2020 Interconnector De-Rating Analysis

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Agenda

- Modelling Approach
  - Concept
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De-Rating Factor Ranges for Interconnected Countries: Modelling Approach

Capacity market rules

SCHEDULE 3A: METHODOLOGY FOR DETERMINING THE DE-RATING FACTORS FOR AN INTERCONNECTOR CMU

This Schedule 3A sets out the methodology for determining the Equivalent Firm Interconnector Capacity ("EFIC") of an Interconnector CMU for the purpose of Rule 2.3.4(c).

The EFIC of an Interconnector CMU ("the relevant Interconnector CMU") for each calendar year ("Year Y") is determined by the Secretary of State as follows:

1. The Secretary of State determines a Forecasted De-rating Factor for each Interconnected Country in accordance with the process described in paragraphs 3 to 6.
2. For the purposes of this Schedule 3A, an Interconnected Country is:
   a. a country or territory in which a Non-GB Part of an Electricity Interconnector of which an Interconnector CMU forms part is located; or
   b. a country or territory in which the Delivery Body considers a Non-GB Part of an Electricity Interconnector may be located by the time that the auction is to be held in respect of which the EFIC of that Electricity Interconnector would need to be determined.
3. The Delivery Body must use stochastic modelling methodology to produce a range of De-Rating Factors for each Interconnected Country for Year Y.
4. The Delivery Body must provide the range of De-Rating Factors to the Secretary of State with the scenarios on which they are based.
5. The Secretary of State may consult such persons of proven technical expertise as the Secretary of State considers appropriate on the range of De-Rating Factors contained in the Electricity Capacity Report provided by the Delivery Body for Year Y.
6. The Secretary of State must determine the Forecasted De-Rating Factor for each Interconnected Country by:
   a. taking into consideration any advice provided by such persons of proven technical expertise as the Secretary of State considers appropriate;
   b. taking into consideration the range of De-Rating Factors provided by the Delivery Body; and
   c. determining the Forecasted De-Rating Factor within the range of De-Rating Factors provided by the Delivery Body.
7. The Secretary of State must adjust the Forecasted De-Rating Factor to take into consideration the technical reliability of each Interconnector CMU to determine the EFIC of that Interconnector CMU.

Interconnector de-rating factors need to be determined to allow interconnectors to participate in the capacity market auctions that reflects the contribution from interconnectors to security of supply.

- The process involves the EMR Delivery Body providing a recommended range based on stochastic modelling but the final, single value is decided by the Secretary of State.
- CM rules were updated for 2019 to remove reference to use of historical de-rating factors.
- The modelling provides a de-rating factor range for interconnected countries for each auction year and doesn't include a reduction for technical reliability.

Interconnector de-rating concept

The purpose of calculating the interconnector de-rating factors is to provide a range of possible de-rating factors across a series of scenarios and sensitivities.
This involves calculating how much flow can be expected across each interconnector during times when the GB system is under stress. This calculation is comprised of two parts:

1. The availability of spare generation capacity in overseas markets.
2. The ability for this power to be transmitted to GB. This is potentially made up of a further two parts:
   a) The ability of interconnectors between non-GB markets to transmit the power to a market that is directly connected to GB (e.g. Germany to France).
   b) The availability of sufficient interconnector capacity from the overseas market to GB (e.g. France to GB via IFA).

The ECR gives a range of possible de-rating factors for each country. The final, single de-rating values for each interconnector are decided by the Secretary of State based on consultation with the Panel of Technical Experts (PTE). This also accounts for technical reliability which is not included in our modelling.

A look back at how our analysis has developed

In previous years there were two elements to the methodology:

- Analysis of historical flows and price differentials provided by Poyry.
- Stochastic modelling of the future European electricity market.

Last year, BEIS removed the requirement for the de-rating factors to be constrained by a 'historical floor' based on the Poyry analysis. As this analysis no longer forms part of the decision making process, BEIS have not commissioned Poyry to provide an update to the analysis this year.

This briefing focusses on the stochastic modelling. Since the first ECR in 2014, National Grid ESO have continuously improved our modelling of European markets to assess the contribution of interconnectors at times of system stress. This has seen a significant change from our early 'net float' assumptions to developing in-house pan-European modelling expertise. In this time we have:

- Procured our pan-European market model, BID3.
- Extended our historic weather to 30 years correlated data across Europe.
- Employed multiple scenarios for Europe.
- Refined our approach to targeting stress periods consistent with the Reliability Standard (e.g. in the 2019 ECR).

This is summarised visually on the next slide.

A look back at how our analysis has developed

2014	2015	2016	2017	2018	2019
Float base case with import sensitivities	Baringa (Plexos) Pan-European stochastic model	Baringa (Plexos) Pan-European stochastic model	National Grid pan-European stochastic model (BID3)	National Grid pan-European stochastic model (BID3) with European scenarios	National Grid pan-European stochastic model (BID3) with European scenarios
High level assumptions	Previous year’s GB scenarios combined with latest interconnector capacities and fuel prices.	Previous year’s GB scenarios combined with latest interconnector capacities and fuel prices.	Current year GB scenarios, interconnector capacities and fuel prices.	Current year GB scenarios, interconnector capacities and fuel prices.	Current year GB scenarios, interconnector capacities and fuel prices.
			Single scenario for Europe	Multiple scenarios for Europe	Multiple scenarios for Europe
	4 year weather history	9 year weather history	30 year weather history	30 year weather history	30 year weather history

Changes for this year

This year we have made changes to our interconnector de-rating factor analysis.

The two main changes are:

1. How we use stress periods in our modelling.
2. Improved model functionality to focus the analysis on the stress periods.

In future years, the participation of interconnectors in the capacity market is likely to be superseded by direct participation of cross-border capacity as set out in Article 26 of Regulation (EU) 2019/943 as part of the Clean Energy Package.

The European Network of Transmission System Operators for Electricity (ENTSO-E) have a mandate to develop a methodology to enable this[(1)]. This includes a methodology to determine the maximum entry capacity for cross-border participation in capacity markets. We will be working closely with ENTSO-E to support and provide input to this work, which is due to be finalised in 2021, and would expect to implement it in our ECR modelling when it is available.

(1) https://consultations.entsoe.eu/markets/proposal-for-cross-border-participation-in-capacit/

Use of stress periods in our modelling

A system stress event occurs when the expected unserved energy is greater than zero[2]. In previous years, our de-rating factor ranges for interconnected countries have been based on analysis of interconnector flows to Great Britain at times when demand in Great Britain was higher than available generation located in Great Britain (i.e. interconnector imports are needed to prevent a loss of load event).

However, this may not strictly lead to unserved energy as available capacity from Europe may mean that a stress event could be avoided in these periods. Therefore, in this year's analysis we extended our modelling such that our interconnector analysis only included periods when the expected energy unserved is greater than zero. Essentially, this means that our interconnector de-rating factor ranges will now be based only on periods for which we expect demand in Great Britain to be higher than available supply *including* imports.

This approach brings our modelling closer to the definition of a stress event. It also offers greater alignment with the methodology used to calculate de-rating factors for limited duration storage and renewables. It is also consistent with the principles that ENTSO-E have already set out in the aforementioned methodology[3].

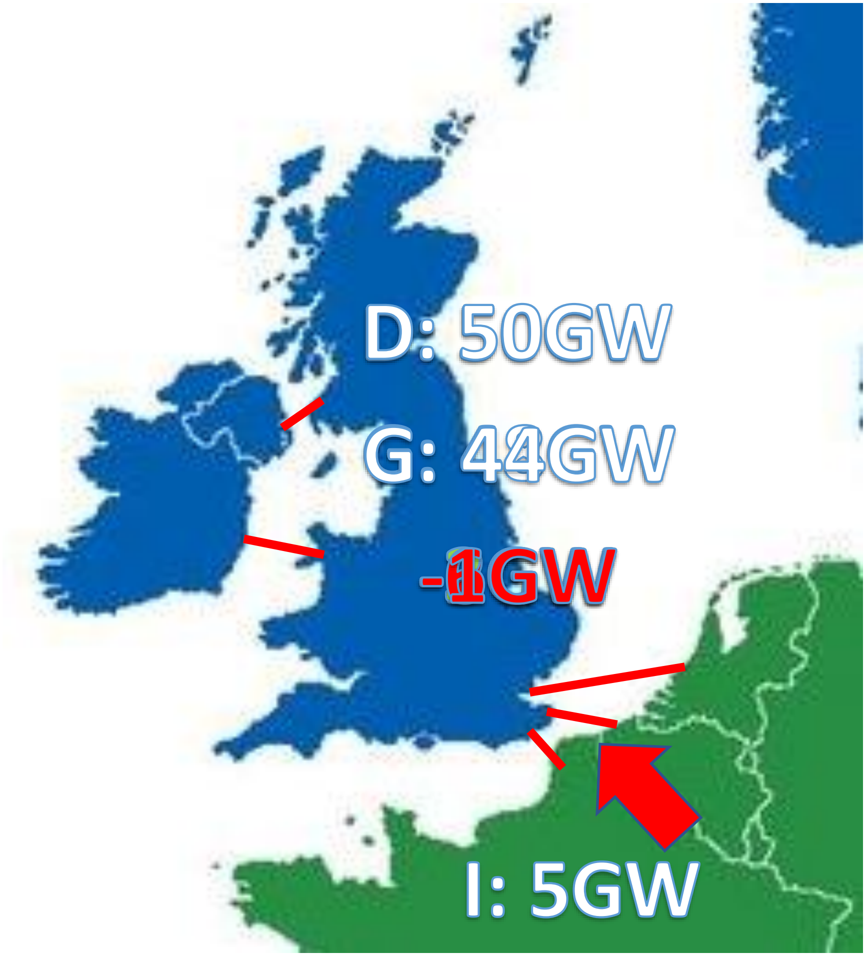
We used a 31-year weather history, so our analysis was based on the 93 tightest periods to be consistent with the Reliability Standard of 3 hours per year loss of load expectation (LOLE), in a similar way to the 2019 ECR. These periods will be the tightest across the entire 31-year history, so some historic weather years will contribute more than others.

(2) See Section 8.4.1. of the Capacity Market Rules: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/822019/Informal_Consolidation_of_Capacity_Market__Rules_July_2019.pdf
(3) See Article 5 in: https://consultations.entsoe.eu/markets/proposal-for-cross-border-participation-in-capacit/supporting_documents/ENTSOE%20Proposal%20for%20crossborder%20participation%20in%20capacity%20mechanisms%20%20for%20public%20consultation.pdf

Stress period examples

Near-stress period
GB Demand: 50GW
GB Generation: 48GW
2GW Shortfall
Available Imports: 5GW
3GW Surplus – Not a stress period, economics determines which plant will be dispatched.

Stress period
GB Demand: 50GW
GB Generation: 44GW
6GW Shortfall
Available Imports: 5GW
1GW Deficit – Stress period, availability of generation in overseas markets and interconnector capacity to transmit this to GB determines interconnector de-rating factor for this time period.



Better modelling of stress periods (1)

In previous years, we have undertaken our interconnector modelling using full, highly detailed annual dispatch simulations. These runs simulated generation and demand across Europe for each hour in the year with a full 30-year weather history. We then filtered on the tightest periods to assess the interconnector flow at times of system stress. In 2019, we refined this approach to target the 90 tightest periods to be consistent with the Reliability Standard of 3 hours LOLE. However, this ultimately means that less than 0.1% of the hours that we modelled were being used to inform the de-rating factor ranges, which is inefficient.

New functionality has been developed in BID3 to identify the tightest periods at the outset. We can then dedicate our modelling resource to only simulating the hours around these periods of interest rather than simulating every hourly period in the year. This means we can study the relevant periods in much more detail than we have previously done.

This approach presents two further modelling opportunities that we weren't able to explore previously. We can now:

1. Better assess the impact of generation availability.
2. Explore the impact of potential changes to the supply and demand outlook in Europe through sensitivities.

Better modelling of stress periods (2)

In BID3, every unit is assumed to have an availability expressed as a % to reflect that there will be periods when a generator won't be available (e.g. forced outage). In our full dispatch simulations, a 1 GW unit with availability of 90% would be assumed to have 900 MW available capacity for 100% of the time. The new approach means that this same unit is now modelled as having 1 GW capacity available for 90% of the time and zero availability for 10% of the time, determined randomly.

This approach is applied to every unit in a market to create an outage pattern for each market. We can then repeat this again and again to create multiple outage patterns for each market. Outage patterns for each market are then randomly selected and combined to create an outage case for all of Europe. Because the simulations are now much quicker as we are only focussing on the stress periods, we can model the stress periods with multiple outage cases for Europe (we used 1000 different cases for each scenario / sensitivity modelled). For each scenario / sensitivity we model, we determined a de-rating factor by taking an average of the import flows across all stress periods and outage cases.

This approach means we can better assess the range of available generation. There will be some cases with higher than average availability and some with lower availability – all of this will now be included in our assessment, whereas previously it was effectively a single outage case. This better reflects the reality of the market and is consistent with our modelling for the target capacity in the ECR using the Dynamic Dispatch Model (DDM).

Better modelling of stress periods (3)

Our supply and demand assumptions for Europe are based on scenarios developed by ENTSO-E and other European TSOs. Our current sources are published in the Future Energy Scenarios (FES) Modelling Methodology and the 2019 ECR.(4)

The supply and demand outlook for Europe is uncertain. The reduced simulation time in our new modelling approach means that we can assess the impact of potential uncertainty that isn't covered by the European scenario assumptions through sensitivity analysis.

In total for each auction year we have modelled 5 scenarios (Base Case + four scenarios in FES 2020) and around 100 sensitivities on each scenario. Each of these has been modelled with 1000 different outage cases – effectively 500,000 simulations. In previous years this number was closer to around 20 (5 scenarios with 3 or 4 sensitivities and a single outage case).

We have modelled sensitivities that cover uncertainty in thermal plant closures in different European markets, additional gas capacity in Germany, interconnector loss assumptions, European demand, French nuclear outages, Norwegian hydro and interconnection.

In response to the PTE feedback we proposed an evidence-based approach on the cases to include that set our de-rating factor range.

(4) http://fes.nationalgrid.com/media/1417/fes-modelling-methods-2019.pdf and https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Electricity%20Capacity%20Report%202019.pdf

Basic BID3 process

BID3 is NGESO's European long-range market simulation tool. It comprises of plant capacity and demand data that is determined by a mix of ENTSO-E data and individual TSO forecasts. It also contains historical output profiles for various renewable generator types and historical demand data.

The modules used for the interconnector de-rating process are the Security of Supply module and the Loss of Load Expectation (LOLE) module.

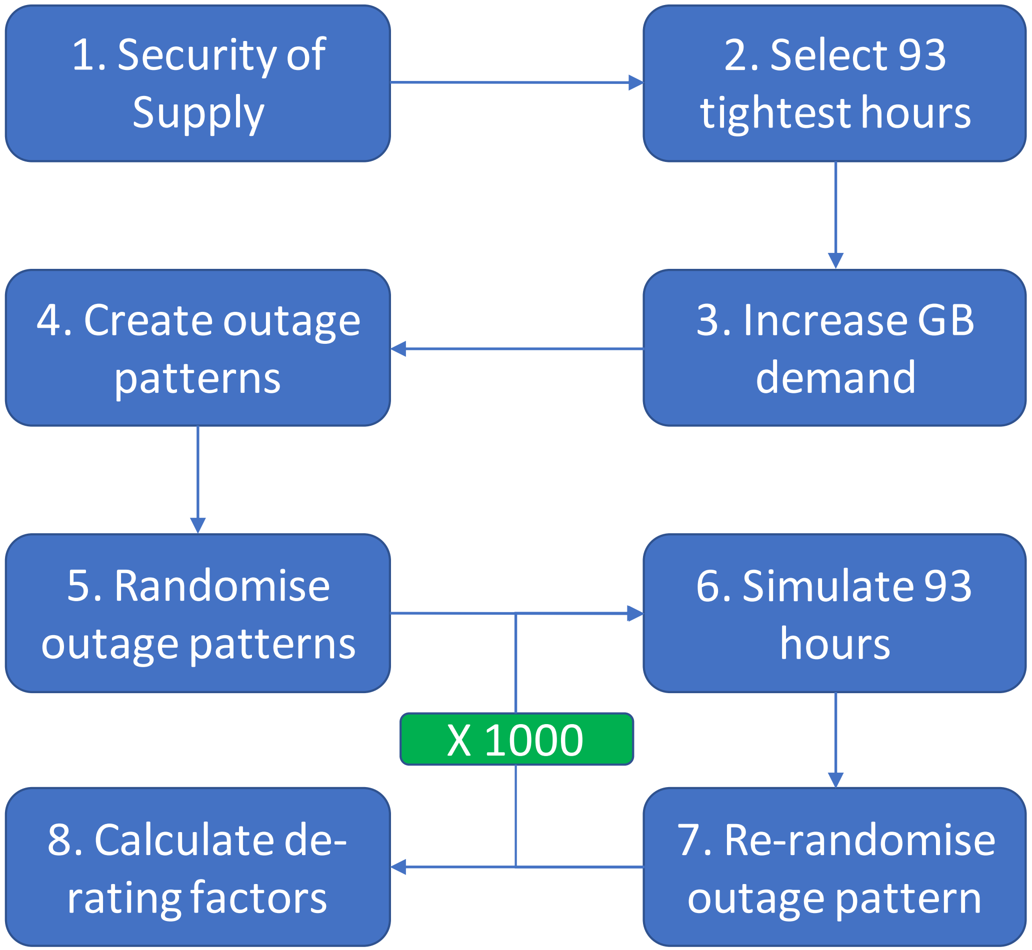
The Security of Supply module is run for the whole year, it is used to determine when the lowest margin hours are in GB.

Of these hours the 93 (31 years of historic weather data × 3 hours LOLE) lowest margin hours are taken forward into the LOLE module. Note that not all of the weather years will be represented in these 93 hours. At this point GB demand is increased to ensure that there will always be energy unserved in these hours. Note that once GB demand is scaled up the availability of generation in GB is essentially irrelevant, as GB is guaranteed to be in load loss. These 93 hours, plus six hours either side of each hour (to take into account the effect of short-term storage; short-term in the LOLE module means 7 hours duration or less), are simulated in more detail. The objective is to determine what capacity is available in the remote markets that can supply the interconnectors.

Numerous outage patterns for the thermal plant in all of the simulated markets are created, each being run for each of the 93 hours. The average of the GB import flows from each market are calculated. The process is repeated for all of the scenarios and sensitivities to form the range of results.

Process diagram

1. Simulate all 8760 hours for each of the 31 weather years for a given scenario.
2. Select the 93 (31 × 3) lowest margin hours.
3. Increase GB demand to ensure that the 93 hours will have unserved energy, regardless of GB capacity plus maximum imports.
4. Create multiple (500) outage patterns for thermal plants in each simulated market.
5. Randomly select an outage pattern for thermal plant in each of the simulated markets.
6. Simulate the 93 hours (plus the 6 hours before and after, to take into account the effect of short-term storage).
7. Pick another set of outage patterns and repeat to give 1000 simulations.
8. Average the imports from each simulation on each of the GB interconnectors, using a capacity weighted average if there is more than one interconnector from a single overseas market.



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Each LOLE tight hour simulation

Unless the six hours either side of the tight hour overlap with those of another tight hour in the same weather year, the LOLE module simulates each tight hour in isolation. The following is how the LOLE module determines the interconnector flows:

- The demand in each market for a given hour is compared to the available generation. For thermal plant this is determined by the random outages, for hydro and renewable plant by the historic weather data. Short-term storage will be optimised across the thirteen hours to minimise load loss.
- The result is the amount of surplus or deficit for each market.
- For those markets in deficit BID3 will look for markets in surplus that can supply the deficit market via interconnectors.
- As all interconnectors have a loss factor, BID3 will find the optimum way to flow power around the simulated markets to minimise load loss. Interconnector capacity limits are respected, but transmission congestion within each market is not modelled.
- Note that as the value of lost load is considered to be the same in all markets, a market that has energy unserved cannot export power to another market.
- The flows on the GB interconnectors are recorded, to be averaged once all the other hours and random outage cases have been simulated. Note that since the GB demand is increased to ensure that there is energy unserved the GB interconnectors cannot export.

Component parameters

BID3 has a large range of parameters for each of type of plant. Some parameters are set by fuel type (gas, coal, biomass, etc.), but each plant can have its own set of parameters. In practice the database splits plant into classes that all have the same parameters. The base dataset is purchased from Afry. Where we have more detailed or up to date data (for example new ENTSO-E scenarios) we will overwrite some of the base assumptions.

- For thermal plant the most important parameter for the LOLE module is the plant availability. For most thermal plant this is defined by calendar month and business or non-business day. This availability is used to determine how often the plant is unavailable in each of the random cases.
- For hydro and renewable plant the most important parameter is the output profile, this is determined by the historical weather data and is not randomised.
- For storage plant the most important parameter is the storage duration. Long term storage (8+ hours) is always assumed to be able to output at full capacity in the LOLE module. Short-term storage (7 hours or less) is assumed to start at a full state of charge at the beginning of the six hours before the tight hour. It is then free to discharge/charge within its capacity limits and may end the simulated period at any state of charge.
- Demand is determined by taking an hour historic profile and multiplying this by the annual forecast demand to give a demand for each hour.
- The capacity of the interconnectors between each simulated market is set using ENTSO-E forecast data. Interconnector flows from non-simulated markets is assumed to be zero.

European scenario assumptions

Our underlying supply and demand assumptions for European countries have not changed since last year's analysis. We had hoped to include the latest ENTSO-E scenario data from the 2020 Ten Year Network Development Plan. However, we encountered problems in the ENTSO-E dataset relating to storage and by the time this was resolved with ENTSO-E, it was too late to use in our 2020 ECR analysis.

However, the impact on the ECR interconnector modelling may not be so great because:

1. There isn't much variation in the European scenarios until beyond 2025; ENTSO-E's scenarios assume a single view until around 2025
2. The changes to the interconnector modelling this year has allowed us to conduct a more thorough analysis of uncertainty in Europe through sensitivity analysis anyway

While the underlying supply and demand assumptions for Europe haven't changed, we have undertaken an exercise to realign them to be consistent with the updated GB scenarios as follows:

- Steady Progression in FES 2020 uses the same European assumptions from Steady Progression in FES 2019
- Leading the Way, Consumer Transformation, System Transformation and the Base Case in 2020 use the same European assumptions from Two Degrees in FES 2019

European sensitivities – description

Sensitivity Name	Description	Justification
Ireland Thermal	Scaling thermal plant capacity in Ireland from 100% to 0% in 10% steps	Ireland has low levels of interconnection, any change in thermal capacity will have a large effect on the de-rating factor
France Nuclear	Reducing nuclear plant capacity in France by up to 20GW in 2GW steps	France relies heavily on nuclear power and has high electricity demand. Recent history has shown that type faults can remove a large amount of capacity for extended periods
Belgium Nuclear	Scaling nuclear plant capacity in Belgium from 100% to 0% in 10% steps	Belgium is due to phase out its nuclear fleet, any plant failures may result in the aging plant not returning to the market
Netherlands Thermal	Scaling thermal plant capacity in Netherlands from 100% to 0% in 10% steps	Netherlands has significant coal capacity which may be phased out due to environmental concerns
Germany Coal	Scaling coal plant capacity (including CHP) in Germany from 100% to 0% in 10% steps	Germany is taking a phased approach to reducing coal capacity. Environmental concerns may accelerate this process
Denmark Thermal	Scaling thermal plant capacity in Denmark from 100% to 0% in 10% steps	Denmark has coal capacity which may be phased out ahead of schedule due to environmental concerns
Sensitivities simulated, but not considered in the results		
European Demand	Demand in all modelled European markets increased by 2% to 20% in 2% steps	The level of peak demand is critical for determining the spare capacity in a given market. If electrification occurs at a faster rate than forecast this may result in significantly higher peak demand.
Norway Hydro	Scaling hydro plant capacity in Norway (simulating a lack of water rather than closure of the plant) from 100% to 0% in 10% steps	Although the 31 weather years should cover a range of hydro inflow, it is possible that these years do not cover all possible inflow levels.
European Thermal	Scaling all thermal plant in all modelled European markets from 100% to 90% in 1% steps	Rather than considering a sensitivity that only affects one market this sensitivity makes a smaller change, but in all markets
Intra-Europe Interconnector Outages and Losses	Including interconnector outages for interconnectors between European markets (not including Great Britain to Europe). Also considering varying AC interconnector losses	Interconnectors in BID3 use a deterministic availability factor that reduces capacity. This can be changed to model discrete outages. Varying the AC interconnector loss level will affect the path that electricity will take across Europe and therefore which interconnector it arrives in Great Britain from
Germany CCGT Increase	Increasing Germany CCGT plant capacity from 0 to 10GW in 1GW steps	Scenario forecasts may underestimate the closure rate of conventional thermal plant in Germany as the market decarbonises
Scenario Interconnector Capacity	Removing interconnectors that have not taken final investment decision from Leading the Way	Interconnectors included in the 2024/25 delivery year which have not yet taken final investment decision may not be commissioned in time

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European sensitivities – setting our range

We propose that the upper end of the range is based on the supply and demand assumptions in our European scenarios. We propose this because:

- The European scenario assumptions show that there is already a capacity surplus in Europe with many countries reporting LOLE values below their Reliability Standards (e.g. ENTSO-E Mid-term Adequacy Forecast Report 2018 and 2019).
- This would indicate limited potential upside as security of supply is already being met.
- Our assumptions do not include strategic reserves held outside the market (e.g. Germany, Belgium) and we don't think this is a credible upside sensitivity. Our understanding is that the conditions relating to State Aid approval place restrictions on their usage and so they cannot be used to support GB.

We considered two approaches for the lower end of the range.

- Removing thermal capacity in each market such that the LOLE just exceeds 3 hours (8 hours in Ireland). This may be considered credible on the basis that as many countries introduce capacity mechanisms, the additional capacity will not be required and close.
- French nuclear outages based on those experienced in winter 2016/17 (we assumed 10 GW). As the nuclear fleet is susceptible to type faults and level of outages occurred relatively recently, we consider this a credible case to set the lower end of the range.

We used the lower one of these two approaches to set the lower end of the de-rating factor range in our analysis – we refer to this as the most onerous sensitivity in the 2020 ECR.

French nuclear sensitivity

In response to the request from the PTE, we have provided additional evidence on the French nuclear sensitivity. This includes information on French nuclear output in recent winters and how this compares to our modelling assumptions in BID3. It is also worth highlighting that potential risks around French nuclear were raised by some industry participants (mainly generators) in responding to the interconnector methodology that was published in April.

Winter	Average nuclear output – December	Average nuclear output – January
2019/20	44 GW	50 GW
2018/19	52 GW	54 GW
2017/18	50 GW	55 GW
2016/17	49 GW	54 GW
2015/16	54 GW	56 GW
2014/15	Data unavailable	59 GW

The data in the table has been extracted from RTE's data portal:
https://www.rte-france.com/en/eco2mix/eco2mix-mix-energetique-en
The average nuclear output has been calculated for Dec and Jan in recent winters. The average is over all hours in the month (i.e. no filtering for peak periods)

Assumptions:

- French nuclear capacity 63 GW and we assume nuclear generates at full output if the unit is available.
- Our modelling assumptions assume nuclear availability around 90% for Dec - Jan so our availability distribution will be centred 57 GW.
- Removing 10 GW nuclear capacity combined with the above availability would see our distribution centred around 48 GW.

Commentary and observations:

- The modelling in our French nuclear sensitivity would have been consistent with French nuclear output in 3 recent winters (2019/20, Dec 2017, Dec 2016), so in our view this forms a credible, likely risk for which the impact on GB energy consumers should be considered.
- The main reason for low output appears to be extended outages around 10 year statutory inspections. December 2019 also appears to have been reduced by inspections required following earthquakes.
- The data may suggest a downward trend in nuclear availability over the last few winters but we should caveat that we've only been able to obtain a relatively short data set to draw any firm conclusions.

De-Rating Factor Ranges for Interconnected Countries: Modelling Results

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2021/22 T-1 results

- Only Ireland has an interconnector (EWIC) that we expect to be available in 2021/22 that doesn't already have a capacity market agreement. Therefore Ireland is the only country we have provided a de-rating factor range for following the protocol in previous ECRs.
- Nemo Link (Belgium), IFA (France), IFA2 (France), Eleclink (France), Moyle (Ireland) and Britned (Netherlands) all secured agreements in the 2021/22 T-4 auctions.
- FES 2020 scenarios and Base Case assume no other new interconnectors will be available in 2021/22
- The cases that set the range are shown in yellow.

Country	Scenarios						Most onerous sensitivity					
	Ave.	BC	CT	ST	LW	SP	Ave.	BC	CT	ST	LW	SP
Ireland	99	99	99	99	98	99	55	58	54	57	53	56

2024/25 T-4 results

- De-rating factor ranges are provided for all countries for 2024/25.
- The lower de-rating factors in Leading the Way arise due to the higher number of interconnectors. Unlike the other scenarios, Leading the Way includes interconnectors that haven't taken final investment decision yet.
- The cases that set the range are shown in yellow.

Country	Scenarios						Most onerous sensitivity					
	Ave.	BC	CT	ST	LW	SP	Ave.	BC	CT	ST	LW	SP
Ireland	52	50	52	50	44	66	29	33	36	33	19	24
France	89	91	91	91	85	86	54	59	57	59	45	50
Belgium	83	88	87	87	71	80	49	54	53	54	39	46
Netherlands	78	84	84	84	63	77	46	49	48	49	34	48
Germany	83	N/A	N/A	N/A	83	N/A	54	N/A	N/A	N/A	54	N/A
Denmark	69	N/A	80	N/A	59	N/A	39	N/A	45	N/A	32	N/A
Norway	100	100	100	100	100	99	95	96	96	96	96	91

Use of Leading the Way

- In our modelling, the de-rating factors for Leading the Way are generally much lower than the other scenarios. This is driven by Leading the Way having a higher GB interconnector capacity (15.1 GW in 2024/25 compared to 8.4 – 9.8GW in the other scenarios and Base Case).
- Leading the Way is the only scenario that includes interconnectors in 2024/25 that haven't started construction or taken final investment decision (FID) yet.
- Recent experience suggests that new interconnectors adopt a more cautious approach to participation in the capacity market – all recent new interconnectors have only participated in the CM once they have taken FID and / or started construction.
- Based on this observation, we do not expect any of these new interconnectors to participate in the 2024/25 T-4 auction. It's still possible that they will be operational by 2024/25, and in theory, could participate in the 2024/25 T-1 auction instead.
- On this basis, we think it is reasonable that the modelled range does not include the de-rating factors from Leading the Way as the de-rating factors are based on interconnection capacity that may not be ready to participate in the 2024/25 T4 auction – this doesn't undermine the credibility of the scenario or mean we consider it less likely, it just reflects the link between the de-rating factors and the projects that we expect to participate in the auction.
- Should these new projects in Leading the Way prequalify for the 2024/25 T-4 auction, then we recommend that interconnector de-rating factors should be revised downwards in light of this when we update the Demand Curve.
- Should these new projects in Leading the Way prequalify for the 2024/25 T-1 auction, then we will reassess their de-rating factors anyway, and this should reflect any interconnector capacity already secured.

Modelled de-rating factors for interconnected countries

Country	2015 ECR	2016 ECR		2017 ECR	2018 ECR		2019 ECR			2020 ECR	
	2019/20 T-4	2017/18 EA	2020/21 T-4	2021/22 T-4	2019/20 T-1	2022/23 T-4	2020/21 T-1	2022/23 T-3	2023/24 T-4	2021/22 T-1	2024/25 T-4
Belgium	58 – 70 54	N/A	65 – 92 77	65 – 85 75	65 – 78 68	35 – 67 50	75 – 98 82	52 – 65 58	38 – 56 46	N/A	46 – 88 68
Denmark	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35 – 35 32	N/A	45 – 80 52
France	50 – 70 52 – 56	45 – 86 59	45 – 88 60 – 65	48 – 80 63 – 69	61 – 92 69 – 73	59 – 86 66 – 71	88 – 99 87 - 92	66 – 81 69 – 75	57 – 79 63 – 69	N/A	50 – 91 69 - 75
Germany	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	54 – 83 N/A
Ireland	2 – 10 6	2 – 58 30	25 – 50 26	29 – 98 14 – 59	35 – 54 26 – 43	24 – 42 33	N/A	30 – 44 56	24 – 32 44	54 – 99 59	24 – 66 49
Netherlands	62 – 80 69	70 – 82 74	70 – 82 74	75 – 81 76	N/A	27 – 62 43	N/A	44 – 55 50	30 – 44 36	N/A	48 – 84 61
Norway	N/A	N/A	76 – 96 78	92 – 99 85	N/A	90 – 100 87	N/A	93 – 99 88	95 – 99 88	N/A	91 – 100 90

Notes:
1. Modelled ranges are shown in black. Actual de-rating factors shown in orange and will include technical availability. Where actuals show a range, this means different interconnectors to that market had different de-rating factors
2. 2017/18 EA represents the Early Auction
3. The 2022/23 T-4 auction did not take place due to CM suspension
4. Netherlands de-rating factors are modelled on a capacity of 1 GW. However, Britned entered the auctions since 2017 with a capacity of 1.32 GW.
5. 2015 and 2016 ECR analysis undertaken by Baringa on behalf of National Grid ESO

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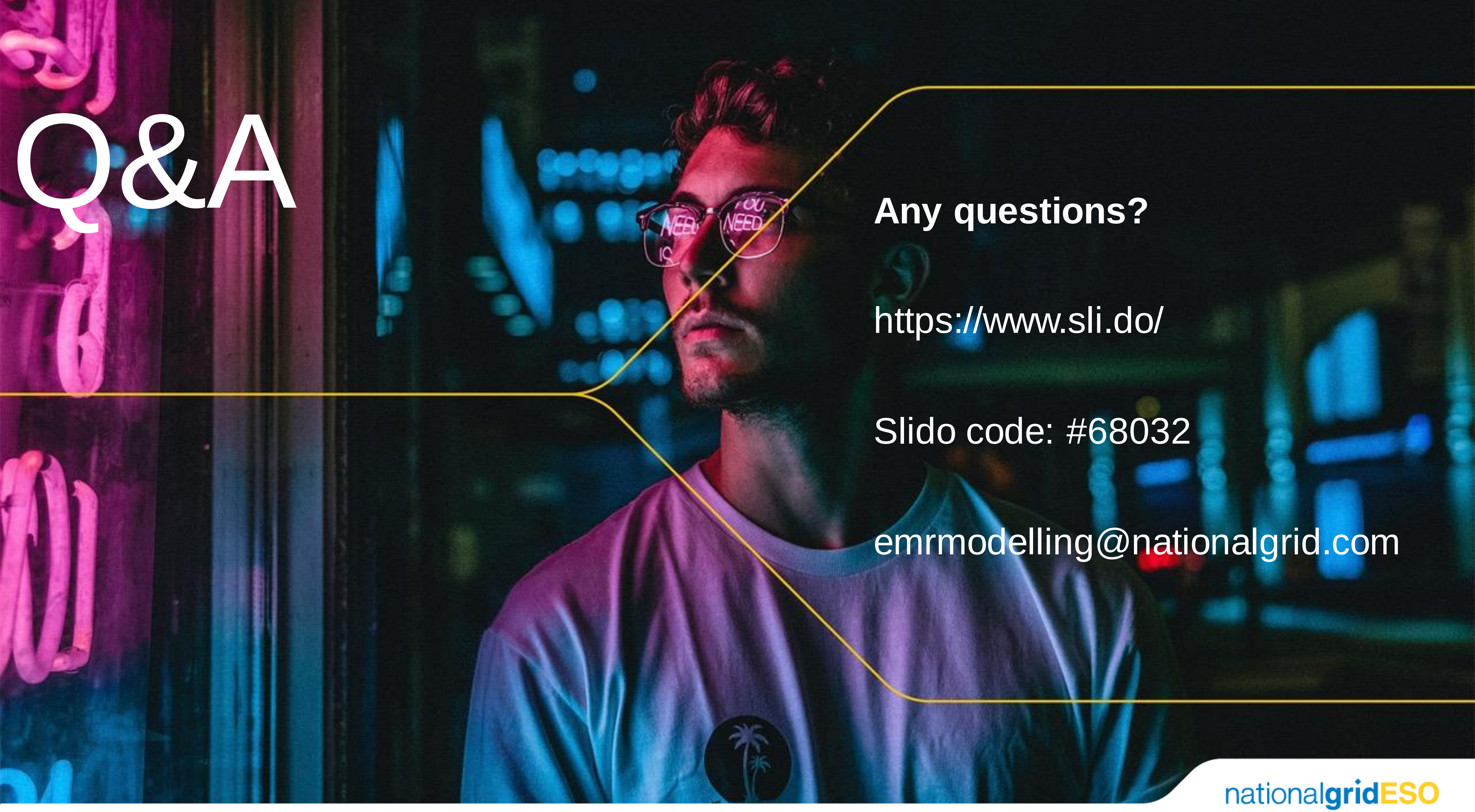
Thoughts for development in the future

- The following are some of the improvements that could be made to the interconnector de-rating process in the future:
  - BID3 input data.
    - Gather more data on the outage rates of interconnectors to improve the input data in BID3.
    - Include flexible demand in the LOLE module.
    - Update the historic demand profiles.
    - Add more recent historic weather data.
    - Provide more transparency to input data, where commercially possible.
  - De-rating calculation process.
    - Refine the technique used for determining the sensitivity threshold.
    - Increase number of sensitivities.
  - Benchmarking.
    - Comparison with past results or results from other models?
      - Difficult due to lack of true stress events in GB.
  - HVDC link technical reliability.
    - Consider including technical reliability in ESO recommended range.



Q&A

Any questions?

https://www.sli.do/

Slido code: #68032

emrmodelling@nationalgrid.com

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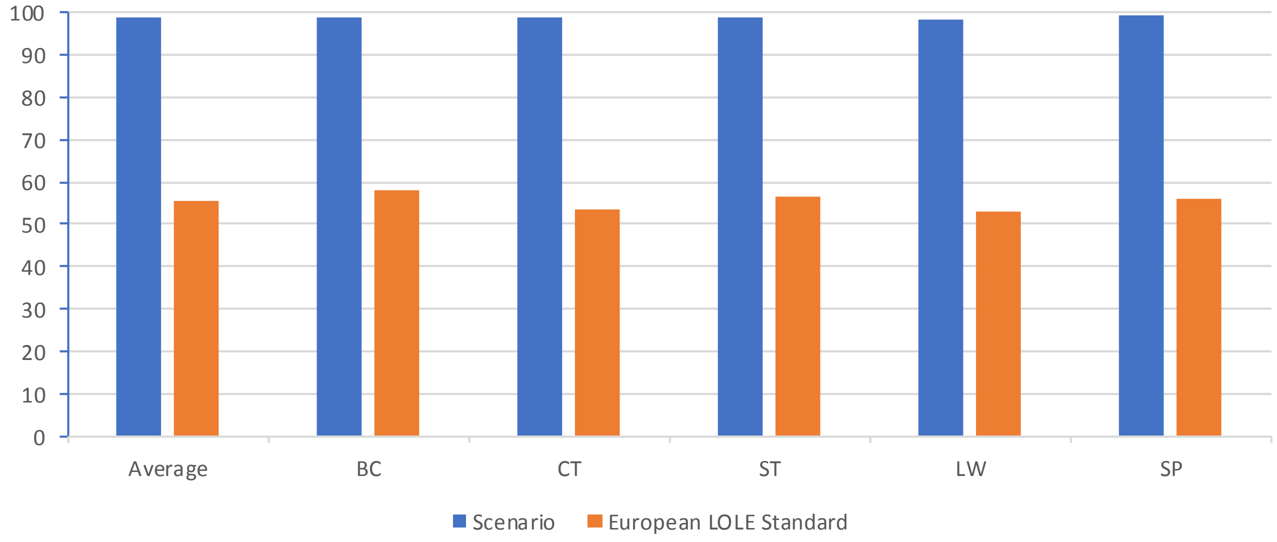
Annex

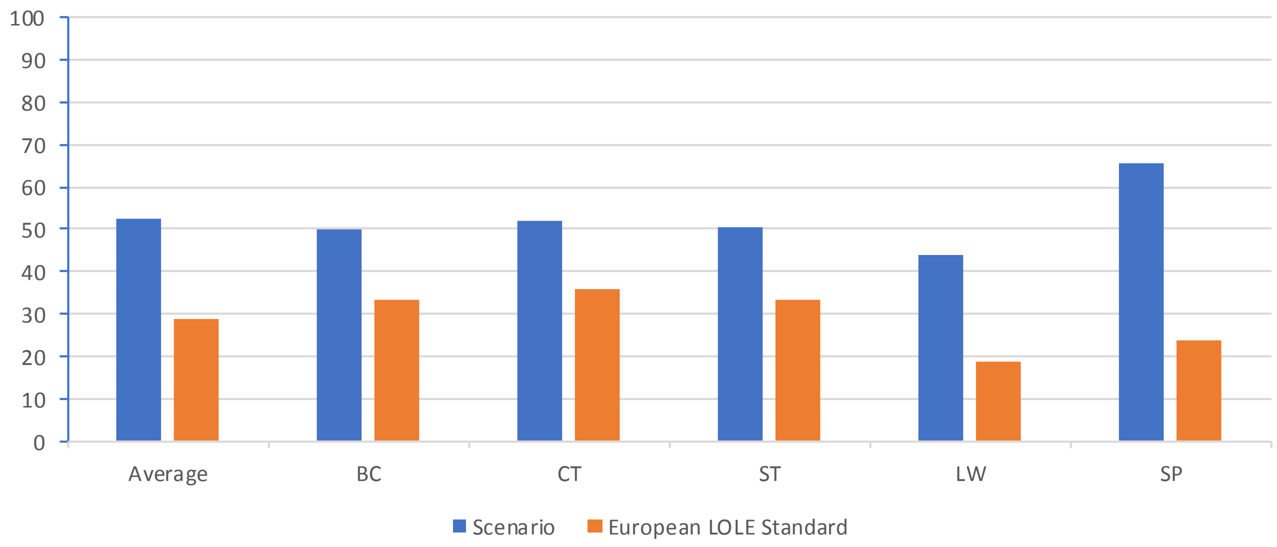
Ireland 2021/22



Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	99	99	99	99	98	99
Most onerous sensitivity	55	58	54	57	53	56
	N/A	Ireland Thermal				

- The modelled range for Ireland is 53% to 99% for 2021/22 (note that the 2021/22 T-4 range in the 2017 ECR was 29% - 99%)
- Ireland is a single energy market economically but currently there are limited physical links between the north and south. This is expected to be rectified with an additional North/South link, planned to be commissioned in 2023.
- The most onerous sensitivity included in our range was Irish thermal closure that resulted in an LOLE of around 8 hours (Irish Reliability Standard)
- Ireland was not affected by the French nuclear closure sensitivity
- Eirgrid's 2019 All-Island Generation Capacity Statement reports a capacity surplus for 2021/22 that will fall in the mid-2020s

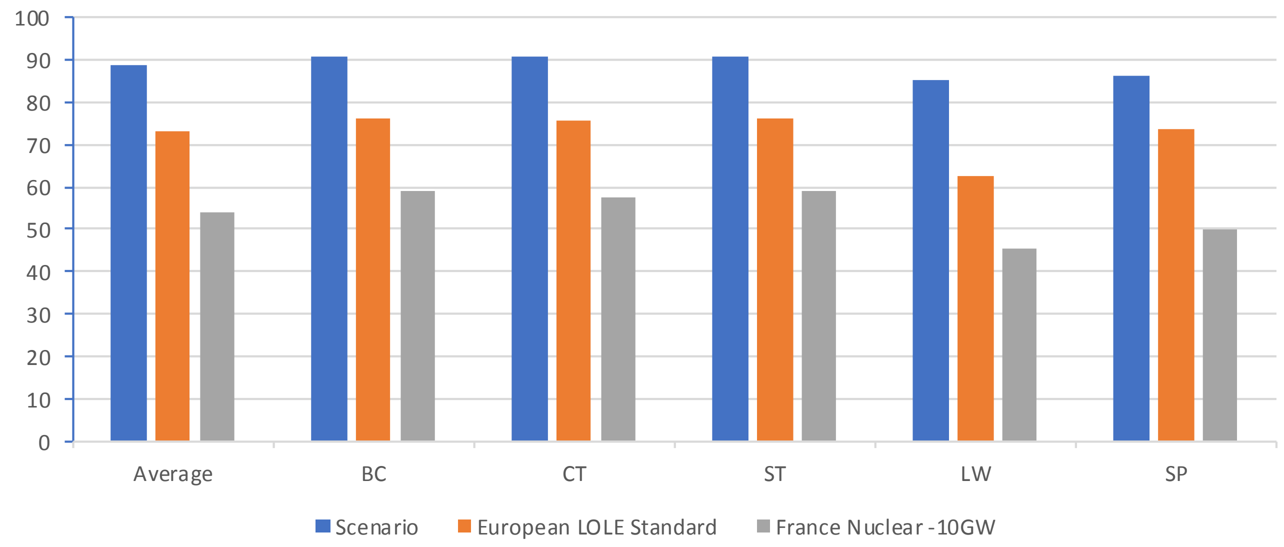
Ireland 2024/25



Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	52	50	52	50	44	66
Most onerous sensitivity	29	33	36	33	19	24
	N/A	Ireland Thermal				

- The modelled range for Ireland is 19% to 66% for 2024/25
- Ireland is a single energy market economically but currently there are limited physical links between the north and south. This is expected to be rectified with an additional North/South link, planned to be commissioned in 2023.
- The most onerous sensitivity included in our range was Irish thermal closure that resulted in an LOLE of around 8 hours (Irish Reliability Standard)
- Ireland was not affected by the French nuclear closure sensitivity
- Eirgrid's 2019 All-Island Generation Capacity Statement reports a capacity surplus for 2021/22 that will fall in the mid-2020s, leading to lower de-rating factors by 2024/25

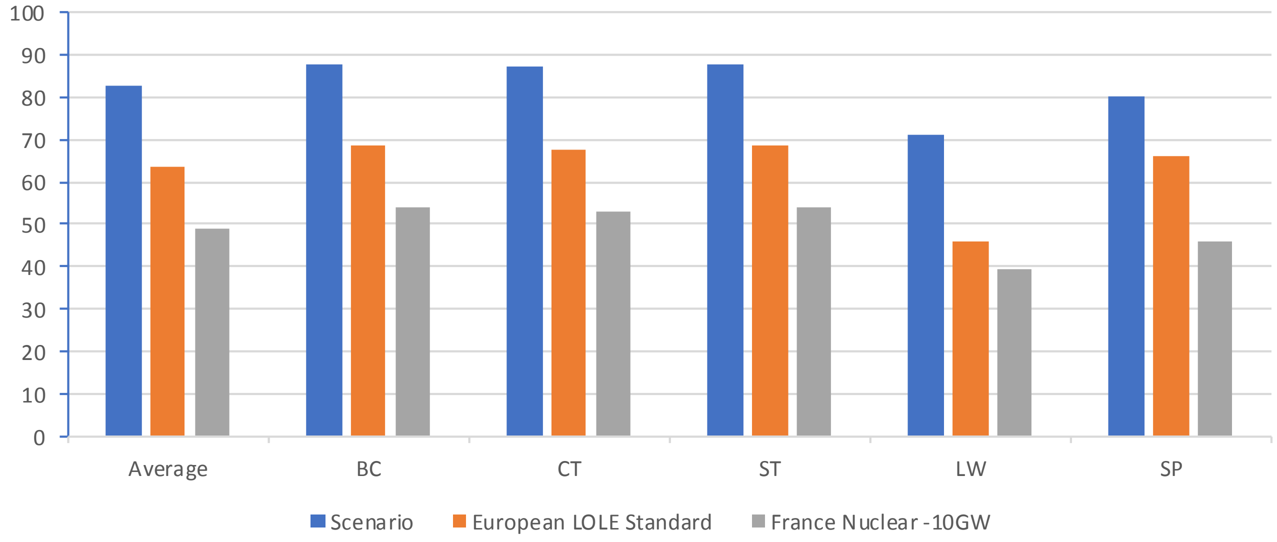
France 2024/25



Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	89	91	91	91	85	86
European LOLE Standard	73	76	75	76	63	74
France Nuclear - 10 GW	54	59	57	59	45	50
Most onerous sensitivity	54	59	57	59	45	50
	N/A	France Nuclear -10 GW				

- The modelled range for France is 45% to 91% for 2024/25
- The French generation margin is generally positive, although French demand is very weather sensitive, so very cold weather results in demand exceeding domestic generation.
- As the interconnector capacity with France grows and nuclear capacity is curtailed, we may see de-rating factors falling in the future.
- High French nuclear outages (e.g. as seen in winter 2016/17) have a big impact on de-rating factors
- IFA2 and Eleclink are expected to be operational by 2021/22
- France is well interconnected to other markets in Europe.

Belgium 2024/25



- The modelled range for Belgium is 39% to 88% for 2024/25
- Belgium plans to phase out nuclear power by 2025, this is the justification for carrying out the Belgium nuclear sensitivity.
- However, high French nuclear outages (e.g. as seen in winter 2016/17) have a big impact on de-rating

Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	83	88	87	87	71	80
European LOLE Standard	63	69	68	69	46	66
France Nuclear - 10 GW	49	54	53	54	39	46
Most onerous sensitivity	49	54	53	54	39	46
	N/A	France Nuclear - 10 GW				

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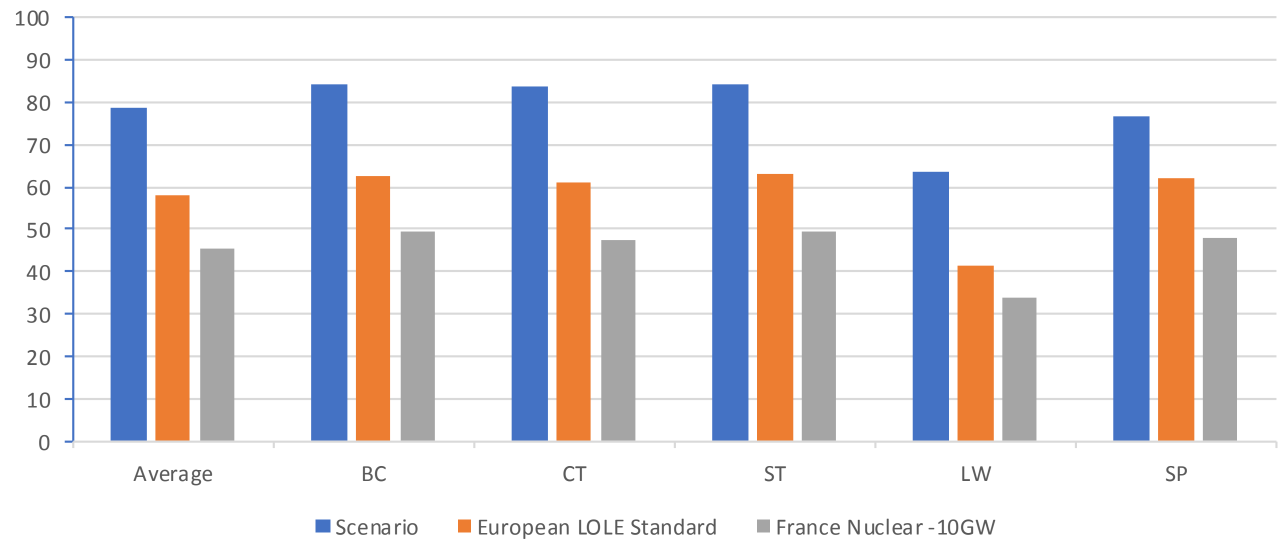
Netherlands 2024/25



Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	78	84	84	84	63	77
European LOLE Standard	58	63	61	63	41	62
France Nuclear - 10 GW	46	49	48	49	34	48
Most onerous sensitivity	46	49	48	49	34	48
	N/A	France Nuclear -10 GW				

- The modelled range for the Netherlands is 34% to 84% for 2024/25
- Similar to Belgium, the de-rating factors are reduced due to reducing margins in surrounding countries as there is very little surplus generation in the Netherlands
- Mothballing of CCGTs and reduced transit flows from Germany due to government policy to close all nuclear plants by 2022 are two of the reasons for this reduction.
- High French nuclear outages (e.g. as seen in winter 2016/17) have a big impact on de-rating

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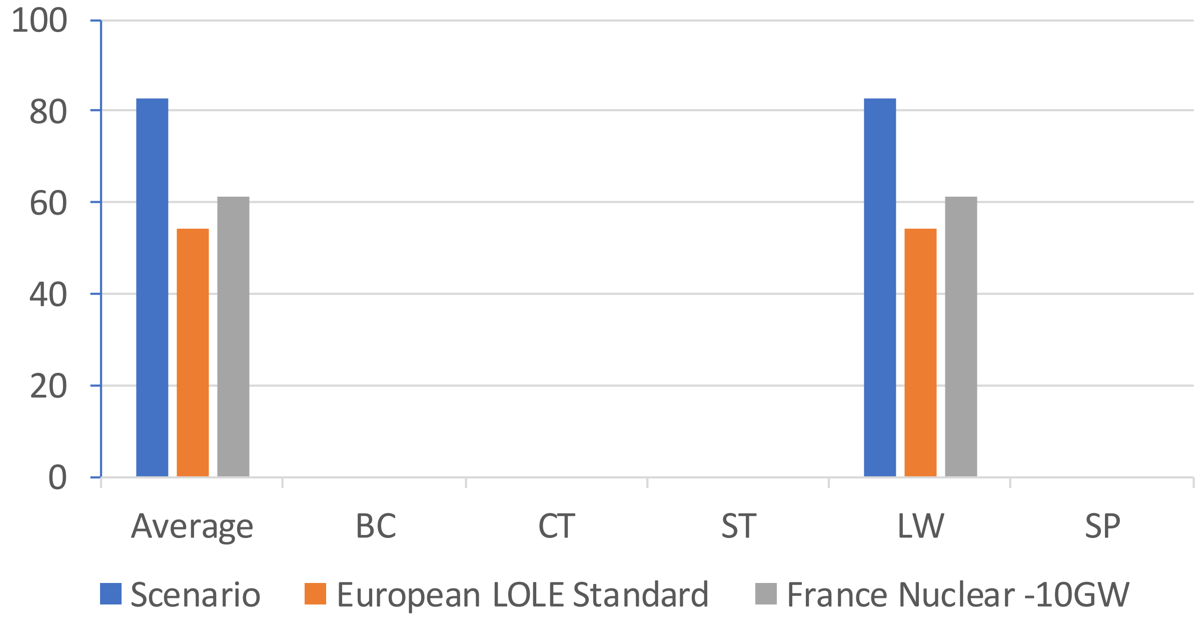
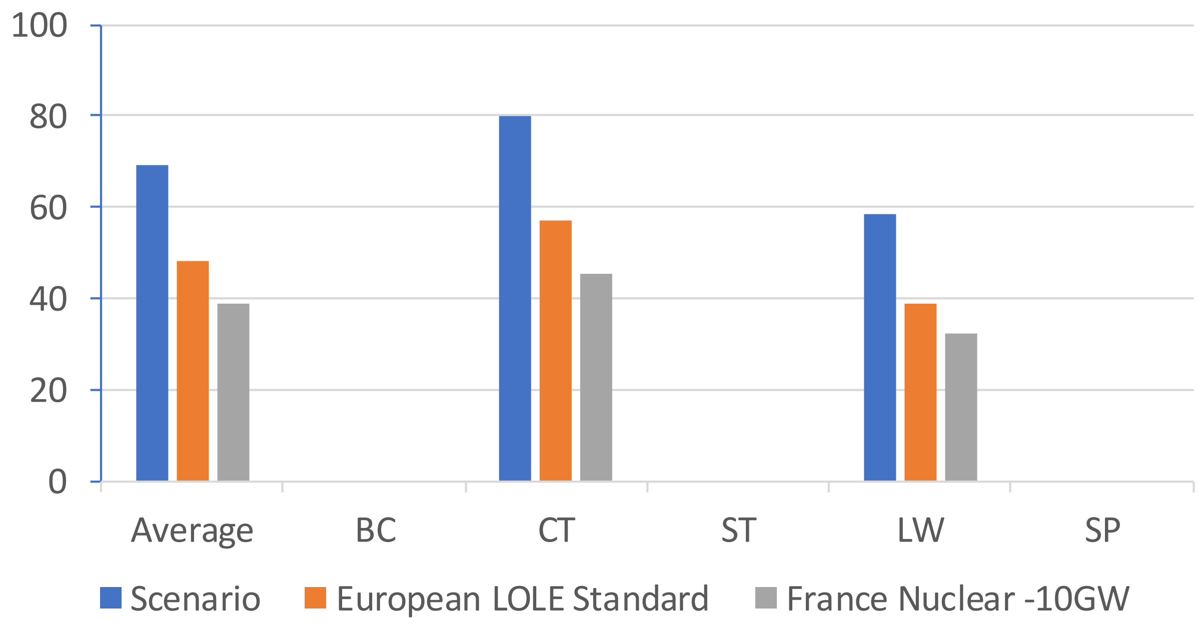
Germany 2024/25



- The modelled range for Germany is 54% to 83% for 2024/25
- German interconnectors only appear in Leading the Way for 2024/25
- Germany will phase out nuclear generation by 2022
- It also holds strategic reserve outside the market. This is not included in our modelling as our understanding is that State Aid conditions relating to its use mean it cannot support GB
- The most onerous sensitivity modelled was closure of coal stations to result in an LOLE around 3 hours

Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	83	N/A	N/A	N/A	83	N/A
European LOLE Standard	54	N/A	N/A	N/A	54	N/A
France Nuclear - 10 GW	61	N/A	N/A	N/A	61	N/A
Most onerous sensitivity	54	N/A	N/A	N/A	54	N/A
	N/A	Germany Coal				

Denmark 2024/25



- The modelled range for Denmark is 32% to 80% for 2024/25
- Danish interconnectors only appear in Leading the Way and Consumer Transformation for 2024/25
- Denmark is generally a price-taker and due to its connectivity with other markets, the French nuclear sensitivity has the biggest impact on its de-rating factor

Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	69	N/A	80	N/A	59	N/A
European LOLE Standard	48	N/A	57	N/A	39	N/A
France Nuclear - 10 GW	39	N/A	45	N/A	32	N/A
Most onerous sensitivity	39	N/A	45	N/A	32	N/A
	N/A	France Nuclear - 10 GW				

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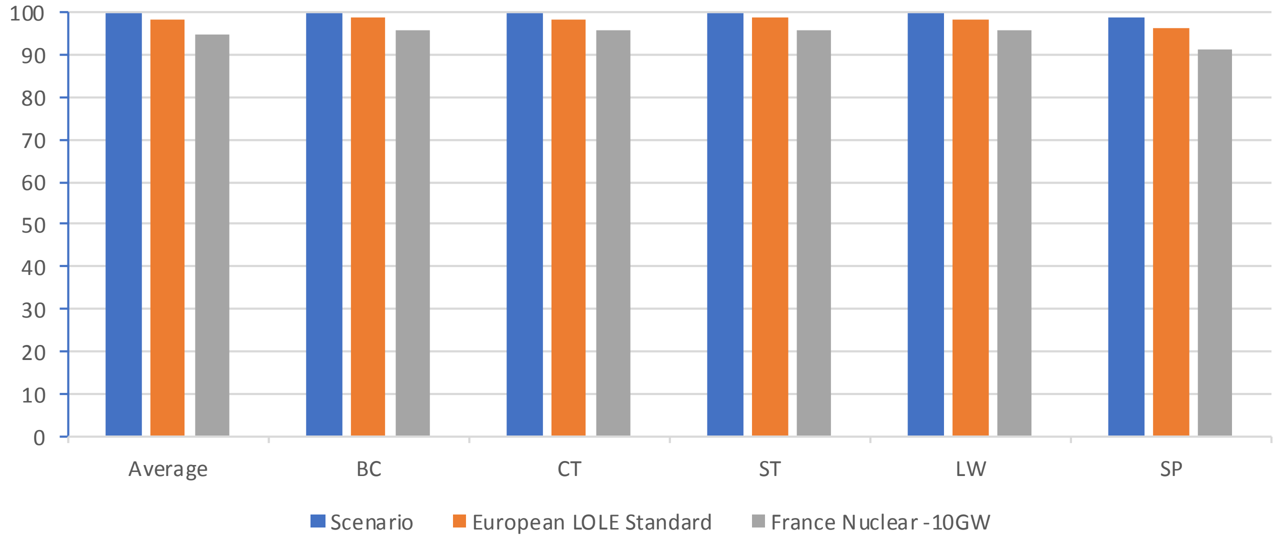
Norway 2024/25



Calculation	Ave.	BC	CT	ST	LW	SP
Scenario	100	100	100	100	100	99
European LOLE Standard	98	99	99	99	98	96
France Nuclear - 10 GW	95	96	96	96	96	91
Most onerous sensitivity	95	96	96	96	96	91
	N/A	France Nuclear - 10 GW				

- The modelled range for Norway is 91% to 100% for 2024/25
- This is due to the large volume of hydro capacity in Norway
- French nuclear outages have a small impact on Norwegian de-rating factors, as Norwegian flows could be diverted to other European countries

European sensitivities – supporting narrative

Our interconnector analysis for each country shows de-rating factors broadly grouped around 2 or 3 values:

1. A high values set by modelling the current supply and demand outlook based on the assumptions in our European scenarios. This is consistent with the current view provided by ENTSO-E and European TSOs. However, these assumptions show a surplus of capacity in Europe meaning that there will likely be stations that aren't economically viable and at risk of closure.
2. An intermediate set of values set by modelling a sensitivity that removes thermal generation in each market such that the estimated LOLE value just exceeds 3 hours. This could be considered a credible pathway as a number of European countries seek to implement capacity mechanisms. The Clean Energy Package is seeking to harmonise how Reliability Standards are calculated, which could lead to similar Reliability Standards across Europe (we assumed 3 hours, as this is consistent with some other countries). In addition, ENTSO-E's methodology to determine the maximum cross-border capacity that can enter neighbouring capacity markets suggests this to be an appropriate approach – although this would effectively be used to set an ***upper*** limit in ENTSO-E's methodology [5]
3. A low set of values set by modelling a sensitivity that assumes 10 GW nuclear outages in France. The nuclear fleet in France is susceptible to type fault issues that could see significant prolonged outages occurring simultaneously. This was evident recently in winter 2016/17, in which the French nuclear availability was around 50 GW in December, rising slowly to around 55 GW by late January. As the installed capacity is 63 GW, we have assumed an average outage level of 10 GW. As the BID3 modelling only covers short-term forced outages, this risk is not fully covered in our modelling and therefore an appropriate sensitivity.

(5) See Article 9 in: https://consultations.entsoe.eu/markets/proposal-for-cross-border-participation-in-capacit/supporting_documents/ENTSOE%20Proposal%20for%20crossborder%20participation%20in%20capacity%20mechanisms%20%20for%20public%20consultation.pdf

Reliability Standards in Europe

There is currently no consensus or consistency in approach to Reliability Standards in Europe. This is set to change in line with Article 25 of Regulation (EU) 2019/943, which will seek to standardise the methodology. The methodology has been developed by ENTSO-E and seeks to define it in LOLE as the ratio of CONE / VoLL – consistent with the approach already implemented in Great Britain. This is expected to be phased in over the next few years. Given the harmonisation of the approach, this could lead to countries adopting similar Reliability Standards. In our sensitivity, we assumed 3 hours LOLE to be consistent with that already established in Great Britain, France and Belgium. Ireland has a higher value of 8 hours LOLE.

Some additional notes on neighbouring countries:

- France and Belgium both have a Reliability Standard of 3 hours LOLE – although there are differences in how this is applied. RTE's 2019 Generation Adequacy Report[6] states that the French standard should be met in all cases that RTE model (p.4.), which is different to Great Britain, where some cases are not covered by the LWR outcome. Belgium also have an additional value of 20 hours LOLE applied to extreme events (1 in 20)
- Netherlands uses 4 hours LOLE (note that if we had used 4 hours in our modelling rather than 3 hours, we expect the de-rating factor for this sensitivity would have been lower)
- Ireland has a Reliability Standard of 8 hours LOLE. While Northern Ireland has a Reliability Standard of 4.9 hours LOLE, the Irish Capacity Statement uses 8 hours LOLE in its All-Island of Ireland assessment. [7]
- Germany, Denmark and Norway don't have a defined Reliability Standard

(6) https://www.rte-france.com/sites/default/files/2019_generation_adequacy_report_-_executive_summary.pdf
(7) http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-All-Island-Generation-Capacity-Statement-2019-2028.pdf

2019 Scenario Two Degrees 23/24

The BID3 database and software is updated frequently, which can introduce some uncertainty when trying to compare new methodologies with old methodologies that were run on older version of BID3.

The table below illustrates some of these changes. In each case the methodology used is the one used in ECR 2019, not ECR 2020.

The ECR row are the results published in the 2019 ECR for the Two Degrees scenario for the T-4 23/24 auction year. The subsequent rows show the change in results with various input data changed, all relative to the 2019 ECR results.

Note that the results published in the 2020 ECR used a new methodology, a new 2020 database and a new version of BID3 (2020.1.1, although this is very similar to 2019.2.1).

2019 Database	BID3 Version	Parameters	IRE	FRA	BEL	NET	NOR	DEN
ECR	ECR	ECR	32%	74%	54%	43%	98%	35%
v1	3.2.2	Old	0%	0%	0%	0%	0%	-1%
v2	3.2.2	Old	0%	0%	-1%	0%	-1%	0%
v2	3.2.2	New	-1%	11%	11%	9%	0%	4%
v2	2019.2.1	New	-2%	12%	16%	14%	2%	9%
Latest	2019.2.1	Old	4%	4%	9%	14%	-1%	12%
Latest	2019.2.1	New	1%	13%	23%	25%	2%	22%