plants.[34] A close to zero or negative correlation coefficient would imply that forced generator outages across GB and the non-GB country do not occur simultaneously, and thus everything else being equal, additional capacity is available through interconnectors to compensate for any unexpected general supply side restrictions in GB, indicating system stress.

3.65 Our analysis also isolates peaking plants because this specific type of plant tends to run only during periods of peak demand, contributing to security of supply. If forced outages of peaking plants in GB and neighbouring countries were correlated, this would mean that in the event of a System Stress Event, there is a greater likelihood of peaking plants in GB and neighbouring countries being unavailable at the same time.

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33 The outages dataset is the same as described in the margin analysis with two filtering differences: we include wind outages but limit the dataset to outages registered as "forced" only. In both datasets, only "Active" outages are included.

34 Peaking generator fuel types include oil and gas.

3.66 The figures that follow demonstrate that correlation coefficients are low, suggesting no strong correlation of forced generator outages between GB and the connected countries (whether for all generator types or for peaking plants in isolation).

Figure 3-8: Forced outages correlation coefficient for all plants and for peaking plants

Note: 2015 is not a complete year as data starts in January 2015; includes oil and gas peaking plant fuel types only.
Source: FTI analysis; ENTSO-E FTP.

3.67 The lack of strong correlation between generators (especially peaking generators) in connected countries suggests that forced outages are unlikely to produce a correlated stress event. Hence, this indicates that coincident low generator availability in GB and the connected countries are highly unlikely to limit the contribution of interconnectors to GB security of supply.

3.68 Further, there is no reason to believe that forced outages are likely to become more correlated over time.

Correlation between wind output

3.69 This analysis calculates the correlation coefficient between actual wind generation in GB and in a given country when wind generation in GB is low (as an indication of periods where low wind generation might contribute to system stress).

3.70 For this analysis, we use a similar sample range as the Base Case. The only difference was that to isolate only periods when wind generation was low, we calculated the correlation over the periods with the lowest 15% of GB wind generation in each year instead of the top 50% of demand. The results are set out in Table 3-3.

Table 3-3: Wind correlation coefficient (variant of the Base Case)

	Belgium	Norway	France	Netherlands	Germany	Denmark
All	0.21	0.24	0.35	0.18	0.14	0.10
2015	0.27	0.06	0.38	0.28	0.23	0.19
2016	0.64	0.50	0.56	0.27	0.01	0.15
2017	0.05	0.22	0.12	0.26	0.15	0.11
2018	0.27	-0.01	-0.04	0.35	0.35	0.41

Note: 2015 is not a complete year as data starts in January 2015. The total number of observations for each country pair is 402.
Ireland results excluded due to incomplete wind data.
Source: FTI analysis; ENTSO-E FTP.

3.71 The wind correlation coefficients between GB and each connected country appear to be low to moderate.[35] Assuming low wind generation could cause a System Stress Event,[36] there does not appear to be a high probability of coincident low wind generation.

Conclusions

3.72 Using historical data to assess the likelihood that a neighbouring market will be able, and willing, to export electricity to Britain over an interconnector during a GB system stress event suffers from one significant drawback. That is that there have been no GB stress events to analyse and so it is not possible to observe what has occurred previously. Therefore, our historical analysis has considered proxies for system stress events, and we have analysed the likelihood of coincidence of system stress between GB and connected (or potentially connected) countries. Our hypothesis is that a neighbouring country should be willing to export to GB at a time of system stress in GB if it has sufficient available generation to do so and that the market prices in the neighbouring market are lower than those observed in GB at that point in time meaning it is economically advantageous to export to Britain.

3.73 The two key metrics used to proxy for system stress were:

- prices - where we assumed that "high" prices in GB are indicative of a relative tight GB system and one that is close to system stress. We then assessed, at those times of high GB prices, how frequently the price in the neighbouring country was even higher - therefore indicating that the neighbouring country would be unlikely to export to GB at that time.
- margins (which is a measure of the excess of generation capacity relative to a country's demand at a given point in time). We assessed those occasions when there was relatively little spare available generation capacity relative to demand in GB and considered whether there was sufficient spare capacity in neighbouring markets at those times to be able to supply electricity across interconnectors.

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35 Under this sample range, there appears to be moderate correlation in 2016 for Belgium, Norway and France.

36 We consider the possibility for low wind generation to cause a System Stress Event to be unlikely as it would reflect greater fundamental concerns if it does so. However, it may contribute to system stress if it occurs in combination with various other low probability events.

3.74 A critical issue when examining the data was where to set the level that would be indicative of a potential stress event in GB. In the context of prices, using a relatively high threshold price for the GB market as indicative of a stress event has the advantage of focussing only on those periods when the GB market was closer to a stress event. The key disadvantage is that, as these are relatively rare events, this reduces the number of observations on which to draw conclusions. Conversely, setting it too low, while having more observations, runs the risk of distorting the analysis by including periods when the GB market was not under a near stress event conditions. The same issue was true of other metrics. To mitigate this problem, we tested a range of different thresholds and sample sizes.

3.75 In summary, these correlations show that:

- when the GB price is high, the non-GB price (i.e., the price in the connected country) is almost always lower; and
- when the GB margin is low; the non-GB price (i.e., the margin in the connected country) is almost always higher.

3.76 Table 3-4 below highlights that the current de-rating factor estimates do not reflect the significant contribution of interconnectors to GB security of supply based on historical evidence of prices.[37]

[37] Analysis of margins shows similar results; a full set of results are provided in appendices.

Table 3-4: Analysis of implied DRFs for current and existing interconnectors

Interconnector	Current assigned de-rating factor	Based on price analysis [1]
Ireland	33%	55-63%
France	66-71%	74-89%
Belgium	50%	74-89%
Netherlands	43%	96-96%
Norway	87%	87-96%
Germany	n/a	85-96%
Denmark	n/a	87-96%

Source: BEIS Capacity Market Auction Parameters for 2022/23.
[1] Price analysis is based on quantifying the proportion of periods where the GB price is higher than EUR150 and the non-GB price is at least 3% lower. For comparative purposes we have made a conservative assumption that technical availability issues would further reduce the probability by 4% for each country.

3.77 Table 3-4 shows that interconnector de-rating factors are significantly lower than would be implied by a comparison of prices between connected countries. In particular, we would note that, for periods when GB demand and prices are both high – indicating system stress – the GB price is almost always higher than prices in the non-GB country. Since, fundamentally, interconnector flows are driven by price differentials, this market signal would suggest interconnectors can contribute significantly to GB security of supply.

3.78 Overall, therefore, drawing on the historical evidence alone, it would seem that the likelihood of neighbouring countries being able to provide support to GB at a time of system stress is very high. Indeed, the historical evidence suggests that the current levels of de-rating factors, as also indicated in the table above, are unduly conservative (resulting in higher than necessary costs for consumers).

3.79 As discussed above, there are limitations to the historical analysis, in particular around the issue of small sample sizes (as noted above, near System Stress Events are extremely rare) and the question of how interconnectors' contributions might change in the future (given the auction looks four years ahead).

3.80 However, given the significant difference between (i) the current de-rating factors applied to existing interconnectors; and (ii) the implied contribution of those interconnectors based on historical analysis (as shown above), it can only be concluded that the current de-rating factors are predicated on a very different energy landscape to that which currently exists.

3.81 Brexit is a process that may well significantly change the energy network landscape (we discuss this further in Section 4 below). However, one could make the observation that relations would need to deteriorate significantly (i.e., to an extent not observed in modern history) for our neighbouring countries to choose actively not to support the GB system in its moment of critical need during periods of domestically available capacity and appropriate price signals.

4. Critique of current forward-looking methodology for interconnector de-rating factors

4.1 As noted in Section 2, interconnector de-rating factors are currently assessed, in principle, using a 'hybrid' methodology which reflects both (i) analysis of historical interconnector performance and (ii) forecasts of future interconnector performance.

4.2 In Section 3 above, we set out our analysis of the contribution of interconnectors to GB security of supply under conditions that proxy system stress, based on *historical* data.

4.3 In this section of the report, we consider how *future* interconnector de-rating factors are set and whether this is appropriate.

4.4 In this section, we:

- provide an overview of the forecasting process;
- summarise and critique the modelling work undertaken by the Delivery Body,[38] in particular how the use of a 'base case' and stress testing seems to decrease de-rating factor estimates;
- set out the steps taken by the PTE including a critique on the way it uses scenarios as well as its recommendation to drop the historical floor to set de-rating factors;
- comment on the decision made by the Secretary of State, who is able to exercise considerable judgement without the requirement to provide justification for the selection; and finally
- set out our conclusions on the grounds for re-considering the interconnector de-rating factor methodology.

38 It is outside the scope of this report to provide a detailed review of the modelling methodology.

Overview of the current process

4.5 The forecast de-rating factor for each interconnector is calculated under the CM Rules, which state:[39]

> *"The Forecasted De-Rating Factor is to be based on a set of de-rating factors for Electricity Interconnectors produced by the Delivery Body using stochastic modelling methodology.*
>
> *The Delivery Body must provide those de-rating factors to the Secretary of State, together with the scenarios on which they are based.*
>
> *The Secretary of State will make a determination of the Forecasted De-Rating Factor for Year Y, taking those de-rating factors into consideration and after consulting such persons of proven technical expertise as the Secretary of State considers appropriate."*

4.6 The current process can be summarised as follows:

- First, the Delivery Body conducts a modelling exercise using a forecasting model called the BID3 model. The BID3 model is a pan-European dispatch model that simulates hourly demand (using historical weather patterns) and generation under different scenarios. The scenarios include a Base Case defined by the Delivery Body, as well as consulted Future Energy Scenarios ("FES") and other sensitivities and stress tests. The results of the Delivery Body's modelling are set out in the Electricity Capacity Report ("ECR") which is submitted to BEIS and published. The ECR sets out ranges of de-rating factors for each interconnector.[40]
- Second, a PTE,[41] sponsored by BEIS, qualitatively assesses the Delivery Body's modelling and makes a recommendation to the Secretary of State regarding interconnector de-rating factors. This recommendation is expressed as a range of figures for each interconnector. The PTE's report is published.[42]

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39 Ofgem (2018): "Consolidated version of the Capacity Market Rules," Schedule 3A.

40 National Grid (2018): "EMR Electricity Capacity Report."

41 Current members include Michael Grubb, Andris Bankovskis, Guy Doyle, Goran Strbac and Derek Bunn.

42 BEIS (2018): "Panel of Technical Experts - Independent Report on National Grid's Electricity Capacity Report 2018."

- Third, the Secretary of State or applicable representative decides on the point de-rating factor estimate for each interconnector. In the most recent CM Auction, this determination was in the form of a letter signed by The Rt Hon Claire Perry MP, Minister of State for Energy and Clean Growth.[43]
- The ECR, the PTE's report and the Secretary's determination are all published, however the process itself involves discussions between BEIS, the Delivery Body, Ofgem and BEIS's PTE throughout.[44]

4.7 The ECR 2018 states the future of potential flows through interconnectors "*is very complex and as a consequence, there is no single answer to the question of what can be assumed to flow through the interconnectors at times of system stress*."[45]

4.8 We agree that interconnector flows are complex and that there is no 'single answer' to the question of flows at times of system stress. This is one of the reasons that our analysis in Section 3 above covers a range of different metrics and methodologies.

4.9 In the remainder of this section we highlight some key concerns regarding the transparency and overall robustness of the process which reduce stakeholder confidence, and also point to some areas of the overall approach which may lead to **overly conservative interconnector de-rating factors undervaluing their significant contribution to security of supply.**

The Delivery Body's modelling

4.10 To calculate the overall capacity to be secured in auctions, the Delivery Body uses a Dynamic Dispatch Model ("DDM"). In the DDM, interconnector flows are "*determined by probabilistic modelling in a similar way to generation technologies, i.e. based around a set of flow distributions obtained from our own pan-European electricity dispatch market modelling using BID3.*"[46]

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43 BEIS (2018): "Capacity Market Auction Parameters 2018, Letter from The Rt Hon Claire Perry MP to Fintan Slye."

44 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018."

45 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018."

46 National Grid (2018): "EMR Electricity Capacity Report," page 14.

4.11 The BID3 model is a complex, commercially available model. It is a dispatch model based on short-run marginal costs, simulating hourly demand and renewable generation based on historical weather patterns, and then allocating flows between countries using linear programming to optimise the cost of generation to meet demand across all modelled countries.

4.12 Whilst the BID3 model used by the Delivery Body is clearly an industry-standard modelling tool, we would observe that this model (and other similar models) is typically used in contexts where a party wishes to understand trends and dynamics over a long time period (for example, evaluating whether an investment (in, say, a generator) will provide a reasonable return over a period of 20-30 years). In our experience, such models are less well suited to assess the market dynamics of particular 'one-off' events (such as the kind of stress event which the CM was designed for).[47]

4.13 Further, as we explain below, the ranges of interconnector performance predicted by the model are relatively large,[48] meaning that their informational content is low, compared to a modelling process that provides tighter ranges. Whilst, to some degree, these ranges are driven by the sensitivities used, they serve to highlight the point (made in Section 2 of this report) that forecasting the performance of an interconnector under a System Stress Event – in four years' time – is clearly very dependent on input assumptions in the modelling. In the subsections below, we comment on:

- the scenarios used in the modelling; and
- the stress tests used in the modelling.

Consulted FES scenarios have a minor role to play and the Base Case is not transparent

4.14 In the Delivery Body's modelling, five different scenarios are reflected. The 'baseline' principal scenario is the Base Case scenario. The full details of this scenario are not made transparent.

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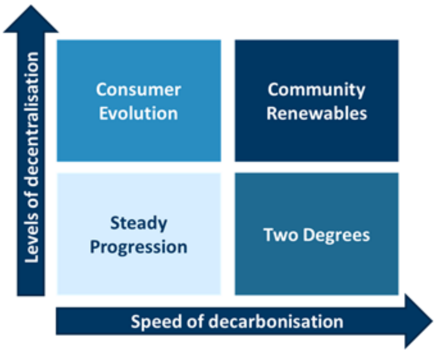
47 It is outside the scope of this report to comment in detail on the BID3 model. However, we would note two potential concerns. Firstly, we do not understand the boundaries of the BID3 model. If it only covers (say) Western Europe, then it might overestimate the risks of coincident stress events. Second, it may be underestimating the option value of storage (i.e., a hydro storage generator in Norway opting not to produce on a given day, because the expected price the next day is higher).

48 See Figure 2-1 in Section 2 for a summary of how ranges have widened.

4.15 In addition to the Base Case scenario, there are four FES scenarios, which are driven by stakeholder feedback. The Delivery Body considers them to be holistic, credible and plausible scenarios. The consultation process regarding the scenarios is transparent, with published outputs. The four scenarios are illustrated in Figure 4-1 below.[49]

Figure 4-1: FES 2018 scenarios



Source: National Grid: Electricity Capacity Report 2018.

4.16 The FES scenarios therefore represent different ways in which the energy system could evolve and are characterised by 'level of decentralisation' and 'speed of decarbonisation'. In our view, they serve as valuable elements of the methodology, reflecting uncertainty in the long-term future of the energy system. However, the PTE notes that the role of the FES scenarios in the ECR calculations are "*actually minor*" and the "*crucial methodological element for the assessment of the capacity to secure is the short-term Base Case, together with its sensitivities.*"[50]

4.17 As we explain further below, the (Base Case) sensitivity analysis plays a very large role in the range that the Delivery Body produces, which serves to reduce the influence of the FES scenarios.

[49] Further information on scenarios can be found in the National Grid EMR Electricity Capacity Report, 2018.

[50] BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018," page 38.

4.18 This means, therefore, that whilst there are five scenarios used (the Base Case plus the four FES scenarios), the Base Case is the critical scenario for the purposes of determining interconnector de-rating factors. Whilst an in-depth query into the mechanics of the Delivery Body's modelling is outside of the scope of this report, it seems to us to be inappropriate to have interconnector de-rating factors so dependent on a single Base Case that is neither transparent nor the result of any stakeholder engagement.

4.19 We would therefore fully agree with the PTE's recommendation of "*full and transparent disclosure of the construction of NG's Base Case in the ECR, given that it represents NG's view rather than that the whole industry as represented in the FESs and plays a dominant role in the analysis*."[51]

Stress tests and results

4.20 In broad terms, interconnector de-rating factors are estimated for each scenario (i.e., Base Case plus the four FES scenarios) and each country by:

- identifying hours where GB demand exceeds domestic generation (excluding interconnector flows); and
- within those hours, calculating the average flow as a percentage of capacity.

4.21 In addition, a stress test is used. In the '5% stress test', demand across Europe is increased by 5% and demand in Ireland is increased by 10%. The forecast range for interconnector performance therefore represents the range observed across ten scenarios: the Base Case, plus four FES scenarios, each with and without the 5% stress test.

4.22 According to the Delivery Body, the 5% stress test was discussed and agreed with the PTE. The Delivery Body states that the de-rating factors are not very sensitive to the exact value selected.[52]

4.23 The Delivery Body also further notes that:

- the stress tests are intended to "*adjust for detailed issues not included in the modelling such as random variation in demand and generation and local network issues, such as constraints within countries*."[53]; and that

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51 Note: NG refers to National Grid. BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018." page 36.

52 National Grid (2018): "EMR Electricity Capacity Report."

53 National Grid (2018): "EMR Electricity Capacity Report." page 10.

- the forecast range is simply the highest to the lowest of the 5 scenario runs under the non-stress and 5% stress conditions.

4.24 Table 4-1 below shows the overall results. For each country, the results are colour-coded with the highest values appearing in green and the lowest values appearing in red. The extreme lower end of the range for each country is highlighted.

Table 4-1: Overall modelling results for interconnector de-rating factors

Country	No sensitivity					5% sensitivity				
	BC	CR	TD	SP	CE	BC	CR	TD	SP	CE
Ireland	42	26	**24**	26	30	36	31	30	31	37
France	**59**	77	81	85	86	68	73	77	79	77
Belgium	36	55	57	67	65	**35**	39	43	44	49
Netherlands	**27**	41	45	62	57	28	31	33	39	40
Norway	100	98	98	98		92	93	93	**90**	

Source: PTE Independent Report on National Grid's Electricity Capacity Report, 2018.
Note: In the table above, "BC" refers to Base Case, "CR" to Community Renewables, "TD" to Two Degrees, "SP" to Steady Progress and "CE" to Consumer Evolution.

4.25 We highlight two high-level concerns we have with the methodology below.

4.26 First, the stress tests are asymmetric. Whilst the Delivery Body says the 5% stress test does not reduce implied de-rating factors in all scenarios,[54] the overall pattern is that the majority of the low values for each country (except Ireland) are driven by the 5% sensitivity. This is shown clearly by the colour-coding in Table 4-1 above.[55] The overall range of results is therefore heavily influenced by an asymmetric and arbitrarily chosen 'downside' factor, which is not the case for other CMU classes.

[54] The 5% stress test reduces the de-rating factor in 18 out of 24 cases. Of the 6 exceptions, 4 are in respect of Ireland.

[55] For Norway, there are 8 results, and 4 out of 4 of the lower half of the results are due to the 5% sensitivity. For France, Belgium and the Netherlands, there are 10 results, and 4 out of 5 of the lower half of the results are due to the 5% sensitivity.

4.27 Second, we would note that, in the absence of the 5% sensitivity, there are three countries (France, Belgium and the Netherlands) where there appears to be a discontinuity between the Base Case and all the FES Scenarios (i.e., a difference of some 20 percentage points). To the extent that the FES scenarios represent four stylised versions of the future GB energy landscape, it is surprising that the Base Case results are clearly very different from any of the FES scenarios.

Panel of Technical Experts

4.28 The PTE is an independent panel of technical experts which scrutinises and performs quality assurance on the analysis carried out by the Delivery Body.[56]

4.29 In recent years the PTE has published a report where (in respect of interconnector de-rating factors) the range of de-rating factors produced by the modelling is used as a basis for a set of recommendations to the Secretary of State.

4.30 Although it presumably is within the PTE's remit to narrow the range of modelling outputs – should they feel it appropriate – they have not done so in any of the four previous auction parameter reports.[57] In our view, this represents a 'missed opportunity' for the PTE to overlay some critical analysis of the range of possible de-rating factors produced by the Delivery Body's modelled scenarios, which in turn would provide more guidance to the Secretary of State.

4.31 Rather, the PTE have made two key recommendations in respect of interconnector de-rating factors:

- As noted above, for each country there are ten different de-rating factor modelling outputs. The PTE has taken a view that different 'ends' of the range for each country can be taken as a proxy for different Brexit scenarios; and
- The PTE has recommended removing the historical 'floor'.

4.32 We discuss each of these below.

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56 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018."

57 In 2015, the PTE widened the range for Ireland, from the original Delivery Body modelled range of 2-10% to 2-25%.

Brexit and scenarios

4.33 The Delivery Body's modelling assumes continued market harmonisation between the UK and Europe once the UK has left the European Union.[58] However, the PTE have noted that:

> *"the degree to which interconnectors contribute to our energy security could be impacted by Brexit and that the de-rating factors they are assigned cannot be adjusted after capacity agreements for these resources have been granted. We therefore recommend that the Secretary of State considers the possible impacts of Brexit when setting interconnector de-rating factors for the T-4 auction this year."*[59]

4.34 The PTE then recommends a 'split' in the de-rating factor ranges for each country for the T-4 Auction, with:

- **higher** de-rating factor values corresponding to **close GB and EU market integration**, amongst other factors. Close EU integration could include intra-day electricity trading, TSO access to balancing markets, security access to strategic reserves, and/or participation in the EU Risk Preparedness Regulation, with respect to neighbouring countries, all of which are associated with the EU Internal Energy Market and/or the EU's Clean Energy Package; and
- **lower** values reflecting **looser EU integration**.

4.35 The PTE have therefore taken a spectrum of de-rating factor results for each country (driven by a combination of different FES scenarios and sensitivities) and then split the spectrum, assigning lower values to a 'loose' EU integration assumption and higher values to a 'close' EU integration assumption.[60]

58 National Grid (2018): "EMR Electricity Capacity Report," page 5.

59 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018," page 30.

60 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018," page 18.

4.36 Our understanding of the PTE's view is that under scenarios which are (i) environmentally driven and (ii) have closer integration, the security of supply benefits of interconnectors will be understated in the modelling, because the modelling does not capture the extent to which countries could share strategic reserves in the future. [61]

4.37 We consider that the way that the scenarios are used to define a range means that the range is potentially biased against interconnectors:

- Our understanding is that the Government's position is for continued regulatory harmony post Brexit, at least in the short term. This means that arguably more weight should be placed on those scenarios identified as reflecting closer EU integration, which, in the PTE's view, means the higher end of the range provided to the Secretary of State.
- As is clear from Table 4-1 above, the 'higher' and 'lower' de-rating factor values are not split by scenario. For all countries except Ireland, the 5% sensitivity, which is set arbitrarily, drives the majority of values in the lower half of the range created by the ten data points for each country. The choice of this sensitivity does not appear to be reflective of future expected market conditions.

No longer using the historical floor

4.38 The PTE recommend that only the BID3 modelling ranges are used for T-4 Auction for 2022/23 rather than using the historical analysis to establish the floor, apparently on the basis of their view that "[s]*ignificant changes in the EU system beyond 2020*" would mean that "*historical flows and price differentials would not be relevant*."[62] The changes referred to are a combination of increased interconnector capacity and the retiring of surplus capacity in connected countries (e.g. mothballing and decommissioning of gas, coal and/or nuclear generation).

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61 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018," page 21.

62 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018," page 76.

4.39 In our view, the threshold for dropping the historical floor should at the very least be an identified significant step-change in the market. It is not clear to us that the PTE have identified a step-change which is significantly different from the ongoing evolution of the market: significant changes in the EU system have been predicted since the beginning of interconnectors' inclusion into the CM. While it is conceivable that such changes might be expected, it is unclear what particular circumstances have now precipitated the decision to remove the historical floor nor why there was no consultation on the removal.

4.40 Notwithstanding the above, it appears to us that the rationale for dropping the historical floor is based on the *results* of modelling rather than *fundamental* factors – e.g. for Belgium and the Netherlands where it is observed that the output modelled range falls significantly below the historical value, suggesting that "*the historical floor no longer remains relevant.*"[63]

4.41 However, as discussed above, the output modelled range is heavily influenced by the 5% sensitivity which appears to us to be a subjective choice of approach.

4.42 The decision to drop the historical analysis is therefore to an extent **driven by the application of a downside sensitivity (as noted above), rather than any identified fundamental step-change in the market.**

4.43 In our view, the **historical floor is, at the very least, a useful crosscheck against the modelling outputs**, given the sensitivity of the model to input assumptions and the uncertainty of results implied by the large ranges produced.

Secretary of State Decision

4.44 Our understanding is that the Secretary of State makes a decision on interconnector de-rating factors having regard to factors including:

- the range of modelled de-rating factors produced by the Delivery Body;
- the advice of the PTE;
- the probability of outages (both unplanned and planned); and
- the impact of interconnector import constraints in GB.[64]

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63 BEIS (2018): "Panel of Technical Experts – Independent Report on National Grid's Electricity Capacity Report 2018," page 20.

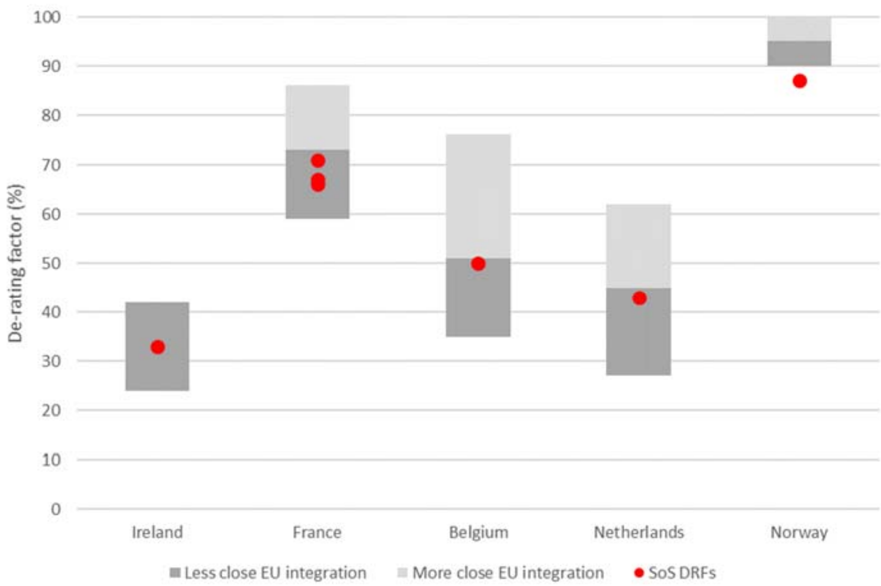
64 Such as contractual import limits on the Moyle Interconnector between Northern Ireland and Scotland of 80MW, entered into by Moyle. Source: ECR 2018: 1.2.

4.45 As noted above, the current rules allow for significant discretion on the part of the Secretary of State, and the letter in which he or she publishes the de-rating factors does not provide any guidance on how the evidence from the ECR or PTE has been interpreted.

4.46 In Figure 4-2 below, we show the Secretary of State decision for each interconnector de-rating factor relative to the ranges recommended by the PTE for each country. Note that:

- the country range (for countries other than Ireland) is split, to represent the PTE's division of the range into 'more close' and 'less close' EU integration scenarios; and
- France shows three different interconnector de-rating factor decisions for each of the three interconnectors for which the Secretary of State has made a determination.[65]

Figure 4-2: Secretary of State de-rating factor decision relative to PTE ranges for 2018 T-4 CM auction



Source: PTE 2018, Letter from the Rt Hon Claire Perry to Fintan Slye.
Note: "SoS DRFs" refers to Secretary of State de-rating factors.

65 The figure shows three different values for France, as there are three interconnectors to France for which de-rating factors are assessed. The differences between GB-France interconnectors is likely driven by technical availability.

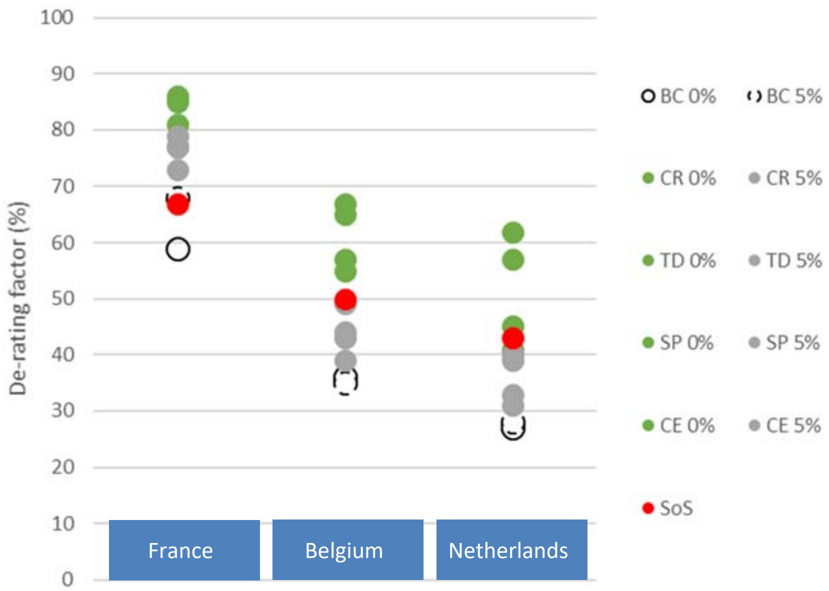
4.47 Figure 4-2 above shows that for Ireland, the de-rating factor is determined to be in the middle of the range produced by the BID3 model.

4.48 However, for France, Belgium and the Netherlands, the de-rating factor is determined to be broadly at the higher end of the 'less close' EU integration scenarios. For these countries:

- the majority of de-rating factor results in the lower end of the range are driven by the 5% sensitivity analysis, rather than any particular FES scenario; and
- the extreme bottom end of the range for these countries is determined by the Base Case.[66]

4.49 These points are further illustrated in Figure 4-3 below, which shows the implied de-rating factor for France, Belgium and the Netherlands under the different BID3 modelling scenarios, as well as the final Secretary of State determination.[67]

Figure 4-3: De-rating factor data points for France, Belgium and the Netherlands



Source: Electricity Capacity Report 2018, BID3 modelling

66 We would also note that for Belgium and the Netherlands, the de-rating factor implied in the Base Case appears to be relatively invariant to whether or not the 5% sensitivity is applied.

67 For clarity for France we show the middle value of the 3 determined de-rating factors.

4.50 Figure 4-3 demonstrates that the range of de-rating factor results would be considerably higher if:

- more weight was placed on the consulted (FES) scenarios rather than the Base Case; and/or
- less weight was placed on the arbitrary downside sensitivity.

Conclusions

4.51 As we have discussed in this section, our view is that the current method of selecting de-rating factors is not appropriate from a process perspective for the following key reasons:

- The modelling process is opaque and non-transparent (the actual model used is not subject to external stakeholder scrutiny).
- The modelling process is technically complex yet produces a range of de-rating factors that is extremely large (due to the large range of scenarios used). As an example, the de-rating factor for Netherlands output from the modelling falls within a range of c.27% to 62%. The extremely large range of de-rating factors produced casts doubt on the usefulness of the modelling exercise.
- The 'Base Case' scenario that is used has not been consulted on and is not transparent. However, this scenario plays a key role in forming the lower bound for France, Belgium and the Netherlands.
- The Panel of Technical Experts has made no substantive comment on the likelihood of different scenarios. Therefore, the range of potential de-rating factors presented to the Secretary of State is wide.
- Ultimately this means that, despite the considerable technical complexity of the modelling process, the de-rating factor choice is to a large extent subjective.

4.52 For these reasons alone, we would conclude that there are grounds for re-considering the interconnector de-rating factor methodology. However, there are also indications that the interconnector de-rating factors may be biased downwards:

- As noted above, the 'Base Case' scenario drives a lot of the lower modelling output results. Without full knowledge of the Base Case used it is not possible to comment directly on its assumptions.

- Placing greater emphasis on the (consulted upon) Future Energy Scenarios ("FES") would, all else equal, likely result in higher de-rating factors for interconnectors, resulting in considerable savings for GB consumers.
- The use of a 5% sensitivity results in a bias towards lower implied interconnector de-rating factors. Providing a more balanced sensitivity analysis would likely result in higher de-rating factors for interconnectors, resulting in considerable savings for GB consumers.

4.53 For these reasons, we conclude there are grounds for re-considering the interconnector de-rating factor methodology. In the next section, we set out some potential options for doing so.

5. Alternative proposals or refinements

5.1 As we have discussed above, the intent of de-rating factors is to represent the amount of reliable capacity that can be ascribed to each potential type of capacity resource. The current approach to setting interconnector de-rating factors relies on both forward-looking modelling (to produce a range of potential implied de-rating factors) and significant subjective judgment.

5.2 We have seen, over time, a widening (and falling) range of de-rating factors implied by the forward-looking methodology. Additionally, we have seen a significant discontinuity between the forecasting results and the Secretary of State decisions, as well as a decision to drop the historical 'floor' that had applied since the introduction of interconnectors into the CM.

5.3 These trends point to a broader issue of the current methodology – that there is an increasing risk that the combination of imperfect forecasting and subjective discretion will undermine the reliability and accuracy of interconnector de-rating factor estimates.

5.4 In a context where the GB energy market is expected to become more complex over time, forecasts will become more uncertain. This means that setting a discretionary point estimate on de-rating factors based on forecasts four years into the future will become more challenging.[68] **To the extent there is a bias towards overly and unduly conservative interconnector de-rating factors, this comes at the expense of significantly increased consumer costs**.

5.5 This five-year CM review presents an opportunity to reassess the fundamental question of how much interconnectors contribute to security of supply in GB during periods of system stress. As such, this section sets out some potential alternative interconnector de-rating options that might allow this significant contribution to be more transparently and accurately reflected.

5.6 We set out the following in turn:

- the inherent difficulties and trade-offs in setting a de-rating factor;

[68] As discussed in Section 3, our view is that the typically moderate changes in the generation fleet over a four-year period means that methodologies based on historical analysis should not be discounted.

- an overview of the range of potential alternative options;
  - centrally-determined historical methodology;
  - centrally-determined modelling;
  - market-based approach; and
- potential 'second-best' interconnector DRF methodologies depending on objectives (in absence of an ideal methodology).

High-level summary of conclusions

(1) Historically, interconnectors have **contributed significantly to GB security of supply in periods nearing system stress**. However, there is a significant disparity between (i) the current de-rating factors for interconnectors and (ii) the implied contribution of interconnectors based on our historical analysis. Whilst such a difference might be reasonable to assume over a 10 or 20-year horizon, the changes to the market over four years are unlikely to be of that order of magnitude.

(2) The prevailing de-rating methodology for interconnectors, set discretionarily by the Secretary of State based on forecasts of future interconnector performance and advice from the PTE, **is not appropriate due to the opaque, overly complex and subjective nature** across the process. This approach tends to be overly conservative at the expense of the consumer. We conclude there are grounds for re-considering the interconnector de-rating factor methodology.

(3) The 5-year review should be used as an opportunity to explore other preferred interconnector de-rating methodologies that would best serve GB consumers. While there is no 'perfect' de-rating methodology, we set out three 'second-best' options – a market-based approach, a historical-based approach with a factor reduction, and a mechanism to update interconnector de-rating factors at T-1. These options are intended to reduce the amount of administrative discretion and judgement which appears to result in overly-conservative interconnector de-rating factors. Over time, these options should reflect contribution of interconnectors to GB security of supply more accurately at least cost to consumers compared to the prevailing methodology.

5.7 We would further note that, as more technologies such as renewable generation, battery storage and DSR play a greater role in the CM in future, the general challenges to forecasting and subjectivity are likely to become magnified. Whilst this report is focused on interconnectors, many of the alternative options we present in this section could be applicable to other technologies. In fact, as the CMU technology spectrum becomes more and more diverse there is likely to be benefits to a more consistent approach across technology classes.

The inherent difficulties and trade-offs in setting a de-rating factor

5.8 It is no surprise that process of determining de-rating factors is inherently difficult due to the nature of the energy market as well as the policy design of the CM.

5.9 The outturn availability of a technology during a System Stress Event is based on both the technical availability and market conditions of that specific technology.

5.10 The size of the technical risk differs by technology. For example, variable renewable generators would face significant risk on its technical availability should they be able to participate in the CM in the future. Variable renewable generators are to a large extent dependent on weather patterns and operators have limited control to provide the required availability when needed.

5.11 The size of the market risk also differs by technology. For interconnector capacity, the market risk on outturn availability is hard to predict as this relies on expected price signals. Thermal generators are also exposed to market risk (albeit to a lesser extent than interconnectors) for example due to linkages with the gas market.

5.12 To account for these challenges, different de-rating factor methodologies have been adopted. Generators are measured based on the average technical availability given their relatively low exposure to market risk during a System Stress Event. Battery storage units are set based on the Equivalent Firm Capacity ("EFC") metric[69] which reflects the reliable capacity it can displace and is determined through technical modelling. On the contrary, de-rating factors for interconnectors are determined mostly on a forward-looking dispatch model basis which estimates the expected interconnector flows during periods where GB margins (excluding interconnector flows) were negative (as a proxy of system stress).[70]

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69 The EFC is defined as "*for a given penetration of that resource, what is the amount of perfectly reliable infinite duration firm capacity it can displace while maintain the exact same reliability level.*" National Grid (2017): 'Duration-Limited Storage De-Rating Factor Assessment – Final Report.'

70 This is explained further in Section 4.

5.13 The further out the forecast is made, the greater the uncertainty and hence the more difficult it is to form a single point estimate. Under the current design of the T-4 CM, the expected availability of eligible technologies must be forecasted four years ahead of a hypothetical System Stress Event. Given that future conditions are uncertain, this forecast is always likely to require some judgment, and there will always be a need to balance the cost to consumers of overly conservative de-rating factors (especially in respect of interconnectors, which generally act to lower the clearing price) with the risks of capacity not being available in a System Stress Event.

5.14 There is, therefore, an inherent challenge in setting interconnector de-rating factors. We would also argue that there are also likely be trade-offs between the virtues of different potential methodologies. These include the following:

- **Historical vs forecast**. Methodologies can be based on historical analysis, or forecasts, or a mix of both. Historical approaches have the advantage of being grounded in empirical evidence and are typically more stable. However, forecasts may provide a better representation of the future, if it can be shown that the future conditions are significantly different to the conditions under which the historical analysis is conducted.
- **Simple vs complex**. A more complex methodology can, in principle, reflect better the underlying complexity of the energy system. However, it runs the risks of providing spurious accuracy, introducing errors, and masking any subjective decisions that are made in the process, and the costs of developing and scrutinising a very complex methodology can be high.
- **Transparent vs non-transparent**. More transparent methodologies can produce more balanced outcomes over time, if the combined experience and evidence bases of multiple stakeholders are appropriately reflected. This provides better signals to the market which will produce more efficient outcomes over time.
- **Prescriptive vs discretionary.** Prescriptive methodologies aim to reduce the influence of subjective or discretionary steps in the process, but can be more inflexible. A methodology which has ‘room’ for more discretion can be better at reflecting more qualitive and uncertain factors. Ultimately, even a fully prescriptive process is likely to reflect a significant amount of judgment insofar as the way the process is designed in the first place.

5.15 Many of these trade-offs overlap to some degree. For example, it is more challenging to make a very complex methodology completely transparent.

5.16 With these trade-offs in mind, the 'perfect' methodology clearly does not exist. However, it is worth noting that more objective methodologies prevent undue influence and have a clear advantage for promoting transparency to stakeholders and the market. For example, more objective methodologies would:

- be less susceptible to political lobbying and undue influence;
- reduce the costs incurred by authorities in developing and communicating the methodology; and
- reduce the costs incurred by stakeholders in responding to and inputting into the methodological debate on an annual basis.

5.17 In turn, we explore the range of each interconnector de-rating factor methodology options below.

Overview of the range of potential interconnector de-rating options

5.18 The original rationale of de-rating when applied to generators was that some of that generation capacity would not be available at the time it would be required. This principle was then extended to interconnectors. But, as explained above, other approaches are possible, which in our view could be categorised into two broad classes:

- **Centrally-determined approach**: these options rely on one or more parties such as the Secretary of State, PTE or Delivery Body centrally administrating the de-rating factors. This approach can be further divided into different specific methodologies; for example, a historical methodology, forward-modelling, or a mixture of the two.
- **Market-based approach**: these options rely on individual parties setting de-rating factors themselves. Individual parties therefore take on a greater proportion of the risk from the central administration (and ultimately consumers).

5.19 Notably, the range of options are not mutually exclusive – different options can be blended and synthesised with one another. For example, de-rating factors set between 2015 and 2017 relied on a forward modelling approach but applied a floor based on a historical methodology.

Centrally-determined: historical methodology

5.20 The key advantage to a historical methodology is that it can be determined in a transparent and prescriptive manner, limiting the need for judgement and reducing the influenceability on decisions on a year-by-year basis.

5.21 However, as we have described above, any historical methodology still requires judgment regarding the 'formula' used to estimate historical de-rating factors. This is because data (albeit being historical, actual data) is still only being used as a proxy to estimate the contribution from a technology class for an event that is non-observable (i.e., a System Stress Event). As we show in Section 3, there are many possible different proxies for the contribution of interconnectors at times of System Stress, and most of these imply de-rating factors higher than as currently assessed.

5.22 To accommodate this shortcoming, one potential option is that the **criteria used to determine historical de-rating factors can be changed or tightened**. Instead of the criteria set by the CM Rules,[71] the criteria could be adapted to better reflect conditions where a System Stress Event is more likely to occur. This may evolve changing the metrics from specific peak demand periods to:

- a proxy based on margins (e.g., as margins approach 500MW);
- prices (e.g., as prices exceed a certain threshold);
- observing only the highest peak demand periods;
- placing greater weight on more recent years; or
- some combination of the four variants.

5.23 Each of these metrics will have separate advantages and disadvantages when used as a proxy for the likelihood of System Stress Events (as well as the *coincidence* of such events with neighbouring countries). Additionally, changing or tightening the criteria might result in fewer data points which means the results may be more susceptible to small sample errors and risks distorting the results.

5.24 Another shortcoming of a historical approach, as recognised by the PTE, is that it does not reflect how the market might change in four years' time, which would affect the market dynamics underpinning the actual flows of an interconnector. This is, of course, one of the reasons why forecast modelling is adopted under the hybrid approach. However, as we have described in Section 4, the forecast modelling approach lacks transparency, relies each year on subjective judgments and is overly conservative due to (among other things) arbitrary downside sensitivities.

71 CM Rules, Schedule 3A.

5.25 Therefore, one further option is to continue to use some form of a historical approach but **apply a predetermined factor reduction** to reflect a more cautious and conservative estimate. For example, the prevailing historical de-rating factor methodology minus a factor, say 5%, could be used to reflect the likely changes in the energy markets in both GB and the connected country.

5.26 This option offers a highly transparent approach – using a historical analysis (properly reflecting periods of high system stress in GB) but applying a simple ‘rule-of-thumb’ reduction to the calculated figure in anticipation of future changes. Different factor reductions could also vary by country to reflect the likely trajectories of different energy markets.

5.27 Whilst the factor reduction will initially be discretionary, once it has been set, it can prevent the potential for further influence and arbitrary judgements. This approach is also less intensive and decreases the amount of time and cost spent on the annual deliberations when determining the de-rating factors.

5.28 As noted above, all potential de-rating factor methodologies are subject to trade-offs. Whilst this potential option would be somewhat of a ‘blunt’ tool, it would certainly have the advantage of being simple, transparent and prescriptive. Transparency is particularly important, as the setting of the factor would reveal the inherent trade-off between cost and cautiousness: e.g., a higher factor would reflect a decision by policy makers to adopt a more cautious, but more costly, approach.

Centrally-determined: forward modelling

5.29 The prevailing de-rating factor methodology relies predominantly on a discretionary judgement based on forward modelling.[72]

5.30 As discussed in Section 4, one of the shortcomings with the forward modelling is its use of vastly different scenarios and sensitivities. This creates a wide range of potential de-rating factors, which in part dilutes the precision and ‘usefulness’ of the estimates. The wide range of possibilities also creates the need for subjective and discretionary judgement when selecting a point estimate.

5.31 To mitigate this effect, one option is to **restrict the scenarios / sensitivities** used in the forward modelling. There are many potential variants to restricting this. These include:

72 Advice from the PTE based on the forward modelling is also considered. The historical de-rating factors that act as a ‘floor’ to de-rating factors derived from the forward-modelling have been removed for the upcoming Capacity Auction.

- removing the (asymmetric) 5% higher peak demand sensitivity or placing less weight on this;
- removing or placing less weight on the Base Case results given they are opaque; and/or
- reducing the number of FES scenarios to the two more credible FES scenarios in four years (or placing more weight on the more credible FES scenarios).

5.32 Another potential forward-looking approach is to **update interconnector de-rating factors at T-1**. Given the uncertainty four years in advance of delivery, de-rating factors could be revised closer to the delivery period when a more credible forward view can be made. There are two outcomes if the forward view of de-rating factors at T-1 is different from T-4:

- if forward-looking de-rating factors are higher in T-1 than in T-4, then the awarded capacity agreement to interconnectors will increase (combined with a countervailing decrease in the demand for the T-1 auction); and
- if forward-looking de-rating factors are lower in T-1 than in T-4, then the awarded capacity agreement to interconnectors will decrease (combined with a countervailing increase in the demand for the T-1 auction).

5.33 As this approach would affect the T-1 auction parameters and outcomes, one challenge would be on how to determine the price at which the awarded capacity for interconnectors at T-4 are ‘bought back’ or ‘sold’. For example, one variant might involve setting the price of the capacity ‘sold’ at the outturn T-1 clearing prices instead of T-4 clearing prices. Different rules could also be considered for existing interconnectors and new build interconnectors to maintain stable price signals from the T-4 auction.

Table 5-1: Working example on updating an interconnector DRF in T-1

	Scenario 1: Forecast DRF increases in T-1	**Scenario 2:** Forecast DRF decreases in T-1
Assumptions	IC nameplate capacity at **1GW** IC DRF at **80%** Awarded capacity at **0.8GW**	
Forecast DRF in T-1	90% (increase awarded capacity by 10%)	70% (decrease awarded capacity by 10%)
Awarded capacity to the interconnector	10% x 1GW x 'sell-on' price	-10% x 1GW x 'buyback' price
Change in T-1 auction parameters	Decrease target capacity by 10% x 1GW = 0.1GW	Increase target capacity by 10% x 1GW = 0.1GW
Change in T-1 auction results	Lower clearing price Decrease in capacity procured	Higher clearing price Increase in capacity procured
Cost to consumers	0.1GW x 'sell-on' price minus counterfactual decrease in T-1 auction cost	Counterfactual increase in T-1 auction cost minus 0.1GW x 'buyback' price

Note: As described in the paragraph above, one challenge for policy-makers is to determine what the 'sell-on' and 'buyback' prices should be.
Source: FTI Consulting.

Market-based approach

5.34 In the original design of the CM, a key question presented to decision-makers was on who should be carrying out the de-rating. DECC identified that "*ostensibly, plant owners have the best information and are in the best position to establish their own de-rating … however this, risks the exercise of market power/gaming*".[73] DECC then concludes that the de-rating of capacity should be undertaken by the Delivery Body and a centrally-determined methodology will be used to "*minimise the possibility of any disputes.*"

73 DECC (June 2013): 'Electricity Market Reform: Capacity Market – Detailed Design Proposals,' paragraphs 62 to 63.

5.35 However, as the CM has evolved over time, the centrally-determined de-rating factor methodology seems to have been unable to minimise the number of disputes nor the potential for the 'gaming' of de-rating factors.

5.36 Nevertheless, one of the key issues that BEIS is seeking to engage with is the question of whether the penalty regime should be strengthened.[74] Whilst this issue is outside the scope of this report, we would note the strong potential link between penalties and the 'gaming' of de-rating factors. In principle, it could be possible to design a penalty regime in such a way that incentivises participants to avoid engaging in potential gaming in the first instance, in a preventative manner.

5.37 If the penalty regime is strengthened, then it may be possible to do so in a way that provides incentives for CMUs to determine their own de-rating factors accurately, therefore removing the key rationale for setting de-rating factors centrally in the first instance. In these circumstances, it could be possible to move the de-rating process from the Delivery Body to the eligible participants, who will have the "*best information and are in the best position to establish their own de-rating.*" In effect, this moves the risk of incorrect de-rating factors from the Secretary of State or Delivery Body (where consumers ultimately bear the cost) to the participants. This aligns with the economic principle of regulation that risk should be taken on by those best placed to manage them.

5.38 A market-based approach can be designed under two broad variants.

- First, participants could select their preferred **de-rated capacity without any restrictions**. In effect, if the penalty regime and secondary markets are designed appropriately, each participant would be incentivised to bid the actual capacity it expects to deliver based on its risk-profile and the potential rewards and penalties. This would allow participants to go above or below their expected availability depending on whether they are more risk-averse or more confident in their performance (or the availability of secondary markets).
- Second, participants could **select their preferred de-rating factors** within a pre-determined range set by the Delivery Body / Secretary of State. This would limit the extent to which participants who are extremely risk-averse, or risk-seeking, could under or over-state their expected availability.

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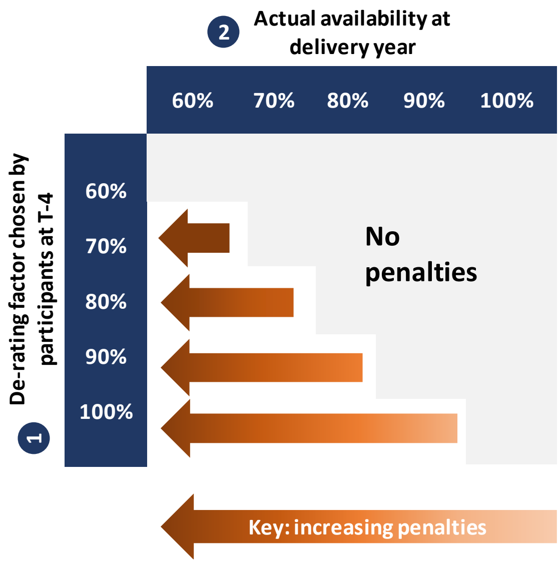
74 BEIS (2018): 'Capacity Market and Emissions Performance Standard Review – call for evidence.'

5.39 To allow for an effective market-based approach, a further change to the CM would be required. There would need to be further reforms to the secondary trading arrangements in order to allow participants to trade over or under-capacity obligations closer to delivery. This would allow participants to better hedge their risk from the T-4 auction all the way up to real-time as more information is revealed.

Figure 5-1: Incentives in a market-based approach



Source: FTI analysis.

5.40 As shown in Figure 5-1 above, under this proposed method each participant first selects its own de-rating factor for the T-4 auction. This sets the bid capacity for each participant which, in turn, will determine the clearing price and awarded capacity from the T-4 auction. In times of system stress during the delivery year, if the actual availability of a participant is lower than the de-rated capacity, the participant will incur penalties. The level of penalties increases the further actual availability is away from the de-rated capacity.

5.41 This means that each participant is responsible for managing its own risk – in how it chooses its de-rated capacity at T-4, based on its expected availability as well as its ability to trade excess or shortfalls of capacity towards the delivery year.

5.42 In view of maximising consumer benefits, the penalty regime must be well-designed to incentivise participants to manage their risk appropriately and to submit bids that accurately reflect its expected availability. This would disincentivise participants from taking on overly 'aggressive' bids that are not commensurate to maximising value to consumers.

5.43 A market-based approach could be applied for each participant across the CM regardless of technology type. This means that a further and very significant benefit of allowing a more market-based approach to de-rating factors is that it could be a truly technology-neutral approach. That is, the incentives could apply similarly across all technology classes.

5.44 Additionally, generators within a technology class would no longer be subject to a de-rating factor estimate calculated by averaging the historical availability across all generators in that technology class. **In effect, this would allow all participants, both within technology class and across technologies, to participate in the CM auction on a level-playing field**, leading to a more efficient outcome for consumers over time**.**

Potential alternative interconnector DRF methodologies

5.45 As discussed earlier in Section 5, setting de-rating factors are inherently challenging due to the uncertainty of the outturn availability for each participant during a System Stress Event. This presents several trade-offs between the potential methodologies, where each methodology will have distinct advantages and disadvantages.

5.46 This means that, in the absence of a 'perfect' de-rating factor methodology, the choice of de-rating factor methodology would depend on which objective decision-makers would like to prioritise.

5.47 Consolidating the descriptions of potential de-rating factor methodologies above, we set out three plausible alternative options (in no preferred order). These are:

- Option A: Market-based approach.
- Option B: Historical-based approach with a factor reduction.
- Option C: Update interconnector de-rating factors at T-1.

5.48 In our view, all of these options could lead to a more balanced view of interconnector de-rating factors, likely resulting in higher de-rating factors for interconnectors and therefore resulting in considerable savings for GB consumers.

5.49 However, recognising there are trade-offs in some other respects, we set out other key advantages (and disadvantages) of these options in Table 5-2 below.

Table 5-2: Advantages and disadvantages to the three alternative approaches

	Option A: Market-based approach	Option B: Historical-based approach with a factor reduction	Option C: Update interconnector DRFs at T-1
Advantages	• Level-playing field across technologies • Level-playing field in each technology class • Each participant can set and manage their own risk (and move risk closer to delivery if preferred) • Limits centrally-administered discretion and interference	• Simple and transparent • Objective approach limiting discretion and potential interference • Factor reduction (that can vary by each country) allows for DRFs to be set conservatively to account for future uncertainty • Trade-off between cost and security is transparent	• Better representation of future market conditions • IC DRFs can be updated as more information is revealed – minimising risk of forecasting errors • Potentially reflects contribution of ICs more accurately
Disadvantages	• Requires a strengthened penalty regime • Requires a strengthened secondary market • Potential compounding effect if multiple participants 'get it wrong' at the same time • Requires belief in 'market-led' approaches	• One-off discretionary decision required when setting factor reduction	• Potential for complicated interactions with T-1 auctions • Uncertainty on the 'buyback' and 'sell-on' prices
Consumer impact	• Better managed risks should reduce consumer costs over time • 'Errors' largely borne by participants instead of consumers	• Unclear impact on consumers (apart from savings through reduced costs of determining DRFs through other complex approaches)	• Potential upside and downside for consumers (but can be designed to be cost-neutral for consumers relative to status quo)

Source: FTI Consulting.

5.50 As discussed in Section 4 of this report, we consider that there are significant challenges to centrally determining de-rating factors (for interconnectors in particular, but the increasing complexity of the market and introduction of new technologies will mean such challenges may become more widespread). Should the penalty regime be strengthened (reducing the incentive for 'gaming'), allowing participants to select their own de-rating factors means that the risk would be set and managed by those best placed to do so. This is one of the key advantages of **Option A**. However, we reiterate that a comprehensive change to the penalty regime and secondary trading arrangements are required to ensure that incentives will be aligned to the best interest of consumers.

5.51 **Options B and C** would require less significant changes to the CM regime and are focused on changes to the interconnector de-rating factor methodology rather than de-rating factors in general. Their key advantages are in restricting the amount of discretion and judgement required in the process for setting interconnector de-rating factors, which, as we explain in this report, appears to result in overly conservative interconnector de-rating factors.

Conclusions

5.52 As noted in Section 2 of this report, the five-year CM review presents an opportunity to reassess the fundamental question of how much interconnectors contribute to security of supply in GB during periods of system stress.

5.53 As we set out in Section 3, empirical analysis shows that when the GB electricity market has been most stressed (i.e., in conditions that are most relevant to GB security of supply), the market conditions that drive interconnector flows are **almost always such that flows to GB would be expected**. Whilst de-rating factors are difficult to estimate (not least because there has not been a system stress event in GB for several decades), it appears to us the current de-rating factors significantly under-estimate this contribution.

5.54 The under-estimation is driven by flaws in the methodology, which, as explained in Section 4, is overly conservative and also heavily influenced by discretion and subjectivity. The Five Year review presents an opportunity to review Interconnector derating methodology to ensure it accurately reflects the significant contribution of interconnectors.

5.55 Our proposals for alternative options would help to solve these problems: Option A moves the risk-setting role from policy-makers to the participants (who are arguably best placed to understand and manage the risk). Options B and C are less 'drastic' changes but have the advantages of restricting the amount of discretion and judgement required in the process for setting interconnector de-rating factors.

Appendix 1
Full set of correlation analysis results presented in Section 3

A1.1 This appendix presents the full set of results for all countries under all sample ranges that accompany Section 3: 'Analysis of interconnectors' contribution to GB security of supply.'

A1.2 For year-specific analysis, year refers to the period commencing 1 April of the previous calendar year and ending 31 March of the stated calendar year.

Prices analysis

Base Case

Figure A1-1: Belgium price analysis (Base Case)

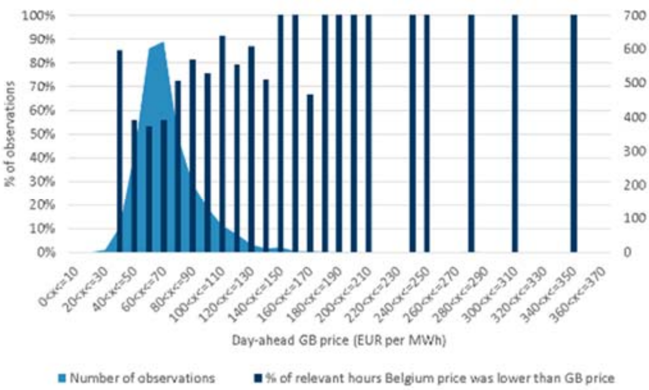


Figure A1-2: Norway price analysis (Base Case)

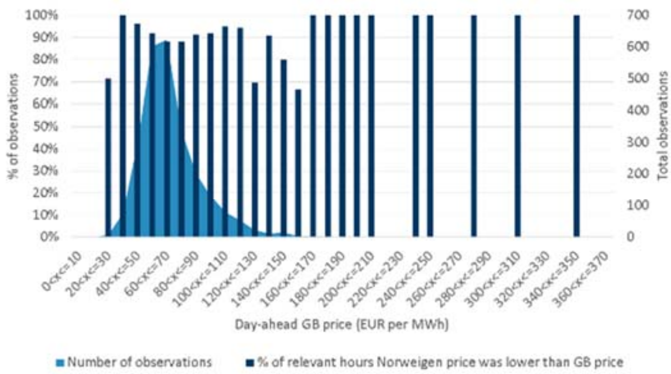


Figure A1-3: France price analysis (Base Case)

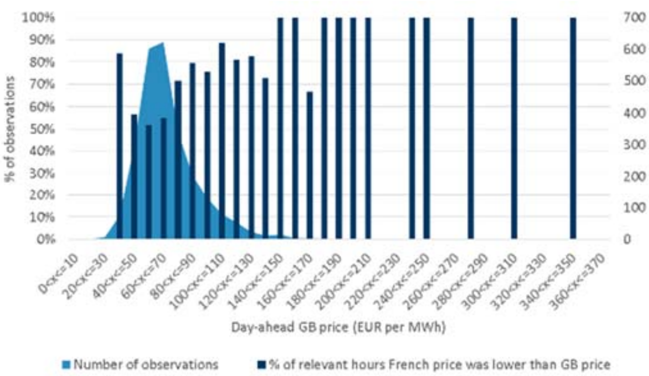


Figure A1-4: Ireland price analysis (Base Case)

Figure A1-5: Germany price analysis (Base Case)

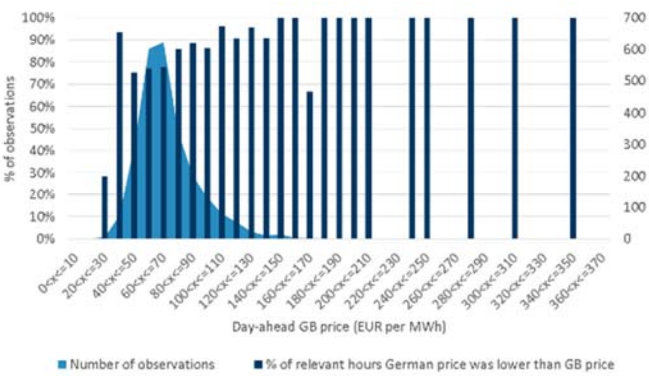


Figure A1-6: Denmark price analysis (Base Case)

Higher Demand Restriction (winter peak)

Figure A1-7: Belgium price analysis (Higher Demand Restriction (winter peak))

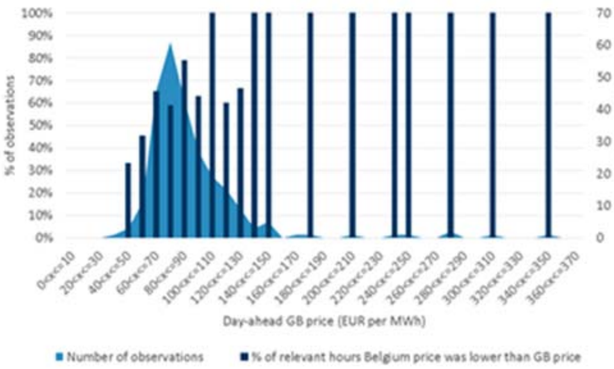


Figure A1-8: Norway price analysis (Higher Demand Restriction (winter peak))

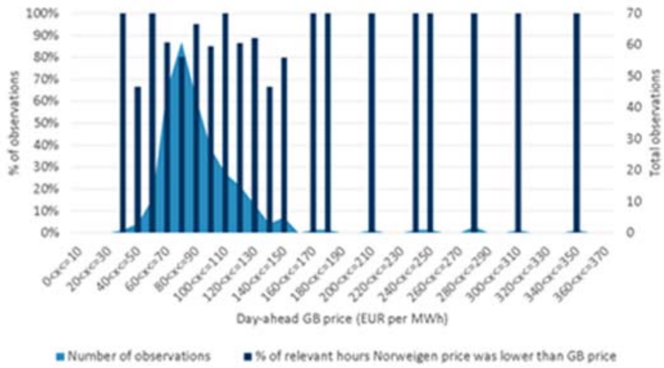


Figure A1-9: France price analysis (Higher Demand Restriction (winter peak))

Figure A1-10: Ireland price analysis (Higher Demand Restriction (winter peak))

Figure A1-11: Germany price analysis (Higher Demand Restriction (winter peak))

Figure A1-12: Denmark price analysis (Higher Demand Restriction (winter peak))

Higher Demand Restriction (all periods)

Figure A1-13: Belgium price analysis (Higher Demand Restriction (all periods))

Figure A1-14: Norway price analysis (Higher Demand Restriction (all periods))

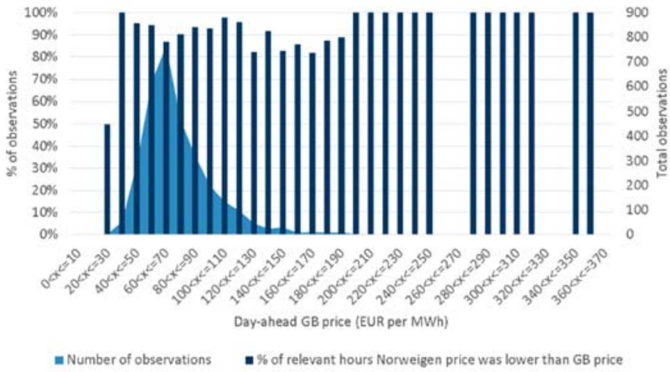


Figure A1-15: France price analysis (Higher Demand Restriction (all periods))

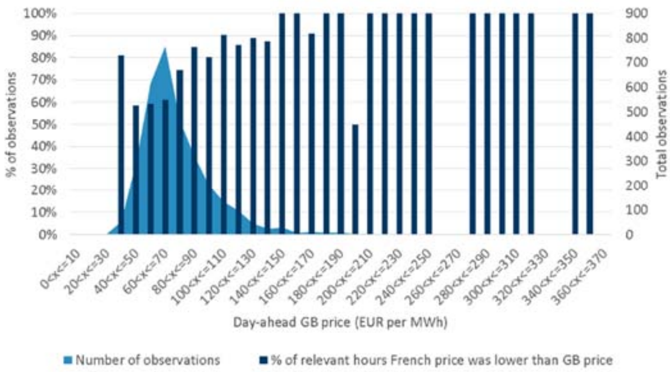


Figure A1-16: Ireland price analysis (Higher Demand Restriction (all periods))

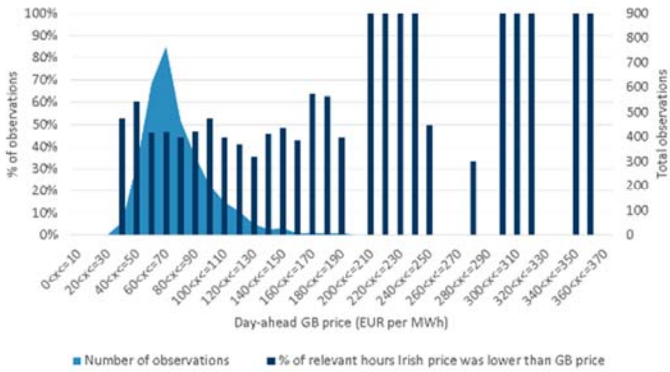
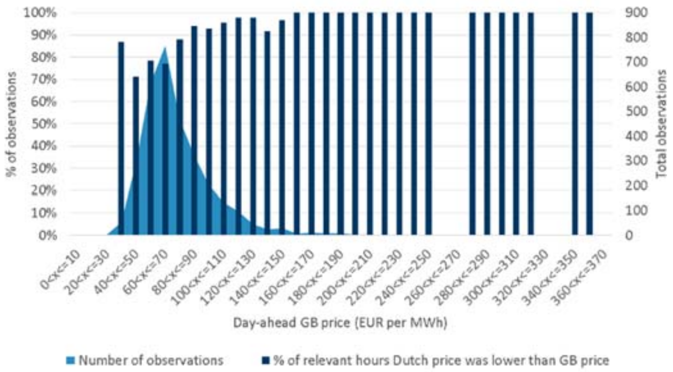


Figure A1-17: Germany price analysis (Higher Demand Restriction (all periods))

Figure A1-18: Denmark price analysis (Higher Demand Restriction (all periods))

Figure A1-19: Netherlands price analysis (Higher Demand Restriction (all periods))



Restricted timeframe (2014+)

Figure A1-20: Belgium price analysis (Restricted timeframe (2014+))

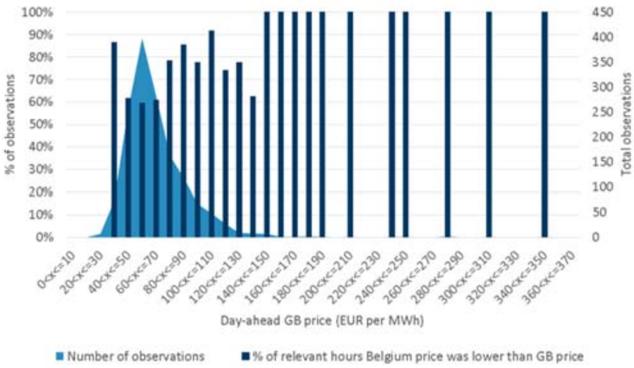


Figure A1-21: Norway price analysis (Restricted timeframe (2014+))

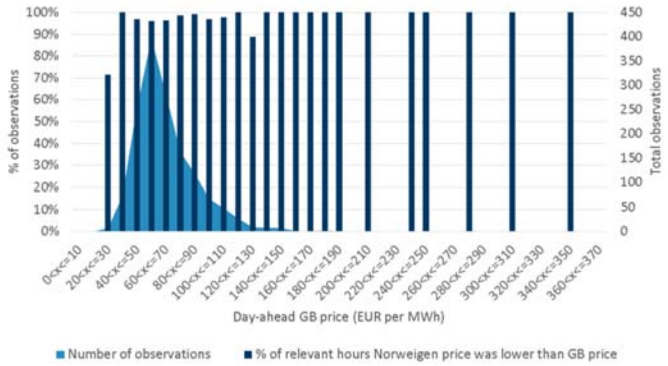


Figure A1-22: France price analysis (Restricted timeframe (2014+))

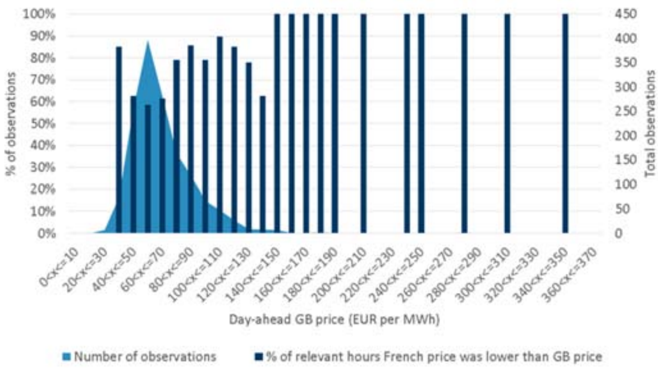


Figure A1-23: Ireland price analysis (Restricted timeframe (2014+))

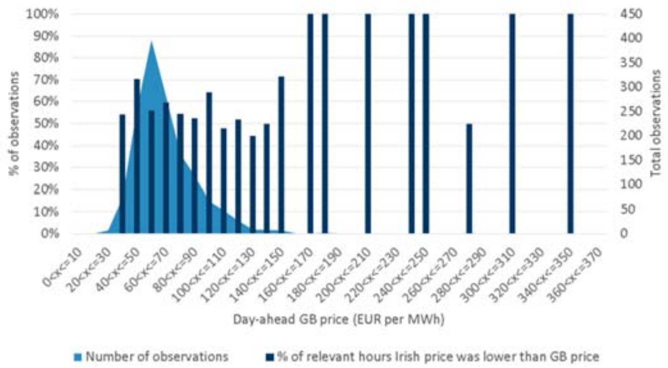


Figure A1-24: Germany price analysis (Restricted timeframe (2014+))

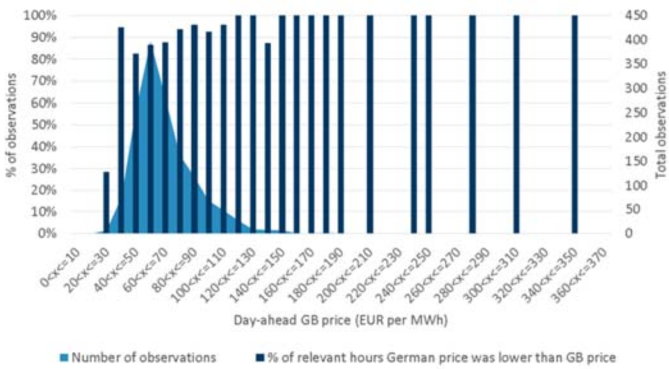
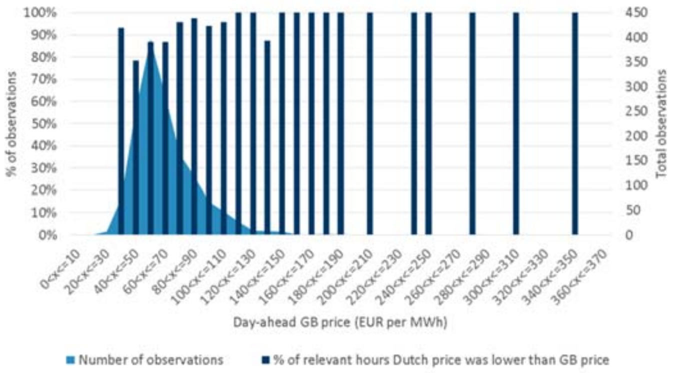


Figure A1-25: Denmark price analysis (Restricted timeframe (2014+))

Figure A1-26: Netherlands price analysis (Restricted timeframe (2014+))



Margin analysis – including wind generation

A1.3 The data used for the margin analysis starts in January 2015, therefore Base Case and Restricted timeframe (2014+) are identical.

A1.4 All datasets are from the ENTSO-E FTP and cover the period 1 January 2015 to 1 September 2018. Installed capacity data is provided yearly at the generation type level (out of which we exclude wind offshore and wind onshore) for each bidding zone. Actual generation data is provided hourly at the generation type level (out of which we only take wind offshore and wind onshore and then combine) for each bidding zone. Outage data is given at the generating unit level, registering the outage beginning and end time by minute, and indicating the unavailable capacity in MW during the outage. First, we only keep "Active" outages, dropping observations of "Withdrawn" or "Cancelled" outages. Then, we clean this data to find the total unavailable capacity by hour in each bidding zone, excluding any outages registered for wind onshore or wind offshore plants. Demand data is provided as hourly total load at the bidding zone level.

Base Case

Figure A1-27: Belgium margin analysis including wind (Base Case)

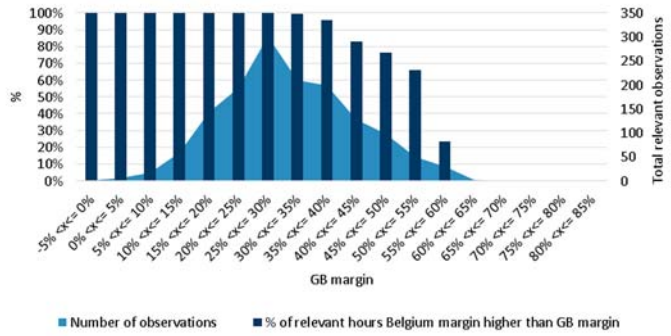


Figure A1-28: Norway margin analysis including wind (Base Case)

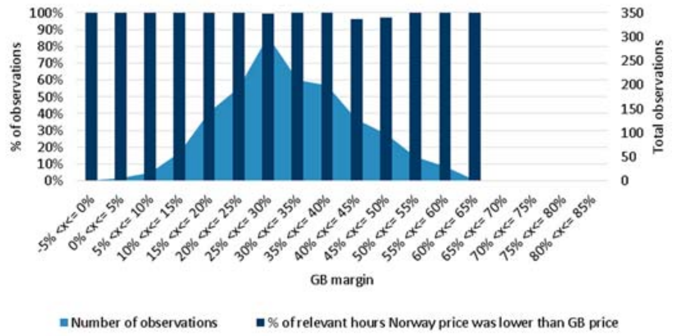


Figure A1-29: Ireland margin analysis including wind (Base Case)

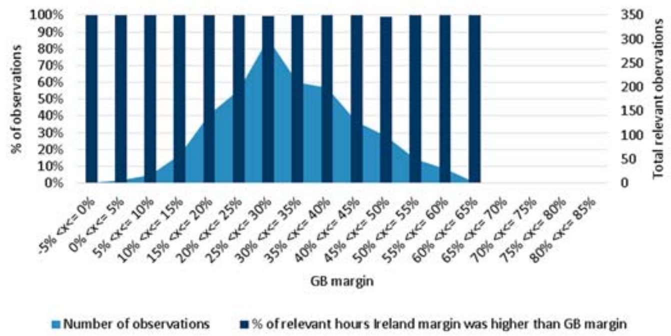


Figure A1-30: Germany margin analysis including wind (Base Case)

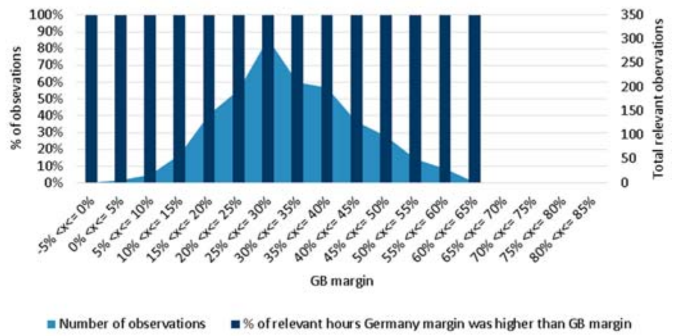
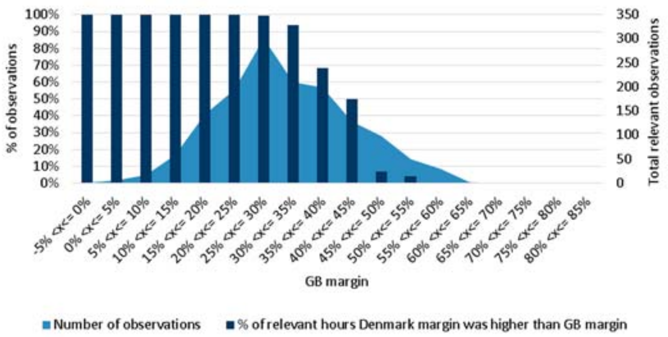


Figure A1-31: Denmark margin analysis including wind (Base Case)



Higher Demand Restriction (winter peak)

Figure A1-32: Belgium margin analysis including wind (Higher Demand Restriction (winter peak))

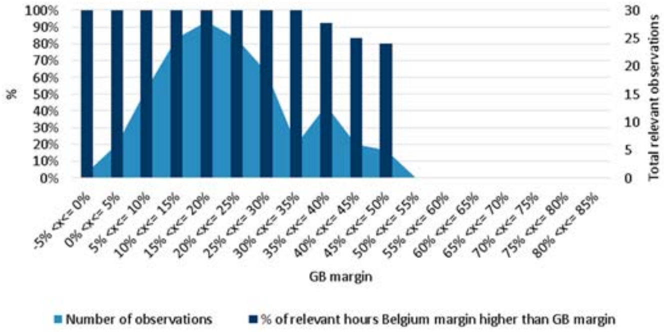


Figure A1-33: Norway margin analysis including wind (Higher Demand Restriction (winter peak))

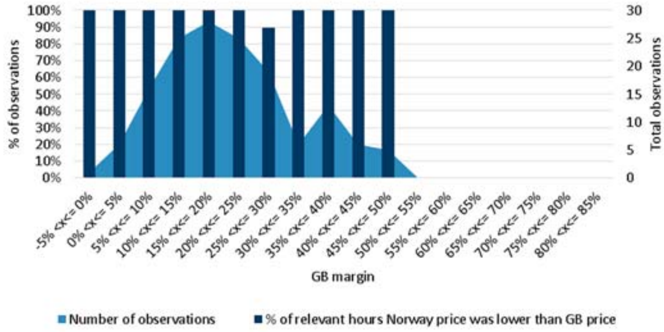


Figure A1-34: France margin analysis including wind (Higher Demand Restriction (winter peak))

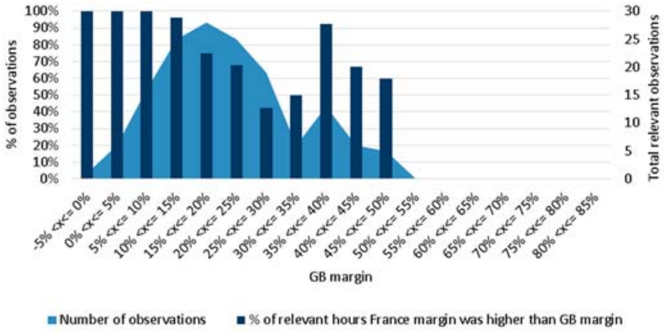


Figure A1-35: Ireland margin analysis including wind (Higher Demand Restriction (winter peak))

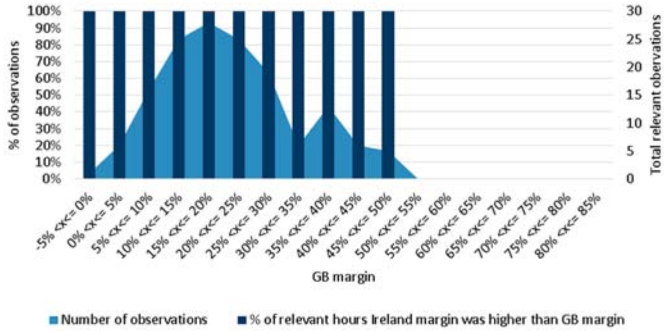


Figure A1-36: Germany margin analysis including wind (Higher Demand Restriction (winter peak))

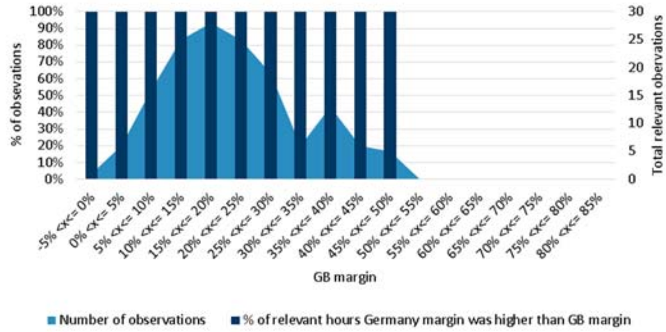


Figure A1-37: Denmark margin analysis including wind (Higher Demand Restriction (winter peak))

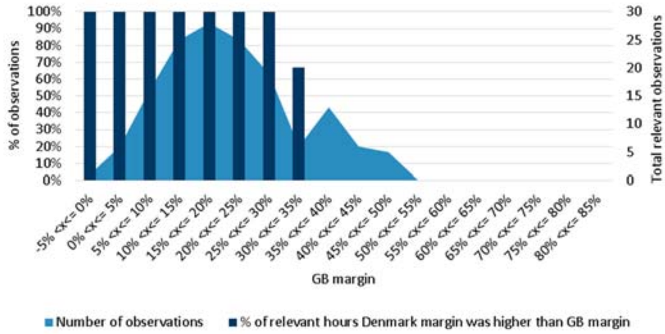
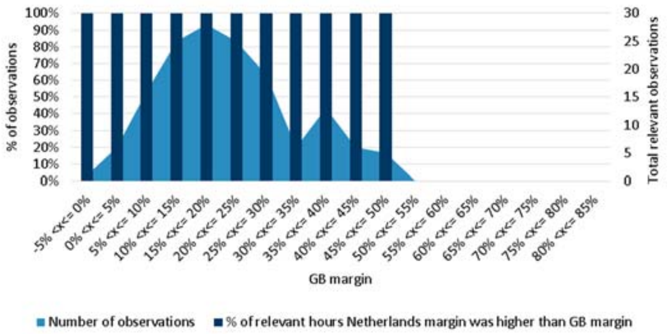


Figure A1-38: Netherlands margin analysis including wind (Higher Demand Restriction (winter peak))



Higher Demand Restriction (all periods)

Figure A1-39: Belgium margin analysis including wind (Higher Demand Restriction (all periods))

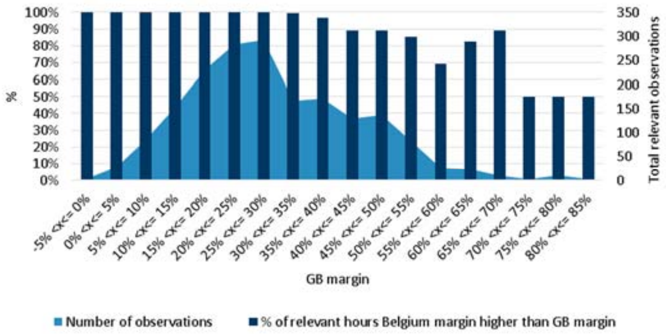


Figure A1-40: Norway margin analysis including wind (Higher Demand Restriction (all periods))

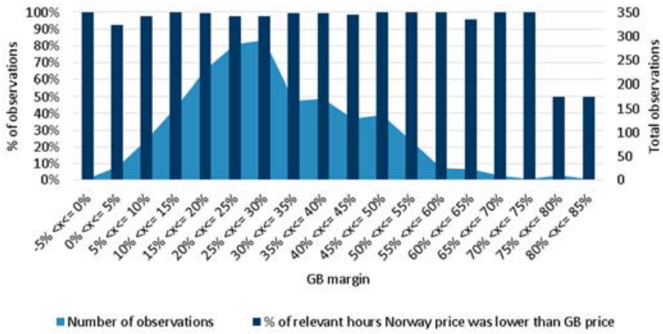


Figure A1-41: France margin analysis including wind (Higher Demand Restriction (all periods))

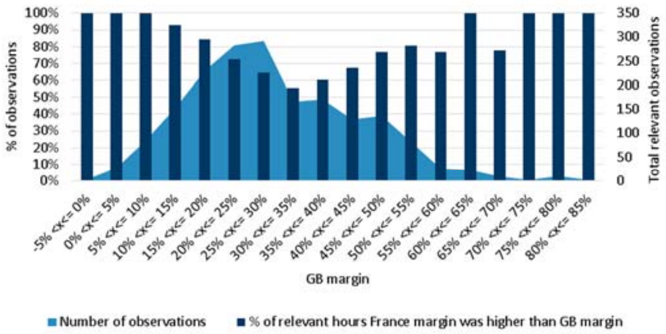


Figure A1-42: Ireland margin analysis including wind (Higher Demand Restriction (all periods))

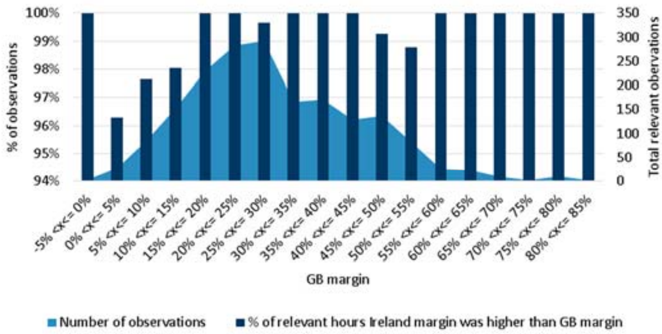


Figure A1-43: Germany margin analysis including wind (Higher Demand Restriction (all periods))

Figure A1-44: Denmark margin analysis including wind (Higher Demand Restriction (all periods))

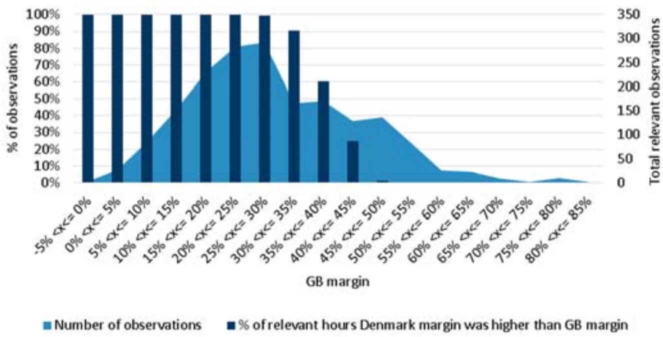
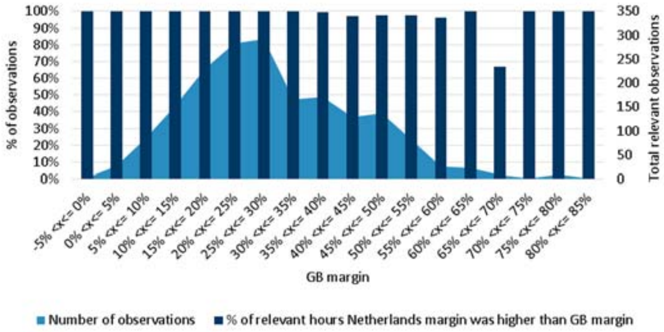


Figure A1-45: Netherlands margin analysis including wind (Higher Demand Restriction (all periods))



Margin analysis – excluding wind generation

Base Case

Figure A1-46: Belgium margin analysis excluding wind (Base Case)

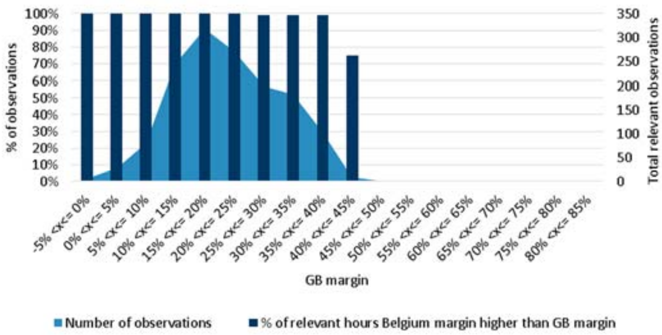


Figure A1-47: Norway margin analysis excluding wind (Base Case)

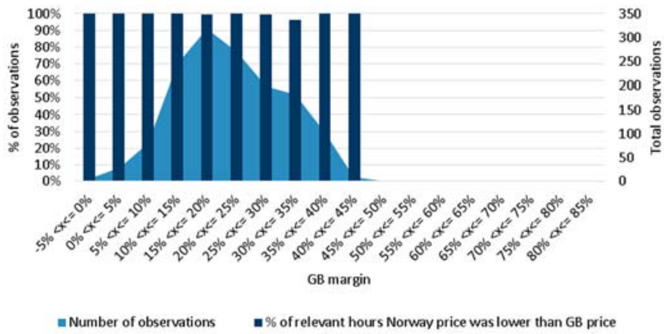


Figure A1-48: France margin analysis excluding wind (Base Case)

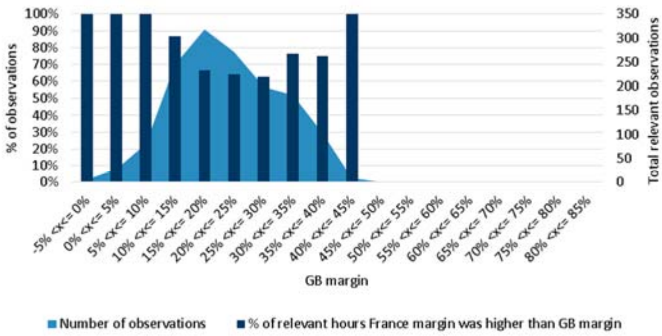


Figure A1-49: Ireland margin analysis excluding wind (Base Case)

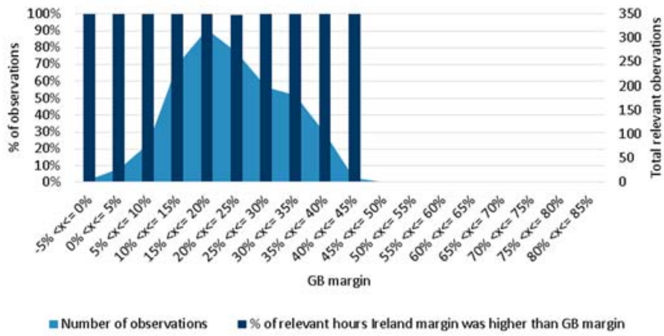


Figure A1-50: Germany margin analysis excluding wind (Base Case)

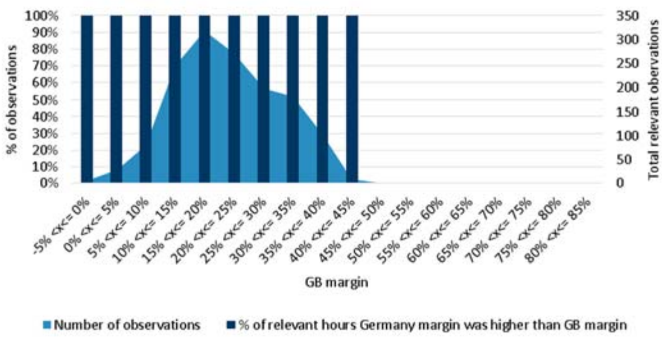


Figure A1-51: Denmark margin analysis excluding wind (Base Case)

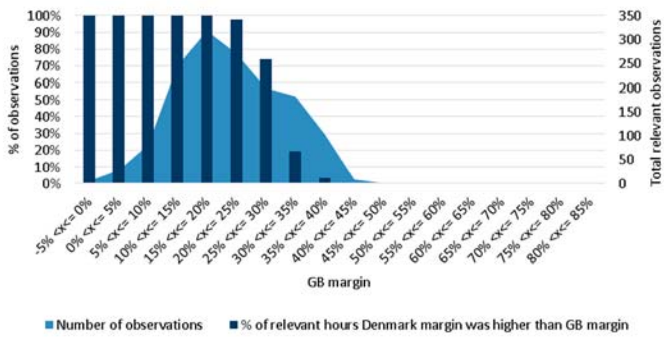
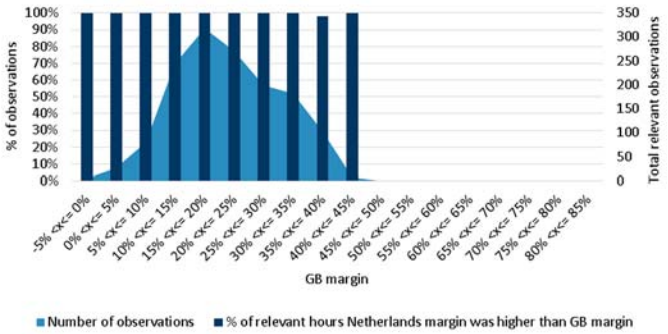


Figure A1-52: Netherlands margin analysis excluding wind (Base Case)



Higher Demand Restriction (winter peak)

Figure A1-53: Belgium margin analysis excluding wind (Higher Demand Restriction (winter peak))

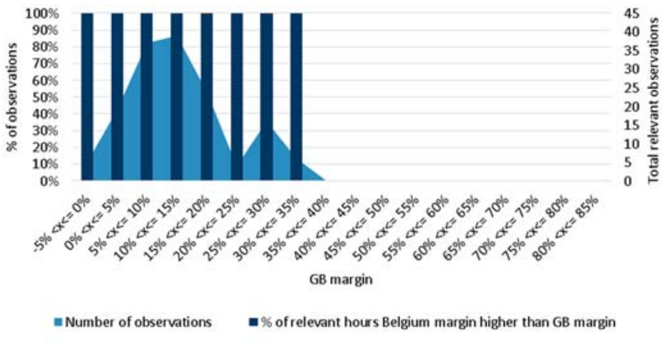


Figure A1-54: Norway margin analysis excluding wind (Higher Demand Restriction (winter peak))

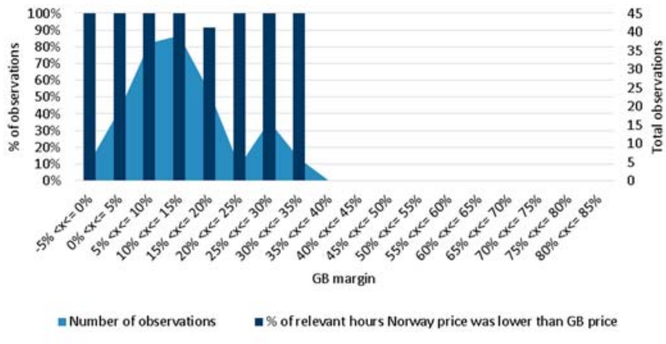


Figure A1-55: France margin analysis excluding wind (Higher Demand Restriction (winter peak))

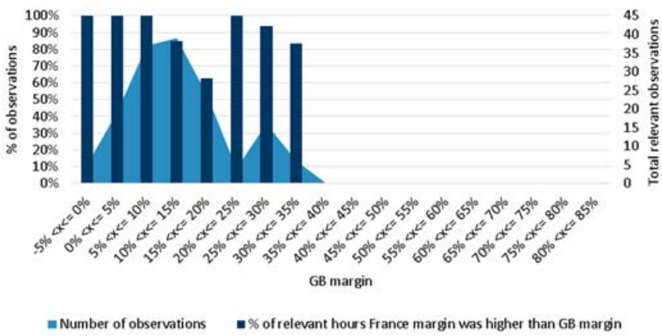


Figure A1-56: Ireland margin analysis excluding wind (Higher Demand Restriction (winter peak))

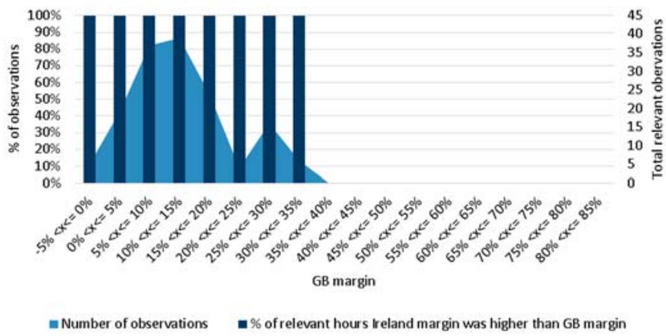


Figure A1-57: Germany margin analysis excluding wind (Higher Demand Restriction (winter peak))

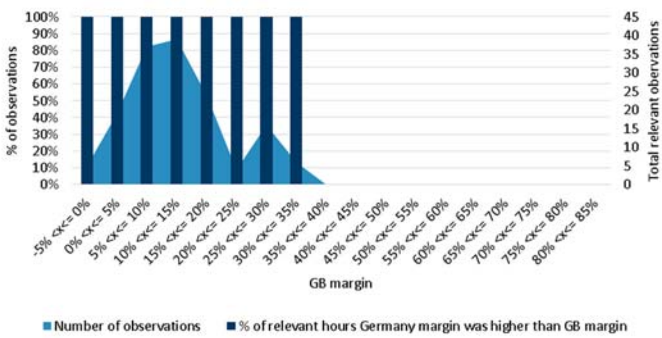


Figure A1-58: Denmark margin analysis excluding wind (Higher Demand Restriction (winter peak))

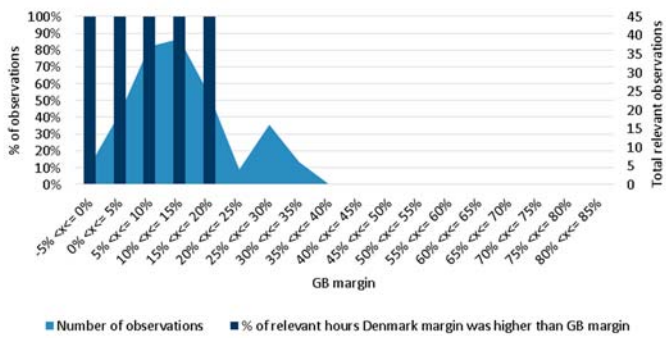
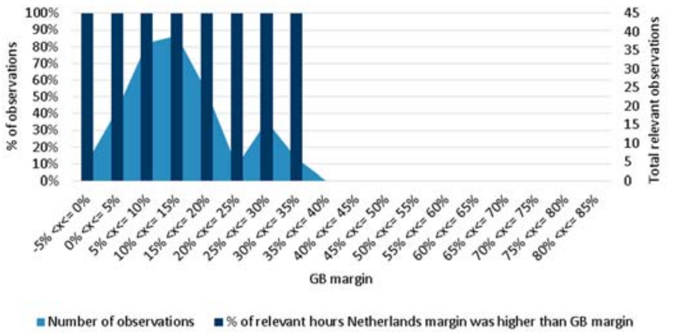


Figure A1-59: Netherlands margin analysis excluding wind (Higher Demand Restriction (winter peak))



Higher Demand Restriction (all periods)

Figure A1-60: Belgium margin analysis excluding wind (Higher Demand Restriction (all periods))

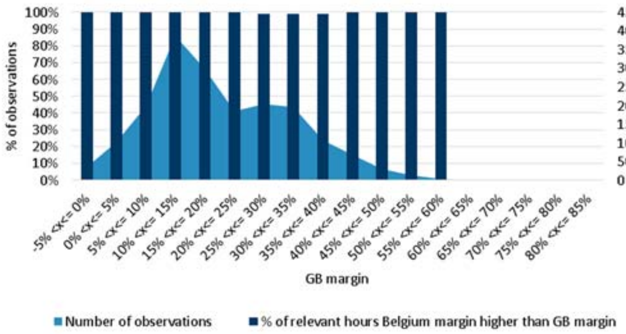


Figure A1-61: Norway margin analysis excluding wind (Higher Demand Restriction (all periods))

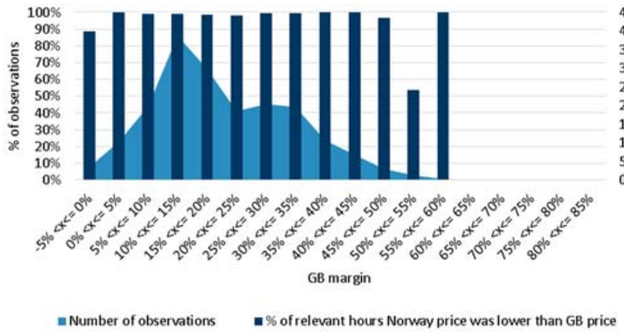


Figure A1-62: France margin analysis excluding wind (Higher Demand Restriction (all periods))

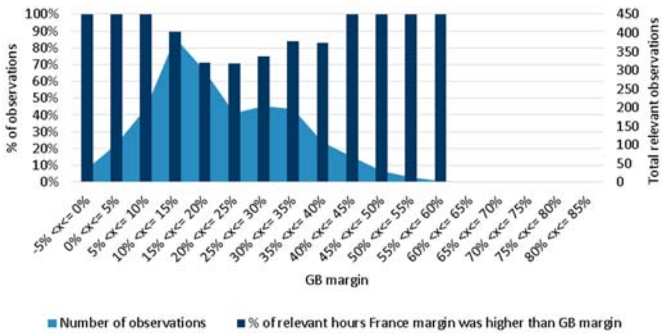


Figure A1-63: Ireland margin analysis excluding wind (Higher Demand Restriction (all periods))

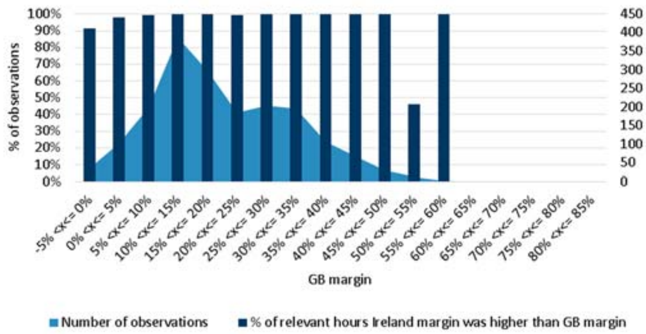


Figure A1-64: Germany margin analysis excluding wind (Higher Demand Restriction (all periods))

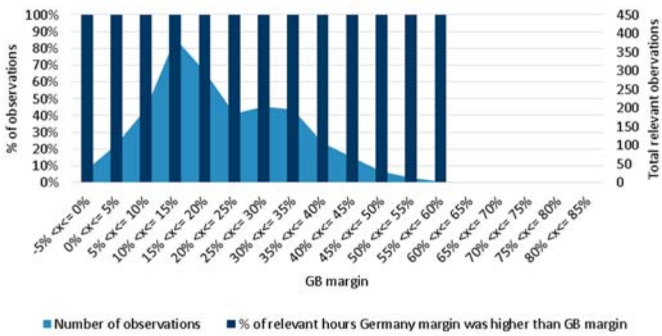


Figure A1-65: Denmark margin analysis excluding wind (Higher Demand Restriction (all periods))

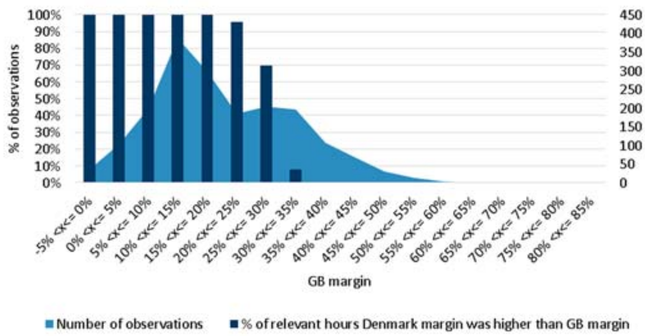
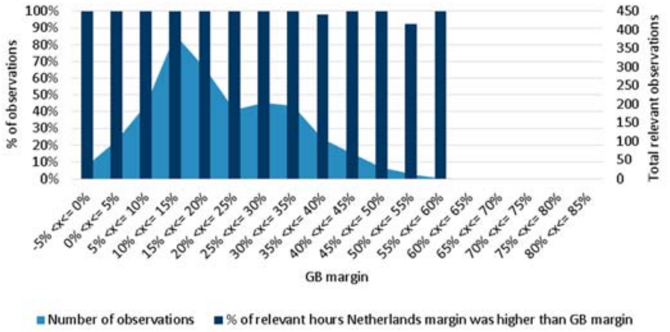


Figure A1-66: Netherlands margin analysis excluding wind (Higher Demand Restriction (all periods))



Margins analysis – price vs. margins

Base Case

Figure A1-67: Belgium price vs margin analysis (Base Case)

Figure A1-68: Norway price vs margin analysis (Base Case)

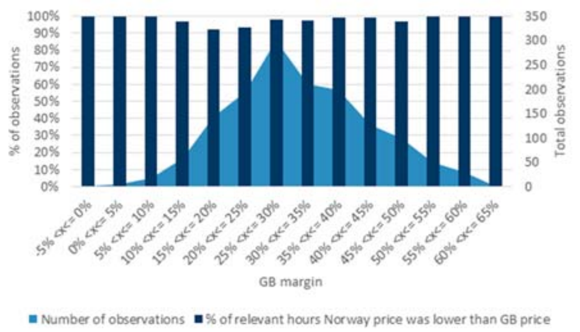


Figure A1-69: France price vs margin analysis (Base Case)

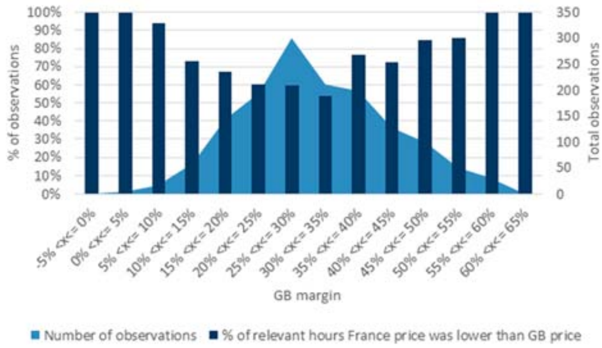


Figure A1-70: Ireland price vs margin analysis (Base Case)

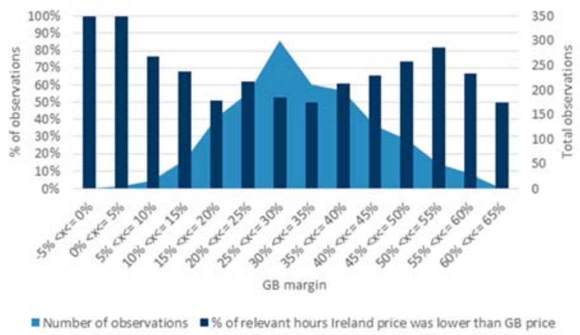
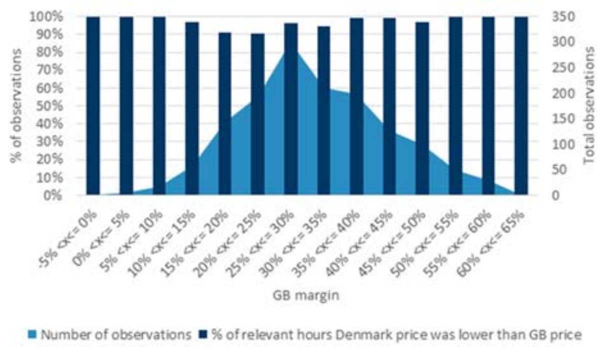


Figure A1-71: Germany price vs margin analysis (Base Case)

Figure A1-72: Denmark price vs margin analysis (Base Case)



Higher Demand Restriction (winter peak)

Figure A1-73: Belgium price vs margin analysis (Higher Demand Restriction (winter peak))

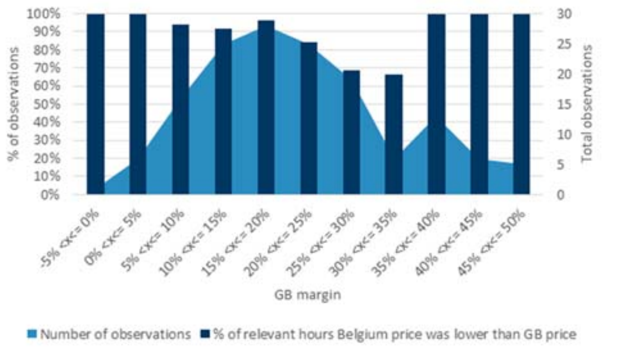


Figure A1-74: Norway price vs margin (Higher Demand Restriction (winter peak))

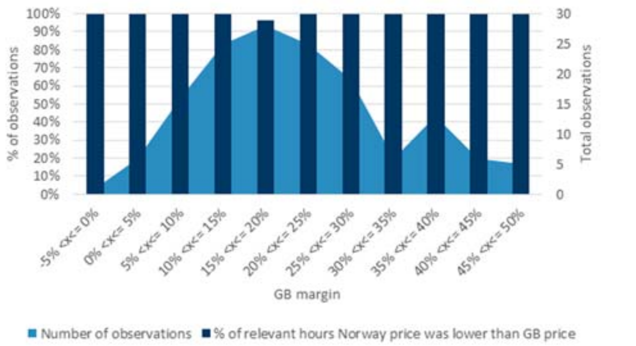


Figure A1-75: France price vs margin analysis (Higher Demand Restriction (winter peak))

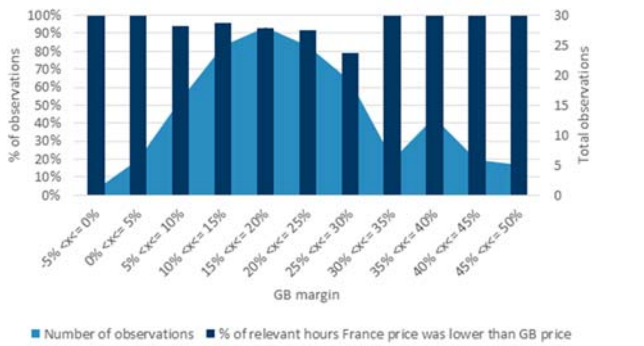


Figure A1-76: Ireland price vs margin analysis (Higher Demand Restriction (winter peak))

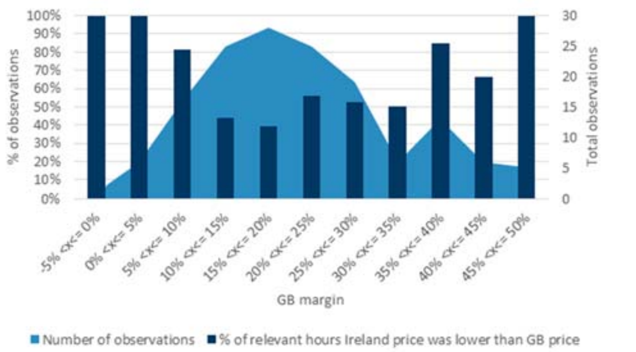


Figure A1-77: Germany price vs margin analysis (Higher Demand Restriction (winter peak))

Figure A1-78: Denmark price vs margin analysis (Higher Demand Restriction (winter peak))

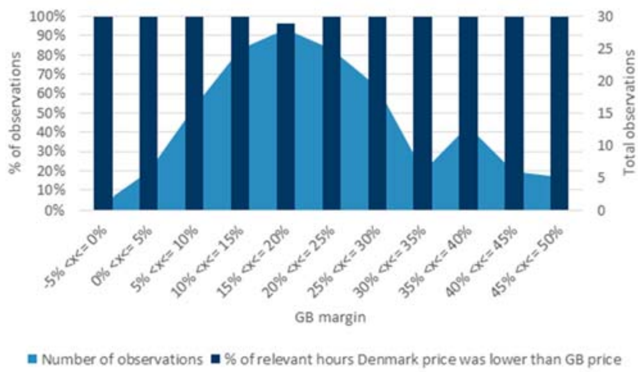


Figure A1-79: Netherlands price vs margin analysis (Higher Demand Restriction (winter peak))

Higher Demand Restriction (all periods)

Figure A1-80: Belgium price vs margin analysis (Higher Demand Restriction (all periods))

Figure A1-81: Norway price vs margin (Higher Demand Restriction (all periods))

Figure A1-82: France price vs margin analysis (Higher Demand Restriction (all periods))

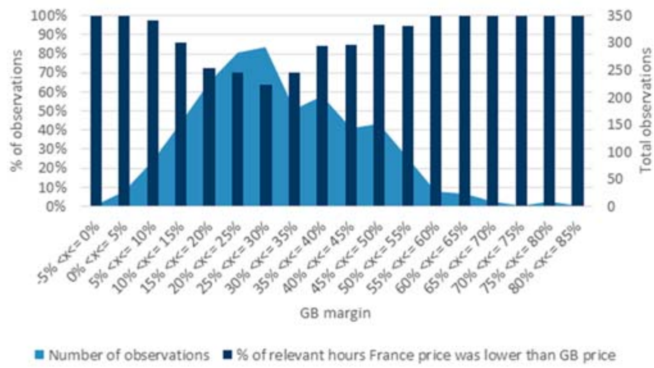


Figure A1-83: Ireland price vs margin analysis (Higher Demand Restriction (all periods))

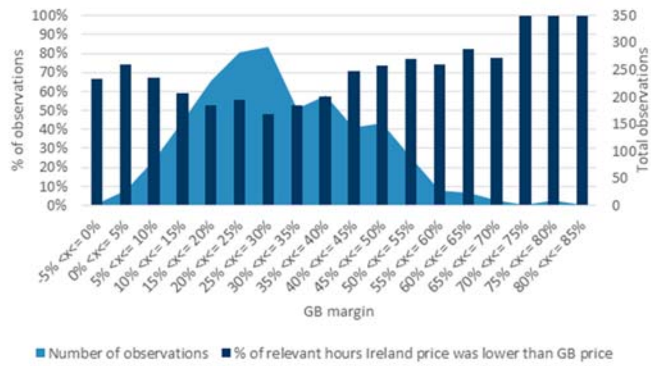


Figure A1-84: Germany price vs margin analysis (Higher Demand Restriction (all periods))

Figure A1-85: Denmark price vs margin analysis (Higher Demand Restriction (all periods))

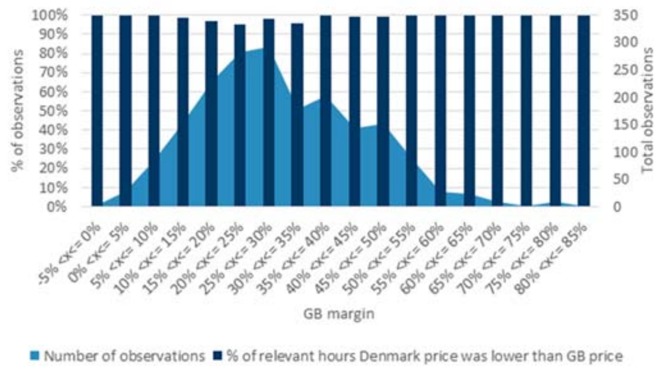
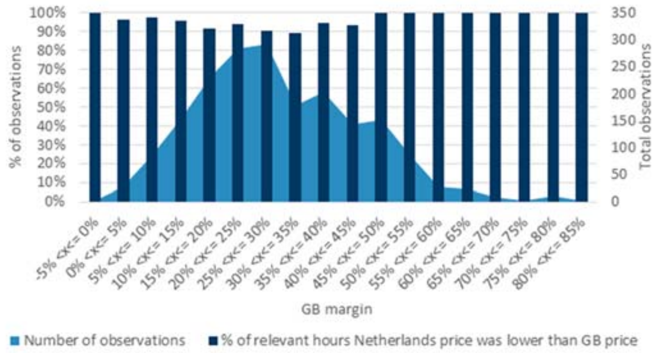


Figure A1-86: Netherlands price vs margin analysis (Higher Demand Restriction (all periods))



Generator outages analysis

A1.5 All time periods are used to compute the correlation coefficients for generator forced outages. To assess the likelihood that generator outages in GB and the connected countries occur simultaneously, we calculate the correlation coefficient, first as an aggregate of generation types and then separately for a subset of peaking plants.[75] A close to zero or negative correlation coefficient would imply that forced generator outages across GB and the non-GB country do not occur simultaneously, and thus everything else being equal, additional capacity will be available through interconnectors to compensate for supply-side restrictions in GB.

A1.6 Our analysis also isolates peaking plants because this specific type of plant runs only during periods of peak demand, contributing to security of supply. If forced outages of peaking plants in GB and neighbouring countries were correlated, this would mean that in the event of a System Stress Event, there is a greater likelihood of peaking plants in GB and neighbouring countries being unavailable at the same time.

Results

Table A1-1: Forced generator outage correlation coefficients for aggregate fuel types

	GB – Belgium	GB – Germany	GB – Denmark	GB – France	GB – Ireland	GB – Nether.	GB - Norway
All	0.07	0.14	0.07	-0.05	0.17	0.47	0.10
2015	0.19	0.10	0.07	0.13	0.28	-0.28	0.08
2016	-0.15	0.14	-0.07	-0.14	0.05	0.12	0.30
2017	0.08	-0.02	0.15	0.00	0.02	0.01	-0.06
2018	-0.08	-0.06	-0.15	0.31	-0.01	0.06	-0.30

Table A1-2: Forced generator outage correlation coefficients for peaking plants

	GB – Belgium	GB – Germany	GB – Denmark	GB – France	GB – Ireland	GB – Nether.	GB - Norway
All	-0.05	0.18	-0.02	0.28	0.27	0.49	n/a
2015	-0.08	0.25	0.09	0.19	0.28	0.01	n/a
2016	0.12	0.32	0.05	-0.05	0.00	0.41	n/a
2017	0.09	0.01	0.05	0.09	-0.07	0.09	n/a
2018	-0.05	-0.36	-0.07	0.20	-0.11	0.00	n/a

[75] Peaking generator fuel types include oil and gas.

Appendix 2
Additional empirical analysis not presented in Section 3

Wind load factor

A2.1 We calculate the wind generation load factor in GB for each period by dividing the total wind generation by the total capacity, using a dataset that provides information for all generation plants in GB.

A2.2 The correlation coefficient was then calculated between:

- GB wind load factors and GB demand; and
- GB prices and GB demand.

A2.3 We first calculate this with no restriction on GB wind load factors and next for a subset of periods when the GB wind load factor was less than 20%.[76]

A2.4 The objective of this analysis is to determine whether low wind output is a key factor driving system stress. Low correlation between wind generation and proxies of system stress indicates that, as wind generation levels change, the probability of GB being under system stress is not affected. Demand and price are used as proxy indicators of system stress as we assume that, during times of stress, demand and prices will be high.

Results

A2.5 Our results suggest that wind is not a key factor driving system stress. Correlation between GB wind generation and demand or price respectively is low. As shown in Table A2-1 and Table A2-2 below, the correlation coefficient is almost zero, suggesting that the relationship between wind generation and the system stress proxies is almost negligible.

A2.6 Even if the correlation between wind output and system stress was very high, this would not itself imply a causal relationship between the two factors. However, that the correlation between the two factors is very low suggests even more so that there is no causal relationship between low wind output and system stress.

[76] All periods were used for this analysis.

Table A2-1: GB wind load correlation with system stress proxy indicators for time periods when GB's wind load factor was less than or equal to 20%

Correlation with	21 Dec 2014 – 31 Jul 2018	2014	2015	2016	2017	2018
Demand	0.00	0.03	0.00	-0.02	0.01	0.08
Price	-0.03	0.36	-0.09	-0.01	-0.04	-0.01

Table A2-2: GB wind load correlation with system stress proxy indicators for all time periods

Correlation with	21 Dec 2014 – 31 Jul 2018	2014	2015	2016	2017	2018
Demand	0.10	-0.02	0.10	0.09	0.10	0.26
Price	-0.07	0.14	-0.20	-0.10	0.01	-0.09

Wind generation

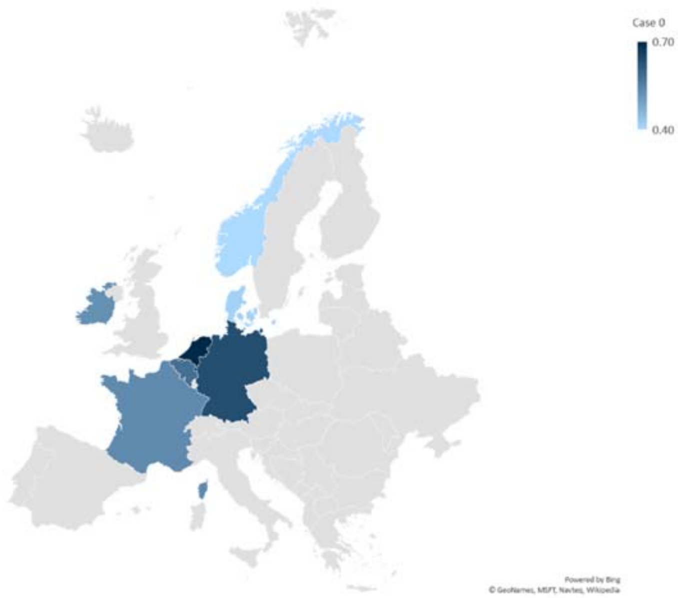
A2.7 This analysis calculates the correlation coefficient between actual wind generation in GB and a given country. Our objective is to determine whether there are still potential benefits from wind generation sources in non-GB countries when wind generation in GB is low.

A2.8 Our dataset begins in January 2015, providing just over three years of data for analysis.

Results

A2.9 Wind correlation between GB and the connected countries is moderate for all countries under the Base Case, as shown in Figure A2-1 below.

Figure A2-1: Wind correlation with GB (Base Case)



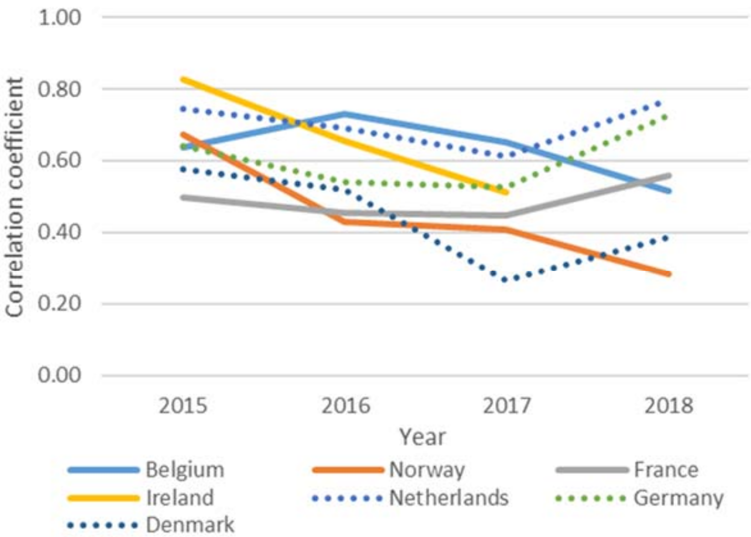
Source: FTI analysis.

A2.10 Following the results obtained in Figure A2-1 above, we expanded our analysis to look at correlation on a year-by-year basis and found no clear trend, as shown in Figure A2-2 below.[77]

[77] A year period starts 1 April of the previous calendar year and finishes on 31 March of the stated calendar year.

A2.11 Wind generation data starts from 1 January 2015, and so the Base Case is equivalent to Restricted timeframe (2014+).

Figure A2-2: Wind correlation with GB (Base Case)



Note: 2015 is not a complete year as data starts in January 2015.
Source: FTI analysis.

A2.12 We have not examined the statistical significance of these correlation figures; it is possible that these results are 'noisy.'

Base Case

Table A2-3: Wind correlation coefficient (Base Case)

	Belgium	Norway	France	Ireland	Nether-lands	Germany	Denmark
All	0.58	0.40	0.54	0.53	0.70	0.64	0.42
2015	0.64	0.67	0.50	0.83	0.74	0.64	0.58
2016	0.73	0.43	0.46	0.65	0.69	0.54	0.52
2017	0.65	0.41	0.45	0.51	0.61	0.53	0.27
2018	0.51	0.28	0.56	n/a	0.77	0.73	0.39

Table A2-4: Wind correlation coefficient – number of observations (Base Case)

	Belgium	Norway	France	Ireland	Nether-lands	Germany	Denmark
All	1,439	1,440	1,439	1,068	1,420	1,440	1,440
2015	337	336	336	330	317	336	336
2016	373	372	371	372	372	372	372
2017	367	366	366	366	365	366	366
2018	367	366	366	0	366	366	366

Higher Demand Restriction (winter peak)

Table A2-5: Wind correlation coefficient (Higher Demand Restriction (winter peak))

	Belgium	Norway	France	Ireland	Nether-lands	Germany	Denmark
All	0.58	0.40	0.57	0.52	0.78	0.71	0.42
2015	0.68	0.54	0.55	0.80	0.74	0.65	0.66
2016	0.72	0.58	0.53	0.63	0.80	0.65	0.59
2017	0.68	0.54	0.48	0.65	0.69	0.60	0.40
2018	0.25	0.30	0.28	n/a	0.70	0.67	0.27

Table A2-6: Wind correlation coefficient – number of observations (Higher Demand Restriction (winter peak))

	Belgium	Norway	France	Ireland	Nether-lands	Germany	Denmark
All	150	150	149	113	148	150	150
2015	40	38	38	38	36	38	38
2016	39	38	37	38	38	38	38
2017	38	37	37	37	37	37	37
2018	38	37	37	0	37	37	37

Note: data starts 1 January 2015, hence 2015 is 1 January 2015 to 31 March 2015.

Higher Demand Restriction (all periods)

Table A2-7: Wind correlation coefficient (Higher Demand Restriction (all periods))

	Belgium	Norway	France	Ireland	Nether-lands	Germany	Denmark
All	0.55	0.32	0.47	0.54	0.67	0.56	0.35
2015	0.59	0.48	0.47	0.42	0.66	0.55	0.45
2016	0.66	0.32	0.45	0.62	0.71	0.61	0.50
2017	0.40	0.39	0.22	0.59	0.60	0.53	0.26
2018	0.52	0.29	0.44	0.43	0.74	0.65	0.43

Table A2-8: Wind correlation coefficient – number of observations (Higher Demand Restriction (all periods))

	Belgium	Norway	France	Ireland	Nether-lands	Germany	Denmark
All	1,910	1,911	1,910	1,502	1,884	1,911	1,911
2015	412	411	411	406	384	411	411
2016	442	440	439	440	440	440	440
2017	440	438	438	438	438	438	438
2018	440	438	438	34	438	438	438

Note: data starts 1 January 2015, hence 2015 is 1 January 2015 to 31 March 2015.

Actual interconnector flow direction

A2.13 The analysis on interconnector flow direction was undertaken for the Base Case. We calculate, for all half-hourly periods relevant to the Base Case, for the listed connected countries, the proportion of periods during which:

- the price in the connected country is higher than the GB price and the interconnector flows from the connected country into GB;
- the price in the connected country is lower than the GB price and the interconnector flows from the connected country into GB;
- the price in the connected country is higher than the GB price and the interconnector flows from GB into the connected country; and
- the price in the connected country is lower than the GB price and the interconnector flows from GB into the connected country.

A2.14 We initially examine this across all years, and then examine it on a year-by-year basis.

A2.15 The results are set out below.

Table A2-9: Interconnector flow between GB and France – all years

		Price	
		FR > GB	***GB > FR***
Flow	***FR to GB***	49%	92%
	GB to FR	51%	8%

Table A2-10: Interconnector flow between GB and Ireland – all years

		Price	
		IE > GB	***GB > IE***
Flow	***IE to GB***	10%	11%
	GB to IE	90%	89%

Table A2-11: Interconnector flow between GB and the Netherlands – all years

		Price	
		NL > GB	***GB > NL***
Flow	***NL to GB***	79%	95%
	GB to NL	21%	5%

Table A2-12: Interconnector flow between GB and Northern Ireland – all years

		Price	
		NI > GB	***GB > NI***
Flow	***NI to GB***	27%	32%
	GB to NI	73%	68%

Table A2-13: Interconnector flow between GB and France – year-by-year

Conditions	2012	2013	2014	2015	2016	2017	2018	Post 2014
FR price > GB price & IC flow from GB to FR	73%	30%	52%	5%	21%	89%	89%	49%
FR price < GB price & IC flow from FR to GB	57%	83%	92%	100%	100%	92%	95%	97%

Note: data only starts 2 January 2012, hence 2012 is 2 January 2012 to 31 March 2012.

Table A2-14: Interconnector flow between GB and Ireland – year-by-year

Conditions	2012	2013	2014	2015	2016	2017	2018	Post 2014
IE price > GB price & IC flow from GB to IE	65%	99%	100%	100%	86%	77%	84%	89%
IE price < GB price & IC flow from IE to GB	9%	0%	0%	0%	18%	30%	9%	15%

Note: data only starts 2 January 2012, hence 2012 is 2 January 2012 to 31 March 2012.

Table A2-15: Interconnector flow between GB and the Netherlands – year-by-year

Conditions	2012	2013	2014	2015	2016	2017	2018	Post 2014
NL price > GB price & IC flow from GB to NL	43%	8%	10%	0%	0%	56%	0%	22%
NL price < GB price & IC flow from NL to GB	63%	92%	96%	100%	100%	99%	99%	99%

Note: data only starts 2 January 2012, hence 2012 is 2 January 2012 to 31 March 2012.

Table A2-16: Interconnector flow between GB and Northern Ireland – year-by-year

Conditions	2012	2013	2014	2015	2016	2017	2018	Post 2014
NI price > GB price & IC flow from GB to NI	0%	97%	84%	99%	89%	39%	83%	79%
NI price < GB price & IC flow from NI to GB	100%	9%	29%	2%	13%	70%	25%	28%

Note: data only starts 2 January 2012, hence 2012 is 2 January 2012 to 31 March 2012.

Interconnector flow relative to GB demand

A2.16 This analysis considers how the direction of interconnector flows changes with respect to GB demand. These results are converted into a percentage to demonstrate the proportion of time that the interconnector is flowing in each direction.

A2.17 The results are set out below.

Figure A2-3: IFA flow direction relative to GB demand (Base Case)

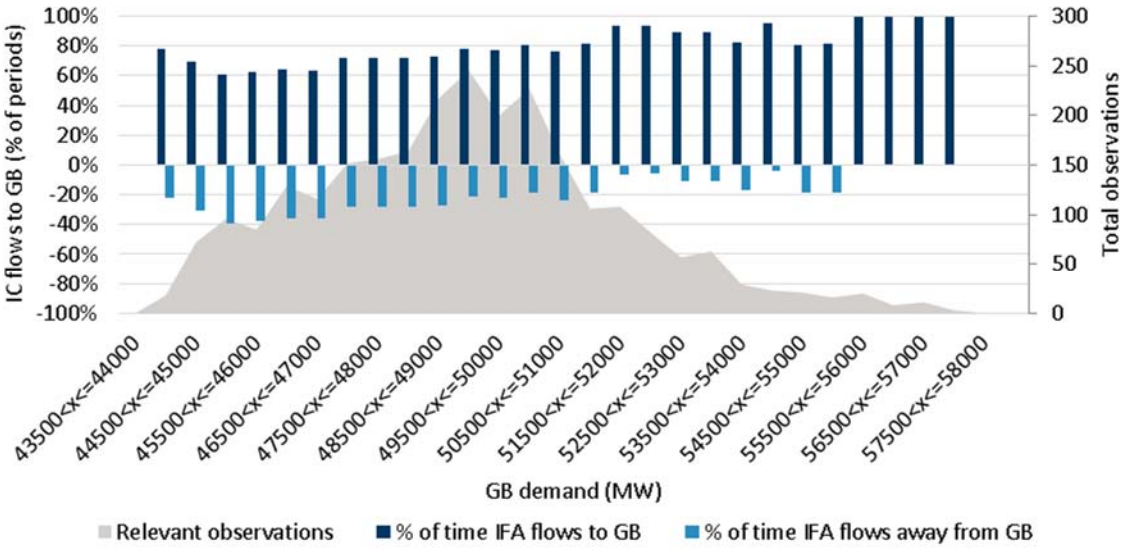


Figure A2-4: EWICs flow direction relative to GB demand (Base Case)

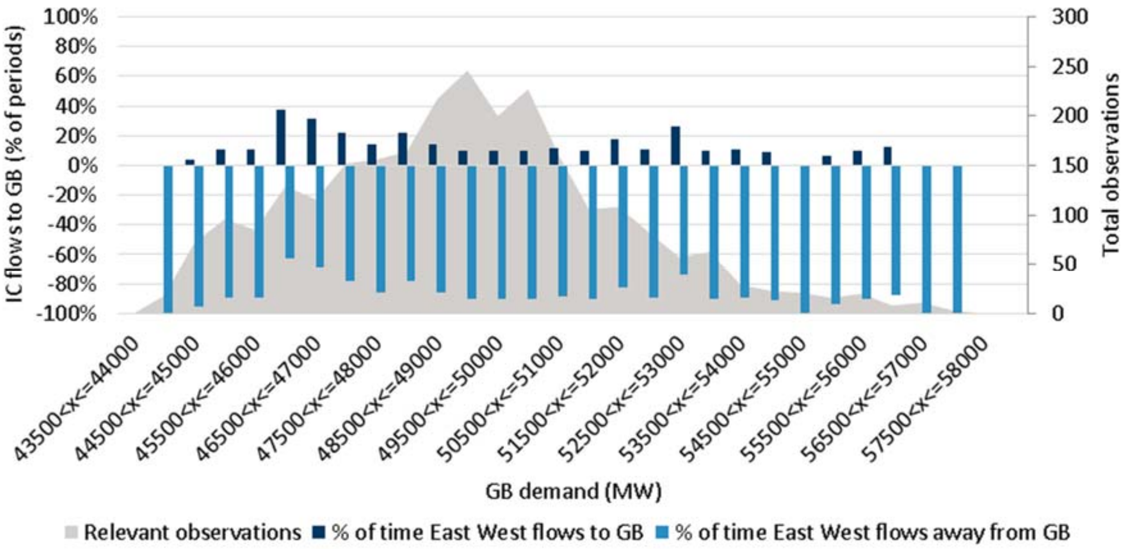


Figure A2-5: BritNed flow direction relative to GB demand (Base Case)

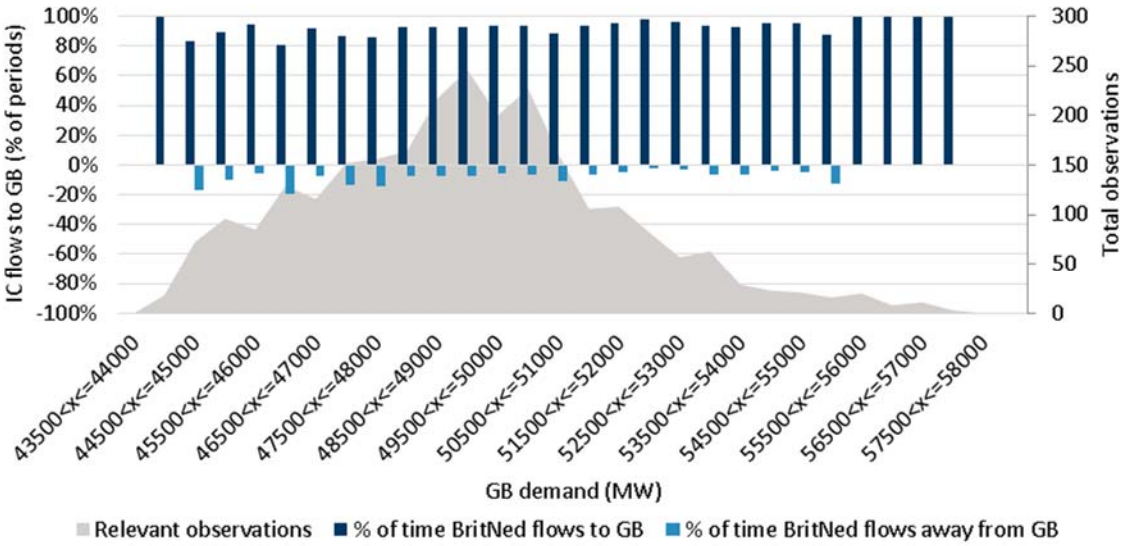


Figure A2-6: Moyle flow direction relative to GB demand (Base Case)

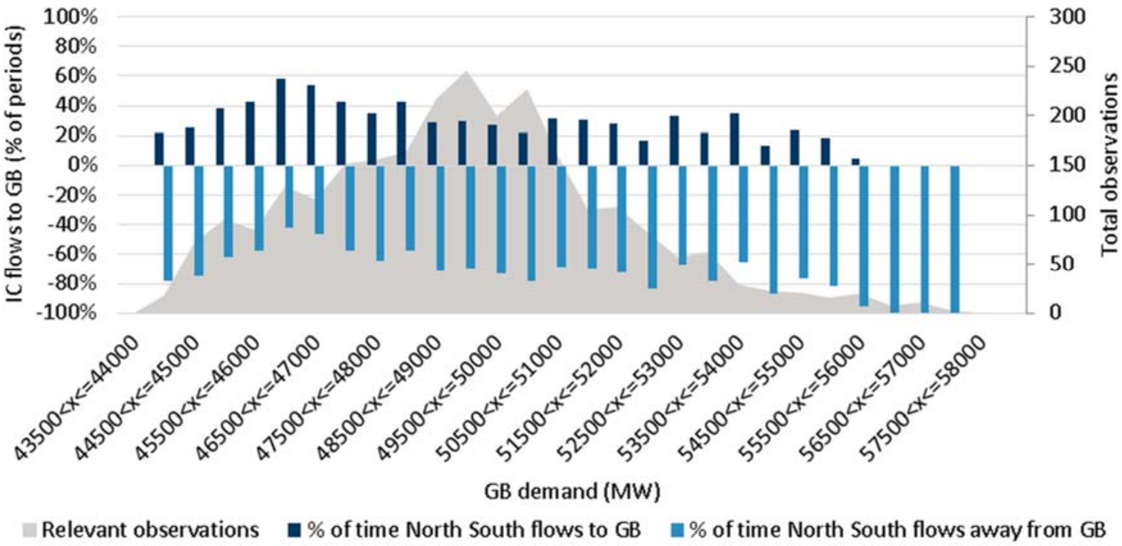


Figure A2-7: IFA flow direction relative to GB demand (Higher Demand Restriction (winter peak))

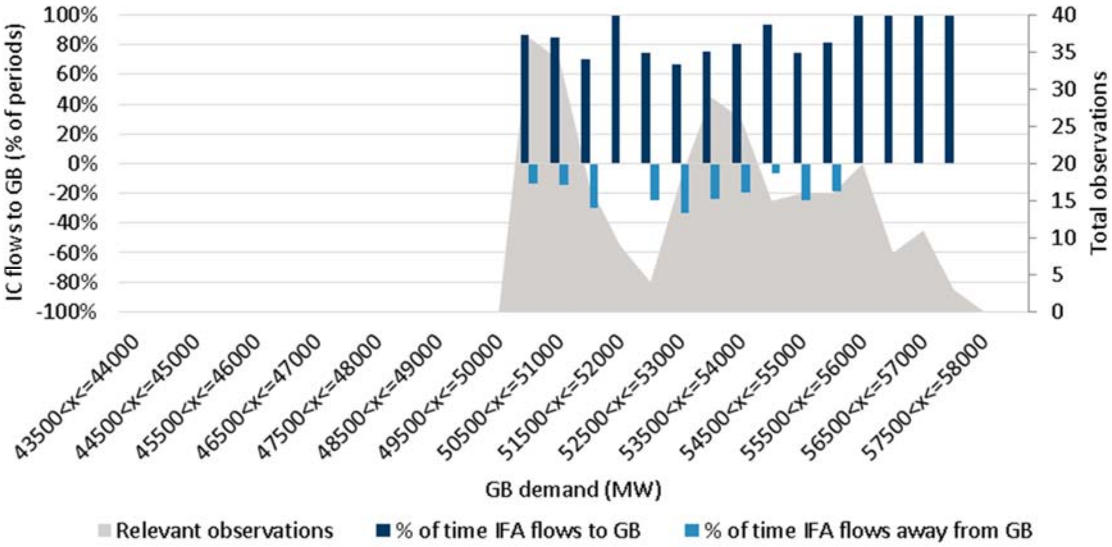


Figure A2-8: East West flow direction relative to GB demand (Higher Demand Restriction (winter peak))

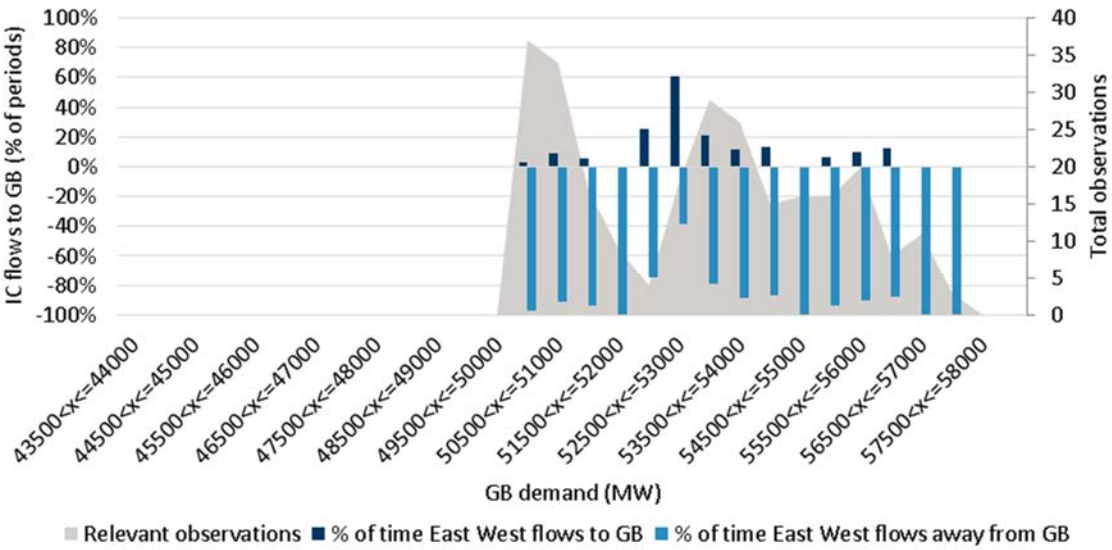


Figure A2-9: BritNed flow direction relative to GB demand (Higher Demand Restriction (winter peak))

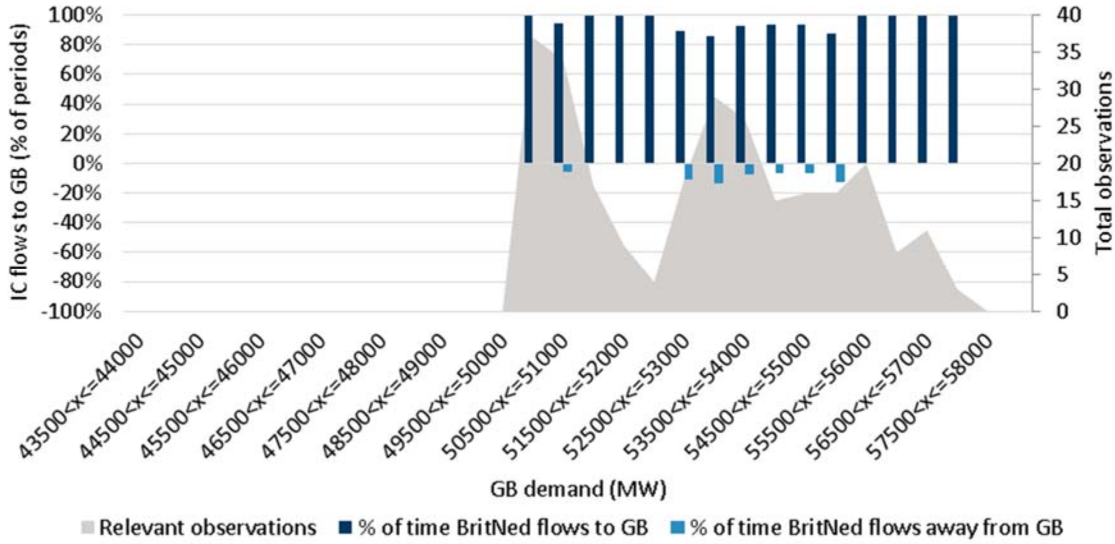
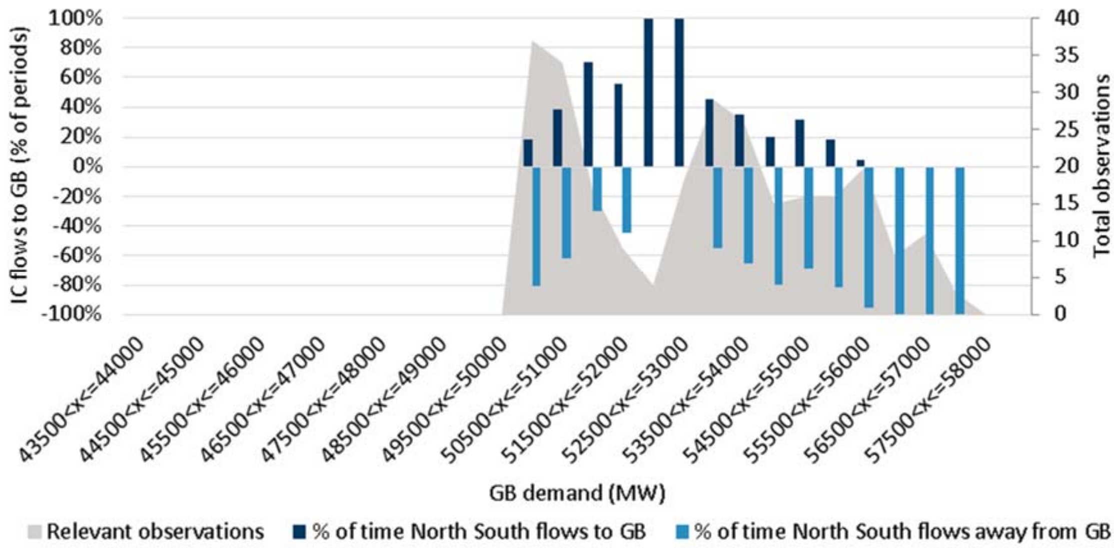


Figure A2-10: North South flow direction relative to GB demand (Higher Demand Restriction (winter peak))



A2.18 We expand on our pricing analysis by calculating the proportion of times when the interconnector flows in the direction implied by the price differential. For example, we calculate the percentage of instances when IFA was flowing into GB when the French price was lower than the GB price.

A2.19 This analysis also uses price data, hence again there is a limitation for Base Case in that GB price data starts on 2 January 2012. For interconnector flow, we use actual output data.

Table A2-17: IFA flow direction for a given price differential (Base Case)

Conditions	2012	2013	2014	2015	2016	2017	2018	Post 2014
FR price > GB price & flow from GB to FR	73%	30%	52%	5%	21%	89%	89%	49%
FR price < GB price & flow from FR to GB	57%	83%	**92%**	**100%**	**100%**	**92%**	**95%**	**97%**

Note: Emphasis added by FTI.
Source: FTI analysis; Appendix Table A2-13.

Table A2-18: BritNed flow direction for a given price differential (Base Case)

Conditions	2012	2013	2014	2015	2016	2017	2018	Post 2014
NL price > GB price & flow from GB to NL	43%	8%	10%	0%	0%	56%	0%	22%
NL price < GB price & flow from NL to GB	63%	92%	**96%**	**100%**	**100%**	**99%**	**99%**	**99%**

Note: Emphasis added by FTI.
Source: FTI analysis; Appendix Table A2-15.

Appendix 3
Peaking plant analysis

A3.1 In addition to the peaking plant analysis described in Section 3, we also assess the availability of GB peaking plants during periods of peak demand, as defined in Table 3-1. The purpose of this analysis is to determine how often GB peaking plants are producing electricity during periods of peak demand. We apply to peaking plants a similar methodology to that applied to interconnectors. We aim to contrast:

- how often GB plants produce electricity during periods of peak demand; with
- their possible generation output during those periods.

A3.2 We undertake our analysis using a dataset that contains hourly actual generation in MWh and installed capacity in MW for each plant in GB from December 2014 to July 2018. We define peaking plants in GB as those which are fuelled by either fossil oil or fossil gas and have a maximum capacity of less than 375MW in the High Case and 300MW in the Low Case. This gives a total of 4,117MW of peaking plant capacity in the High Case and 2,277MW of peaking plant capacity in the Low Case.

A3.3 For each of the High Case and Low Case above, and for a specified set of relevant periods (Base Case, Higher Demand Restriction (winter peak), and Higher Demand Restriction (all periods)) we calculate, in total and for each year, the number of hours during those specified relevant periods in which peaking plants produce electricity.[78] We multiply this by the total peaking plant capacity in MW to give the maximum possible generation over relevant periods.

A3.4 We also identified the total actual generation of the identified peaking plants in MWh over the relevant periods. We divide this by the maximum possible generation over the relevant periods to give actual generation as a proportion of maximum possible generation over the relevant periods.

[78] As our dataset only contained data from December 2014 to July 2018, the Case 3 results were identical to the Case 1 results.

A3.5 The expectation is that, as the definition of peak demand narrows, peaking plants should be more likely to be producing electricity.

A3.6 The results of this analysis are presented in the tables below:

Table A3-1: The availability of GB peaking plants during periods of peak demand

Base Case /3 4GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	1,192	0	188	467	189	348
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	5,928	0	1,634	1,791	1,210	1,293
Actual generation as a proportion of maximum possible generation	**20%**	**n/a**	**11%**	**26%**	**16%**	**27%**

Higher Demand Restriction (winter peak) 4GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	177	0	23	89	29	36
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	618	0	161	263	86	107
Actual generation as a proportion of maximum possible generation	**29%**	**n/a**	**15%**	**34%**	**33%**	**34%**

Higher Demand Restriction (all periods) 4GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	1,551	0	297	643	206	405
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	7,868	0	2,133	2,474	988	2,273
Actual generation as a proportion of maximum possible generation	**20%**	**n/a**	**14%**	**26%**	**21%**	**18%**

No Filters 4GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	16,278	53	4,003	6,574	4,325	1,324
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	133,391	1,087	36,065	36,164	36,065	24,010
Actual generation as a proportion of maximum possible generation	**12%**	**5%**	**11%**	**18%**	**12%**	**6%**

Base Case /3 2GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	529	0	88	165	87	188
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	3,279	0	904	990	669	715
Actual generation as a proportion of maximum possible generation	**16%**	**n/a**	**10%**	**17%**	**13%**	**26%**

Higher Demand Restriction (winter peak) 2GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	83	0	11	36	15	21
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	342	0	89	146	48	59
Actual generation as a proportion of maximum possible generation	**24%**	**n/a**	**12%**	**25%**	**31%**	**36%**

Higher Demand Restriction (all periods) 2GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	675	0	137	224	95	219
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	4,351	0	1,179	1,368	546	1,257
Actual generation as a proportion of maximum possible generation	**16%**	**n/a**	**12%**	**16%**	**17%**	**17%**

No Filters 2GW set						
	Total	**2014**	**2015**	**2016**	**2017**	**2018**
Actual generation of peaking plants (Total GWh)	7,323	43	1,976	2,244	2,261	800
Maximum possible generation over relevant periods (GW x # hrs of relevant prices)	73,775	601	19,947	20,001	19,947	13,279
Actual generation as a proportion of maximum possible generation	**10%**	**7%**	**10%**	**11%**	**11%**	**6%**

A3.7 Based on these results, peaking plants are generating more often as the definition of peak demand narrows, as expected.

A3.8 The low percentages in the results above illustrate that applying a similar form of the interconnector de-rating factor methodology to peaking plants implies peaking plants perform worse than their known capabilities.

Appendix 4
Data sources for empirical analysis

A4.1 The following table outlines the data sources used for the analysis primarily presented in Section 3 and Appendices 1 and 2. Our analysis uses data up to August 2018.

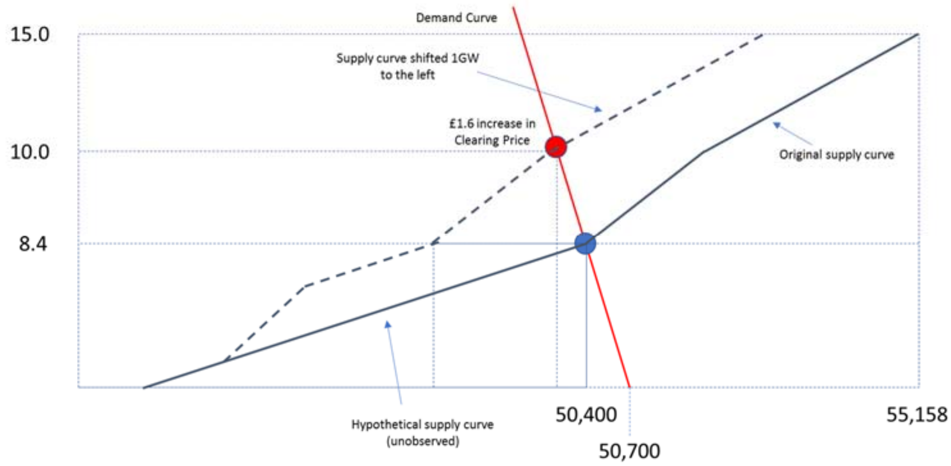
Table A4-1: Data sources

Metric	Source 1	Unit	Source 2	Unit	Time period
Price	FTI-CL Energy dataset (ENTSO-E, EnergyMarket Price, respective exchanges)	MWh	ENTSO-E FTP ("Day-Ahead Price")	MWh	Jan 2012 – Aug 2018
Demand (total load)	ENTSO-E Country Package	MW	ENTSO-E FTP ("Actual Total Load")	MW	Jan 2010 – Aug 2018
Unit-level actual generation and installed capacity	ENTSO-E FTP ("Actual Generation Per Unit")	MW	-	-	Jan 2015 – Aug 2018
Type-level actual generation and installed capacity	ENTSO-E FTP ("Aggregated Generation Per Type")	MW	-	-	Jan 2015 – Aug 2018
Outages	ENTSO-E FTP ("Outages (Generating Unit)")	MW	-	-	Jan 2015 – Aug 2018
Interconnector Flow	ELEXON (“FUELHH”)	MW	ELEXON (“INTOUTHH ")	MW	Nov 2008 – Aug 2018

Appendix 5
Supply / Demand Figure

A5.1 Figure A5-1 below illustrates the potential impact on the clearing price if there was 1GW less capacity than that which cleared in the most recent auction. For example, if interconnector de-rated capacity was reduced by 1GW through lower DRFs, this would in effect 'shift the supply curve' upwards, increasing the clearing price.

Figure A5-1: Potential impact on the 2017/18 T-4 Auction with 1GW



A5.2 Figure A5-1 indicates that the clearing price would increase by about £1.6 per kW if 1GW of capacity.

A5.3 The analysis above is indicative and based solely on published information on the relevant supply and demand curves.