I-SEM
Capacity Market:
Methodology for the Calculation of the Capacity Requirement and De-rating Factors

June 2018

Disclaimer

Table of Contents

Executive Summary

On the 1st July 2016, NIAUR and CER issued decisions on proposed modifications to licences held by SONI ltd. and EirGrid Plc. These modifications add responsibility for the Capacity Market Code (CMC) to the suite of obligations that are already placed on us under our TSO licences. The SEM Committee (Decision Paper SEM-15-103) has also tasked the TSOs to develop the analytical methods to calculate the Capacity Requirement and De-rating Factors for the Capacity Market.

On the 8th December 2016 the SEM Committee published an I-SEM CRM Capacity Requirement and De-rating Methodology Decision Paper (SEM-16-082). Appendix 1 of the decision paper (SEM-16-082a) was a TSO report on the methodology for the capacity requirement and de-rating factors for all units except for interconnectors. De-rating Factors for interconnectors were addressed in Appendix 2 of the RA consultation paper.

On the 3rd July 2017, the SEM Committee published a decision paper (SEM-17-040b) to the methodology. On the 13th of March 2018, the SEM Committee published a consultation (SEM-18-009a) with proposals for the enduring methodology for storage de-rating factors and the de-rating factor approach to be applied to DSUs that have limited duration for their demand reduction. The methodology detailed in this document incorporates the changes resulting from both SEM-17-040b and SEM-18-009a.

The methodology set out here has been developed to comply with SEM Committee decisions. These include decisions on the High Level Design, CRM Detailed Design and the decision paper accompanying this report.

The report presented here is an update to Appendix 1 above and reflects the decisions made by the SEM Committee on the items raised during the consultation period. The purpose of this document is to detail the methodology. The rationale for the decisions and responses to issues raised during the consultation paper are addressed in the accompanying RA paper.

The methodology presented in this document builds on the existing generation adequacy methodology that is employed by the TSOs to produce the annual Generation Capacity Statements. It has been adapted to use multiple demand scenarios and to enable the determination of marginal de-rating factors.

In accordance with SEM Committee decision SEM-16-082, units are divided into a number of technology categories. Outage statistics are calculated for each of these categories using historical SEM outage data. The proposed de-rating methodology calculates the marginal benefit of each unit type and size to the system. Each unit's marginal de-rating factor is calculated as the MW change in surplus (above the adequacy standard) due to the addition of the unit, divided by the MW capacity of the unit. This is done for the range of unit types and size categories and demand scenarios. The de-rated capacity requirement for each demand scenario is the sum of the de-rated capacity of the units required to satisfy the adequacy standard.

A Least-Worst Regrets analysis is performed to select the demand forecast level to be used for the Capacity Market auction and associated capacity requirement. The de-rating factors are those that are used to derive the capacity requirement selected by the Least-Worst Regrets analysis.

1 Introduction

On the 1st of July 2016, NIAUR and CER issued decisions on proposed modifications to licences held by SONI ltd. and EirGrid Plc. These modifications add responsibility for the Capacity Market Code (CMC) to the suite of obligations that are already placed on us under our TSO licences. The SEM Committee (Decision Paper SEM-15-103) has also tasked the TSOs to develop the analytical methods to calculate the capacity requirement and de-rating factors for the Capacity Market.

On the 8th December 2016, the SEM Committee published an I-SEM CRM Capacity Requirement and De-rating Methodology Decision Paper. Appendix 1 of the decision paper was a TSO report on the methodology for the capacity requirement and de-rating factors for all units except for interconnectors. De-rating Factors for interconnectors were addressed in Appendix 2 of the RA consultation paper.

On the 3rd July 2017, the SEM Committee published a decision paper (SEM-17-040b) to the methodology. On the 13th March 2018, the SEM Committee published a consultation (SEM-18-009a) with proposals for the enduring methodology for storage de-rating factors and the de-rating factor approach to be applied to DSUs that have limited duration for their demand reduction. The methodology detailed in this document incorporates the changes resulting from both SEM-17-040b and SEM-18-009a.

The methodology set out here has been developed to comply with SEM Committee decisions. These include decisions on the High Level Design, CRM Detailed Design and the decision paper accompanying this report. The report presented here is an update to Appendix 1 above. Where differences occur, the text in this document takes precedence.

This document outlines the methodology for setting the de-rated capacity requirement and for the de-rating of generating units and demand side units as part of qualification for the Capacity Market. The methodology builds on the existing generation adequacy methodology that is employed by the TSOs to produce the annual Generation Capacity Statement. It has been adapted to use multiple demand scenarios and to enable the determination of marginal de-rating factors.

The methodology for de-rating of Interconnectors is outside the scope of this document.

The de-rated capacity requirement reflects the aggregate de-rated capacity required to satisfy the unconstrained All-Island adequacy standard. The RAs may choose to adjust the auction capacity requirement from this de-rated capacity requirement for a number of reasons, including (but not limited to) non-bidding capacity, de-rating factor tolerance bands and expected failure to deliver capacity.

If the characteristic of the units in the system and demand patterns change significantly it may be appropriate to review this methodology.

2 Overview of Methodology

This section presents a brief overview of the methodology for determining the de-rated capacity requirement and the de-rating factors for capacity market units. The methodology involves the general steps outlined in Figure 1.

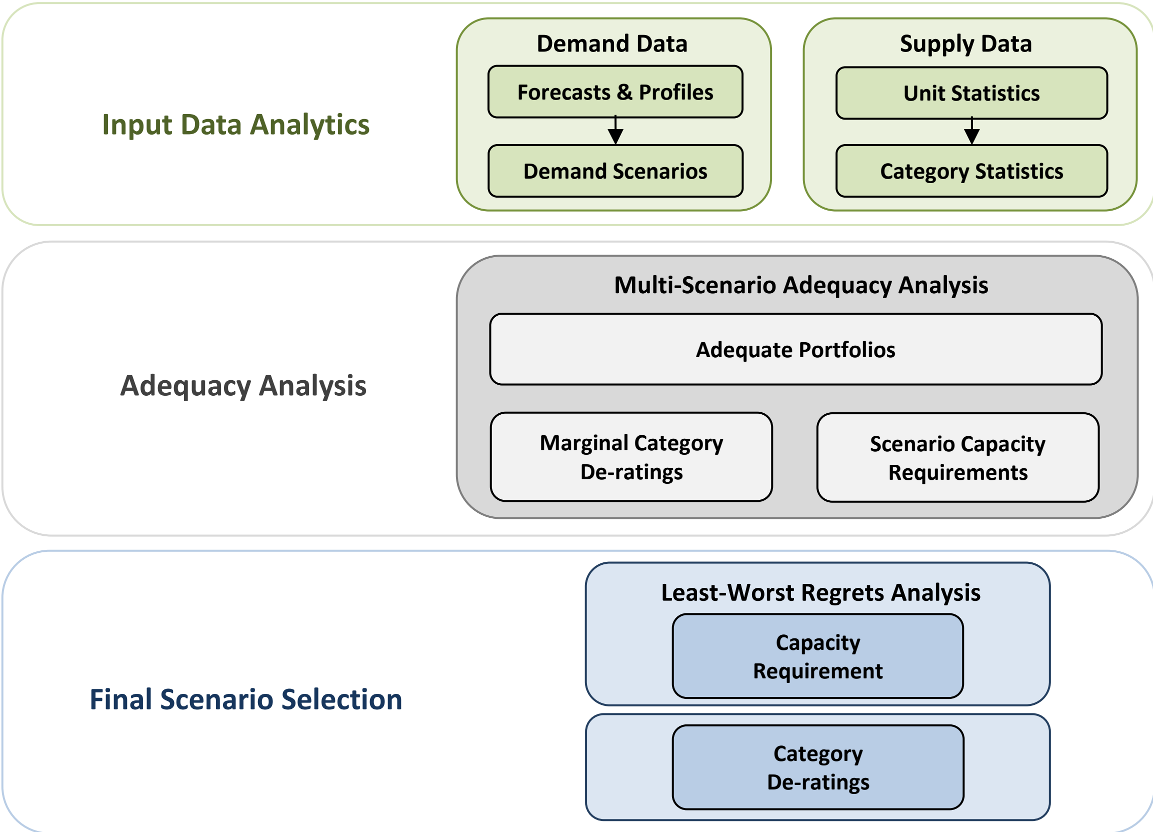


Figure 1: Conceptual Overview of the Capacity Requirement and De-rating Methodology

The Input Data Analytics phase involves sourcing and processing the demand data and power supply data to be used in the analysis.

Forecasts of future demand are needed to determine the capacity required to serve that demand. The methodology uses a range of demand scenarios for each Capacity Market Year required. The demand scenarios differ based on annual demand growth and how that demand is distributed (or profiled) across the year. The information to form these demand scenarios is sourced from the latest EirGrid and SONI's Generation Capacity Statement (GCS) or equivalent document.

The methodology uses the historical outage data of capacity market units, such as generators. This outage data includes the level of forced, scheduled and ambient outages. A separate process is outlined for determining availability data for technologies that do not currently exist within the SEM.

Each capacity market unit is associated with a "technology class", e.g. "steam turbines" and "hydro". Average outage statistics for each technology class are formed from the historical outage data for the individual capacity market units within that technology class.

The Multi-Scenario Adequacy Analysis phase seeks to derive de-rating factor curves as a function of the size of a unit. These curves can be applied to the MW capacity of the capacity market units belonging to that technology class to give a de-rated capacity. The starting point for analysing marginal de-rating is the production of one or more capacity adequate portfolios. A capacity adequate portfolio comprises of a set of capacity market units that together satisfy the LOLE adequacy standard for a given demand scenario. A capacity adequate portfolio is formed from the set of existing capacity market units expected to be in the auction and new capacity market units. These portfolios provide a reference or base set of data relative to which the marginal de-rating analysis can be performed.

A marginal technology class de-rating factor is determined by looking at the impact on adequacy of adding a single notional unit of a specific technology class and size to each capacity adequate portfolio for a demand scenario. The de-rating factor for that unit is calculated by dividing the MW increase in surplus caused by the addition of this unit by the MW size of that unit. This same process is followed for each technology class and each size class.

The de-rating factor curves for each technology class are averaged across the capacity adequate portfolios associated with a demand scenario. This gives a single de-rating factor curve for each technology class for that demand scenario. Applying these de-ratings to the units within each capacity adequate portfolio also gives the de-rated capacity requirement. The largest of these de-rated capacity requirements is the value associated with that demand scenario.

The final scenario selection serves to identify which demand forecast level will be chosen as the basis for de-rating factors and the de-rated capacity requirement for that Capacity Year. Based on SEM Committee decision paper SEM-15-103 (paragraph 2.4.3) a “least-worst regrets” analysis is performed. The least-worst regrets analysis simulates the performance of the capacity adequate portfolios for each “base” demand scenario across all potential “other” demand scenarios:

- If the other demand scenarios have greater demand than the base demand scenario, then the levels of unserved energy would rise at an incremental cost equal to the Value of Lost Load (VoLL), which is measured on a €/MWh basis.
- If the other demand scenarios have lower demand than the base demand scenario, then the base scenario has more capacity than is required to satisfy the LOLE adequacy standard. The difference between the capacity requirements of the two scenarios reflects the cost of surplus capacity, which is priced at the Cost of New Entrant (Net-CONE) on a €/MW basis.

Values for VoLL, Net-CONE, and the LOLE standard are therefore required in order to calculate the de-rating factors and adequacy standard. Values for VoLL and Net-CONE will be set by the SEM Committee in a timely manner in advance of the auction process, as discussed in SEM-16-073 (paragraphs 2.1.2 and 6.1.1). A value of 8 hours LOLE for the island was decided on in SEM-15-103 (paragraph 2.2.16).

The least-worst regrets analysis calculates the maximum total regret cost for each demand scenario and selects the demand scenario with the lowest maximum total regret cost. The de-rating factors are averaged across all demand scenarios at that demand forecast level and the average values will be used for the capacity market qualification and auction process. The scenario capacity requirements are also averaged across all demand scenarios at that demand forecast level to give the Capacity Requirement that will be used for the capacity market qualification and auction.

The SEM Committee may choose to adjust the auction capacity requirement from this de-rated capacity requirement for a number of reasons, including (but not limited to) non-bidding capacity, de-rating factor tolerance bands and expected failure to deliver capacity. Such adjustments are beyond the scope of the methodology presented in this document.

3 Demand Scenarios

3.1 Introduction

This section describes the approach for forming demand scenarios, where a demand scenario is a combination of an annual demand forecast (both peak MW and total MWh) and a demand profile which describes how to allocate that demand across all the half-hours in a year.

3.2 Source of Demand Forecasts

The demand forecast data used in setting the Capacity Market capacity requirement and in determining de-rating factors is sourced from EirGrid and SONI's current Generation Capacity Statement (GCS) or equivalent document. The GCS provides detail of both the source and development of demand forecast data.

The GCS low and high forecasts of MW peak demand and annual GWh total energy requirement (TER) are taken as the extreme demand forecasts. These forecasts reflect All-Island demand and include transmission and distribution losses.

An additional number of demand forecasts are interpolated at intervals between these to provide up to ten distinct annual demand forecast levels (illustrated in Figure 2). The forecast demand profiles used in the analysis are built (using the historical base profiles discussed below) so that the energy and peak match the forecasted energy and peaks of these demand levels.

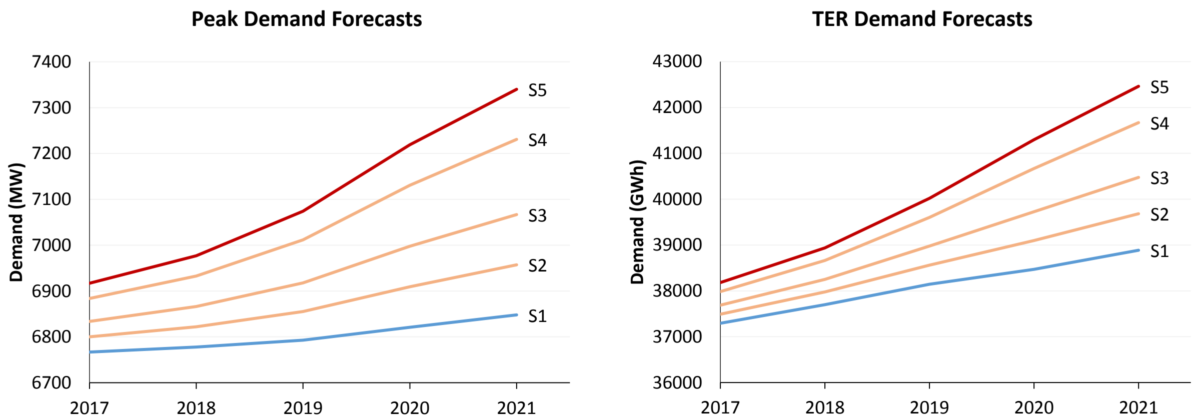


Figure 2: Formation of the Demand Forecasts

3.3 Source of Demand Profiles

The de-rating analysis is based on half-hourly demand data. A set of annual demand profiles based on a number of historical All-Island demand profiles is used in the methodology. A set of demand scenarios is formed by combining each demand forecast level with each demand profile. Each demand scenario comprises a distinct set of half-hourly demand values for a year reflecting the pattern of demand profile used, with a peak demand and total annual energy requirement from the demand forecast. As with the previous CPM methodology and the GCS analysis all adequacy calculations are based on a 52 week year.

The number of hours in the year where demand is very close to peak demand can have a significant impact on the LOLE for a given portfolio of capacity market units. As different demand scenarios are based on different demand profiles, the data has a diverse mix of demand over the year and variability of demand within the year.

3.4 Non-Market Demand

The SEM Capacity Requirement is a market capacity requirement and therefore generation that is expected to be outside the SEM is subtracted from the demand profile. In order to estimate the amount of non-market generation for future years, it is necessary to forecast the installed capacity of each class of non-market generation. This information is sourced from the Generation Capacity Statement. Unless otherwise known, it is assumed that any generator less than 10 MW is not in the market. This assumption may be reviewed if necessary.

It is also important to predict the performance of these non-market units, i.e. their capacity factor, as this determines the level of annual demand from the TER that they offset. This is done by examining the current generators in this sector based on historical data. To adjust the peak for the non-market wind, it is proposed to not use the annual capacity factor, but rather the Wind Capacity Credit which is lower, but could give a more realistic view of what these units might be contributing at any time (see section 3.5(c) of the current GCS). Solar units greater than 10 MW are assumed to be in the market, while those less than 10 MW are assumed not to be in the market. Data from ENTSO-E's Pan-European Climate Database is used to estimate a capacity factor for non-market solar.

3.5 Reserve Requirement

The SEM Committee has decided (SEM-16-082, paragraph 3.4.17) that a reserve requirement will not be included in the methodology for the T-1 transitional auctions.

4 Supply Data and Statistics

4.1 Introduction

This section presents the data sources used by this methodology for capacity market units. This data is primarily used to define average outage statistics for the different technology categories. It is important to note that while average outages for each technology class is based on existing SEM unit data, the technology categories themselves allow the de-rating methodology to consider units which were not operating in the SEM during the period covered by the data, provided they are of a similar technology as that represented by an existing technology class. The possibility of new entrant units that are not comparable with proposed technology categories is discussed separately below.

4.2 Units used in the Methodology

The set of existing units that are used to set up the portfolios used in the methodology are based on information provided in the latest GCS. These units are typically listed in Appendix 2 of the GCS.

4.3 Sources of Data for Existing Units

4.3.1 Availability Statistics

Availability statistics are sourced for different unit types as follows.

- CCGT, Gas OCGT, Distillate OCGT, Coal, Hydro, Demand Side, AGU, Peat, Oil, Pumped Storage and CHP units. The methodology generally uses a period of five consecutive years for each technology class. However, if the number of units within that technology class is small, where good quality data is available a ten year period is used.
    - EDIL (Electronic Dispatch Instruction Logger) records provide participant submitted:
        - Forced outage data
        - Scheduled outage data
        - Ambient outage data
- Wind units
    - Metered energy data and SCADA availability data are used to derive aggregate total annual availability profiles.

The EDIL data is the same that is used in the publicly available EirGrid and SONI Monthly Availability Reports. The data give average monthly MW capacity reductions for each of forced outage, scheduled outage, ambient outage, and the total of these outages. These monthly averages are converted to a percentage capacity reduction and are averaged over 12 calendar months to give an average annual percentage capacity reduction due to each of forced outage, scheduled outage and ambient outage for each unit and for each of the years of historical data considered.

4.3.2 Generation and Run-Hour Data

Interval metered generation data are required to determine the run-hours for each unit. Total annual run-hours are used below in determining the average technology category outage statistics. The generation data used is half-hour Metered Generation data (used in market settlement) extracted from the SEM settlement database.

4.3.3 Retirement Data

The GCS may provide information on planned retirements of units where this information has been supplied by the generator. This information can be used to exclude such units from portfolios employed in the marginal de-rating process if the planned retirement is due to occur before the Capacity Market Year to be studied. Retiring units are not excluded in defining average availabilities for technology categories. Retaining these units in the sample set allows the statistics to reflect a diverse array of ages of capacity market units. It also ensures that the analysis captures a larger range of outage events, which makes the statistics less volatile.

4.4 Sources of Data for New Units

The methodology is also required to produce de-rating factors for units that do not currently exist in the SEM. This means new units of an existing technology type and new units of a technology type that does not yet exist in the SEM. The approach for dealing with these units is set out in the following two subsections.

4.4.1 New Unit, Existing Category

New capacity that conforms to one of the existing technology categories set out in this methodology take on the values associated with that technology category. The approach for determining marginal de-rating can determine de-ratings for a unit of any size for a given technology category. This provides a default de-rating for any new unit that falls in the same technology category, and no additional data is required for such a unit.

4.4.2 New Unit, New Category

New capacity that does not conform to the existing categories is given values associated with the system average. This contributes to defining its initial de-rating factor. If the new unit accepts a multiple year reliability option contract the de-rating factor could be increased over time as actual performance data becomes available, but it cannot be decreased. For the avoidance of doubt, their reliability option quantity would only increase if they traded further in the primary or secondary auctions.

The treatment of other variable resources (e.g. solar, tidal, wave) will be based on a half-hourly variable generation profile using the relevant annual 1 MW normalized resource profile (i.e. an annual profile of values between 0 and 1 is applied to the installed capacity of that variable resource). These profiles would be incorporated into the methodology using a similar approach as is used for wind capacity.

4.5 Treatment of Aggregated Generator Units

The individual components of aggregated generator unit will be assigned de-rating factors based on the technology class that applies to them. The total de-rated capacity of the AGU will then be the sum of the de-rated capacity of its components.

5 Technology Classes

5.1 Introduction

The SEM Committee has decided that the de-rating factors should be calculated based on technology classes (see SEM-15-103). This section describes the approach for defining technology classes to use in the de-rating methodology.

5.2 Approach

Each capacity market unit subject to de-rating is associated with a technology class. The aim is to have similar types of units in the same technology class. De-rating factors will be determined by technology class, rather than by individual units. This is because the availability of the units in a technology class is a statistically more robust and reliable measure of future performance than the availability of the units in isolation. As an illustration, a rare type of outage that might be expected to occur once in twenty years would distort the results for an individual unit if that event happened within the five years of source data. However, if there are eight units in the technology class then over five years (i.e. 40 years of data) the event might be expected to occur twice within the technology class during the five years. The volatility of de-rating factors is also reduced by this approach.

A key advantage of this approach is that a unit with a long outage, if assessed on its own data could be significantly de-rated requiring the system to procure more capacity when it is not necessary.

There are limitations in using technology categories. For example, the de-rating factors of the technology class may be less favourable for the most reliable units in the technology class while over-stating the de-rated capacity for the least reliable units in the technology class.

On the other hand, a group average approach gives an incentive to keep the availability of a capacity market unit above the group average. If a unit's reliability is slipping relative to the group average, then this can expose the operator to increased costs in mitigating the risks of failing to deliver on reliability options. This encourages its operator to increase maintenance, or if this is not viable, to consider retiring the unit.

5.3 Selected Technology Classes

The technology classes that apply in this methodology are shown in Table 1. These have been determined by the RAs in accordance with SEM-16-082, paragraph 2.3.5 and set out in SEM-18-030.

Technology Class	Unit types included
Gas Turbine	CCGT, Gas and Distillate OCGT, Large CHP, Reciprocating Diesel
Hydro	Hydro
Steam Turbine	Oil, Coal and Peat fired boilers
Pumped Hydro Storage	Pumped Hydro Storage
System Wide	All of the above
Other Storage	Battery Storage, CAES, Flywheel
DSU	Demand Side Units
Wind	Wind
Solar	Solar
Interconnector	Interconnectors

Table 1: Types of Units in each Technology Class

The selected technology classes were adopted as they provide a reasonable trade-off between homogeneity of units and sample size. The homogeneity of units is reflected by grouping them based on their primary turbine technology (gas, steam, water, wind) or as demand response or storage units. By keeping the number of categories small the average number of units and hence data points in each technology class is increased, improving the quality of statistics.

For the initial auctions, DSUs and potential new storage units (that are not pumped hydro units) will be treated as new technology and assigned the system-wide outage statistics. In addition, where they are duration limited this will also be taken into account. These unit types will eventually form their own categories once their availability data is deemed to be representative of their operation in the SEM under the I-SEM design.

5.4 Averaged Availability Statistics for Technology Classes

A number of different methodologies were assessed for calculating average availability statistics for the technology classes. These included a simple average, a capacity weighted average, an output weighted average and a run-hour weighted average. The run-hour weighting methodology was selected as giving greater weighting to the more frequently running units was considered to give a good trade-off between the various issues considered and has the advantage of reducing the contribution of units that have rare but very long outages, limiting the impact these have on the class weighting.

The average run-hour weighted forced outage rate is calculated for each technology class (except for variable resources such as wind which is explained below) using:

$$\{\sum_{unit}\sum_{year} (\text{Annual Run Hours})_{unit} \times (\text{Average Forced Outage Rate})_{unit}\} / \{\sum_{unit}\sum_{year} (\text{Annual Run Hours})_{unit}\},$$

where "unit" denotes the capacity market units in that technology class and "year" denotes each of the years of capacity market unit data used. The annual run hours of a unit reflect the sum total of hours for which the unit had a non-zero level of export. The system-wide run-hour weighting is calculated using the same process as above by using a system-wide class that includes all units. A similar approach is used to calculate the run-hour weighted average for scheduled and ambient outages.

It is important to be aware that there will be a correlation between forced outage rates of units and the level of capacity available. Currently there is a surplus of capacity and as a result some generators will be utilised less than they would be were there no surplus of capacity. This will tend to lower their forced outage rates. If the capacity situation becomes tighter, then these units will likely be required to run more and this could increase their forced outage rates. This in turn would imply a higher de-rated capacity requirement. While it is considered that the run-hour weighting approach is most suitable for the current system, the approach to calculating will need to adapt to best reflect the performance characteristics of the system. The effects of high impact low probability events will also be monitored and change may be required in future to account for these effects.

Ambient outages are profiled across the year for the gas turbine units. These ambient outages are mainly temperature related and are minimal during the winter peak.

The availability of the wind technology class is based on the actual output of all wind units relative to their installed capacity and defines a profile of wind generation for a year. Wind generator output is correlated to weather conditions and hence to demand. To account for this, the wind profile and demand profile applied to a given demand scenario are both based on the same historical year in the subsequent analysis described below.

6 Multi-Scenario Adequacy Assessment

6.1 Selection of Portfolios for Different Demand Scenarios

Section 3 described the approach for defining the demand forecasts and demand profiles used in this methodology. A demand scenario is a combination of one of the demand forecasts and one of the demand profiles (including any non-market and reserve requirement adjustments). This produces a half-hourly sequence of demand for a year, with the same peak and annual demand as the demand forecast. The Capacity Market Year is expected to commence at 23:00 BST September 30th each year and the demand profiles account for this.

Figure 3 depicts how this method is used to generate the different demand scenarios for each capacity year. *ds* is used to denote one specific demand scenario within the set *DS* of demand scenarios.

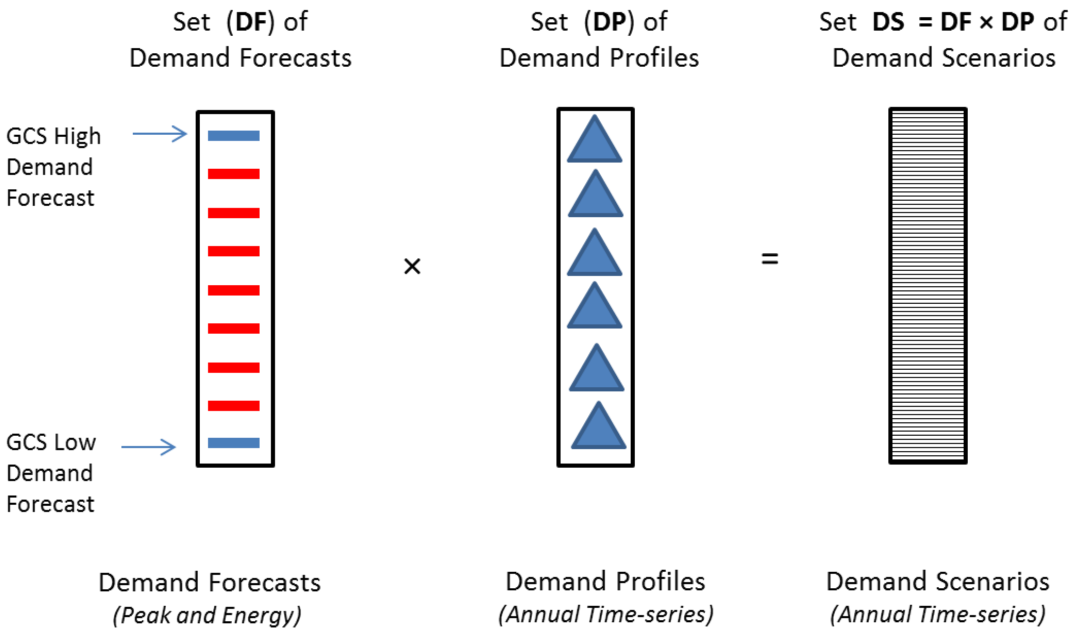


Figure 3: Formation of the Demand Scenarios

For each demand scenario the method determines a set of capacity adequate portfolios of generators. How this is done is illustrated in Figure 4 below. A number of capacity adequate portfolios are modelled for each demand scenario and this is to simulate a range of possible auction outcomes.

The starting point is a set (*G*) of capacity market units.[1] For each capacity year, generators that have indicated that they will have closed prior to that capacity year, as specified in GCS, are removed. It is important to understand that this set *G* only serves to provide a diverse set of representative capacity market units that can be drawn from in the analysis; the nature of the specific individual units in the set *G* has no material impact on the final de-rating factors.[2]

---

[1] For the purpose of the illustrations, in this section only units – generators and demand-side units – within the set *G* that are to be de-rated are shown, but other sources of supply such as interconnectors and non-market generation are accounted for and are assumed to contribute energy in serving demand.

[2] If the set *G* of existing generators was capacity deficient then additional notional capacity would be added to the set to ensure that it could cover the requirements. This additional capacity would comprise a set of units with the properties of each category but of different sizes such that the aggregate pool of units has the same average availability as the existing generators.

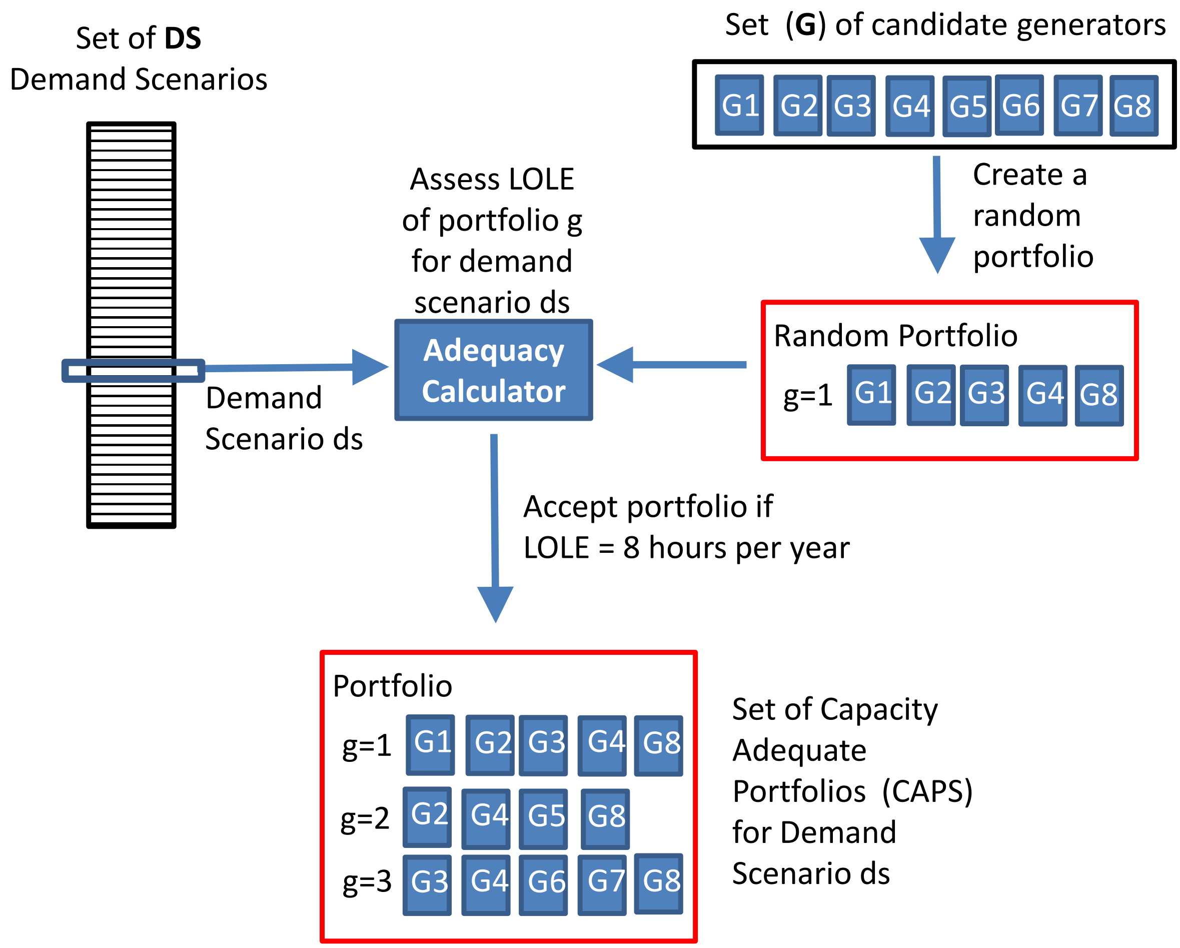


Figure 4: Determining Capacity Adequate Portfolios for each Demand Scenario

For each demand scenario *ds* a set of randomly selected portfolios are each tested with an "adequacy calculator" that assesses the degree to which that portfolio achieves the LOLE adequacy standard. Those random portfolios that pass this test form the set of capacity adequate portfolios for that demand scenario. A number of capacity adequate portfolios are modelled for each demand scenario. A capacity credit for wind is calculated for each of the demand scenarios using the approach described in section 6.2 and this capacity credit is used in the formation of the portfolios.

Figure 5 shows how the Adequacy Calculator processes CAPs portfolio *g* given demand scenario *ds*. The half-hourly demand from demand scenario *ds* and how the scheduled outages and ambient outages are distributed across time are shown.

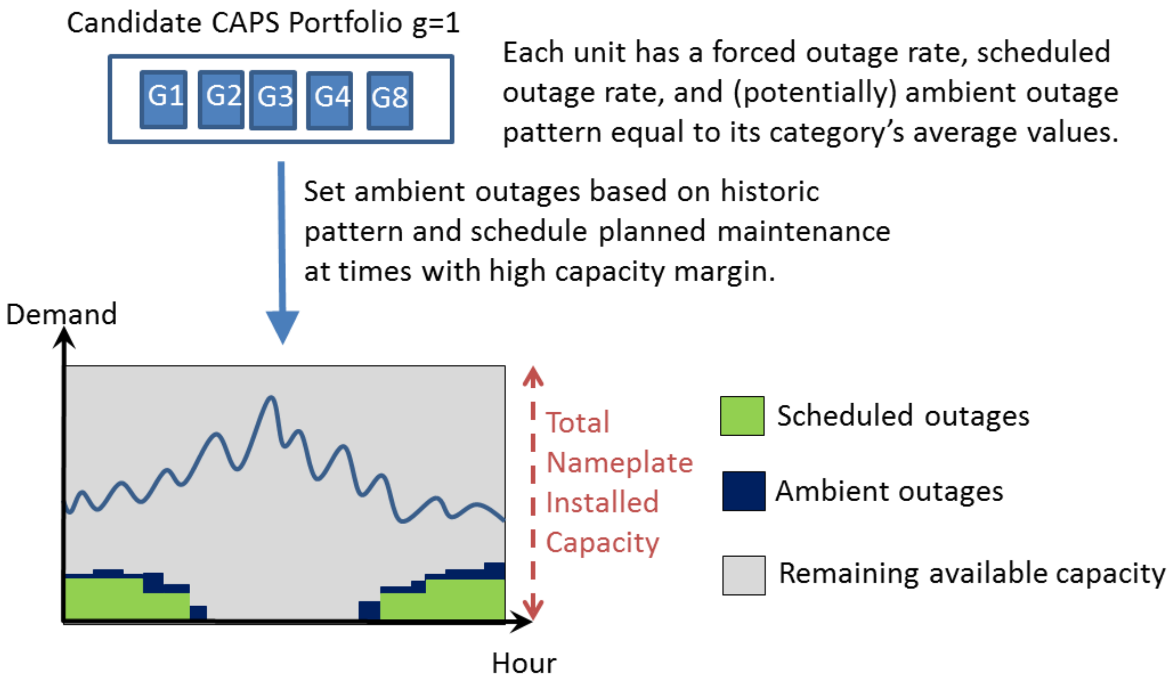


Figure 5: Allowing for ambient outages and scheduled outages in the Adequacy Calculator

The Adequacy Calculator applies ambient outages in months where they historically occur. These reduce the capacity available from individual generating units.

The Adequacy Calculator schedules maintenance (or scheduled) outages for each unit. The availability statistics imply the number of days per year that the unit is on scheduled outage. The scheduled outage for a unit occurs as one continuous outage (though the length of the outage is rounded to the nearest five days to reduce the complexity of the problem). The Adequacy Calculator schedules each outage at the time of the greatest surplus of available generation over demand given the outages already scheduled (i.e. maximises the minimum margin for each outage). Outages are scheduled in order of decreasing size (measured in terms of the product of unit size and outage duration). The grey shaded area indicates the remaining available installed capacity before forced outages are applied.

Scheduled outages do not significantly affect the de-rating factors, but the cumulative impact of the scheduled outages can affect the capacity requirement.

This processing of ambient and scheduled outages leaves a set of available generating units in each half hour with a capacity that has been adjusted for ambient effects and for scheduled outages. The Adequacy Calculator then simulates forced outages of capacity market units independently for each individual half-hour to assess the level and probability of unserved load in that half-hour.[3]

For each half-hour there is a set of capacity market units that are not on scheduled outage and which have had their capacities adjusted for ambient outages. Each of these units has a forced outage rate, so

[3] This approach is based on established methods used in the production of the GCS. The European Network of Transmission System Operators - Electricity (ENTSO-E) is in the process of testing approaches that simulate the actual operation of the market within a dispatch model.

given that scheduled and ambient outages have already been addressed, its expected availability is one less its forced outage rate.

The Adequacy Calculator determines the level of unserved energy for every permutation of forced outage that could occur in a half-hour. This allows a loss of load probability (LOLP) and Expected Unserved Energy (EUE) value to be determined for that half-hour.

Repeating this process for each half-hour of the year in demand scenario ds gives the annual total LOLP and EUE for portfolio *g*. If the LOLE is within a set tolerance of the adequacy standard then the portfolio is accepted as capacity adequate.

6.2 Marginal De-Rating Process

6.2.1 De-Rating Process Description

The Marginal De-Rating process involves adding a single notional unit to a capacity adequate portfolio for a given demand scenario and determining the de-rating of the notional unit. The notional unit will have the outage statistics of one of the technology categories and will be of a specific MW capacity. To build up a curve of de-rating factors as a function of unit size for just one technology class it is necessarily to repeatedly solve this problem with notional units of different capacities. This process needs to be repeated independently for each technology class to build up a full set of curves. shows how the de-rated capacity for a notional unit is deduced.

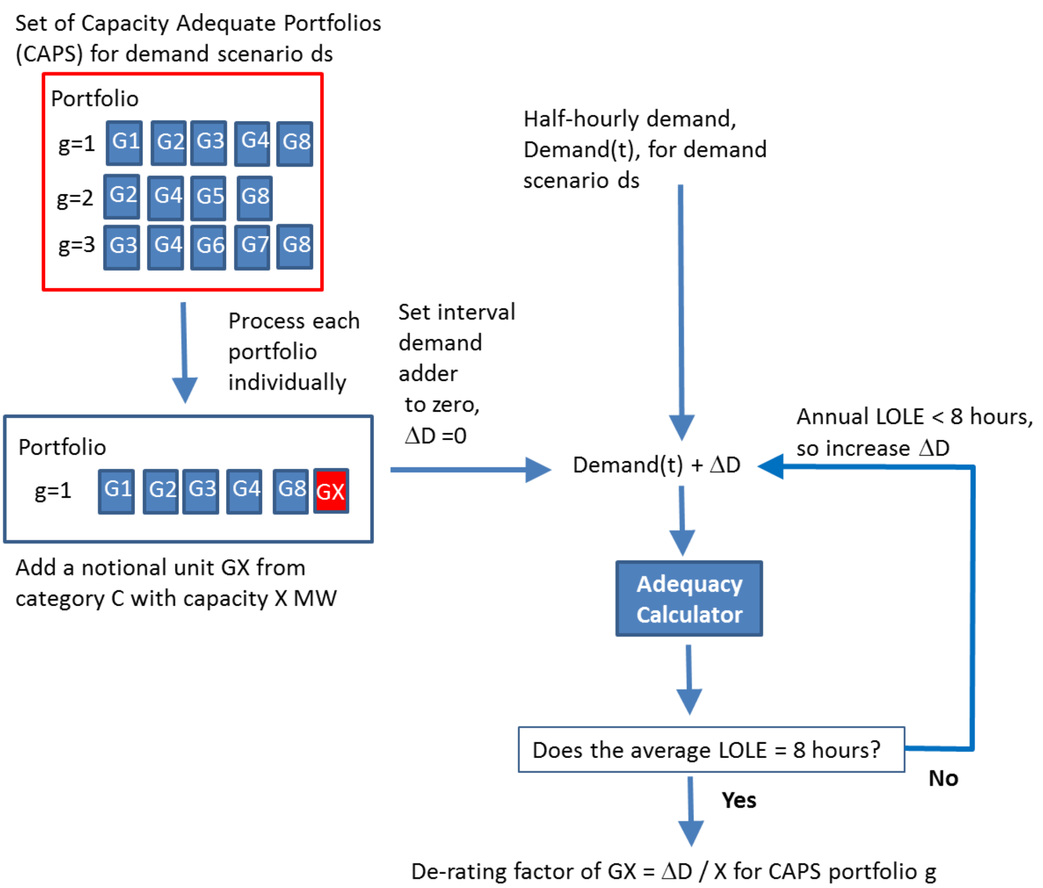


Figure 6: Schematic of the Marginal De-Rating Approach

The notional unit (*GX*) is added to each capacity adequate portfolio for demand scenario ds. Each updated portfolio is then processed individually. shows the processing of profile *g*=1. The Adequacy Calculator is run again but with the demand in all hours increased by some amount ΔD. With ΔD = 0 the demand is exactly the demand against which the original portfolio g=1 satisfied the LOLE adequacy standard. With the additional capacity of unit *GX* the portfolio will now give an LOLE more adequate than the standard. The value of ΔD is increased until the LOLE of the new portfolio equals the adequacy standard again. The de-rating factor of unit *GX* is then defined as the ratio of ΔD to the capacity *X* of unit *GX*.

If unit *GX* is totally reliable then the LOLE will rise to the adequacy standard only when $\Delta D=X$ and the de-rating factor will be 1. This means that the de-rated capacity of GX will be its installed capacity of *X*. However, if *GX* is less reliable then the de-rating factor will be less than 1.

By repeating this process for each technology class and by varying the capacity of unit *GX* it is possible to determine a set of de-rated availabilities for any unit of any size belonging to a class.

The wind de-rating factors for each demand scenario are calculated in a first pass using capacity adequate portfolios that do not contain wind. Then the de-rated capacity of wind is fixed in the portfolios for the second pass where all other de-rating factors and scenario capacity requirements are calculated. The following are the main steps:

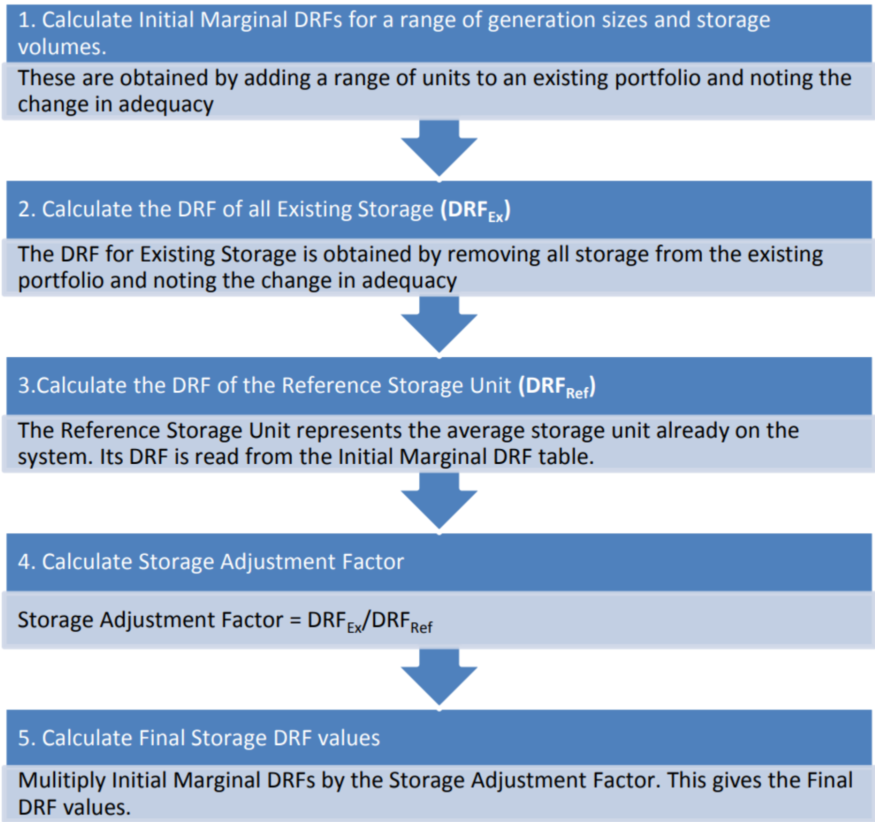
For the relevant capacity year:

- Set up the starting base portfolio which includes all existing units and any known entries/exits for the relevant capacity year. Wind is not yet included in the portfolio.
- Add or remove units until the portfolios are at the 8-hour standard for each demand scenario
- Then add the assumed installed capacity for wind to the portfolios. Currently this assumed installed capacity is that installed capacity that is required to meet the renewable targets for each forecast demand level (i.e. low to high).
- The change in surplus caused by the addition of this wind is divided by the installed capacity of wind to give it's de-rating factor and as with all other units there will be a wind de rating factor calculated for each demand scenario
- The resulting de-rated capacity of wind for that demand scenario will be fixed in the portfolios for the second (main) pass where all other de-rating factors and scenario capacity requirements are calculated.
- The final de rating factor for wind is the average of the wind de-rating factors for all the demand wind profile pairs at that demand level rather than the specific demand scenario.

De-rating factors for other variable units (e.g. solar and tidal) will be calculated using a similar method as outlined above for wind.

6.2.2 Marginal De-Rating Process for Storage units

The marginal de-rating of storage units is complex as both the storage and generation component can vary in size. The generation component is treated as a load modifier (i.e. it reduces the peak demand until the associated reservoir is depleted) and replenishes the reservoir during the lowest demand periods. As the volume of storage on the system increases, its incremental contribution to reducing LOLE declines as the demand peak is increasingly flattened and the ability to refill the reservoir without raising LOLE in off-peak hours declines. The following process is used to calculate storage derating curves:



De-rating curves are produced based on size and storage durations. There will be a set of de-rating curves for pumped hydro storage units (based on its historical outage statistics) and another set of de-rating curves for other new storage types (such as batteries, compressed air and flywheels) that are based on system wide outage statistics.

In accordance with SEM-16-082, a de-rating curve applicable to DSUs will be calculated based on system-wide outage statistics. In addition, in accordance with SEM-18-030, for DSUs with Maximum Down Times of more than six hours, a de-rating curve based on the system wide curve will apply. For DSUs with Maximum Down Times of the than or equal to six hours, the de-rating curves based on the calculation for Other Storage will apply based on the duration of the Maximum Down Time.

6.2.3 Marginal De-Rating Process for Interconnectors

De-rating factors for Interconnectors will be calculated in accordance with the RA Interconnector de-rating methodology updated in SEM-18-030. Forced outage rates, scheduled outage rates and the relevant import capacities for each interconnector are provided by the RAs. These are then treated the same as other technology types in the marginal de-rating process. The final de-rating factor for an Interconnector is calculated by multiplying the de-rating factor that applies to their size class by the External Market De-rating Factor, which is provided by the RAs.

6.3 Determining the De-Rated Capacity Requirements for each Demand Scenario

The process described thus far produces for a given demand scenario:

- A set of capacity adequate portfolios, each having:
  - A curve of de-rating factors as a function of unit size for each technology class.

By applying the de-rating curves to each unit within a capacity adequate portfolio, the de-rated capacities for those units can be deduced. The de-rated capacity requirement for that portfolio is set to the sum of these unit de-rated capacities.

For each demand scenario, a different de-rated capacity requirement will be determined for each capacity adequate portfolio. Only the capacity adequate portfolio with the largest de-rated capacity requirement can be sure of satisfying the LOLE standard for any combination of potential portfolios that could result from an auction. In consequence, the De-rated capacity requirement for a demand scenario will be set to the largest de-rated capacity requirement for any capacity adequate portfolio produced for that scenario. While lower choices for the de-rated capacity requirement may still satisfy the LOLE standard for some mix of units, there is no guarantee that the auction will produce that mix of units.

For each demand scenario, a different set of de-rating factor curves will also be generated for each capacity adequate portfolio. The methodology defines a single set of de-rating curves for each demand scenario, with the de-rating factor for a unit of a given MW size and technology being the average de-rating factor across all capacity adequate portfolios for that demand scenario for a unit of that size and technology.

7 Selecting the Capacity Requirement and De-rating Factors to be used for Qualification

7.1 Selection of the Optimal Demand Scenario

The methodology thus far has determined capacity adequate profiles for each demand scenario and has determined a de-rated capacity requirement and de-rating curves for each demand scenario. However, it is not known which demand scenario will actually transpire.

If the de-rated capacity requirement for the lowest demand scenario is implemented then the capacity adequate portfolios associated with it may fall significantly short of meeting the LOLE adequacy standard if the highest demand scenario actually occurs. This could result in load shedding at times where there is inadequate capacity to serve the higher than expected demand. The cost of each unit of shortage is equal to the VoLL. Hence the market faces a high cost if it fails to procure enough capacity.

If the de-rated capacity requirement for the highest demand scenario is implemented then the capacity adequate portfolios associated with it may significantly exceed the LOLE adequacy standard if the lowest demand scenario actually occurs. The market would have paid for capacity which it turns out not to require. Hence the market faces a high cost in the form of idle capacity that must be funded by the capacity auction.

The SEM Committee has decided (SEM-15-103, paragraph 2.4.3) that a Least-Worst Regrets approach should be used to find a de-rated capacity requirement that seeks to minimise the combined cost of over-procuring capacity and incurring high demand curtailment costs (beyond those implied by the LOLE standard).

7.2 Description of the Least-Worst Regrets Analysis

Figure 7 illustrates the scenarios of capacity shortfall and capacity surplus that can arise if the de-rated capacity requirement is set based on demand scenario *ds* when a different demand scenario *k* occurs.

To perform this analysis, it is necessary to determine for each demand scenario:

- The excess expected unserved energy beyond the adequacy standard if another demand scenario occurs.
- The capacity surplus, being the amount by which the de-rated capacity requirement for the demand scenario exceeds the capacity required if another demand scenario occurs.

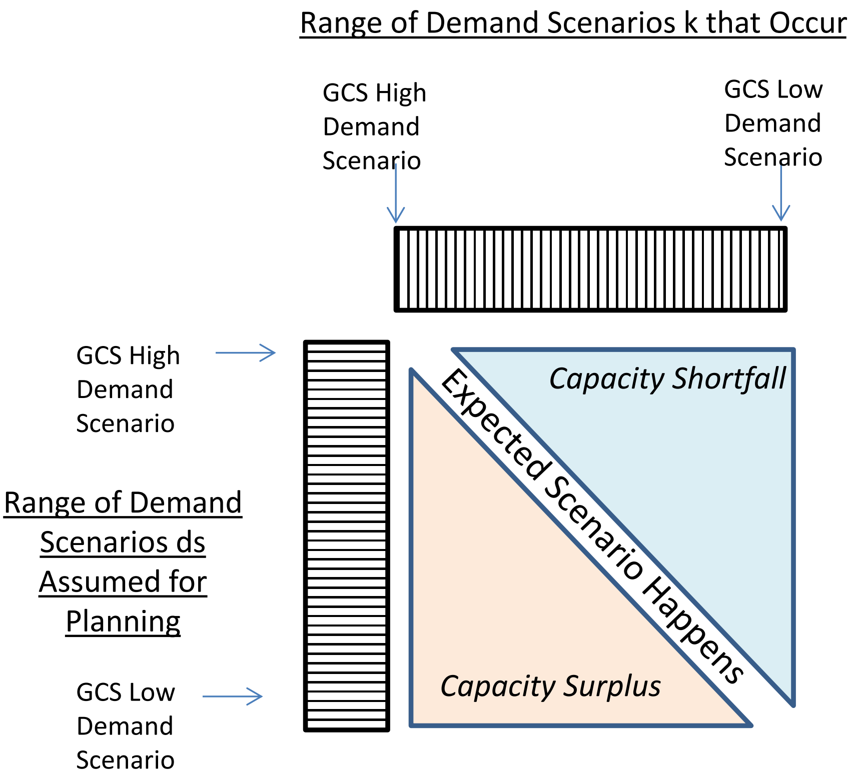


Figure 7: Least-Worst Regrets Analysis

Figure 8 illustrates the process for determining the excess EUE for each combination of demand scenarios. Each capacity adequate portfolio for demand scenario *ds* is simulated with the Adequacy Calculator for every demand scenario *k* in the set of demand scenarios *DS*. In each case the EUE value is determined.[4]

[4] While it may seem intuitive that the EUE value should only increase for demand scenarios with higher forecast demand than demand scenario k, this is not necessarily the case. How demand is profiled across the year can differ

However, as some unserved energy would have occurred if demand scenario *ds* had applied, this EUE must be subtracted to get the excess EUE. Unserved energy in the SEM is priced at VoLL. Averaging the excess EUE across all the capacity adequate portfolios for demand scenario ds and multiplying this average by the VoLL places a value on the Regret Cost of Capacity Shortfall for demand scenario *ds* if demand scenario *k* occurs.

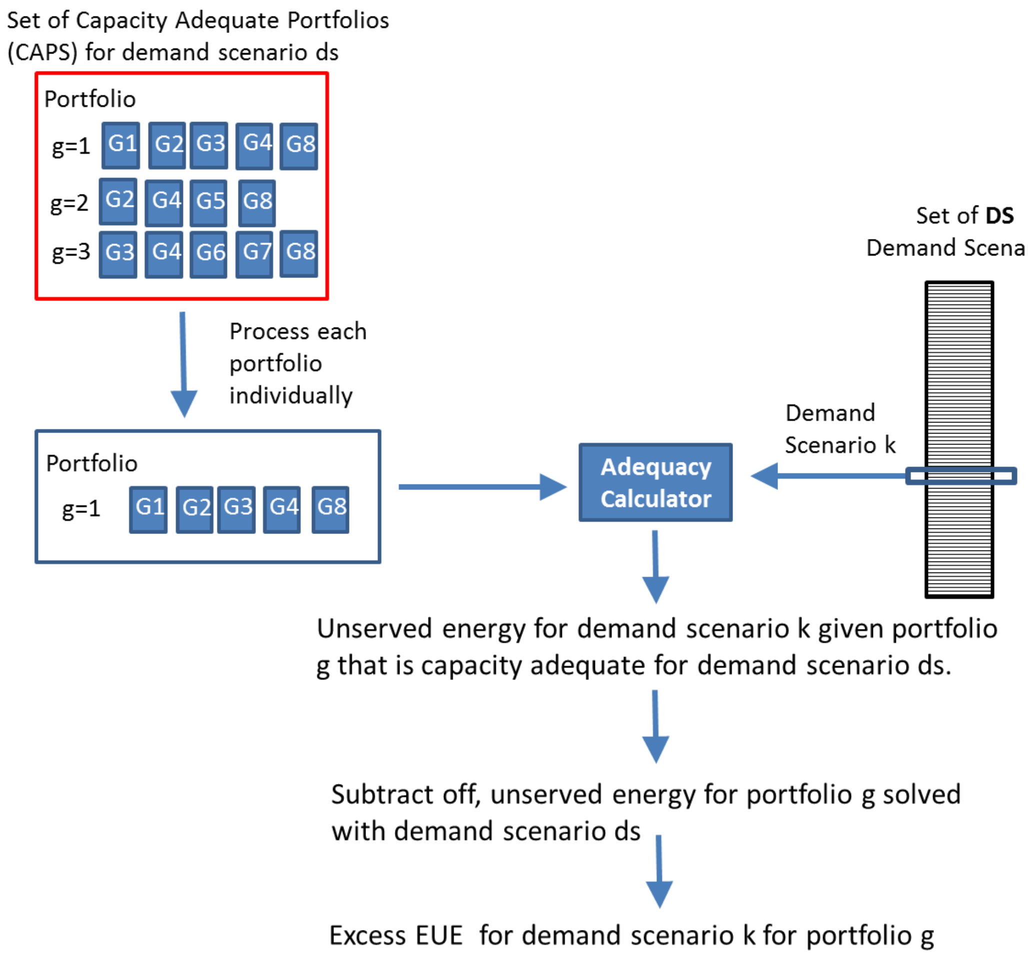


Figure 8: Determination of the annual EUE for each alternative demand scenario that could occur

The de-rated capacity requirement for each demand scenario *ds* is defined in section 6. If demand scenario *k* occurs, and corresponds to a lower capacity requirement, then the amount of surplus capacity procured is the difference between the de-rated capacity requirements for these demand scenarios. This capacity is assumed to be priced at the Net Cost of New Entrant (Net-CONE) value[5]. Multiplying the Net-CONE by

between demand scenarios and these different profiles can result in an increased EUE even if the peak demand does not exceed that in the base demand scenario k.

[5] For the first auctions, in the absence of a Net CONE value the current BNE value [5] may be used https://www.semcommittee.com/news-centre/fixed-cost-bne-peaking-plant-capacity-requirement-and-acps-2017-consultation-published

the surplus capacity places a value on the Regret Cost of Capacity Surplus for demand scenario *ds* if demand scenario *k* occurs.

The least-worst regrets analysis calculates the maximum total regret cost for each demand scenario and selects the demand scenario with the lowest maximum total regret cost. The de-rating factors are averaged across all demand scenarios at that demand forecast level and the average values will be used for the capacity market qualification and auction process. The scenario capacity requirements are also averaged across all demand scenarios at that demand forecast level to give the Capacity Requirement that will be used for the capacity market qualification and auction.

Whilst not foreseen, it may be required to set de-rating factors to be applied to a unit or technology class not considered in the TSO analysis. If such was required, it would be for the RAs to decide on the de-rating factor to be applied.

The following gives an illustrative example of the least-worst regrets analysis. Note that these are for illustrative purposes only.

7.3 Illustrative Example of Least-Worst Regrets Analysis

The illustrative example uses a total of eight demand scenarios. As outlined above there are three main steps to the least-worst regrets analysis.

EUE Cost (m€):		Outturn Scenario							
		S1	S2	S3	S4	S5	S6	S7	S8
Input Scenario	S1	0	0	15	28	20	64	88	72
	S2	4	0	22	37	28	79	108	88
	S3	0	0	0	8	3	28	44	34
	S4	0	0	0	0	0	15	28	20
	S5	0	0	0	4	0	22	36	28
	S6	0	0	0	0	0	0	7	3
	S7	0	0	0	0	0	0	0	0
	S8	0	0	0	0	0	0	4	0

Capacity Cost (m€):		Outturn Scenario							
		S1	S2	S3	S4	S5	S6	S7	S8
Input Scenario	S1	0	3	0	0	0	0	0	0
	S2	0	0	0	0	0	0	0	0
	S3	8	11	0	0	0	0	0	0
	S4	14	17	6	0	2	0	0	0
	S5	11	14	3	0	0	0	0	0
	S6	24	27	16	10	13	0	0	0
	S7	29	32	21	15	17	5	0	2
	S8	27	30	19	13	16	3	0	0

Total Regret Cost (m€):		Outturn Scenario									
		S1	S2	S3	S4	S5	S6	S7	S8	Max Regret	Least-Worst Regret
Input Scenario	S1	0	3	15	28	20	64	88	72	106	
	S2	4	0	22	37	28	79	108	88	129	
	S3	8	11	0	8	3	28	44	34	54	
	S4	14	17	6	0	2	15	28	20	35	
	S5	11	14	3	4	0	22	36	28	45	
	S6	24	27	16	10	13	0	7	3	27	27
	S7	29	32	21	15	17	5	0	2	32	
	S8	27	30	19	13	16	3	4	0	30	

Figure 9: Illustrative example of least-worst regrets analysis

Step 1: Calculate Regret Cost of excess EUE (too little capacity):

If the outturn demand is higher than that in the scenario being evaluated, using that scenario would lead to the purchase of less capacity than is required. This, in turn would increase the MWh level of expected unserved energy. The regret costs are calculated by multiplying the excess expected unserved energy MWh value by VoLL and are given in the top table of Figure 9.

Step 2: Calculate Regret Cost of Excess Capacity

If the outturn demand is lower than that in the scenario being evaluated, using that scenario would lead to the purchase of more capacity than is required. The regret costs are calculated by multiplying the excess capacity MW value by Net-CONE and are given in the middle table of Figure 9.

Step 3: Calculate total regret cost and select the Least Worst Regret:

The two components of regret cost are summed and combined into a single table, and the worst regret cost for each is determined. The scenario that has the lowest worst regret cost is selected as being the optimal scenario. This is given in the bottom table of Figure 9.

The example highlights that significant under procurement leads to higher costs than the same level of over-procurement. This results in the selected demand scenario tending towards the high demand forecast.

The de-rating factors are averaged across all demand scenarios at that demand forecast level and the average values will be used for the capacity market qualification and auction process. The scenario capacity requirements are also averaged across all demand scenarios at that demand forecast level to give the Capacity Requirement that will be used for the capacity market qualification and auction.

8 Format of Results

This section sets out the format of results that will be produced by the methodology.

8.1 Marginal De-rating Factors

Table 2 is illustrative of the format in which de-rating factor results will be published. A marginal de rating factor will be listed for each technology and size class. Table 3 contains the storage de-rating curves that will be used by storage units (and DSUs with Maximum Down Time ≤ 6 hrs).

Table 2: De-Rating Curves by Technology Class and Initial Capacity

Initial Capacity (IC) (MW not de-rated)	DSU >6 hrs	Gas Turbine	Hydro	Steam Turbine	Interconnecto r	System Wide
0 ≤ IC ≤ 10						
10 < IC ≤ 20						
…	…	…	…	…	…	…
480 < IC ≤ 490						
490 < IC ≤ 500						

Table 3: Format of results for Storage-De-rating Factors

	Hours of Storage (linear interpolation applies for durations between 30 min intervals)												
Initial Capacity (IC) (MW)	**0.0**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**5.5**	**6.0 or greater**
0 ≤ IC ≤ 10													
10 < IC ≤ 20													
…	…	…	…	…	…	…	…	…	…	…	…	…	…
180 < IC ≤ 190													
190 < IC ≤ 200													

8.2 Capacity Requirements

Table 4 below is an illustration of the format that the Capacity Requirement will be published for each auction These values will represent the forecasted capacity requirement to satisfy the LOLE adequacy standard for the unconstrained all-island system.

	2017/18	2018/19	2019/20	2020/21
Indicative Capacity Requirement				

Table 4: Format of Capacity Requirement Results in MW of de-rated capacity

9 Operational Considerations

The methodology presented in this document is designed to calculate the aggregate de-rated capacity required to satisfy the unconstrained All-Island LOLE adequacy standard. This approach treats all de-rated capacity as equivalent and makes no allowance for network considerations, such as ensuring that there is adequate capacity available in specific regions allowing for transmission limitations and the risk of transmission outages impacting on available generation.

It is possible therefore that the loss of load expectation could be higher than predicted if the theoretically available capacity from a portfolio of generators cannot be delivered due to transmission or security limitations. These situations cannot be resolved simply by increasing the capacity requirement without consideration of where that capacity is located. In the market today, the power system may have significantly more capacity than is theoretically required to meet peak demand, but operationally situations do arise where combinations of planned outages and transmission limitations can mean that the supply and demand situation in specific regions is very tight.

It follows that a Capacity Market auction result that satisfies the de-rated capacity requirement will not necessarily allow the TSOs to operate the power system within its operational limits while still satisfying the LOLE standard. Operational considerations are not accounted for in this methodology.

10 Glossary

Terminology	Meaning
Adequacy Calculator	A process that determines the LOLE associated with a demand scenario and a portfolio of units.
Auction Capacity Requirement	The aggregate de-rated capacity targeted to be supplied from generating units and demand side units in the capacity auction.
Capacity Market Unit	One or more generating units or demand side units eligible to participate in the capacity auction.
Capacity Year	A 12-month period commencing 1 October and associated with a de-rated capacity requirement.
Demand Forecast Level	A level of forecast demand for a year, comprising a peak value (MW) and a cumulative value (MWh). This includes transmission and distribution losses and is net of generation on the demand site that is not separately metered.
Demand Profile	A half-hourly set of MWh demand levels for a historical year. This includes transmission and distribution losses and is net of generation on the demand site that is not separately metered.
Demand Scenario	A half-hourly set of MWh demand levels, net of embedded generation, derived from a demand forecast and a net demand profile such as to produce the same peak and annual consumption as the demand forecast. A reserve level to cover the largest single infeed is then applied.
De-Rated Capacity	The capacity expected to be available from a capacity market unit after allowing for forced, scheduled and ambient outages.
De-rated capacity requirement	The aggregate de-rated capacity targeted to be supplied from generating units and demand side units required to satisfy the LOLE Standard
De-Rating Factor	The proportion of a unit's capacity that is deemed to be capable to contribute to the Capacity Requirement
Expected Unserved Energy (EUE)	The LOLP probability weighted level of unserved energy. This may be calculated by hour or accumulated over a year.
Generation Capacity Statement (GCS)	An annual EirGrid and SONI planning report projecting future All Island demand growth and system capacity adequacy.

Terminology	Meaning
LOLE Standard	This is the level of LOLE required to be satisfied by the de-rated capacity requirement. It is currently set to 8 hours per year.
Loss of Load Expectation (LOLE)	The accumulative total LOLP for a year to give the expected number of hours per year in which there is inadequate capacity to meet demand.
Loss of Load Probability (LOLP)	The probability that there is inadequate capacity to meet demand in any given hour.
Maximum Down Time	As defined in the relevant Grid Code.
Portfolio	A set of generating units and demand side units that represent those available in the SEM at a particular time and which are eligible for inclusion in the auction.
Qualification	A process for qualifying a generating unit, demand side unit or interconnector for participation in a capacity auction.
Technology Classes	Groupings of generator and demand-side unit technologies used for the purposes of averaging availability data