System Services - 2030 Volumes

Indicative Portfolio Capability Analysis

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Executive Summary

The SEM Committee is currently consulting on the high-level design of new System Services arrangements for which go-live is planned for 1 May 2024. The aim of these new arrangements is to provide market-based procurement of System Services where appropriate but also to give the right investment signals to obtain the required capabilities to operate at higher levels of SNSP in the future to support delivery of the 2030 renewable electricity ambitions in Ireland and Northern Ireland.

In order to support the work being undertaken by the regulatory authorities, EirGrid and SONI conducted analysis on indicative System Services volumes and requirements for 2030 based on three illustrative portfolios. The reason for developing three portfolios is to demonstrate that the System Services needed to operate the power system at very high SNSP levels could be provided by a range of technologies. The portfolios were developed solely for the purpose of this analysis and do not represent desired, expected or optimal portfolios.

This paper summarises the results of the preliminary analysis undertaken and indicates the system services capabilities that could be delivered to enable operation at high SNSP levels provided that the right investment signals are given. Additional work on system services volumes and requirements will be undertaken in 2022 and stakeholders will be kept up to date on the outcomes from this further analysis either through a revision of this paper or through publication of additional documents. In addition, EirGrid and SONI are actively engaging with the regulatory authorities on the topic of system services volumes and the outcome of these ongoing discussions will be reflected in future publications.

Based on ongoing work and professional judgement, the analysis described in this paper focused on the reserves and ramping products (separately, studies have been launched regarding the requirements for low carbon sources of inertia in which inertia, reactive power and short circuit level are considered) and involved the following steps:

1. Develop three illustrative portfolios for 2030 (these are assumed capacity adequate);
2. Estimate the Capability Volume (i.e. installed system services capabilities) of each portfolio;
3. Define a case study (a snapshot with peak demand and high wind, likely to reach a high level of SNSP) for which we:
    - Estimate the Real-Time Volume Requirements;
    - Estimate the likely Available Volume for each portfolio;
    - Check that the likely Available Volume meets the Real-Time Requirements.

Assumptions have been made throughout the paper to estimate the Capability Volume (i.e. installed system services capabilities) and an extreme scenario (high wind and peak demand) where most of the services are assumed to be provided by low carbon technologies sources has been chosen to estimate the Available Volume and Real-Time Requirements.

While reserve requirements in real time operation will continue to be a function of the Largest Single Infeed (LSI) and will not change significantly by 2030, the ramping requirements will increase as the level of Variable Renewable Energy Sources (VRES) increases (from 5 GW installed today to over 10 GW by 2030).

Based on this single case study and the assumptions made (e.g. significant volumes of fast acting reserves from Demand Response available, gas turbines flexible enough to provide ramping services from a cold state), the analysis shows that the Available Volume for each portfolio is sufficient to meet the Real-Time Requirements assumed.

However, many assumptions have been made and different choices can significantly change the results of this analysis. The portfolios on which this analysis is based are also likely to be different based on market forces and the TSOs are committed to a technology neutral stance.

As this analysis focuses on a single case study and considers only the existing system services products, further work will be carried out in 2022:

- Ramping analysis: With larger forecast errors for VRES in MW terms in the future, further analysis will have to be carried out and longer duration ramping products may be proposed;
- Volumes and requirements for different system conditions: Although most system services requirements will not fundamentally change by 2030, the range of technologies that provide them will be more diverse as we will operate across a wider range of SNSP levels (i.e. 10% SNSP, 50% SNSP, 70% SNSP, 80% SNSP,…, up to 95% SNSP). Further work will be carried out to indicate the likely requirements and volumes available when operating at different SNSP levels, and the number of days/hours for which we would expect to operate at these different SNSP levels will also be considered;
- Technical and locational requirements for Inertia, Reactive Power and Short Circuit level: In the context of the Low Carbon Inertia Services project, studies have been launched to assess inertia, reactive power and short circuit level requirements. As part of this project, a public consultation on the technical and locational requirements will be launched in 2022.

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1 Introduction

1.1 Scope

As part of the DS3 Programme, new System Services arrangements were introduced in 2016, which enable EirGrid and SONI to procure a range of services from providers of different technology types to support the operation of the transmission system and enable SNSP levels up to 75%[1].

In the future power system by 2030, the System Services required to operate a safe, secure and economic power system will need to be provided by a more diverse portfolio. Indeed, when operating in high renewable power scenarios with SNSP levels up to 95%, most conventional generators are likely to be offline as the target is to reduce to four or less conventional units, with most of the System Services provided by low carbon technology sources. However, in low renewable power scenarios, more conventional generators are likely to be online providing a range of System Services and will compete for service provision with other technologies.

The SEM Committee is currently consulting on the high-level design of new System Services arrangements for which go-live is planned for 1 May 2024. The aim of these new arrangements is to provide market-based procurement of System Services where appropriate but also to give the right investment signals to obtain the required capabilities to operate at higher levels of SNSP in the future to support delivery of the 2030 renewable electricity ambitions in Ireland and Northern Ireland.

Thus, the objective of this paper is to assess, based on three different illustrative portfolios, what the System Services volumes and requirements might be in 2030. This work involved the following steps:

1. Develop three illustrative portfolios for 2030 (these are assumed capacity adequate).
2. Estimate the Capability Volume of each portfolio.
3. Define a case study (a snapshot with peak demand and high wind, likely to reach a high level of SNSP) for which we:
    - estimate the Real-Time Volume Requirements;
    - estimate the likely Available Volume for each portfolio;
    - check that the likely Available Volume meets the Real-Time Requirements.

Caveats:

- The portfolios have been developed solely for the purpose of estimating the Capability Volume for each of the services and **do not represent desired, expected or optimal portfolios**;
- The three portfolios presented here are assumed capacity adequate. There is a separate programme of work being coordinated by the CRU considering security

[1] SNSP stand for System Non-Synchronous Penetration. A trial of the SNSP level up to 75% commenced in April 2021.

of supply issues[2] that will ultimately influence the 2030 portfolio from a capacity adequacy perspective;

- This exercise does not provide the Real-Time Volume Requirements for different system condition profiles (e.g. hour, day, season, windy or not, etc.);
- The analysis focuses on the reserves and ramping products (separately, studies have been launched regarding the requirements for low carbon sources of inertia where inertia, reactive power and short circuit level are considered); and
- Across all three portfolios and for all technologies, transmission constraints have not been considered when estimating the volumes.

1.2 Terminology relating to Volumes

Several important terms are used throughout this paper and their respective meanings are described below:

- **Capability Volume**

These are the volumes of System Services installed.[3]

- **Available Volume**

This is the volume of service that can be provided by a service provider at a given time. This volume varies depending on the state of the service provider, e.g. heat state, connected to the system or not, fully charged or not, dispatch.

- **Real-Time Volume Requirements**

These are the volumes of System Services which are required at any point in time to ensure that system security is maintained. These requirements vary depending on system conditions.

1.3 Definition of System Services products

A short description of the existing System Services products4 is provided below:

[2] https://www.cru.ie/cru-publishes-security-of-supply-information-note/
[3] The Capability Volume for each service is equivalent to the total contracted volume of a service in the current Regulated Arrangements.
[4] Detailed description: http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-SS-Protocol-v3.0.pdf

Service Name	Abbreviation	Unit of Payment	Short Description
Synchronous Inertial Response	SIR	MWs²h	(Stored kinetic energy)*(SIR Factor – 15)
Fast Frequency Response	FFR	MWh	MW delivered between 2 and 10 seconds
Primary Operating Reserve	POR	MWh	MW delivered between 5 and 15 seconds
Secondary Operating Reserve	SOR	MWh	MW delivered between 15 to 90 seconds
Tertiary Operating Reserve 1	TOR1	MWh	MW delivered between 90 seconds to 5 minutes
Tertiary Operating Reserve 2	TOR2	MWh	MW delivered between 5 minutes to 20 minutes
Replacement Reserve – Synchronised	RRS	MWh	MW delivered between 20 minutes to 1 hour
Replacement Reserve – Desynchronised	RRD	MWh	MW delivered between 20 minutes to 1 hour
Ramping Margin 1	RM1	MWh	The increased MW output that can be delivered with a good degree of certainty for the given time horizon.
Ramping Margin 3	RM3	MWh	
Ramping Margin 8	RM8	MWh	
Fast Post Fault Active Power Recovery	FPFAPR	MWh	Active power (MW) >90% within 250 ms of voltage >90%
Steady State Reactive Power	SSRP	Mvarh	(Mvar capability)*(% of capacity that Mvar capability is achievable)
Dynamic Reactive Response	DRR	MWh	MVAr capability during large (>30%) voltage dips

Table 1: Short description of the existing products

Remarks:

- We focus our analysis on the reserves and ramping products
- We do not consider the two services that are currently not contracted (Fast Post-Fault Active Power Recovery -FPFAPR and Dynamic Reactive Response - DRR)

2 Portfolio development

Based on ongoing work and on professional judgement, we developed three illustrative portfolios which we believe could provide the required level of capacity adequacy and System Services. We have named the portfolios as follows:

- Portfolio 1 – Gas Turbines-Led;
- Portfolio 2 – Mix (more balanced amount of Gas Turbines, Energy Storage Power Station or ESPS and Demand Response);
- Portfolio 3 – Demand-Led.

The purpose of developing three portfolios is to illustrate that the System Services needed to operate the power system at very high SNSP levels could be provided by a range of technologies.

As a baseline for all three portfolios, we used the generation portfolio from the Generation Capacity Statement (GCS) 2021-2030[5]. The GCS includes the existing units in 2021 and the successful units in the T-4 capacity market auctions but removes the units that are assumed to close by 2030 (e.g. Moneypoint, Tarbert, etc.). As the adequacy assessment studies performed in the GCS 2021-2030 show an adequacy deficit by 2030, we developed different scenarios to bridge this deficit which led to the creation of the three different portfolios listed above (see Figure 1).

We created Portfolio 1 – entitled Gas Turbines-Led, which assumes a significant amount of gas turbines and Energy Storage Power Stations (ESPS). For the purpose of the

[5] https://www.eirgridgroup.com/site-files/library/EirGrid/208281-All-Island-Generation-Capacity-Statement-LR13A.pdf

System Services Volumes exercise, we assumed the Portfolio 1 to be capacity adequate, and used it as a starting point for creating two other potential portfolios in 2030.

We have assumed the same demand across all the portfolios, with a peak demand of 8.75 GW in 2030. However, for Portfolios 2 and 3, we consider that a greater share of this demand is flexible and therefore provides some System Services. Thus, for Portfolio 2 – entitled Mix, we decreased the assumed amount of generation capacity from gas turbines and increased the assumed level of demand response capacity, while we went further with this approach for Portfolio 3 – entitled Demand-Led. As we used the de-rating factors[6] while shifting those capacity amounts, we have assumed that these 2 portfolios are also capacity adequate based on fixed de-rating factors for the purposes of this work.

Note that in building the portfolios we have not included all types of technologies. This is done for simplification, to have the portfolios consist of technologies with certain characteristics for illustrative purposes and is not intended to indicate that other technologies with similar characteristics are not desirable or cannot make a valuable contribution.

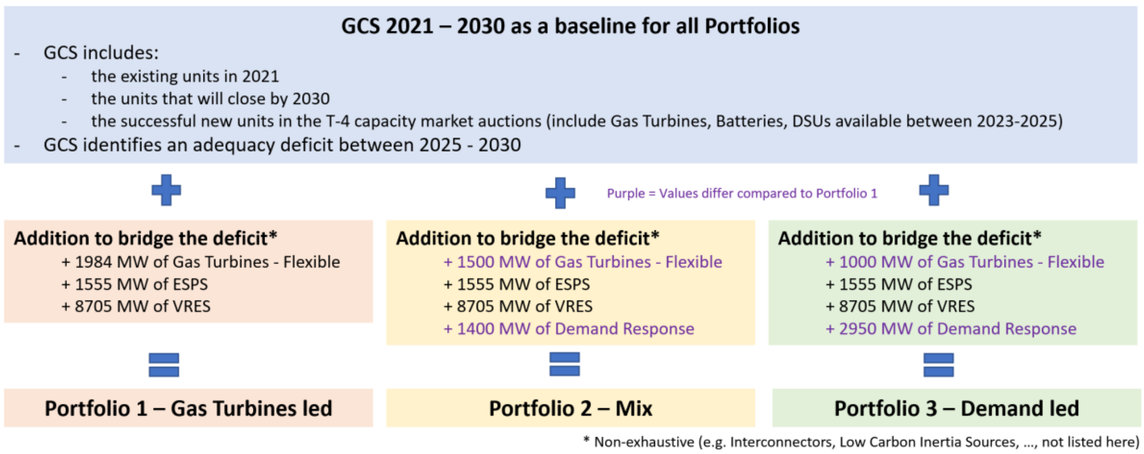

Figure 1: Portfolios development principle

Further work is currently being undertaken to look at both the volume and capacity required to meet our future adequacy needs out to 2030. This separate analysis uses Plexos modelling which allows for a diverse range of system conditions to be considered (as every hour of the year is modelled) whereas the analysis presented in this paper focuses on a single snapshot of system conditions. We will look to build on this work into the future work plans to help us to more accurately model the volume of System Services required.

In Appendix 1, we describe the full portfolios and their installed capacities per technology.

[6] De-rating factors for Gas Turbines based on T-4 Capacity Auction and 30% for Demand Response

3 Capability Volume

3.1 Capability of each technology

In order to determine the Capability Volume of each portfolio, we estimated the system services capability of each technology as a percentage of the installed capacity. For example, a wind farm of 100 MW able to provide 10 MW of SOR has a capability of 10% for this service, while a 20 MW battery able to provide 20 MW of SOR has a capability of 100%.

Depending on the technology, we estimated the capability based on:

- **Historical data**: the percentage is equal to the current contracted capabilities divided by the current installed capacities. We used this type of data when an existing technology provides generally more capability than the minimum requirements (e.g. gas turbines) or when the additional MW assumed installed in the 2030 portfolios is negligible compared to what is already installed in 2021. No re-assessment is done for the new units added (e.g. Demand Response - Industrial);
- **Professional judgement**: we estimated the percentage based on analysis or work ongoing in EirGrid and SONI. We used this approach when there are no existing minimum requirements and/or historical data does not necessarily reflect the future capabilities of a new technology (e.g. Demand Response - Residential);
- **Minimum requirements**: the percentage is defined in the Grid Codes. We used this approach for technologies which we considered likely to provide just the minimum requirements (e.g. Wind farms, Solar PV).

In addition, we have defined two categories reflecting the level of maturity of a technology to provide the capability:

- **Established**: technology for which we have a high degree of confidence that the capability will be provided (e.g. gas turbines have already demonstrated that they can provide most services);
- **Developing/New**: technology for which we are less certain that the capability will be provided at the level estimated (e.g. capability estimated for Demand Response – Residential has not been proven yet and barriers may remain).

Table 2 (see below) illustrates the capability contribution for some of the technologies. We list the capability percentage/factors estimated for all technologies in Appendix 2.1.

Type of technology	Capability maturity	FFR	POR	SOR	TOR1	TOR2	RRS	RRD	SSRP	SIR	RM1	RM3	RM8
Gas Turbine - Flexible	Established	Low	Low	Low	Low	Medium	High	High	High	High	High	High	High
DC interconnector	Established	Low	Low	Low	Low	Low	No contribution	No contribution	Medium	No contribution	No contribution	No contribution	No contribution
Demand Response – Residential	Developing / New	High	High	High	High	No contribution	No contribution	No contribution	No contribution	No contribution	No contribution	No contribution	No contribution
Demand Response - Industrial	Established	Medium	Medium	Medium	Medium	Medium	No contribution	Medium	No contribution	No contribution	High	Low	Low
Demand Response – LEDU	Developing / New	High	High	High	High	No contribution	No contribution	No contribution	No contribution	No contribution	No contribution	No contribution	No contribution
ESPS – Energy & Reserve	Developing / New	High	High	High	High	High	No contribution	High	High	No contribution	High	No contribution	No contribution
ESPS – Reserve-Only	Established	High	High	High	High	No contribution	No contribution	No contribution	High	No contribution	No contribution	No contribution	No contribution
ESPS – Long Duration	Developing / New	High	High	High	High	High	No contribution	High	High	No contribution	High	High	No contribution
VRES	Developing / New	Low	Low	Low	Low	No contribution	No contribution	No contribution	High	No contribution	No contribution	No contribution	No contribution

Capability as a % of Installed Capacity: Low, Medium, High, No contribution

Table 2: Capability contribution (i.e. Capability as a percentage of Installed Capacity) for some technologies

Table 3 gives additional information for each technology.

Technology type consideration	
Gas Turbine - Flexible	Includes flexible gas turbines which can provide RM1 to RM8 in the cold state. The ability of gas turbine technology to provide a range of System Services is well established.
DC interconnector	Includes the HVDC interconnectors Moyle, EWIC, Greenlink and Celtic. The ability of HVDC technology to provide a range of reserves and reactive power System Services is well established.
Demand Response - Residential	Includes resistive electric space/water heating, heat pumps, domestic appliances and electric vehicles which could provide fast-acting reserves. An average load (installed capacity) is considered for these devices which leads to a high contribution in Figure 2. While there is currently no significant level of capability realised from these sources, they are considered a potentially significant source of System Services in the future.
Demand Response - Industrial	Includes industrial sites that can provide a range of System Services through back-up generators and/or interruptible processes that allow them to reduce their demand. The capability of some industrial demand to provide short term demand response is well established.
Demand Response – LEDU (Large Electricity Demand Users)	Includes Data Centres. Although some LEDU have fossil fuel backup generators to ensure reliability, the use of these for system services is assumed to be limited due to carbon emissions. We have assumed that only fast-acting reserves can be provided through short term management of their demand. While some level of LEDU response makes up part of existing DSU response this is a relatively small portion of the potential capability which we believe could be realised in the future.
ESPS – Energy & Reserves	An average duration of 2 hours is assumed and provision of a range of System Services is assumed accordingly. While short term battery response capability (up to 30 minutes) has been demonstrated on the system today, this longer-term capability is considered developing technology.
ESPS – Reserve-Only	An average duration of 30 minutes is retained and provides a range of System Services is assumed accordingly.

	Short term battery response capability (up to 30 minutes) for the provision of reserves is currently active on the power system.
ESPS – Long Duration	An average duration of 6 hours is assumed and provision of a range of System Services is assumed accordingly While short term battery response capability (up to 30 minutes) has been demonstrated on the system today, this longer-term capability is considered developing technology.
VRES	Includes Solar PV and Wind Farms which can provide reserves and reactive power system services according to the Grid Code requirements. The capability and ability to utilise services from VRES is considered to be in the 'developing' category.

Table 3: Technology type consideration for Capability Volume

Additional remarks:

- These capabilities reflect our assumptions, based as far as possible on our ESPS estimates, but may well be different in 2030.
- No change to Grid Code standards is assumed.

3.2 Capability Volume of each portfolio

Based on the estimated capability percentage/factors defined above, we estimated the Capability Volume (i.e. the installed capability) for each service and for the three portfolios:

- Appendix 2.2: Capability Volume for Portfolio 1 – Gas Turbines-Led;
- Appendix 2.3: Capability Volume for Portfolio 2 – Mix;
- Appendix 2.4: Capability Volume for Portfolio 3 – Demand-Led.

Figure 2 shows a comparison of the Capability Volume provided by the three portfolios and the current Contracted Capability in June 2021 (after DS3 procurement Gate 4B). For each portfolio, a distinction can be made between the Capability Volume coming from established technologies (portion of the full-coloured bar) and those from developing / new technologies for which we have less certainty (part of the shaded bar). Refer to Section 3.1 for the distinction between the technologies.

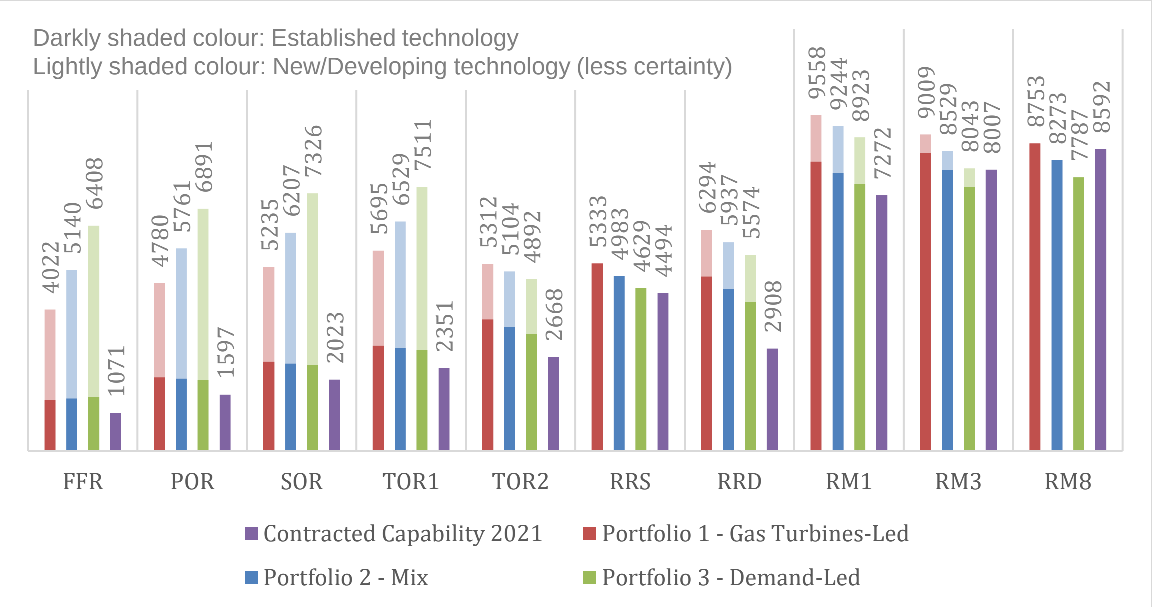

Figure 2: Capability Volume comparison (in MW)

Note that, due to more diversified portfolios in 2030, the Capability Volume (i.e. installed capacities) for fast acting reserves are generally far higher than the Contracted Capability 2021 level. However, this is not the case for the longer duration products which are assumed in this work not to be provided by the new low carbon system services providing technologies. For example, RM8 is mainly provided by large synchronous units today and, as we have assumed more closures than new conventional units by 2030, in portfolios 2 and 3 the Capability Volume of RM8 is assumed to be slightly lower than it is today.

4 Case study

4.1 Case study description

Since the Capability Volume defined above for the different portfolios does not reflect the Available Volume under different system conditions, we have undertaken a case study to check that the Available Volume in each portfolio will meet the Real-Time Requirements. The case study (a snapshot of system conditions) is described as follow:

Case study: peak demand and high wind	
Peak Demand	8.75 GW
Export	2 GW
Large Synchronous units	0 sets synchronised (cold)
VRES	10.5 GW online (14.3 GW installed)
Other small-scale generation sources	0.25 GW
Min. inertia	17500 MWs

Table 4: Case study description

We selected this particular case study, for which we assume an SNSP level close to 100%, in order to evaluate an extreme operational scenario where, for instance:

- the Real-Time Requirements for ramping products are likely to be the highest (due to the high wind conditions) and,
- the contribution of the large synchronous units is likely to be the lowest (0 sets synchronised / online). Note that this is not stating that we can operate with zero synchronous units but rather testing this scenario from the provision of System Services perspective.

4.2 Real-Time Requirements

For the case study described in Section 4.1, we estimated the Real-Time Requirements for the reserves and ramping products.

As a reminder, this exercise does not focus on inertia and reactive power requirements as a study is currently underway to determine requirements for Low Carbon Inertia Solutions where inertia, reactive power and short circuit level requirements are considered.

4.2.1 Reserves requirements for the case study

The requirements for the reserve products are directly related to the size of the Largest Single Infeed (LSI). For this case study, we considered an LSI of 700 MW which matches the capacity of the Celtic Interconnector. While it is acknowledged that the Celtic Interconnector is assumed to be exporting in this scenario, so not actually the LSI, we could still have an LSI of this magnitude in the form of a single off-shore wind connection so we believe it is an appropriate LSI to use in an assessment of an extreme scenario. This assumption leads to the Real-Time Requirements below:

Services	MW	Real-Time Requirements for the case study
FFR	525	75% of LSI
POR	525	75% of LSI
SOR	525	75% of LSI
TOR1	700	100% of LSI
TOR2	700	100% of LSI
RR	700	Amount needed to restore the situation to pre-incident level. Provided by RRS and/or RRD

Table 5: Reserves requirements of the case study

Remarks:

- The operational policy for FFR requirements is under development. For the purposes of this analysis, we have assumed FFR requirements that match those of POR and SOR.
- The normal[7] requirements for POR and SOR (being 75% of LSI rather than 100% of LSI as it is for TOR1/2 and RR) reflects the historical performance of reserve providers (mainly conventional generators providing automated frequency governor response) and demand response (the natural response of load on the system to a frequency deviation) allowing us to maintain frequency within limits. Changes to the sources of reserve (power inverter based resources such as batteries and further HVDC interconnector) and the response of system demand (an increasing proportion of large and small scale power inverter based load) could change the overall frequency response characteristics of the power system and drive changes in the proportions of reserve that we require. The process for reviewing and changing the levels of reserve required is governed under the

[7] Under certain system conditions (such as at times of high risk to the secure operation of the power system or when a unit is under test) the POR and SOR reserve requirements can be increased to 100 %.

EirGrid/SONI Synchronous Area Operational Agreement (Title 2, Article 3, Dimensioning Rules for FCR)[8].

- The connection of a larger offshore wind farm (greater than 700 MW) or the specific case where a storm would lead to high speed shutdown are not considered in Table 5 but could potentially lead to a larger LSI by 2030.

4.2.2 Ramping requirements for the case study

The requirements for the ramping products are mainly related to the level of, and uncertainty associated with, VRES but are also a function of demand profiles and interconnection capacity and ramp rates.

To estimate our requirements in 2030, we analysed data from January 2018 to January 2019[9] to establish a relationship between the level of VRES installed and the ramping margin 1 hour and 8 hours required for that particular period. Based on these results, and factoring in demand and interconnector ramps which will be much greater in magnitude than they are today (i.e. demand will increase by 30% and our interconnection capacities will double), we estimated the requirements for RM1, RM3 and RM8 in 2030 below:

Services	Real-Time Ramping Margin Requirements assumed for the case study (MW)
RM1	1900
RM3	2800
RM8	4700

Table 6: Ramping requirements assumed for the case study

Remarks:

- These requirements are those estimated for the case study considering the maximum VRES infeed (VRES online = 10.5 GW) and based on the existing products.
- There is a high degree of uncertainty associated with these ramping requirements and whether these products will enable us to operate in these conditions.
- More analysis is required on ramping margin requirements potentially including the development of longer-term ramping products (see Section 5.1 for next steps).

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[8] Synchronous-Area-Operational-Area-for-the-Ireland-and-Northern-Ireland-S....pdf (eirgridgroup.com)

[9] https://www.researchgate.net/profile/Corinna-Moehrlen/publication/340502313_Probabilistic_forecasting_tools_for_high-wind_penetration_areas_an_Irish_case_study/links/5e8d7f324585150839c79b9b/Probabilistic-forecasting-tools-for-high-wind-penetration-areas-an-Irish-case-study.pdf?origin=publication_detail

4.3 Available Volume

4.3.1 Availability factors

In order to define the Available Volume for each portfolio (i.e. the volume of service that can be provided under the case study conditions), we define Availability factors for each technology which reflect:

- the average annual availability based on the historical availability over the last 5 years (based on outage rates);
- the availability specific to the case study (depending on system conditions and dispatch).

For example, the average annual availability based on a 5-year period (based on outage rates) for Wind farms/Solar PV (VRES) is 98%. However, the grid cannot accommodate more VRES than the peak demand and exports assumed in the case study, which means that the amount of VRES online compared to installed VRES is assumed not to exceed 73% (10.5 GW maximum online / 14.3 GW installed). Therefore, the global availability factor is assumed to be 72% (73% x 98%) for the case study.

Table 7 gives the availability factors estimated for some technologies. The Availability factors estimated for all the technologies and per service are given in the Appendix 3.1.

Technology	Global availability factor	Comments on the assumptions
Gas Turbines - Flexible	0% / 94% (RM products)	Availability (based on outage rate): 94% Availability case study: 0% (offline) Note: flexible units can provide RM1 to RM8 in the cold state
Demand Response - Residential - LEDU - Industrial	55%	Availability case study: 55% (average availability based on data demand response – industrial) Note: availability might be higher in a peak demand scenario and for Data Centres and Residential demand, however, estimation is difficult, so 55% retained for the 3 types of Demand Response
ESPS - Reserve-Only (0.5h) - Energy & Reserve (2h) - Long Duration (6h)	57%	Availability (based on outage rate): 95% Availability case study: 60% (some batteries might be charging and other might not be fully charged) Note: same assumptions chosen for the 3 types of batteries
VRES	72%	Availability (based on outage rate): 98% Availability case study: 73% (10.5 GW maximum online / 14.3 GW installed)

Table 7: Availability factors for some technologies for the case study

Additional remarks:

- These capabilities reflect our assumptions, based as far as possible on our ESPS estimates, but may well be different in 2030.
- These availability factors are difficult to predict, especially for batteries and demand response, as these technologies can be used for both energy and system services. Additionally, these factors must consider that the batteries are unlikely to all be fully charged at the same time and that the Available Volume of

Demand Response will be related to the share of flexible demand being consumed at a given time.
- The availability factors proposed above are specific to this case study and are not representative of other system condition profiles.

4.3.2 Available Volume of each portfolio

Based on the Capability Volume estimated in Section 3.2 and the Availability factors estimated in Section 4.3.1, we estimate the Available Volume for the three portfolios which can be found in:
- Appendix 3.2: Available Volume for Portfolio 1 – Gas Turbines-Led;
- Appendix 3.3: Available Volume for Portfolio 2 – Mix;
- Appendix 3.4: Available Volume for Portfolio 3 – Demand-Led.

Figure 3 shows the Available Volume per portfolio and per service, and the Real-Time Requirements estimated for this specific case study. For each portfolio, a distinction can be made between the Capability Volume coming from established technologies (portion of the full-coloured bar) and those from developing / new technologies for which we have less certainty (part of the shaded bar). Refer to Section 3.1 for the distinction between the technologies.

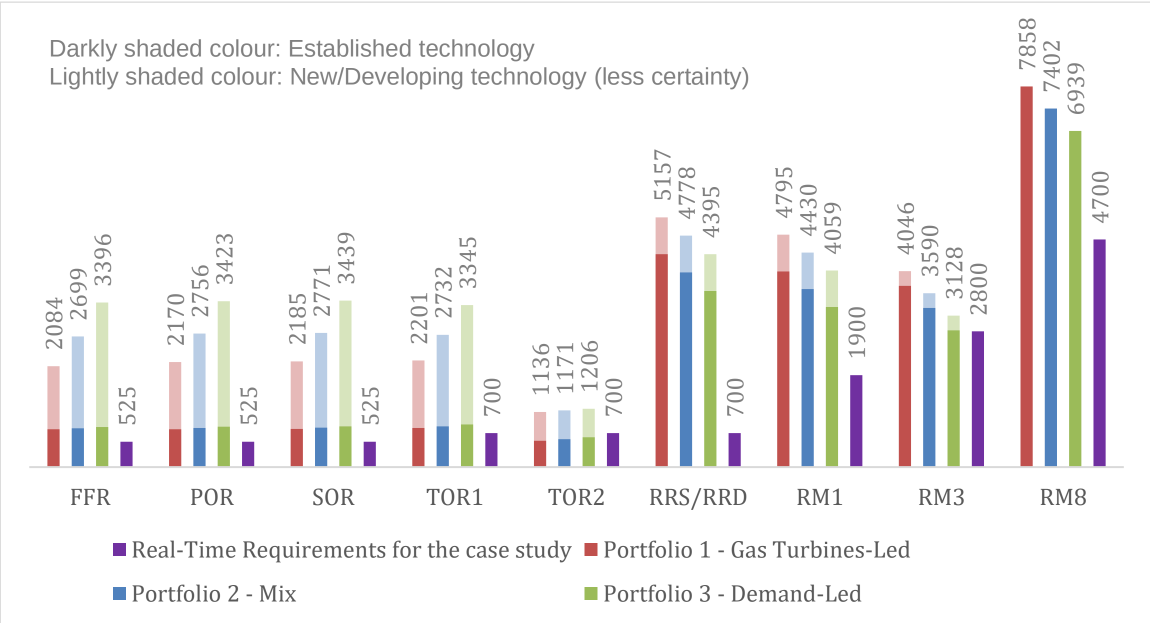

Figure 3: Available Volume vs Real-Time requirements per service (in MW)

4.4 Comparison of Available Volume and Real-Time Requirements

The table below shows the Available Volume per portfolio and per service, and the Real-Time Requirements estimated for this specific case study.

Available Volume for the case study	FFR	POR	SOR	TOR1	TOR2	RRS	RRD	SSRP	SIR	RM1	RM3	RM8
	MW	MW	MW	MW	MW	MW	MW	MVAR	MWs2	MW	MW	MW
Portfolio 1 - Gas Turbines-Led	2084	2170	2185	2201	1136	0	5157	17574	498750	4795	4046	7858
Portfolio 2 - Mix	2699	2756	2771	2732	1171	0	4778	17574	498750	4430	3590	7402
Portfolio 3 - Demand-Led	3396	3423	3439	3345	1206	0	4395	17574	498750	4059	3128	6939
Real-Time Requirements for the case study	525	525	525	700	700	700				1900	2800	4700

Table 8: Available Volume compared to Real-Time Requirements for the case study

Based on this single case analysis and the assumptions chosen (e.g. significant volumes of fast acting Reserves from Demand Response available, Gas Turbines flexible enough to provide Ramping services in the cold state, etc.), the Available Volume for each portfolio is sufficient to meet the Real-Time Requirements assumed.

However, a significant share of the Available Volume presented above comes from technologies classified as "Developing/New technology" (see Figure 3 shaded part) for which we are less certain that the capability will be provided at the level estimated.

Additionally, as we will have larger forecast errors for VRES in MW terms in the future, further analysis will have to be carried out and new ramping products may be required (see Section 5.1 for next steps).

Additional remarks:

- The Ramping Margin products 3 and 8 hours (RM3 and RM8) are mainly provided by the Gas Turbines offline in this case study.
- The Replacement Reserves (RR) is assumed to be provided by the Available Volume of RRS and/or RRD.

Caveats:

- Many assumptions have been made throughout this paper; different choices can significantly change the results of this analysis.
- The portfolios on which this analysis is based are also likely to be different based on market forces and the TSOs are committed to a technology neutral stance.
- These outcomes are only valid for the specific case study presented.

5 Next steps

5.1 Ramping challenges and analysis

Ramping products were developed a few years ago to accommodate a larger share of Variable Renewable Energy Sources (VRES) by 2020 while managing the risk of forecast errors. Based on past studies, the 1, 3- and 8-hours ramping products were considered the most appropriate products to mitigate this risk.

By 2030, almost three times as much VRES capacity is expected, demand is expected to increase by 30% and interconnection capacity will double leading to much greater ramping duties combined with greater forecast errors. For example, under certain system conditions as suggested in Section 4, up to 10.5 GW of VRES could be dispatched at certain times. With such significant changes, where the power system will often be operating at SNSP levels between 75% and 95%, the 1-, 3- and 8-hours products originally designed for lower levels of VRES may not be able to meet this challenge and longer duration ramping products may also be required.

Further analysis will be carried out to estimate the potential ramping duty and forecast errors in 2030, and to assess the types of products required to mitigate these increasing ramping duties combined with increasing uncertainties.

5.2 Requirements for different system conditions

The analysis carried out in this paper focused on an extreme case study (likely to reach a level of SNSP level up to 95%) that shows the Available Volume of System Services and the Real-Time Requirements needed to operate the power system in these system conditions.

In the Detailed Design phase of the Future Arrangements, further work will be done to define the short- and long-term requirements for different system condition profiles (e.g. high/average/low wind infeed, high/low demand, etc.)

Table 9 shows relevant volumes-related tasks included in our forthcoming Shaping Our Electricity Future roadmap.

Description	Start	End
Develop methodology and process for: (i) determining System Services auction volumes (day/week ahead, depending on HLD decision) (ii) forecasting longer-term system services requirements (e.g. year-ahead horizon)	Q2 2022	Q4 2023
Implement: (i) auction volume determination process ahead of first System Services auction (ii) longer-term system services requirements (e.g. year-ahead horizon)	Q4 2023	Q1 2024

Table 9: Volumes-related tasks included in the Shaping Our Electricity Future Roadmap

Appendix 1: All-Island Portfolios – Assumed Installed Capacity 2030 (MW or MWs)

	Portfolio 1 - Gas Turbines-Led Gas Turbines-Led All Island	Portfolio 2 - Mix Mix All Island	Portfolio 3 - Demand-Led Demand-Led All Island
Gas Turbine - Flexible (MW)	**3458.5**	**2964.5**	**2464.5**
Gas Turbine - Less Flexible (MW)	**4363**	**4363**	**4363**
Hydro (MW)	**216**	**216**	**216**
Steam Turbine - Small (MW)	**133**	**133**	**133**
Steam Turbine - Large (MW)	**0**	**0**	**0**
PHES (MW)	**292**	**292**	**292**
Gas Turbine - OCGT 1500h limit (MW)	**700**	**700**	**700**
DC interconnector (MW)	**2150**	**2150**	**2150**
Demand Response - Residential (MW)	**0**	**600**	**1200**
Demand Response - Industrial (MW)	**806**	**1006**	**1206**
Demand Response - Data Centres (MW)	**0**	**600**	**1350**
ESPS - Energy & Reserve (MW)	**1062.2**	**1062.2**	**1062.2**
ESPS - Reserve-Only (MW)	**392.6**	**392.6**	**392**
ESPS - Long Duration (MW)	**535**	**535**	**535**
VRES (Wind, Solar PV) (MW)	**14314**	**14314**	**14314**
Low Carbon Inertia Sources (MWs)	**17500**	**17500**	**17500**

Appendix 2.1: Technology Capability as percentage of the Installed Capacity (or factor)

Capability retained for the Portfolios

Type of technology	Capability as percentage of the Installed Capacity											
	FFR	POR	SOR	TOR1	TOR2	RRS	RRD	SSRP	SIR	RM1	RM3	RM8
Gas Turbine - Flexible	0.00	0.17	0.19	0.27	0.55	0.71	0.95	0.68	30.02	1.00	1.00	1.00
Hydro												
Steam Turbine - Small		0.05	0.06	0.06	0.10	0.59		0.44	9.87	0.65	0.81	0.81
Steam Turbine - Large												
PHES												
DC interconnector	0.21	0.21	0.21	0.21	0.21			0.37				
Demand Response - Residential	0.80	0.70	0.70	0.50								
Demand Response - Industrial	0.19	0.22	0.23	0.33	0.32		0.55			0.90	0.07	0.07
Demand Response - LEDU	1.00	1.00	1.00	1.00								
ESPS - Energy & Reserve	1.00	1.00	1.00	1.00	1.00		1.00	0.66		1.00		
ESPS - Reserve-Only	1.00	1.00	1.00	1.00				0.66				
ESPS - Long Duration	1.00	1.00	1.00	1.00	1.00		1.00	0.66		1.00	1.00	
VRES (Wind, Solar PV)	0.10	0.10	0.10	0.10				0.66				
Low Carbon Inertia Solutions								0.66	30.00			

Appendix 2.2: Capability Volume: Portfolio 1 – Gas Turbines-Led

Portfolio 1 - Gas Turbines-Led

Portfolio 2030 - Capability Volume	Capacity All Island	FFR MW	POR MW	SOR MW	TOR1 MW	TOR2 MW	RRS MW	RRD MW	SSRP MVAR	SIR MWs2	RM1 MW	RM3 MW	RM8 MW
Gas Turbine - Flexible (MW)	**3458.5**	9.7	573.4	656.6	922.7	1912.1	2428.9	3264.0	2345.8	99554.8	3440.2	3440.2	3440.2
Gas Turbine – Less Flexible (MW)	**4363**	77.7	345.3	481.6	592.8	708.4	2341.0	832.0	3134.5	439224.9	3316.5	4099.0	4381.0
Hydro (MW)	**216**	0.0	5.0	25.0	57.0	148.0	209.0	209.0	182.0	1375.2	213.8	216.0	216.0
Steam Turbine - Small (MW)	**133**	0.0	5.9	8.0	7.5	17.5	62.0	0.0	59.6	177.6	84.6	87.5	87.5
Steam Turbine - Large	**0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHES	**292**	287.8	80.0	272.0	292.0	292.0	292.0	292.0	332.0	36750.0	584.0	584.0	584.0
DC interconnector	**2150**	452.6	452.6	452.6	452.6	452.6	0.0	0.0	794.0	0.0	0.0	0.0	0.0
Demand Response - Residential	**0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Demand Response - Industrial	**806**	244.6	247.7	254.7	288.9	208.4	0.0	362.0	0.0	0.0	591.6	47.0	44.8
Demand Response - LEDU	**0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BES - Energy & Reserve	**1062.2**	1048.2	1058.1	1058.1	1058.1	1038.1	0.0	799.7	696.7	0.0	792.2	0.0	0.0
BES - Reserve-Only	**392.6**	382.6	382.6	382.6	382.6	0.0	0.0	0.0	252.5	0.0	0.0	0.0	0.0
BES - Long Duration	**535**	535.0	535.0	535.0	535.0	535.0	0.0	535.0	353.1	0.0	535.0	535.0	0.0
VRES (Wind, Solar)	**14314**	983.7	1094.5	1109.2	1106.1	0.0	0.0	0.0	7136.0	0.0	0.0	0.0	0.0
Low Carbon Inertia Solutions	**17500**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11550.0	525000.0	0.0	0.0	0.0
Total		**4022.0**	**4780.0**	**5235.4**	**5695.5**	**5312.2**	**5332.9**	**6293.8**	**26836.3**	**1102083**	**9557.9**	**9008.7**	**8753.5**

Appendix 2.3: Capability Volume: Portfolio 2 – Mix

Portfolio 2 - Mix

Portfolio 2030 - Capability Volume	Capacity	FFR	POR	SOR	TOR1	TOR2	RRS	RRD	SSRP	SIR	RM1	RM3	RM8
	All Island	MW	MW	MW	MW	MW	MW	MW	MVAR	MWs2	MW	MW	MW
Gas Turbine - Flexible (MW)	**2965**	9.7	490.8	562.0	791.1	1640.3	2078.9	2797.1	2008.0	84727.3	2946.2	2946.2	2946.2
Gas Turbine - Less Flexible (MW)	**4363**	77.7	345.3	481.6	592.8	708.4	2341.0	832.0	3134.5	439224.9	3316.5	4099.0	4381.0
Hydro (MW)	**216**	0.0	5.0	25.0	57.0	148.0	209.0	209.0	182.0	1375.2	213.8	216.0	216.0
Steam Turbine - Small (MW)	**133**	0.0	5.9	8.0	7.5	17.5	62.0	0.0	59.6	177.6	84.6	87.5	87.5
Steam Turbine - Large (MW)	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHES (MW)	**292**	287.8	80.0	272.0	292.0	292.0	292.0	292.0	332.0	36750.0	584.0	584.0	584.0
DC interconnector (MW)	**2150**	452.6	452.6	452.6	452.6	452.6	0.0	0.0	794.0	0.0	0.0	0.0	0.0
Demand Response - Residential (MW)	**600**	480.0	420.0	420.0	300.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Demand Response - Industrial (MW)	**1006**	283.0	291.5	300.6	354.3	271.7	0.0	472.0	0.0	0.0	771.4	61.3	58.4
Demand Response - LEDU (MW)	**600**	600.0	600.0	600.0	600.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESPS - Energy & Reserve (MW)	**1062**	1048.2	1058.1	1058.1	1058.1	1038.1	0.0	799.7	696.7	0.0	792.2	0.0	0.0
ESPS - Reserve-Only (MW)	**393**	382.6	382.6	382.6	382.6	0.0	0.0	0.0	252.5	0.0	0.0	0.0	0.0
ESPS - Long Duration (MW)	**535**	535.0	535.0	535.0	535.0	535.0	0.0	535.0	353.1	0.0	535.0	535.0	0.0
VRES (Wind, Solar PV) (MW)	**14314**	983.7	1094.5	1109.2	1106.1	0.0	0.0	0.0	7136.0	0.0	0.0	0.0	0.0
Low Carbon Inertia Solutions (MWs)	**17500**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11550.0	525000.0	0.0	0.0	0.0
Total	-	**5140.3**	**5761.2**	**6206.7**	**6529.2**	**5103.7**	**4982.9**	**5936.9**	**26498.5**	**1087255**	**9243.7**	**8529.0**	**8273.1**

Appendix 2.4: Capability Volume: Portfolio 3 – Demand-Led

Portfolio 3 - Demand-Led

Portfolio 2030 - Capability Volume	Capacity All Island	FFR MW	POR MW	SOR MW	TOR1 MW	TOR2 MW	RRS MW	RRD MW	SSRP MVAR	SIR MWs2	RM1 MW	RM3 MW	RM8 MW
Gas Turbine - Flexible (MW)	**2464.5**	9.7	407.1	466.2	657.8	1365.3	1724.7	2324.5	1666.0	69719.8	2446.2	2446.2	2446.2
Gas Turbine - Less Flexible (MW)	**4363**	77.7	345.3	481.6	592.8	708.4	2341.0	832.0	3134.5	439224.9	3316.5	4099.0	4381.0
Hydro (MW)	**216**	0.0	5.0	25.0	57.0	148.0	209.0	209.0	182.0	1375.2	213.8	216.0	216.0
Steam Turbine - Small (MW)	**133**	0.0	5.9	8.0	7.5	17.5	62.0	0.0	59.6	177.6	84.6	87.5	87.5
Steam Turbine - Large (MW)	**0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHES (MW)	**292**	287.8	80.0	272.0	292.0	292.0	292.0	292.0	332.0	36750.0	584.0	584.0	584.0
DC interconnector (MW)	**2150**	452.6	452.6	452.6	452.6	452.6	0.0	0.0	794.0	0.0	0.0	0.0	0.0
Demand Response - Residential (MW)	**1200**	960.0	840.0	840.0	600.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Demand Response - Industrial (MW)	**1206**	321.3	335.3	346.5	419.6	335.0	0.0	582.1	0.0	0.0	951.2	75.6	72.0
Demand Response - LEDU (MW)	**1350**	1350.0	1350.0	1350.0	1350.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESPS - Energy & Reserve (MW)	**1062.2**	1048.2	1058.1	1058.1	1058.1	1038.1	0.0	799.7	696.7	0.0	792.2	0.0	0.0
ESPS - Reserve-Only (MW)	**392**	382.0	382.0	382.0	382.0	0.0	0.0	0.0	252.1	0.0	0.0	0.0	0.0
ESPS - Long Duration (MW)	**535**	535.0	535.0	535.0	535.0	535.0	0.0	535.0	353.1	0.0	535.0	535.0	0.0
VRES (Wind, Solar PV) (MW)	**14314**	983.7	1094.5	1109.2	1106.1	0.0	0.0	0.0	7136.0	0.0	0.0	0.0	0.0
Low Carbon Inertia Solutions (MWs)	**17500**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11550.0	525000.0	0.0	0.0	0.0
Total		**6408.1**	**6890.8**	**7326.3**	**7510.6**	**4892.0**	**4628.7**	**5574.3**	**26156.1**	**1072247**	**8923.5**	**8043.3**	**7786.7**

Appendix 3.1: Availability factors for the case study

Availability factors for the case study

Type of technology	Availability factors for the case study (VRES 10.5 GW, 0 sets synchronised, high export)											
	FFR	POR	SOR	TOR1	TOR2	RRS	RRD	SSRP	SIR	RM1	RM3	RM8
Gas Turbine - Flexible	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.94	0.94	0.94
Gas Turbine - Less Flexible	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.94
Hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.96	0.96	0.96
Steam Turbine - Small		0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
Steam Turbine - Large												
PHES	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.47	0.47	0.47
DC interconnector	0.95	0.95	0.95	0.95	0.95			0.95				
Demand Response - Residential	0.55	0.55	0.55	0.55	0.55							
Demand Response - Industrial	0.55	0.55	0.55	0.55	0.55		0.55			0.55	0.55	0.55
Demand Response - LEDU	0.55	0.55	0.55	0.55	0.55							
ESPS - Energy & Reserve	0.57	0.57	0.57	0.57	0.57		0.57	0.57		0.57		
ESPS - Reserve-Only	0.57	0.57	0.57	0.57				0.57				
ESPS - Long Duration							0.57	0.57		0.57	0.57	
VRES (Wind, Solar PV)	0.72	0.72	0.72	0.72				0.72				
Low Carbon Inertia Solutions								0.95	0.95			

Appendix 3.2: Availability Volume for the case study: Portfolio 1 – Gas Turbines-Led

Portfolio 1 - Gas Turbines-Led

Portfolio 2030 - Available Volume	FFR MW	POR MW	SOR MW	TOR1 MW	TOR2 MW	RRS MW	RRD MW	SSRP MVAR	SIR MWs2	RM1 MW	RM3 MW	RM8 MW
Gas Turbine - Flexible	0.0	0.0	0.0	0.0	0.0	0.0	3068.2	0.0	0.0	3233.8	3233.8	3233.8
Gas Turbine - Less Flexible	0.0	0.0	0.0	0.0	0.0	0.0	782.1	0.0	0.0	0.0	0.0	4118.1
Hydro	0.0	0.0	0.0	0.0	0.0	0.0	200.6	0.0	0.0	205.2	207.4	207.4
Steam Turbine - Small	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Steam Turbine - Large	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHES	0.0	0.0	0.0	0.0	0.0	0.0	146.0	0.0	0.0	274.5	274.5	274.5
DC interconnector	430.0	430.0	430.0	430.0	430.0	0.0	0.0	754.3	0.0	0.0	0.0	0.0
Demand Response - Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Demand Response - Industrial	134.5	136.2	140.1	158.9	114.6	0.0	199.1	0.0	0.0	325.4	25.9	24.6
Demand Response - LEDU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESPS - Energy & Reserve	597.5	603.1	603.1	603.1	591.7	0.0	455.9	397.1	0.0	451.6	0.0	0.0
ESPS - Reserve-Only	218.1	218.1	218.1	218.1	0.0	0.0	0.0	143.9	0.0	0.0	0.0	0.0
ESPS - Long Duration	0.0	0.0	0.0	0.0	0.0	0.0	305.0	201.3	0.0	305.0	305.0	0.0
VRES (Wind, Solar PV)	703.8	783.0	793.5	791.3	0.0	0.0	0.0	5105.1	0.0	0.0	0.0	0.0
Low Carbon Inertia Solutions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10972.5	498750.0	0.0	0.0	0.0
Total	**2083.8**	**2170.4**	**2184.8**	**2201.5**	**1136.3**	**0.0**	**5156.8**	**17574.2**	**498750**	**4795.4**	**4046.4**	**7858.4**

Appendix 3.3: Availability Volume for the case study: Portfolio 2 – Mix

Portfolio 2 - Mix	Portfolio 2030 - Available Volume	FFR	POR	SOR	TOR1	TOR2	RRS	RRD	SSRP	SIR	RM1	RM3	RM8
		MW	MW	MW	MW	MW	MW	MW	MVAR	MWs2	MW	MW	MW
	Gas Turbine - Flexible	0.0	0.0	0.0	0.0	0.0	0.0	2629.3	0.0	0.0	2769.4	2769.4	2769.4
	Gas Turbine - Less Flexible	0.0	0.0	0.0	0.0	0.0	0.0	782.1	0.0	0.0	0.0	0.0	4118.1
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	200.6	0.0	0.0	205.2	207.4	207.4
	Steam Turbine - Small	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Steam Turbine - Large	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PHES	0.0	0.0	0.0	0.0	0.0	0.0	146.0	0.0	0.0	274.5	274.5	274.5
	DC interconnector	430.0	430.0	430.0	430.0	430.0	0.0	0.0	754.3	0.0	0.0	0.0	0.0
	Demand Response - Residential	264.0	231.0	231.0	165.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Demand Response - Industrial	155.6	160.3	165.3	194.9	149.4	0.0	259.6	0.0	0.0	424.3	33.7	32.1
	Demand Response - LEDU	330.0	330.0	330.0	330.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	ESPS - Energy & Reserve	597.5	603.1	603.1	603.1	591.7	0.0	455.9	397.1	0.0	451.6	0.0	0.0
	ESPS - Reserve-Only	218.1	218.1	218.1	218.1	0.0	0.0	0.0	143.9	0.0	0.0	0.0	0.0
	ESPS - Long Duration	0.0	0.0	0.0	0.0	0.0	0.0	305.0	201.3	0.0	305.0	305.0	0.0
	VRES (Wind, Solar PV)	703.8	783.0	793.5	791.3	0.0	0.0	0.0	5105.1	0.0	0.0	0.0	0.0
	Low Carbon Inertia Solutions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10972.5	498750.0	0.0	0.0	0.0
	Total	**2698.9**	**2755.5**	**2771.0**	**2732.4**	**1171.2**	**0.0**	**4778.4**	**17574.2**	**498750**	**4429.9**	**3590.0**	**7401.5**

Appendix 3.4: Availability Volume for the case study: Portfolio 3 – Demand-Led

	Portfolio 2030 - Available Volume	FFR MW	POR MW	SOR MW	TOR1 MW	TOR2 MW	RRS MW	RRD MW	SSRP MVAR	SIR MWs2	RM1 MW	RM3 MW	RM8 MW
Portfolio 3 - Demand-Led	Gas Turbine - OCGT	0.0	0.0	0.0	0.0	0.0	0.0	2185.0	0.0	0.0	2299.4	2299.4	2299.4
	Gas Turbine - CCGT	0.0	0.0	0.0	0.0	0.0	0.0	782.1	0.0	0.0	0.0	0.0	4118.1
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	200.6	0.0	0.0	205.2	207.4	207.4
	Steam Turbine - Small	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Steam Turbine - Large	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PHES	0.0	0.0	0.0	0.0	0.0	0.0	146.0	0.0	0.0	274.5	274.5	274.5
	DC interconnector to external market	430.0	430.0	430.0	430.0	430.0	0.0	0.0	754.3	0.0	0.0	0.0	0.0
	Demand Response - Residential	528.0	462.0	462.0	330.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Demand Response - Industrial	176.7	184.4	190.6	230.8	184.3	0.0	320.1	0.0	0.0	523.2	41.6	39.6
	Demand Response - LEDU	742.5	742.5	742.5	742.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	BES - Energy & Reserve	597.5	603.1	603.1	603.1	591.7	0.0	455.9	397.1	0.0	451.6	0.0	0.0
	BES - Reserve-Only	217.7	217.7	217.7	217.7	0.0	0.0	0.0	143.7	0.0	0.0	0.0	0.0
	BES - Long Duration	0.0	0.0	0.0	0.0	0.0	0.0	305.0	201.3	0.0	305.0	305.0	0.0
	VRES (Wind, Solar)	703.8	783.0	793.5	791.3	0.0	0.0	0.0	5105.1	0.0	0.0	0.0	0.0
	Low Carbon Inertia Solutions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10972.5	498750.0	0.0	0.0	0.0
	Total	**3396.2**	**3422.8**	**3439.5**	**3345.5**	**1206.0**	**0.0**	**4394.7**	**17574.0**	**498750**	**4058.8**	**3127.8**	**6939.0**