Generator Output Reductions

Calculation methodology, assumptions applied and Northern Ireland results for 2014 and 2020

9 September 2013

System Operator for Northern Ireland

DISCLAIMER

SONI, the Transmission System Operator (TSO) for Northern Ireland, makes no warranties or representations of any kind with respect of this document, including, without limitation, its quality, accuracy and completeness. The TSO does not accept liability for any loss or damage arising from the use of this document or any reliance on the information it contains. Use of this document and the information it contains is at the user's sole risk.

CONTENTS

1. SUMMARY

On 25th October 2011 the System Operator for Northern Ireland (SONI) launched a consultation entitled, "Generator Connection Process; ITC Methodology to determine FAQs and Generator Output Reductions Analysis." This paper consulted on the following two areas:

1. SONI's proposal to implement a policy of firm and non-firm transmission access rights for generator connections in Northern Ireland (NI) including a proposed Incremental Transfer Capability (ITC) methodology to calculate Firm Access Quantities (FAQ)
2. SONI's proposal to provide an estimate of the potential incidences of Generator Output Reduction (GOR) at each transmission node in NI including indicative constraint and curtailment figures for sample study years

Issues raised by respondents in relation to FAQ allocation and the ITC methodology were addressed in a subsequent paper published on 20th December 2012 entitled, "Generator Connection Process; Allocation of Transmission FAQ in NI and ITC Methodology to determine FAQs." A decision paper was subsequently published 22 July 2013.

While the October 2011 paper covered both FAQ and GOR processes SONI decided that for the December 2012 paper it was not "...*appropriate at this stage to conclude the discussions regarding generator output reductions as there is still a significant amount of ongoing consideration by both Industry and Regulators.*"

This paper is intended to conclude the process by addressing all the outstanding issues with regard to Generator Output Reductions and advising all parties of SONIs next steps in fully implementing revised processes. More specifically the following topics will be covered:

- Issues raised by respondents specifically on the GOR analysis presented in the October 2011 consultation
- SONIs response to these issues raised and how they will be accommodated going forward
- Consideration of recent Single Electricity Market Committee (SEMC) decisions
- Application of All Island modelling techniques and methodology for estimation of GOR forecasts in N Ireland
- N Ireland system and network assumptions to be applied
- Indicative N Ireland GOR results for 2014 and 2020 based on an all-island methodology

Over the coming months SONI propose to establish new and revise existing working practices with NIE so that FAQ allocation along with GOR Reports will be incorporated into each new or revised connection offer issued by either SONI (transmission) or NIE (distribution). SONI and NIE will amend the Transmission Interface Agreement (TIA) to reflect the new working arrangements and these agreed amendments to the TIA will be submitted to UREGNI for approval.

The information in this paper clearly identifies estimated GOR for 2014 and 2020. SONI propose to issue additional information for the intervening years by Q1 2014.

2. INTRODUCTION

This paper provides an overview of how SONI will provide the analysis of GOR in NI following the initial Consultation in 2011. It provides SONI's responses to points raised on the GOR methodology and results presented in the initial Consultation paper. Details of the issues raised, subsequent responses and actions can be found in Section 3.

Since the 2011 Consultation Paper, important SEMC decisions in relation to the treatment of GOR have been published. Those affecting GOR have been summarised in Section 3.

Following the feedback from the initial NI GOR results, SONI present a methodology for GOR analysis in NI which is closely harmonised with EirGrid Gate 3 Constraint Reports. SONI's initial NI GOR forecast is presented in Section 5 with indicative results for GOR in 2014 and 2020 in NI shown in Section 6.

Details on modelling assumptions can be found in the Appendix A.

3. RESPONSES TO OCTOBER 2011CONSULTATION

The October 2011 consultation provided interested parties the opportunity to express their views on whether, "...the proposed assumptions on which the Generator Output Reductions (GOR) analysis shall be based are considered to be correct."

SONI welcomes the responses received from the following parties who commented specifically on the GOR proposals:

- ABO Wind
- Bord Gáis Energy
- DW Consultancy
- Energia
- ESB Wind Development
- Mainstream Renewable Power
- NIE
- Northern Ireland Renewables Industry Group (NIRIG)
- Renewable Energy Systems Limited
- SSE
- TCI Renewables

Overall respondents were encouraged that SONI were attempting to present future levels of constraint and curtailment and that it had been recognised that the level of GOR has an effect on project financing. There was general concern among most respondents that the levels of curtailment and constraints presented in the analysis were very high, commenting that this would likely deter investment in renewable generation by increased difficulty in financing projects. Consequently there was concern that All Island 2020 targets would not be achieved. The response submitted by NIRIG is supported by most of the respondents listed above.

The comments received were in relation to the following topics:

- Study years presented
- All Island modelling approach
- Interconnector assumptions
- GOR linked to North-South tie-line
- SEMC decisions
- 200MW "dead band" from Excel model
- System Non-Synchronous Penetration (SNSP)
- Generation Build-Out Rate
- Operational rules
- Second iteration of GOR analysis

Further details on these issues and subsequent SONI responses are presented below.

3.1. STUDY YEARS

The October 2011 consultation included GOR analysis and indicative results for 2012 and 2016. A number of respondents commented that these study years did not provide industry participants with an outlook of levels of constraint and curtailment beyond the construction of the second North-South tie-line. One respondent suggested that a 10 year forecast for constraint and curtailment levels should be presented on an annual basis with others indicating that results of these interim years would be useful in understanding changes in GOR levels.

SONI Response:

SONI agree that initial GOR results presented did not provide an outlook on constraint and curtailment levels following the construction of the second North-South tie-line and agree that this would be useful. The reason SONI originally presented results for 2016 was to show interested parties the effect on GOR levels with Northern Ireland Electricity's (NIE) Medium Term Plan (MTP) investments implemented.

In Section 5 of this decision paper, SONI present their position on GOR forecasting for NI. Also presented in this paper are indicative results for constraint and curtailment for 2014 and 2020 (see Section 6).

3.2. ALL ISLAND MODELLING APPROACH

Although respondents recognised that SONI's Excel model provided indicative GOR results, many commented on the need to use a more sophisticated modelling package, such as Ventyx PROMOD IV. In addition, the Excel model employed in obtaining GOR results took account of the NI transmission system only. Most respondents commented that an All Island approach would provide more accurate GOR results and would also help to align GOR analysis in both SONI and EirGrid. Many respondents also commented that SONI and EirGrid modelling assumptions and methodology should be harmonised for consistency.

SONI Response:

SONI have now purchased Ventyx PROMOD IV transmission system economic modelling package and have engaged with EirGrid in developing All Island assumptions and models to be employed in constraint and curtailment analysis in both jurisdictions as shown in see Appendix A.

3.3. INTERCONNECTION ASSUMPTIONS

In the GOR analysis presented in the October 2011 consultation, the Moyle interconnector was modelled by using historic import/export data. Some respondents commented that these historical flows were likely to contribute to the increased levels of curtailment presented. Many respondents commented that basing Moyle assumptions on historical interconnector flows may not be realistic in light of the recent changes in policy regarding System Operator (SO) counter trading to facilitate Priority Dispatch.

SONI Response:

SONI recognises that the recent SEM-11-062 publication, "Principles of Dispatch and the Design of the Market Schedule in the Trading and Settlement Code," provides a hierarchy for priority dispatch, stating that the SO should aim to avoid curtailment by reducing the output of conventional generation along with SO-SO counter trading on the interconnectors as a priority. This has been addressed in the All Island PROMOD IV model, where during times of curtailment, the Moyle interconnector and the East West Interconnector (EWIC) are set up to export excess energy to Great Britain (GB). This is consistent with EirGrid modelling assumptions for Gate 3 Constraint Reports (see Appendix A.4). It is worth noting that for this decision paper the two interconnectors are not modelled to import energy from GB in the All Island PROMOD IV models.

Since the initial consultation, it is important to note that assumptions on the available capacity of the Moyle interconnector have changed in line with the recent cable fault on one pole of the interconnector. This is detailed in Section A.4.2.

3.4. GOR LINKED TO NORTH-SOUTH TIE LINE

Some respondents commented that GOR as a result of insufficient capacity on the North-South tie-line should be classed as a constraint event rather than a curtailment event. The reason for this is that the GOR could be alleviated by further network reinforcement.

SONI Response:

SONI agree with the response and this has been addressed in the All Island PROMOD IV model where GOR as a result of an overload on the North-South tie-line is treated and categorised as a constraint. This is in line with the SEM-11-086 Clarification Note on the "Treatment of Price Taking Generation in Tie-Breaks in Dispatch in the Single Electricity Market and Associated Issues."

3.5. SEMC DECISIONS

Some respondents requested that any further All Island modelling should include any SEMC decisions relating to GOR in tie-break situations.

SONI Response:

Following recent SEMC decisions, the SOs are now in a position to implement these new rules (see Section 4) and are modelled, where possible, in the All Island PROMOD IV model. These are detailed in Appendix A.7.

3.6. 200MW "DEAD BAND"

Some respondents commented that the 200MW "dead band" used in the initial GOR analysis to allow for operational decisions during periods of GOR was subjective and that it should be removed in any further GOR studies.

SONI Response:

SONI agree that the "dead band" figure of 200MW is subjective, but that it was included in the Excel model as an attempt to model SO real time decisions to reduce curtailment on the island by entering into SO-SO trading on the interconnector. This "dead band" is not modelled in the All Island PROMOD IV model. SO-SO trading on the interconnectors (export to GB only) is modelled as explained previously in Section 3.3. It should be noted that the interconnector capacities are derated to account for trading imperfections and losses. Further details on this can be found in Appendix A.4.4.

3.7. SYSTEM NON-SYNCHRONOUS PENETRATION

Some respondents commented that All Island SNSP could not be accurately represented in the Excel model when only the NI transmission system was modelled.

SONI Response:

SONI accept the comment that SNSP is applied on an All Island basis. Applying the SNSP rule to the NI system only, as was done in the Excel model, could result in artificially high curtailment levels in NI. The All Island PROMOD IV model applies the SNSP rule on an All Island basis, so it will provide a better representation of curtailment levels on the Island (see Section A.5.1).

3.8. GENERATION BUILD-OUT RATE

It was noted in the responses received that the GOR analysis included only one scenario for the generation build-out rate for NI. The analysis only accounted for a 100% generation connection rate, hence representing the "worst case" scenario for GOR.

SONI Response:

SONI recognise that only one generation build-out rate was modelled in the original GOR analysis, however, the generation connection assumptions were SONI's best estimates made using the latest connection information available from NIE at the time. SONI are still proposing to use this 'best estimate' approach (in conjunction with NIE) when creating the build out rate for new on shore generation in NI. However, SONI have created two build out scenarios for new offshore generation in this study (see Appendix A.1.1 and A.1.2).

3.9. OPERATIONAL RULES

It was commented that SONI were employing "optimistic views" on the operational rules employed in the Excel model for GOR analysis, whereas SONI's views on generation build-out rate seemed pessimistic.

SONI Response:

This comment provided little detail on which operational rules the respondent was referring to and as a result SONI cannot comment on this. Nevertheless, SONI present the joint operational assumptions employed in the All Island PROMOD IV constraints model in Appendix A.5.

3.10. SECOND ITERATION OF GOR ANALYSIS

All respondents expressed an interest in using the existing Excel model to carry out a second iteration of the GOR analysis to provide indicative constraint and curtailment results for 2012 and 2016 in Q1 2012. It was requested that the following modelling assumptions were employed:

- Full export on Moyle interconnector
- Remove 200MW "dead band"
- Allocate GOR to controllable generation only

SONI Response:

Taking other comments into account SONI have not carried out any further analysis using the Excel model with the above suggested assumptions. Instead SONI have used the Ventyx PROMOD IV modelling package using all-island modelling techniques and assumptions. SONI now present indicative GOR results for NI for 2014 and 2020.

4. RECENT SEMC PUBLICATIONS

Since the initial consultation paper, the SEMC have consulted on and published key decisions relating to GOR both in dispatch and in the SEM. Specific SEMC papers include:

- SEM-11-105: "Principles of Dispatch and the Design of the Market Schedule in the Trading and Settlement Code" [1]
- SEM-13-012: "Constraint Groups arising from SEM-11-105"[2]
- SEM-13-010: "Treatment of Curtailment in Tie-Break Situations"[3]

A summary of the decisions affecting modelling and analysis of GOR in the SEM are presented below:

Constraints: Generation which best alleviates a specific constraint is reduced as a priority.

Constraints in a Tie-Break Situation: Outside of constraint groups, generation is reduced on a pro-rata basis. Within a constraint group, generation is reduced on a grand-fathered basis in the following order – non-firm, partially firm and firm generation.

Constraint Groups: Two constraint groups have been identified on an All Island basis, the first in Donegal and the second in the South-West of Ireland. The constraint group in Donegal exists today, with the constraint group in the South West of Ireland coming into effect when the new 220kV stations are built in the region. No constraint group has been identified in NI.

Curtailment: Pro-rata allocation of energy to be curtailed.

Details of how these rules have been translated to the All Island PROMOD IV model can be found in Appendix A.7.

5. GENERATOR OUTPUT REDUCTION FORECAST

SONI recognise that industry participants are very keen to have information on constraint and curtailment levels in NI. This report presents indicative information on potential levels of constraint and curtailment in NI for years 2014 and 2020. SONI plan to produce a supplementary report providing information on the potential levels of constraint and curtailment in NI for interim years between 2014 and 2020. Further NI GOR studies will be performed when there are significant changes to the modelling assumptions employed in this report that may change GOR results.

---

[1] SEM-11-105: Treatment of Price Taking Generation in Tie Breaks in Dispatch in the Single Electricity Market and Associated Issues

[2] SEM-13-012: Constraint Groups arising from SEM-11-105 and SEM-12-076: Proposed Constraint Groups arising from SEM-11-105

[3] SEM-13-010: Treatment of Curtailment in Tie-Break Situations

6. GENERATOR OUTPUT REDUCTION RESULTS

SONI have carried out an initial GOR study using All Island PROMOD IV models for the years 2014 and 2020 to provide indicative GOR results for before and after the construction of the second North-South tie-line. In addition to the second North-South tie-line, the models also contain other NI network reinforcements that SONI are aware of at this stage. These are listed in Appendix C. The modelling and analysis employs, as far as is possible, a common set of All Island assumptions which have also been used in EirGrid's Gate 3 Constraints Reports. The modelling assumptions are presented in Appendix A.

NI GOR scenarios and results for 2014 and 2020 are presented on the following basis. The level of GOR that controllable wind generation in NI might expect to experience in the two study years is reported on a NI system and nodal basis. NI is not modelled as a Constraint Group therefore in a tie-break situation controllable wind is reduced on a pro-rata basis for transmission constraints.

6.1. SCENARIOS

For onshore wind generation in NI, only one generation build out rate is assumed in this study. It is based on a "best estimate" approach where SONI use the latest generator connection information from NIE to determine the likely generation to connect during each study year. SONI also take into consideration renewable energy targets for 2020, hence the onshore wind installed by 2020 should allow these renewable energy targets to be met. A complete list of NI wind generation connection assumptions on a nodal basis for each study year is provided in Appendix B.

For offshore wind and tidal generation in NI, two build out rates are assumed in this study. Scenario A assumes that the capacity of offshore wind and tidal generation connected will allow 2020 renewable targets to be met (40% renewable generation by 2020). Scenario B assumes that 100% of the expected capacity of offshore wind and tidal generation will connect by 2020 and therefore exceed renewable energy targets (approx. 45% renewable generation by 2020). Details can be found in Appendix A.1.2 and Appendix B.

For IE, only one wind generation build out rate has been employed. The installed wind capacity for Ireland is based on build out Scenario 2 employed in the Gate 3 Constraints Reports[4] which assumes 33% uptake of Gate 3 applicants in 2014 and 2020 which is sufficient to meet the 40% renewable targets by 2020.

6.2. RISKS

It should be highlighted that the GOR analysis presented is for two discrete years only. This study is based on a set of assumptions accurate at the beginning of the modelling process. Any changes in assumptions such as network reinforcement, generator capacity, connection dates and connection nodes, fuel prices, operational rules etc. could mean the actual levels of constraint and curtailment differ from those reported. It should also be noted that constraint and curtailment figures are presented for 2014 and 2020 only. Constraint and curtailment figures for interim years may be higher than those reported for 2014 and 2020.

It is important to draw attention to the fact that Moyle and EWIC are set up to export to GB only. Imports from GB are not modelled. Currently the interconnectors generally import energy from GB therefore the interconnector flows reported by the model are likely to differ from actual interconnector flows. Hence the GOR levels presented in this report could be viewed as a 'best case' scenario and dependent on the SOs ability to trade on the interconnectors.

[4] Additional information on Scenario 2 can be found in EirGrid's Gate 3 Constraint Reports

6.3. INSTALLED WIND CAPACITY

The installed wind capacity for Northern Ireland is divided into the wind connected prior to study year and the wind assumed to connect during the study year. Figures include both onshore and offshore wind. The capacities of controllable and uncontrollable wind are also indicated.

Installed Wind Capacity			
Year/Scenario	2014	2020 Scenario A	2020 Scenario B
Northern Ireland Wind Capacity			
Additional Wind (MW)	142	538	938
Existing Wind (MW)	541	683	683
Total Wind (MW)	683	1222	1622
Of which is Controllable (MW)	598	1121	1521
Ireland Wind Capacity			
Total Wind (MW)	2222	3884	3884
All Island Wind Capacity			
Total Wind (NI + IE) (MW)	2905	5106	5506

Table 1: *Installed Wind Capacity Assumptions*

6.4. INTERPRETING RESULTS

The All Island PROMOD IV models for 2014 and 2020 are run, producing annual hourly conventional and renewable generation dispatches and interconnector flows from the All Island system to GB. The results were further analysed and processed to ensure wind generation reductions were applied as per SEMC rules. Total wind reduction is calculated by comparing the wind availability to the wind dispatch on a system level. For the hours where a wind reduction was required, the reduction is categorised as a constraint or a curtailment, depending on the reason for the reduction. The model will only apply wind reduction to generation that is deemed to be controllable.[5]

The model aims to reduce wind generation that has the greatest effect in alleviating a transmission constraint as a priority. In NI, where a tie-break situation arises in relation to a transmission constraint, wind reduction is applied on a pro-rata basis as per SEMC rules. There are no constraint groups in NI. In the event of a curtailment where all wind generation has an equal effect in alleviating the issue, the model will reduce wind generation on a pro-rata basis. Curtailment is shared between NI and IE on the ratio of available controllable wind during the hour where the curtailment issue exists.

The wind constraint and curtailment results on a NI system level and on a nodal basis are presented. For each node, a table of results shows the total capacity of wind connected at that node. This is broken down into the capacity of additional wind connecting during each study year/scenario as well as the capacity of controllable wind generation at that node. The annual wind energy available at that node is also provided for the study year/scenario and includes both controllable and uncontrollable generation. The amount of curtailed and constrained controllable energy is presented in terms of GWh and as a percentage of controllable energy available at that node. The wind energy reduction for both constraints and curtailment is also given. The results graph displays the tabulated results for each year/scenario.

Wind reduction as a result of curtailment is presented as a range, with a lower value and a higher value. The lower value represents the curtailment figure for controllable wind generation determined by the model. The higher value is derived by adding onto this curtailment value from the model the

[5] All wind generators with a capacity greater than 5MW were deemed to be controllable except those wind farms known to have grid code derogations, including those connected before 1st April 2005.

energy exported on the interconnectors that would have otherwise been curtailed. Therefore the range of curtailment results represents the amount of curtailment that was avoided due to exporting wind energy of the interconnectors. It is important to highlight this higher value as the model assumes that there is always capacity on the interconnectors to export to GB. Consequently the result for combined constraints and curtailment at the node is also presented as a range.

6.5. SYSTEM WIND GENERATION RESULTS

The overall system constraint and curtailment results for Northern Ireland for study years 2014 and 2020 are shown below. Results for Ireland are not provided. The results presented are expressed as a percentage of controllable available energy.

Overall NI System Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Results			
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 2: *Overall NI System Results*

The model assumes that wind that would otherwise be curtailed is exported whilst obeying interconnector capacity limits. The following table details the amount of energy that is modelled as being exported on the interconnectors. This information is intended to give readers an insight into how the modelling of the interconnectors influence the results of the study. A description of the interconnector modelling assumptions is provided in Appendix A.4. Note that the interconnector export capacities are derated by 20% in the model to account for lack of perfect foresight etc.

Overall Interconnector Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Interconnector Export Capacity			
Moyle (MW)	200	64	64
EWIC (MW)	424	424	424
Exports			
Moyle (GWh)	28	73	101
EWIC (GWh)	12	369	518
Total (GWh)	40	442	619

Table 3: *Overall Interconnector Results*

6.6. NODAL RESULTS

The following sections provide the nodal results for NI. Available energy figures correspond to the total energy available at each node. Constraint and curtailment figures refer to controllable wind only.

6.3.1. AGHYOULE

Aghyoule – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	68	68	68
Total Wind (MW)	68	68	68
Of which is Controllable (MW)	54	54	54
Results			
Available Energy (GWh)	172	173	173
Curtailed Energy (GWh)	0 - 1	4 - 9	7 - 13
Constrained Energy (GWh)	1	0	0
Curtailed + Constrained Energy (GWh)	1 - 2	4 - 9	7 - 13
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 4: *Aghyoule Results*

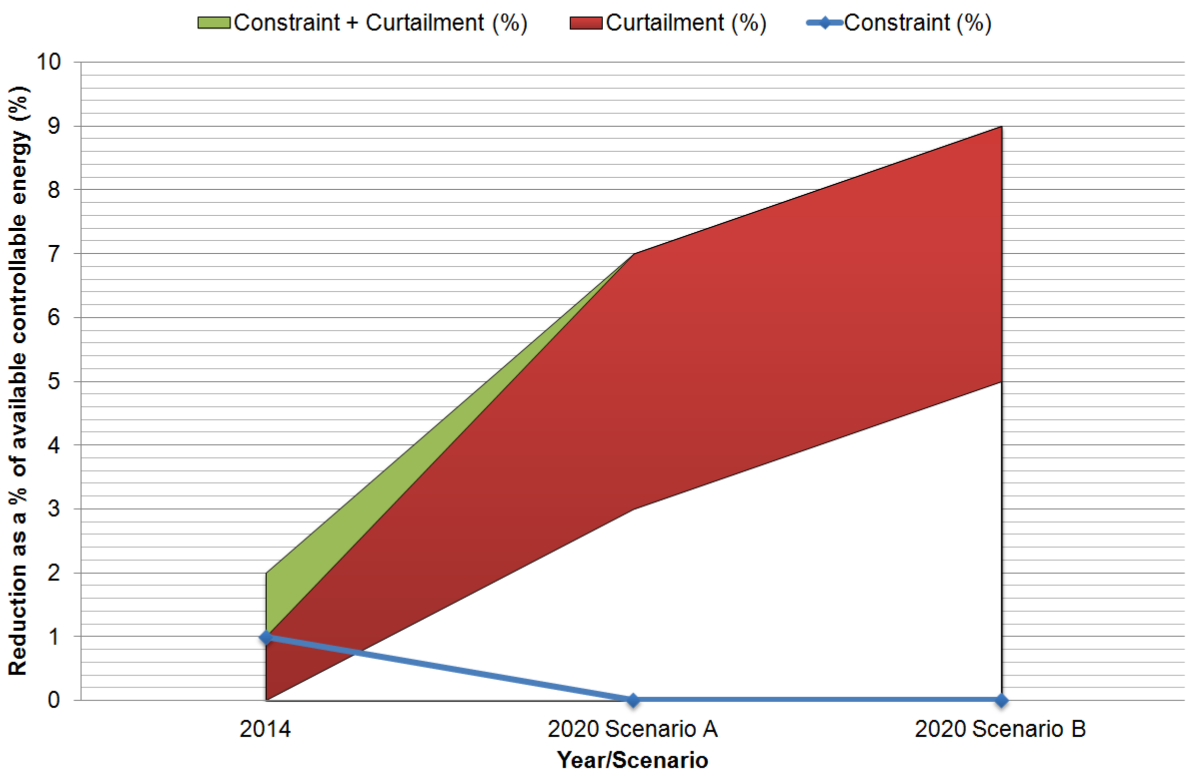

Figure 1: *Aghyoule results for 2014 and 2020*

6.3.2. ANTRIM

Antrim – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)		2	2
Existing Wind (MW)		0	0
Total Wind (MW)		2	2
Of which is Controllable (MW)		0	0
Results			
Available Energy (GWh)		5	5
Curtailed Energy (GWh)		0	0
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		0	0
Curtailment (%)		0	0
Constraint (%)		0	0
Curtailment and Constraint (%)		0	0

Table 5: *Antrim Results*

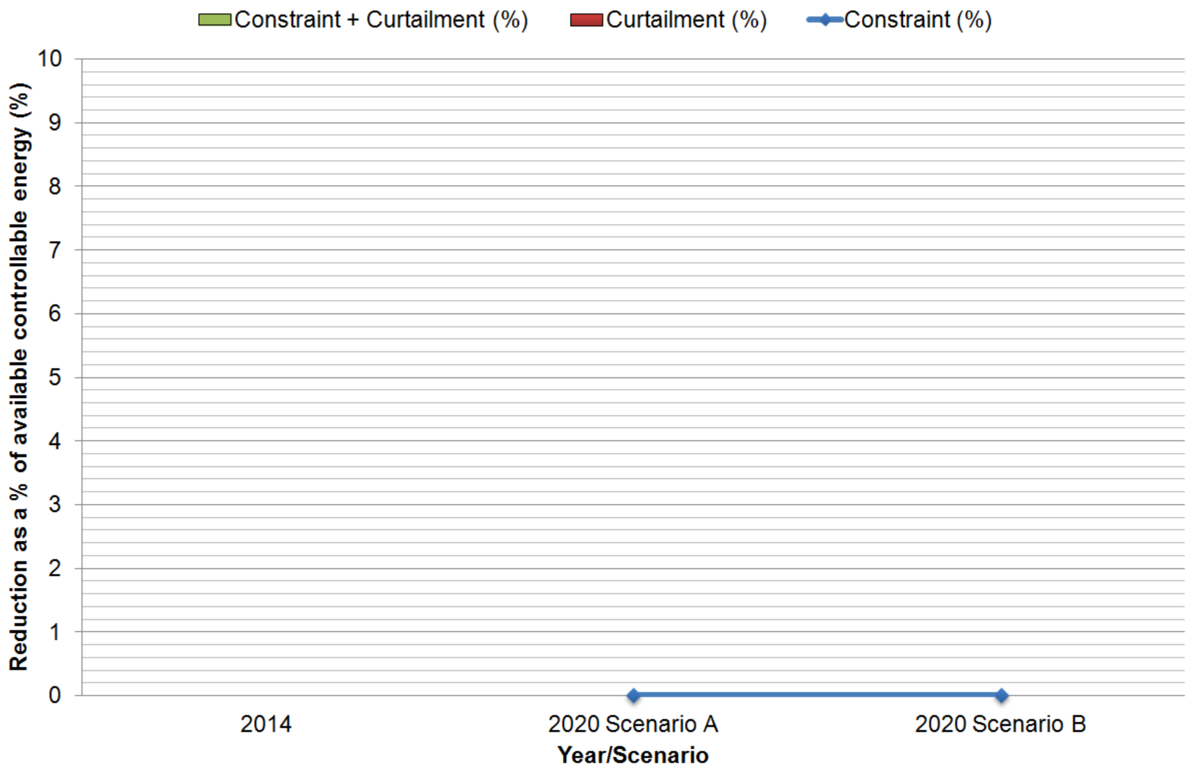

Figure 2: *Antrim results for 2020*

6.3.3. BALLYMENA

Ballymena – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	6	0	0
Existing Wind (MW)	5	11	11
Total Wind (MW)	11	11	11
Of which is Controllable (MW)	6	6	6
Results			
Available Energy (GWh)	28	28	28
Curtailed Energy (GWh)	~0	0 - 1	1 - 2
Constrained Energy (GWh)	0	0	0
Curtailed + Constrained Energy (GWh)	~0	0 - 1	1 - 2
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	0	0	0
Curtailment and Constraint (%)	0 - 1	3 - 7	5 - 9

Table 6: *Ballymena Results*

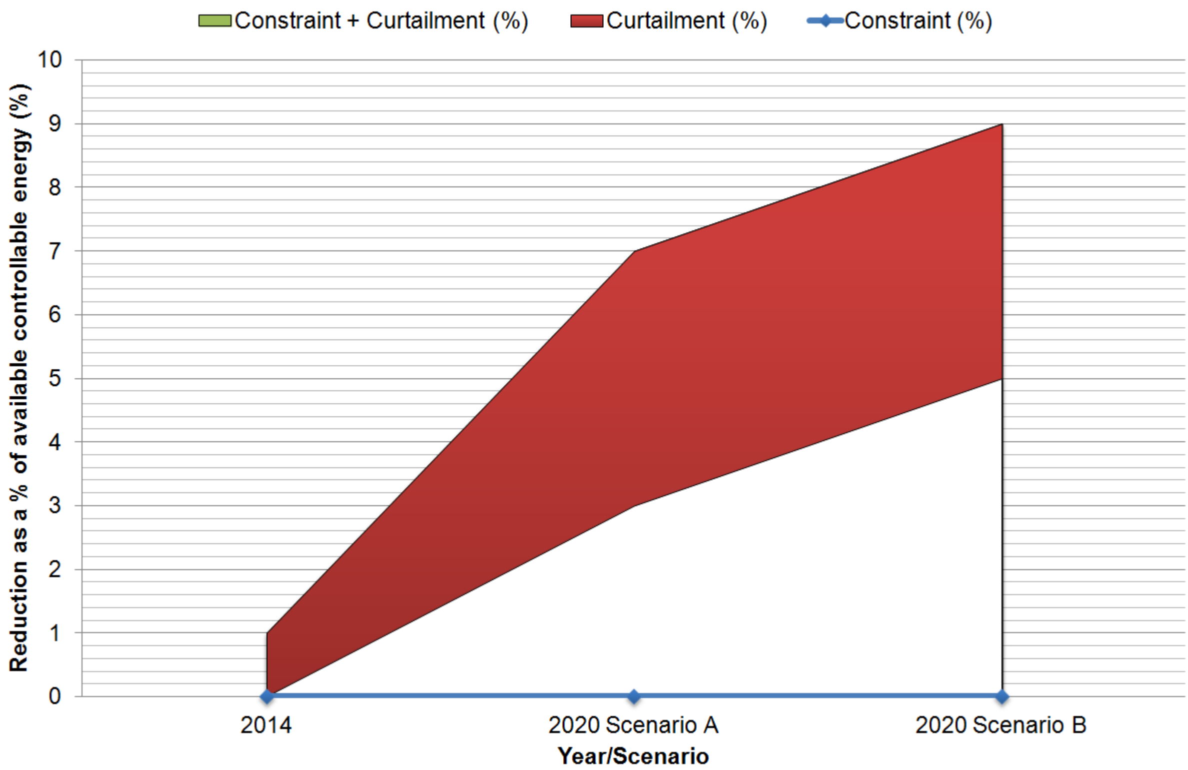

Figure 3: *Ballymena results for 2014 and 2020*

6.3.4. BROCKAGHBOY

Brockaghboy – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)		66	66
Existing Wind (MW)		0	0
Total Wind (MW)		66	66
Of which is Controllable (MW)		66	66
Results			
Available Energy (GWh)		169	169
Curtailed Energy (GWh)		5 - 11	8 - 16
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		5 - 11	8 - 16
Curtailment (%)		3 - 7	5 - 9
Constraint (%)		0	0
Curtailment and Constraint (%)		3 - 7	5 - 9

Table 7: *Brockaghboy Results*

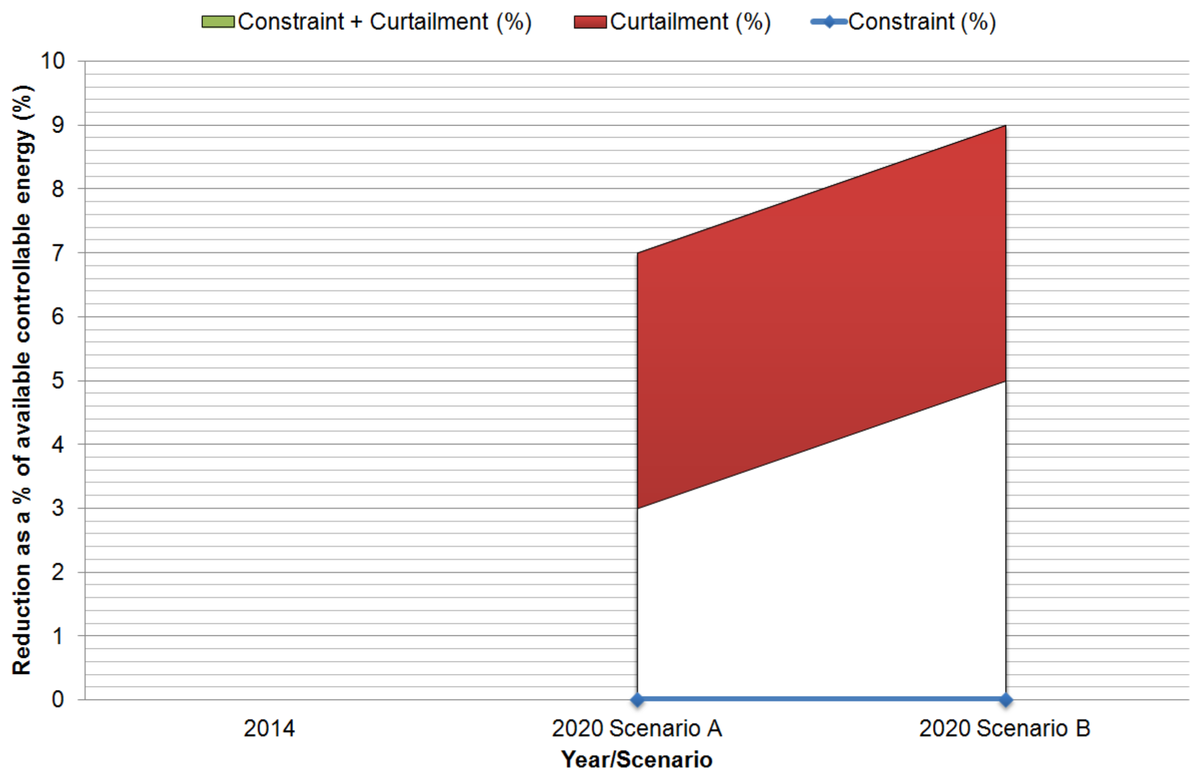

Figure 4: *Brockaghboy results for 2020*

6.3.5. CARNMONEY

Carnmoney – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	14	14	14
Total Wind (MW)	14	14	14
Of which is Controllable (MW)	14	14	14
Results			
Available Energy (GWh)	35	35	35
Curtailed Energy (GWh)	~0	1 - 2	2 - 3
Constrained Energy (GWh)	0	0	0
Curtailed + Constrained Energy (GWh)	~0	1 - 2	2 - 3
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	0	0	0
Curtailment and Constraint (%)	0 - 1	3 - 7	5 - 9

Table 8: *Carnmoney Results*

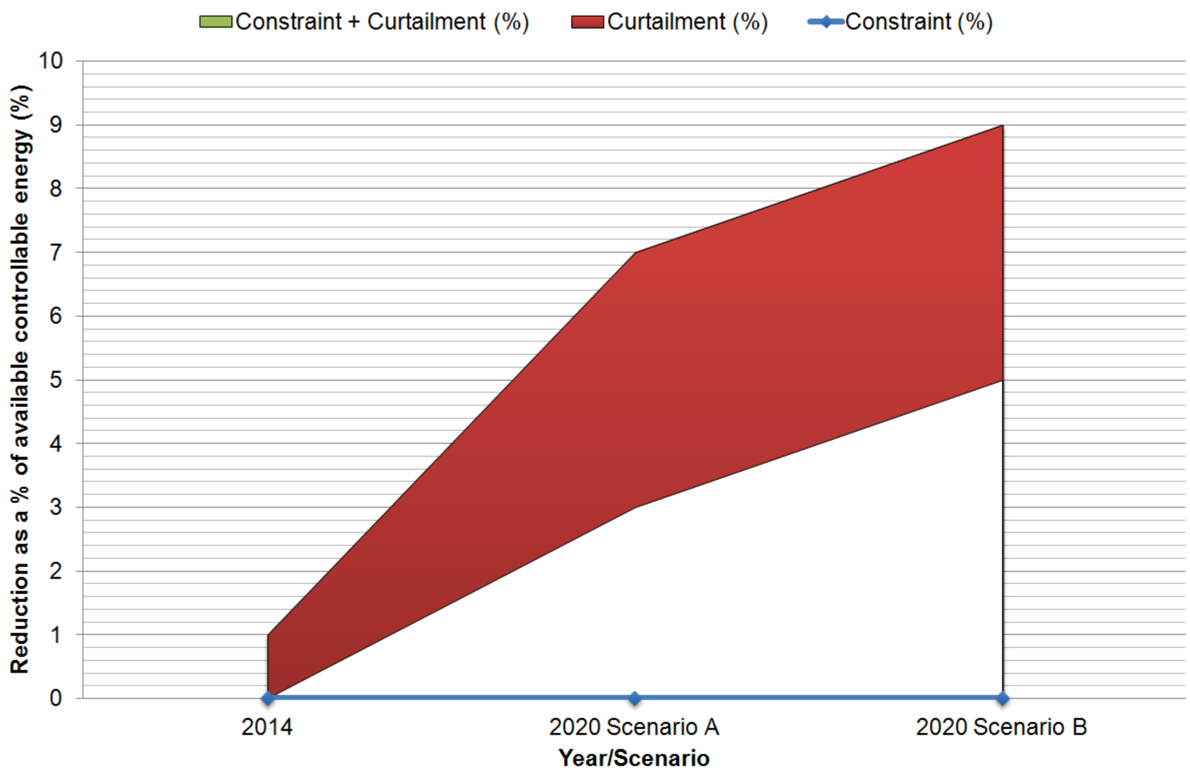

Figure 5: *Carnmoney results for 2014 and 2020*

6.3.6. CASTLEREAGH[6]

Castlereagh – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)		200	600
Existing Wind (MW)		0	0
Total Wind (MW)		200	600
Of which is Controllable (MW)		200	600
Results			
Available Energy (GWh)		648	1943
Curtailed Energy (GWh)		19 - 42	91 - 179
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		19 - 42	91 - 179
Curtailment (%)		3 - 7	5 - 9
Constraint (%)		0	0
Curtailment and Constraint (%)		3 - 7	5 - 9

Table 9: *Castlereagh Results*

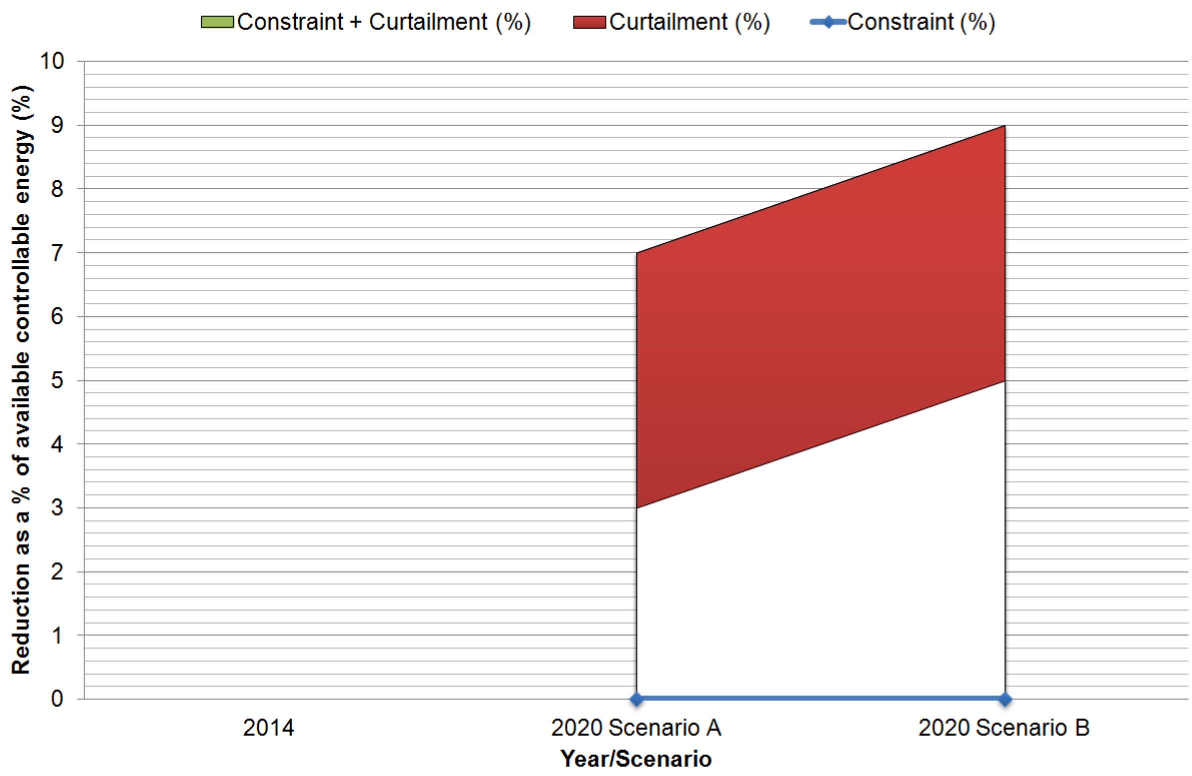

Figure 6: *Castlereagh results for 2020*

[6] Castlereagh 275kV node or another appropriate connection node for NI East coast offshore wind generation.

6.3.7. COLERAINE

Coleraine – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	63	0	0
Existing Wind (MW)	45	108	108
Total Wind (MW)	108	108	108
Of which is Controllable (MW)	103	103	103
Results			
Available Energy (GWh)	276	276	276
Curtailed Energy (GWh)	0 - 2	8 - 17	12 - 24
Constrained Energy (GWh)	1	0	0
Curtailed + Constrained Energy (GWh)	1 - 3	8 - 17	12 - 24
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	~0	0	0
Curtailment and Constraint (%)	0 - 1	3 - 7	5 - 9

Table 10: *Coleraine Results*

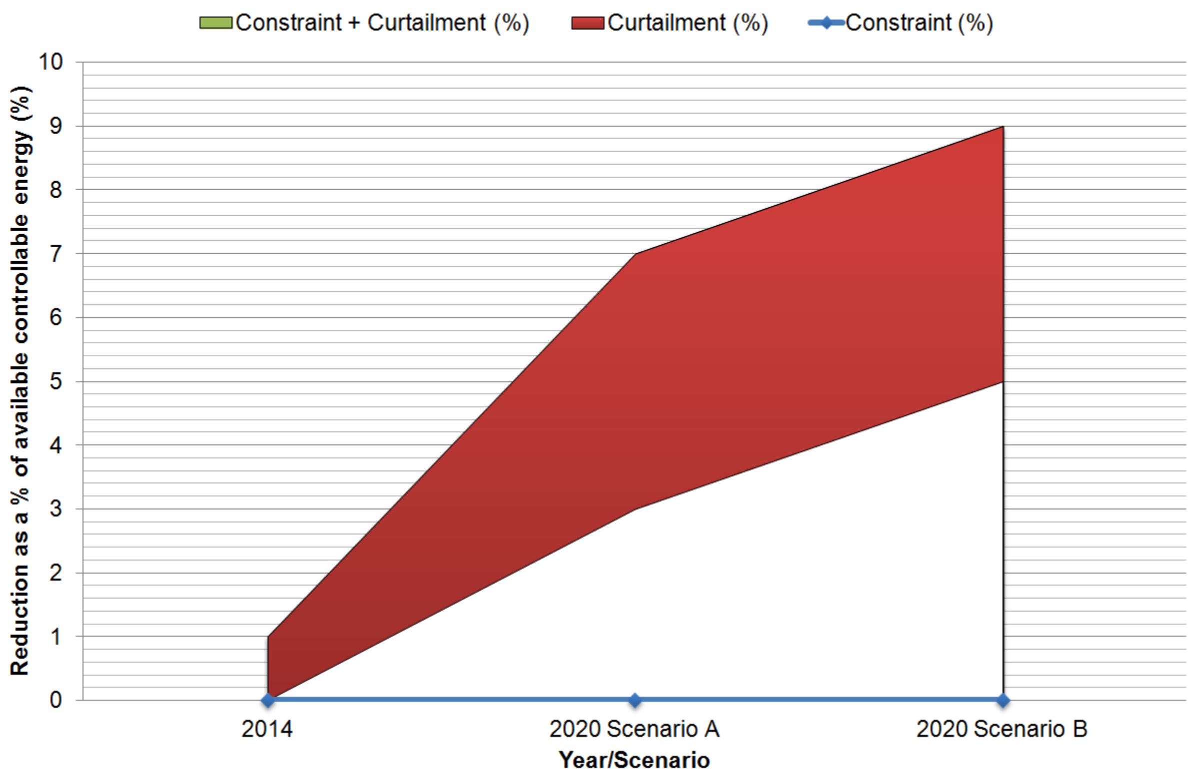

Figure 7: *Coleraine results for 2014 and 2020*

6.3.8. DRUMNAKELLY

Drumnakelly – Wind Generation Results			
Year/Scenario	2014	2020 Scenario A	2020 Scenario B
Wind Capacity at Node			
Additional Wind (MW)		3	3
Existing Wind (MW)		0	0
Total Wind (MW)		3	3
Of which is Controllable (MW)		0	0
Results			
Available Energy (GWh)		7	7
Curtailed Energy (GWh)		0	0
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		0	0
Curtailment (%)		0	0
Constraint (%)		0	0
Curtailment and Constraint (%)		0	0

Table 11: *Drumnakelly Results*

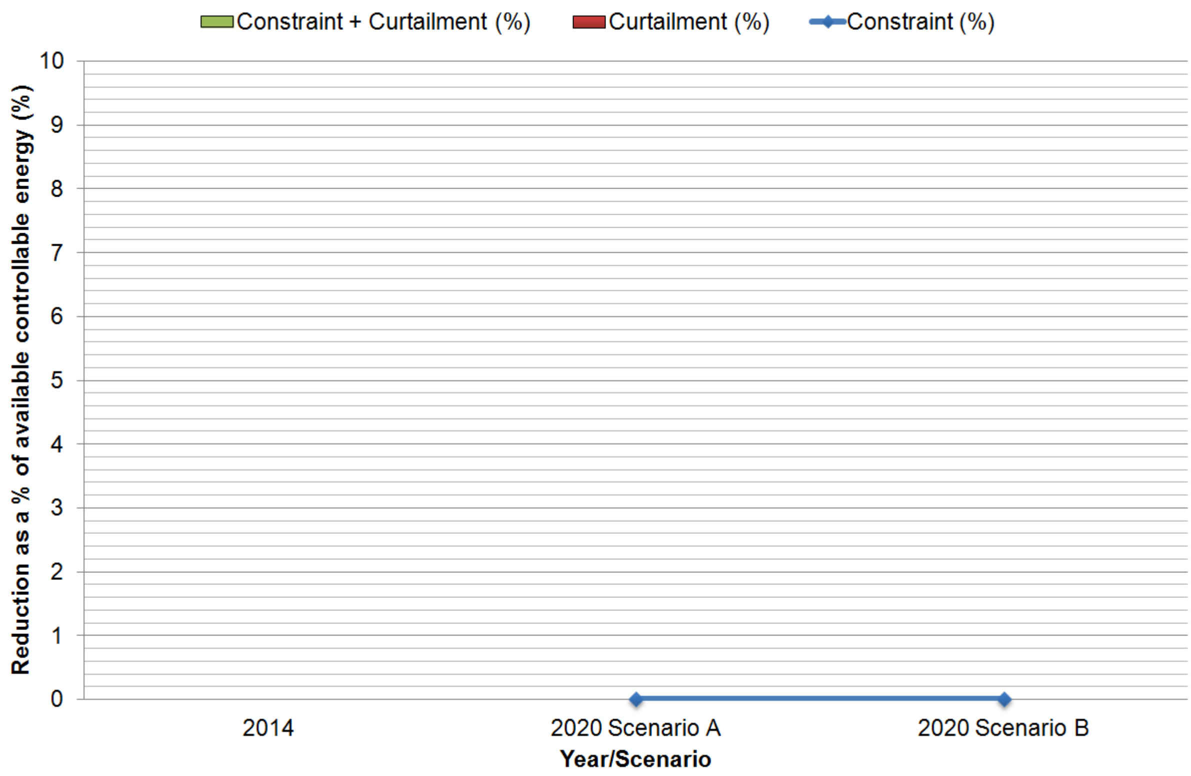

Figure 8: *Drumnakelly results for 2020*

6.3.9. DRUMQUIN

Drumquin – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)		82	82
Existing Wind (MW)		0	0
Total Wind (MW)		82	82
Of which is Controllable (MW)		82	82
Results			
Available Energy (GWh)		209	209
Curtailed Energy (GWh)		6 - 14	10 - 19
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		6 - 14	10 - 19
Curtailment (%)		3 - 7	5 - 9
Constraint (%)		0	0
Curtailment and Constraint (%)		3 - 7	5 - 9

Table 12: *Drumquin Results*

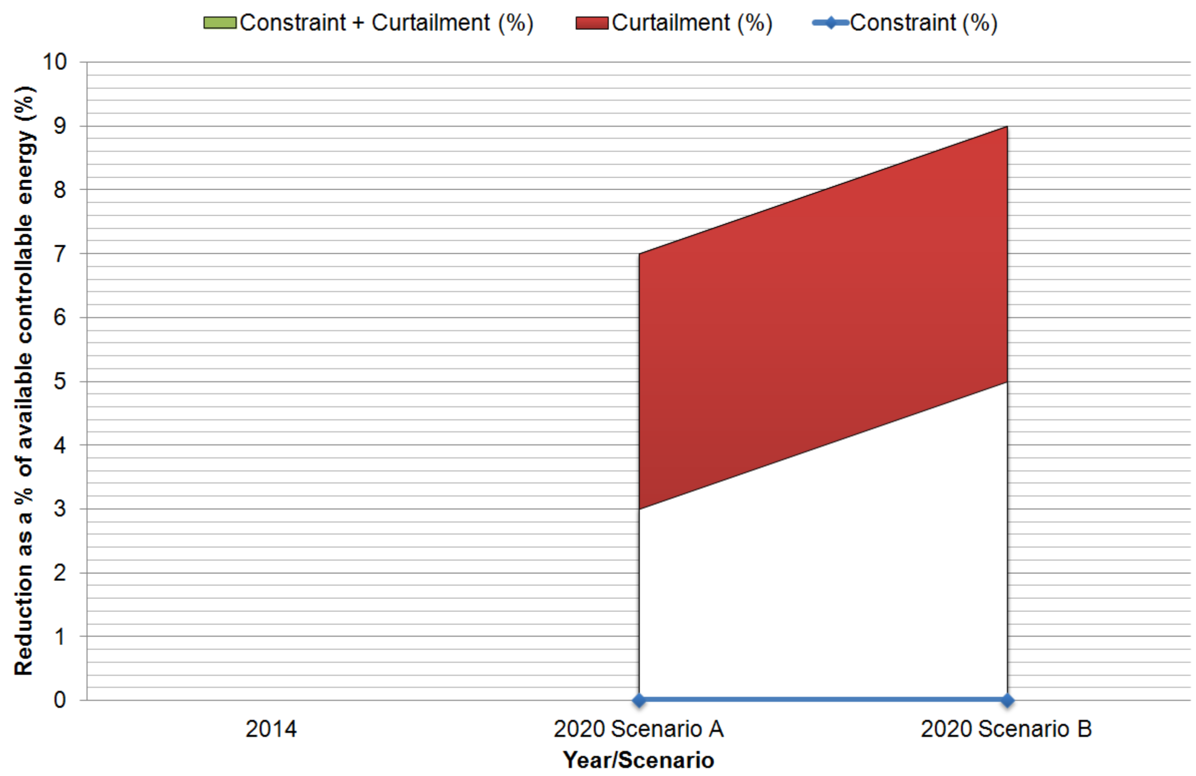

Figure 9: *Drumquin results for 2020*

6.3.10. DUNGANNON

Dungannon – Wind Generation Results			
Year/Scenario	2014	2020 Scenario A	2020 Scenario B
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	18	18	18
Total Wind (MW)	18	18	18
Of which is Controllable (MW)	18	18	18
Results			
Available Energy (GWh)	45	45	45
Curtailed Energy (GWh)	~0	1 - 3	2 - 4
Constrained Energy (GWh)	~0	0	0
Curtailed + Constrained Energy (GWh)	~0	1 - 3	2 - 4
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	~0	0	0
Curtailment and Constraint (%)	0 - 1	3 - 7	5 - 9

Table 13: *Dungannon Results*

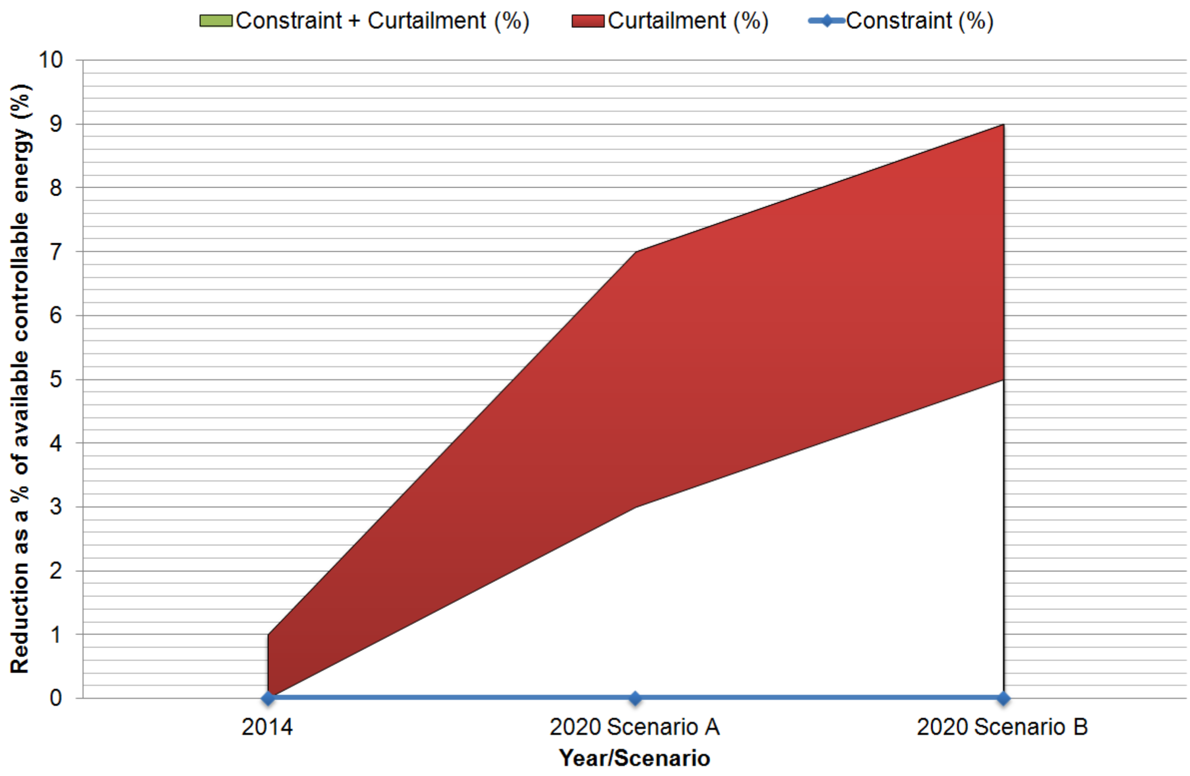

Figure 10: *Dungannon results for 2014 and 2020*

6.3.11. EDEN

Eden – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	3	3	3
Total Wind (MW)	3	3	3
Of which is Controllable (MW)	0	0	0
Results			
Available Energy (GWh)	6	6	6
Curtailed Energy (GWh)	0	0	0
Constrained Energy (GWh)	0	0	0
Curtailed + Constrained Energy (GWh)	0	0	0
Curtailment (%)	0	0	0
Constraint (%)	0	0	0
Curtailment and Constraint (%)	0	0	0

Table 14: *Eden Results*

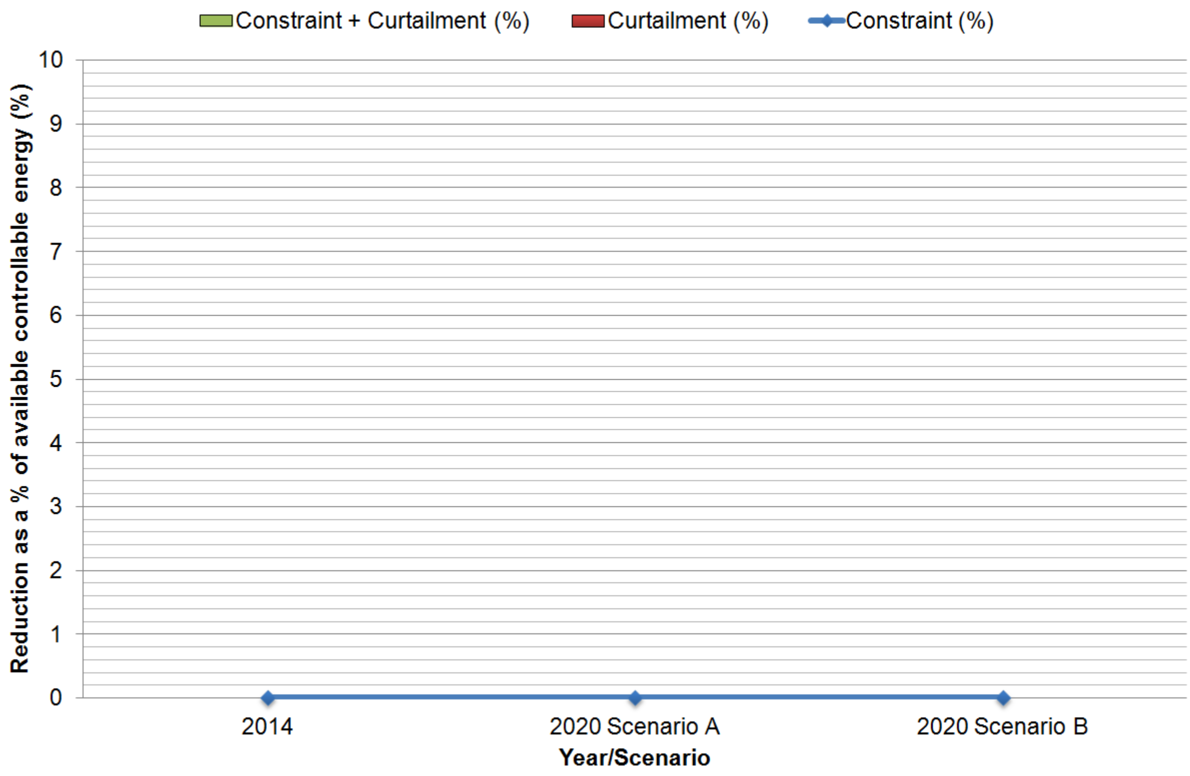

Figure 11: *Eden results for 2014 and 2020*

6.3.12. ENNISKILLEN

Enniskillen – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	3	3
Existing Wind (MW)	17	17	17
Total Wind (MW)	17	20	20
Of which is Controllable (MW)	17	17	17
Results			
Available Energy (GWh)	43	50	50
Curtailed Energy (GWh)	~0	1 - 3	2 – 4
Constrained Energy (GWh)	~0	0	0
Curtailed + Constrained Energy (GWh)	0 - 1	1 - 3	2 – 4
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 15: *Enniskillen Results*

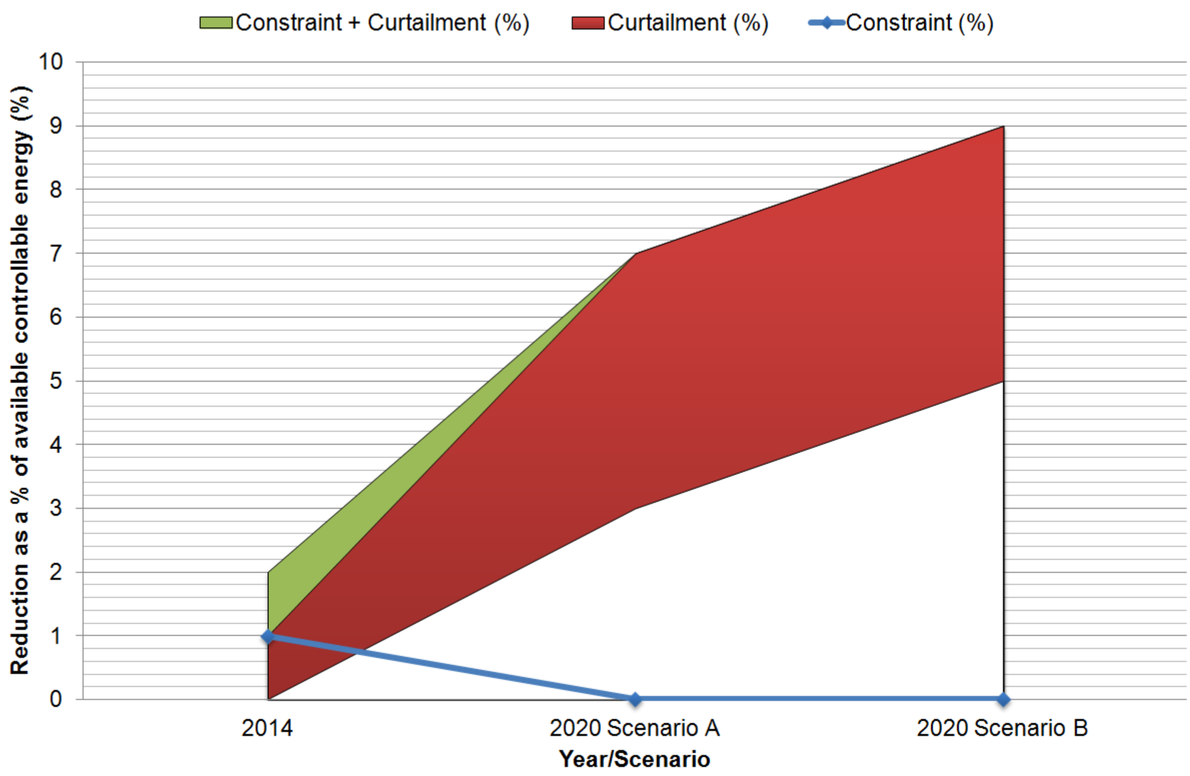

Figure 12: *Enniskillen results for 2014 and 2020*

6.3.13. GORT

Gort – Wind Generation Results			
Year/Scenario	2014	2020 Scenario A	2020 Scenario B
Wind Capacity at Node			
Additional Wind (MW)		57	57
Existing Wind (MW)		0	0
Total Wind (MW)		87[7]	87[6]
Of which is Controllable (MW)		87	87
Results			
Available Energy (GWh)		224	224
Curtailed Energy (GWh)		7 - 15	11 - 21
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		7 - 15	11 - 21
Curtailment (%)		3 - 7	5 - 9
Constraint (%)		0	0
Curtailment and Constraint (%)		3 - 7	5 - 9

Table 16: *Gort Results*

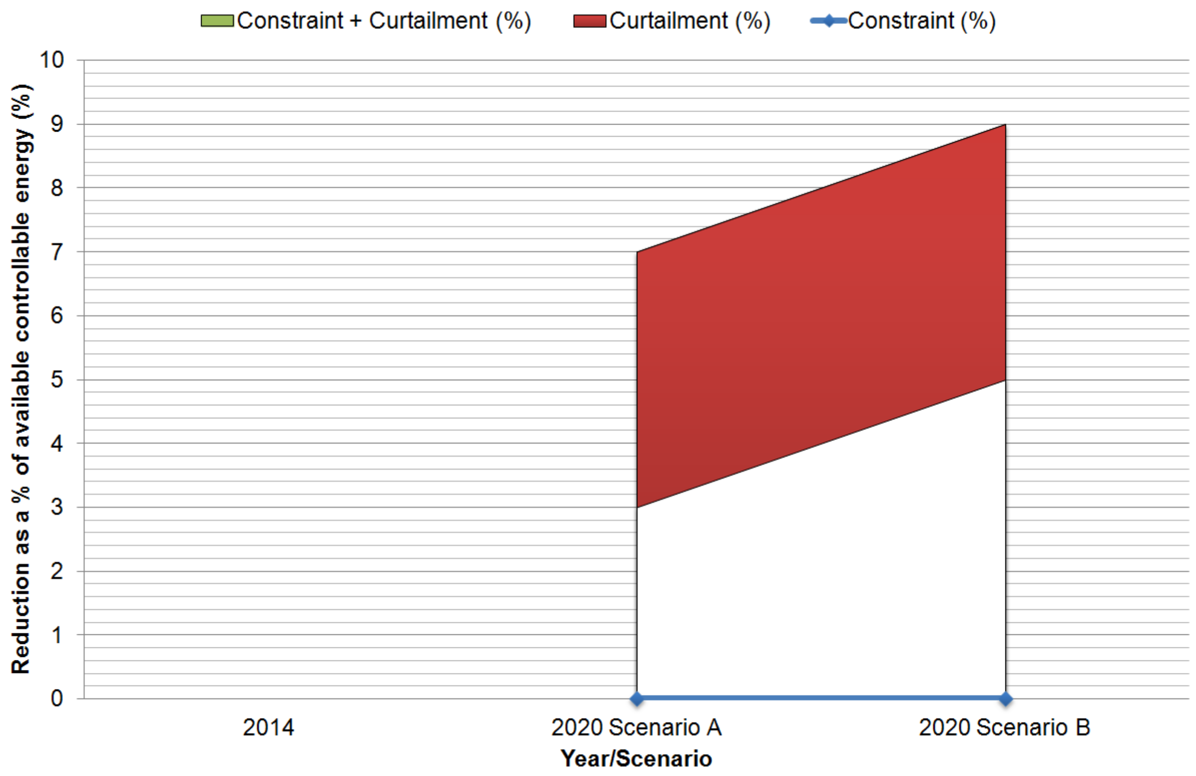

Figure 13: *Gort results for 2020*

[7] 30MW wind transfers from Omagh in 2015.

6.3.14. KILLYMALLAGHT

Killymallaght – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	21	21	21
Total Wind (MW)	21	21	21
Of which is Controllable (MW)	21	21	21
Results			
Available Energy (GWh)	53	53	53
Curtailed Energy (GWh)	~0	2 - 4	3 - 5
Constrained Energy (GWh)	~0	0	0
Curtailed + Constrained Energy (GWh)	0 - 1	2 - 4	3 - 5
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 17: *Killymallaght Results*

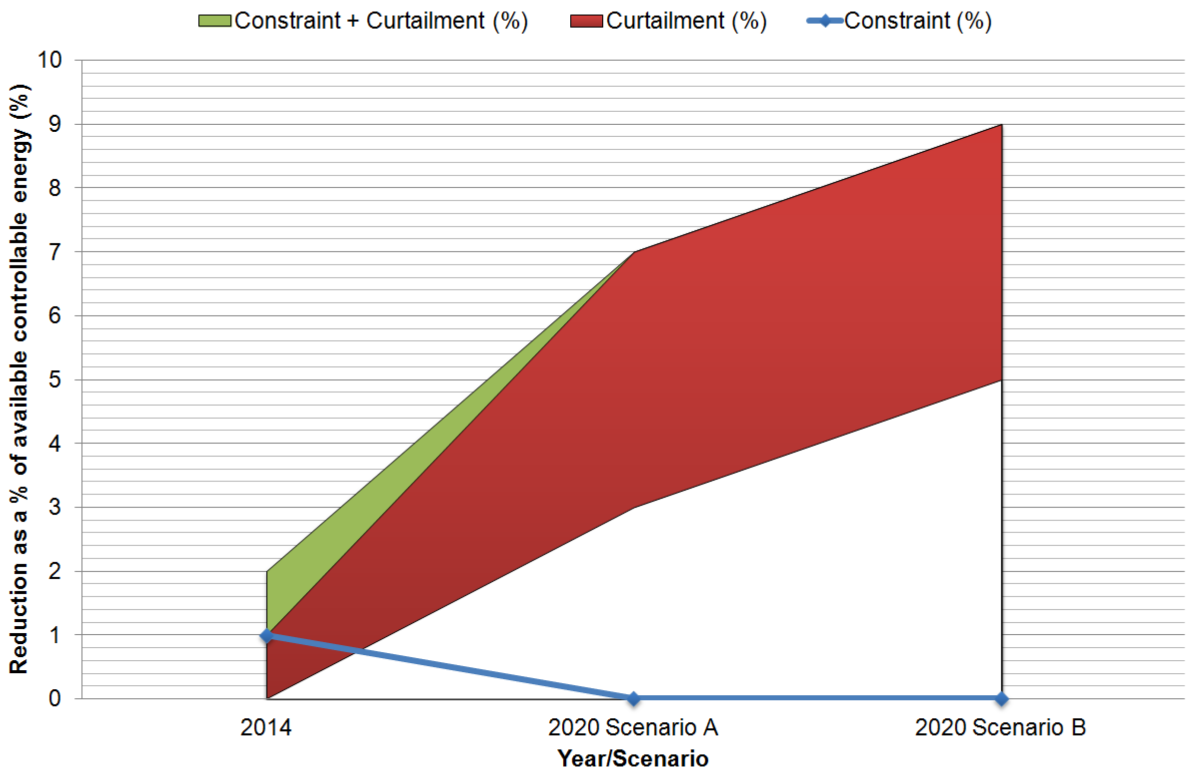

Figure 14: *Killymallaght results for 2014 and 2020*

6.3.15. LARNE

Larne – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	15	15	15
Total Wind (MW)	15	15	15
Of which is Controllable (MW)	10	10	10
Results			
Available Energy (GWh)	38	38	38
Curtailed Energy (GWh)	~0	1 - 2	1 - 2
Constrained Energy (GWh)	0	0	0
Curtailed + Constrained Energy (GWh)	~0	1 - 2	1 - 2
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	0	0	0
Curtailment and Constraint (%)	0 - 1	3 - 7	5 - 9

Table 18: *Larne Results*

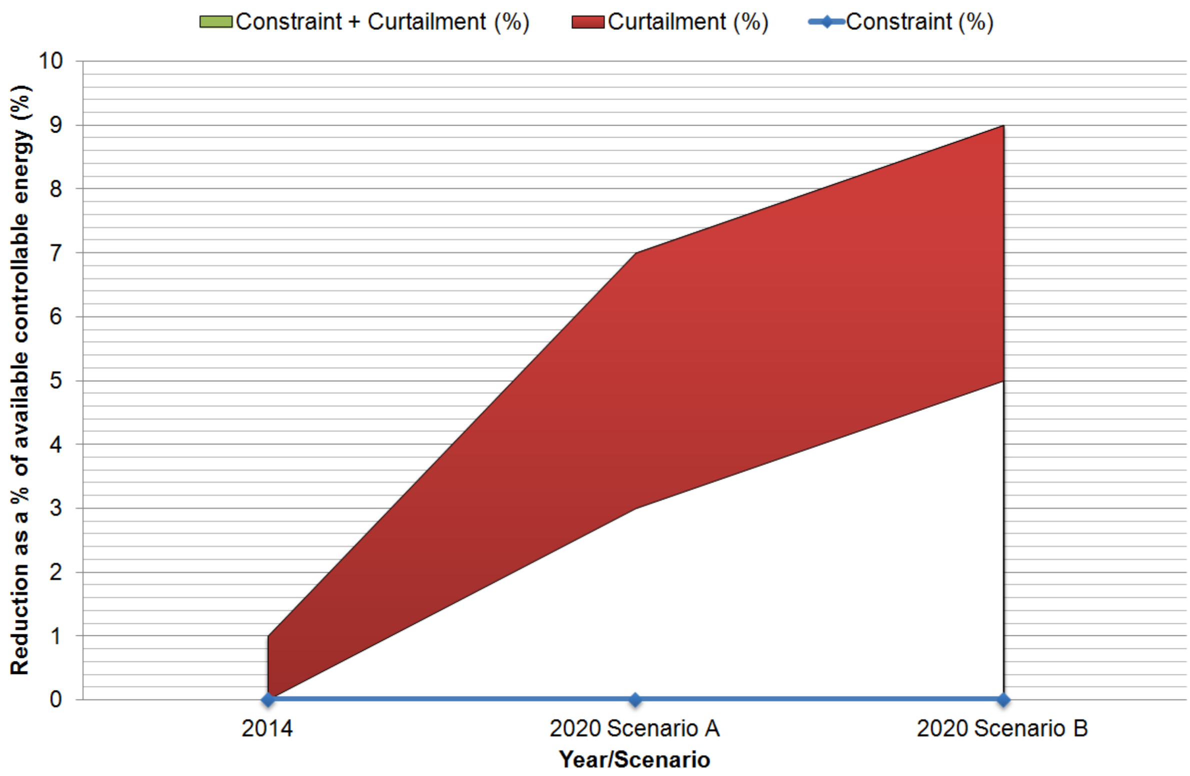

Figure 15: *Larne results for 2014 and 2020*

6.3.16. LIMAVADY

Limavady – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	12	12
Existing Wind (MW)	38	38	38
Total Wind (MW)	38	50	50
Of which is Controllable (MW)	12	24	24
Results			
Available Energy (GWh)	96	127	127
Curtailed Energy (GWh)	~0	2 - 4	3 - 6
Constrained Energy (GWh)	~0	0	0
Curtailed + Constrained Energy (GWh)	~0	2 - 4	3 - 6
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	~0	0	0
Curtailment and Constraint (%)	0 - 1	3 - 7	5 - 9

Table 19: *Limavady Results*

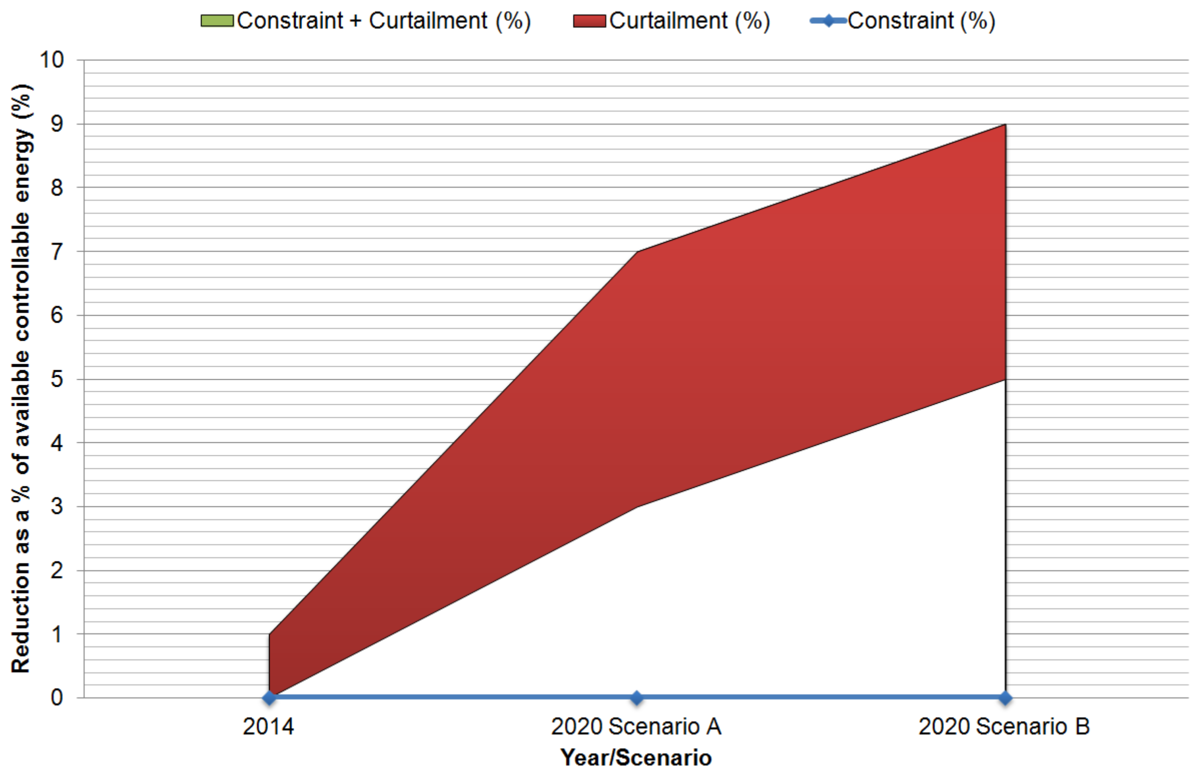

Figure 16: *Limavady results for 2014 and 2020*

6.3.17. LISAGHMORE

Lisaghmore – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	18	18	18
Total Wind (MW)	18	18	18
Of which is Controllable (MW)	15	15	15
Results			
Available Energy (GWh)	38	45	45
Curtailed Energy (GWh)	~0	1 - 3	2 - 4
Constrained Energy (GWh)	~0	0	0
Curtailed + Constrained Energy (GWh)	~0	1 - 3	2 - 4
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 20: *Lisaghmore Results*

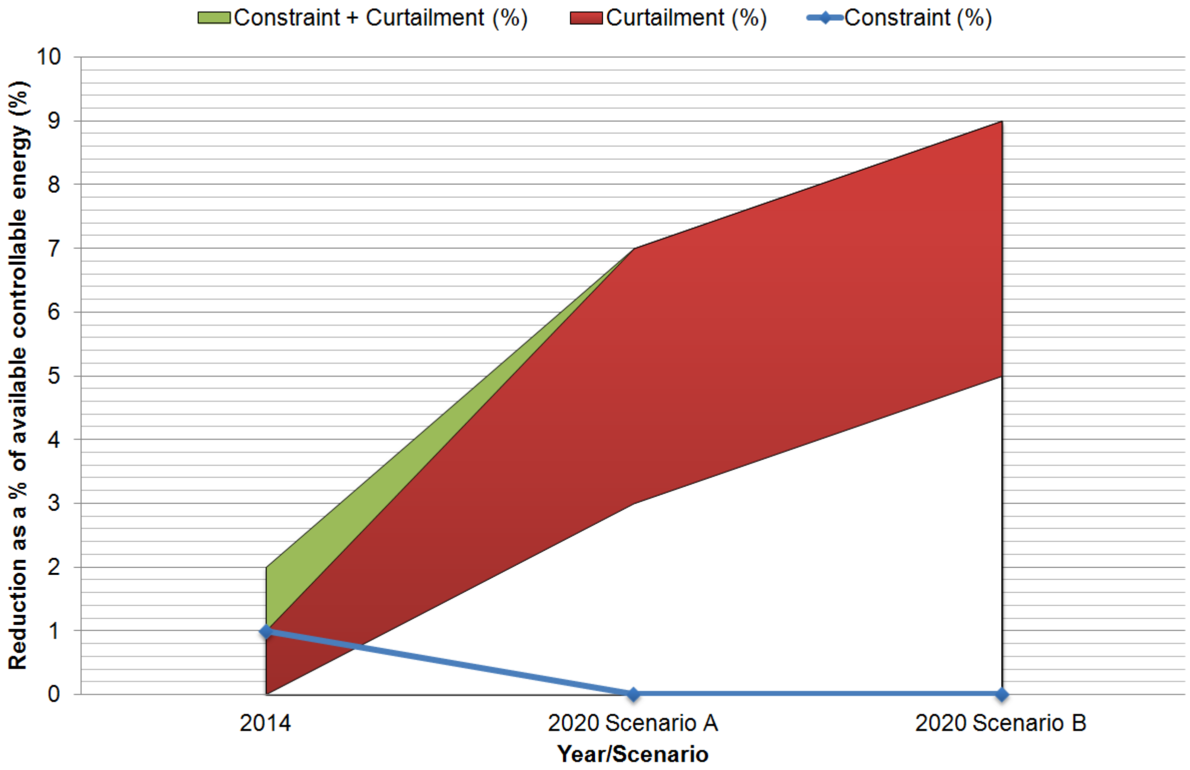

Figure 17: *Lisaghmore results for 2014 and 2020*

6.3.18. MAGHERAKEEL

Magherakeel – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	73	0	0
Existing Wind (MW)	51	124	124
Total Wind (MW)	124	124	124
Of which is Controllable (MW)	124	124	124
Results			
Available Energy (GWh)	314	315	315
Curtailed Energy (GWh)	0 - 2	10 - 21	15 - 29
Constrained Energy (GWh)	3	0	0
Curtailed + Constrained Energy (GWh)	4	10 - 21	15 - 29
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 21: *Magherakeel Results*

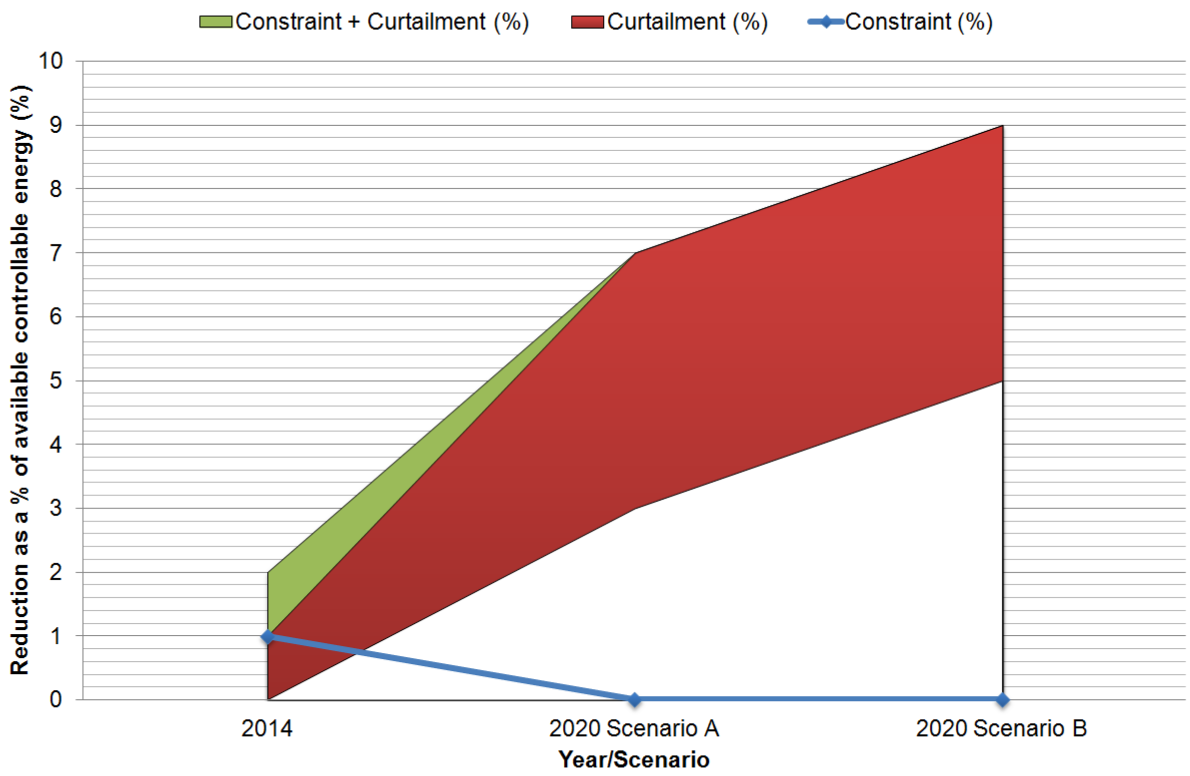

Figure 18: *Magherakeel results for 2014 and 2020*

6.3.19. MID ANTRIM

Mid Antrim – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)		38	38
Existing Wind (MW)		0	0
Total Wind (MW)		38	38
Of which is Controllable (MW)		35	35
Results			
Available Energy (GWh)		96	96
Curtailed Energy (GWh)		3 - 6	4 - 8
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		3 - 6	4 - 8
Curtailment (%)		3 - 7	5 - 9
Constraint (%)		0	0
Curtailment and Constraint (%)		3 - 7	5 - 9

Table 22: *Mid Antrim Results*

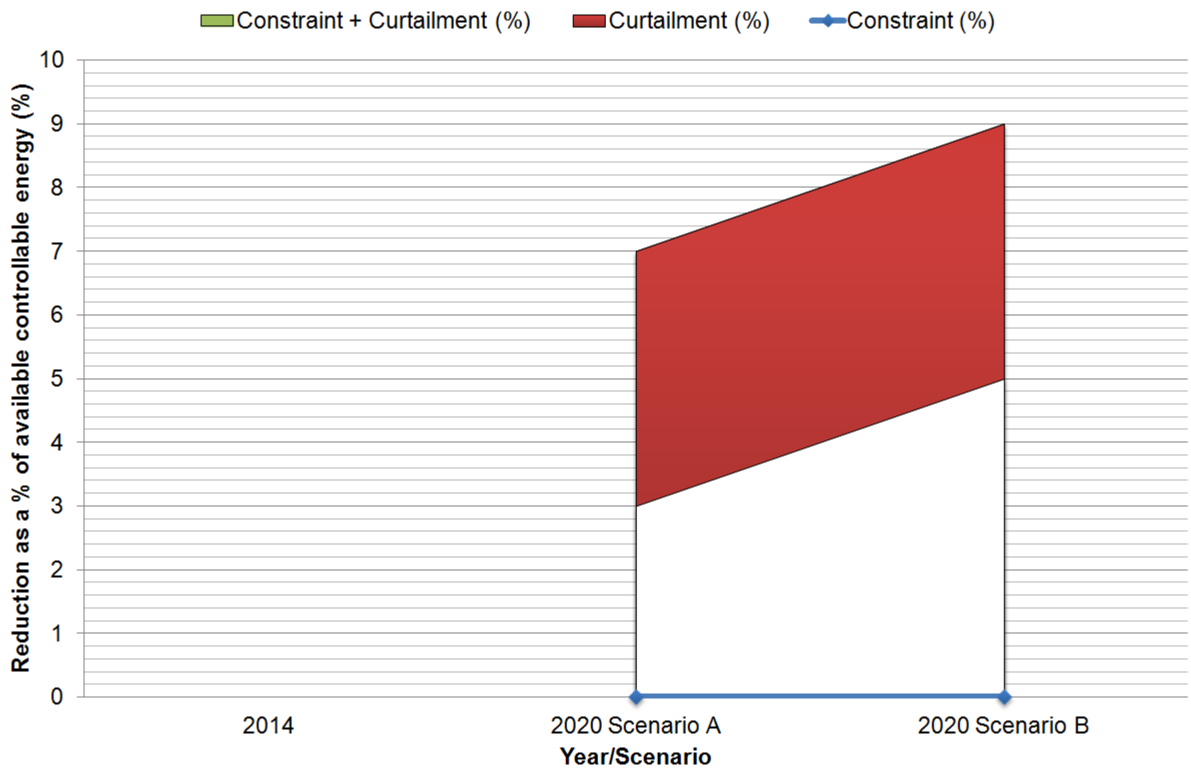

Figure 19: *Mid Antrim results 2020*

6.3.20. OMAGH

Omagh – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	126	96	96
Total Wind (MW)	126	96[8]	96[7]
Of which is Controllable (MW)	108	78	78
Results			
Available Energy (GWh)	321	245	245
Curtailed Energy (GWh)	0 - 2	6 - 13	9 - 18
Constrained Energy (GWh)	2	0	0
Curtailed + Constrained Energy (GWh)	2 - 4	6 - 13	9 - 18
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 23: *Omagh Results*

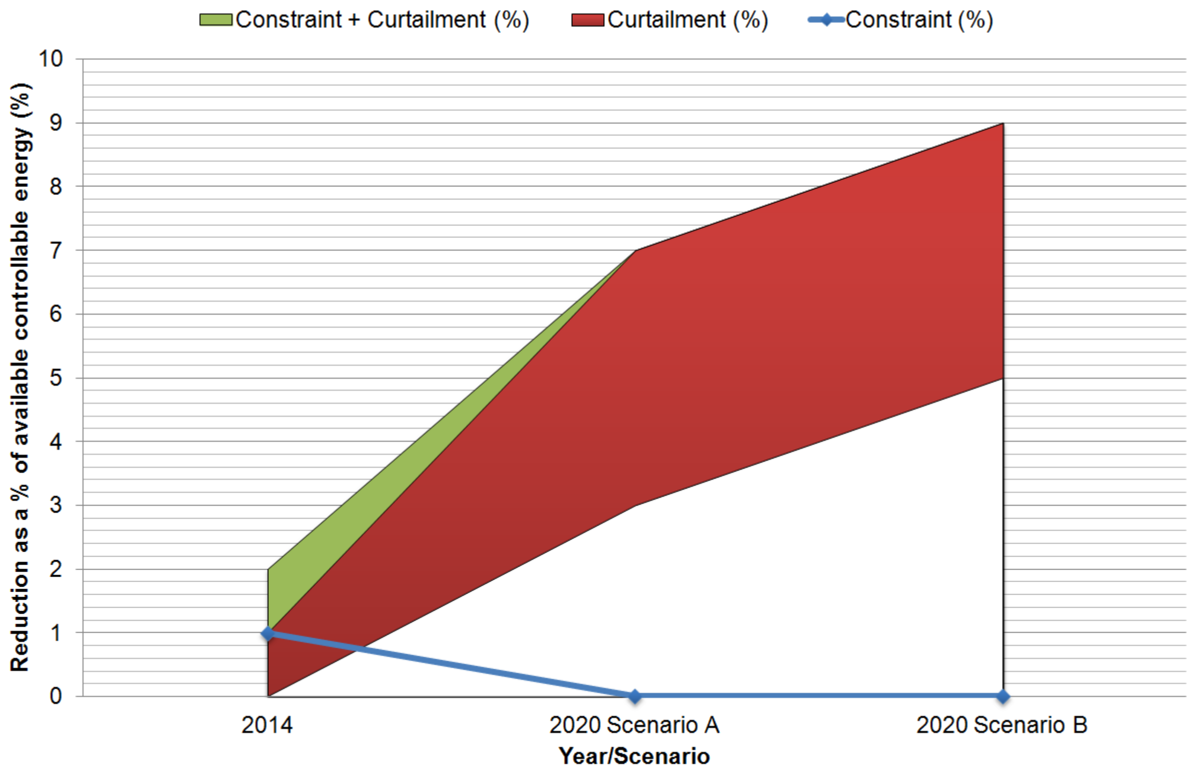

Figure 20: *Omagh results for 2014 and 2020*

[8] 30MW wind transfers to Gort in 2015.

6.3.21. SLIEVE KIRK

Slieve Kirk – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	74	74	74
Total Wind (MW)	74	74	74
Of which is Controllable (MW)	74	74	74
Results			
Available Energy (GWh)	188	188	188
Curtailed Energy (GWh)	0 - 1	6 - 13	9 - 17
Constrained Energy (GWh)	1	0	0
Curtailed + Constrained Energy (GWh)	1 - 2	6 - 13	9 - 17
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 24: *Slieve Kirk Results*

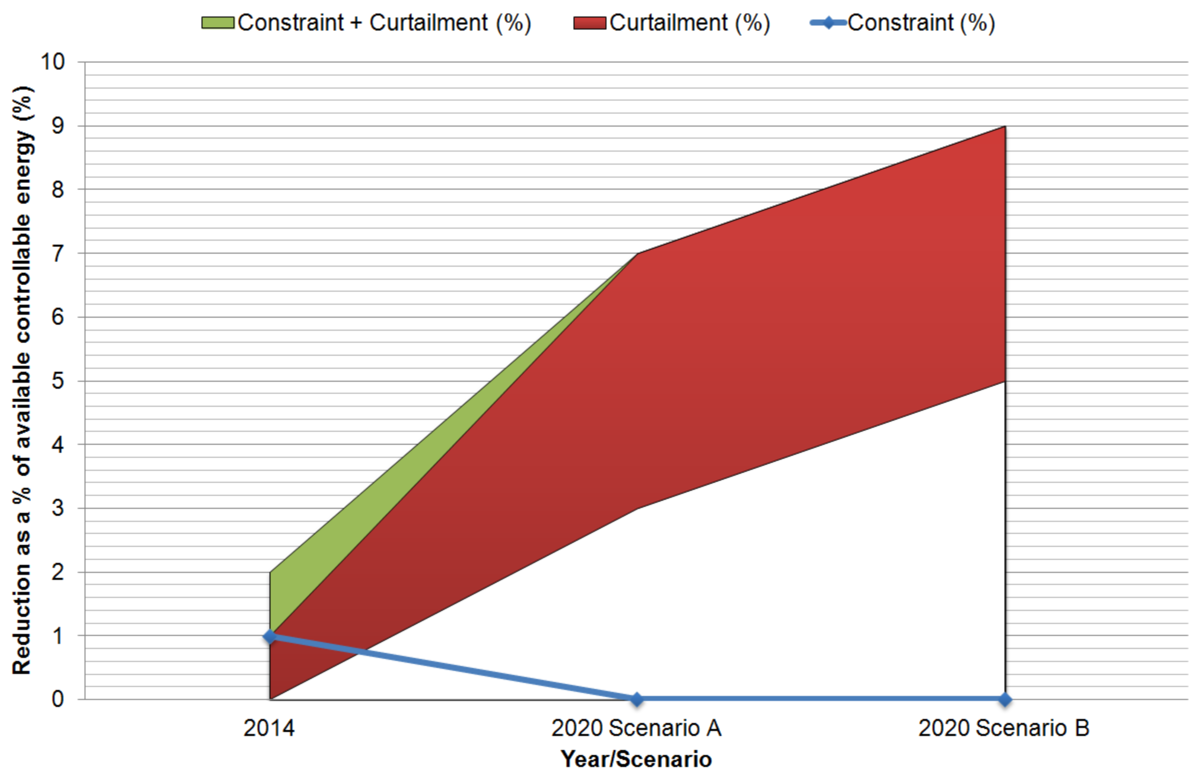

Figure 21: *Slieve Kirk results for 2014 and 2020*

6.3.22. STRABANE

Strabane – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)	0	0	0
Existing Wind (MW)	28	28	28
Total Wind (MW)	28	28	28
Of which is Controllable (MW)	22	22	22
Results			
Available Energy (GWh)	70	70	70
Curtailed Energy (GWh)	~0	2 - 4	3 - 5
Constrained Energy (GWh)	~0	0	0
Curtailed + Constrained Energy (GWh)	0 - 1	2 - 4	3 - 5
Curtailment (%)	0 - 1	3 - 7	5 - 9
Constraint (%)	1	0	0
Curtailment and Constraint (%)	1 - 2	3 - 7	5 - 9

Table 25: *Strabane Results*

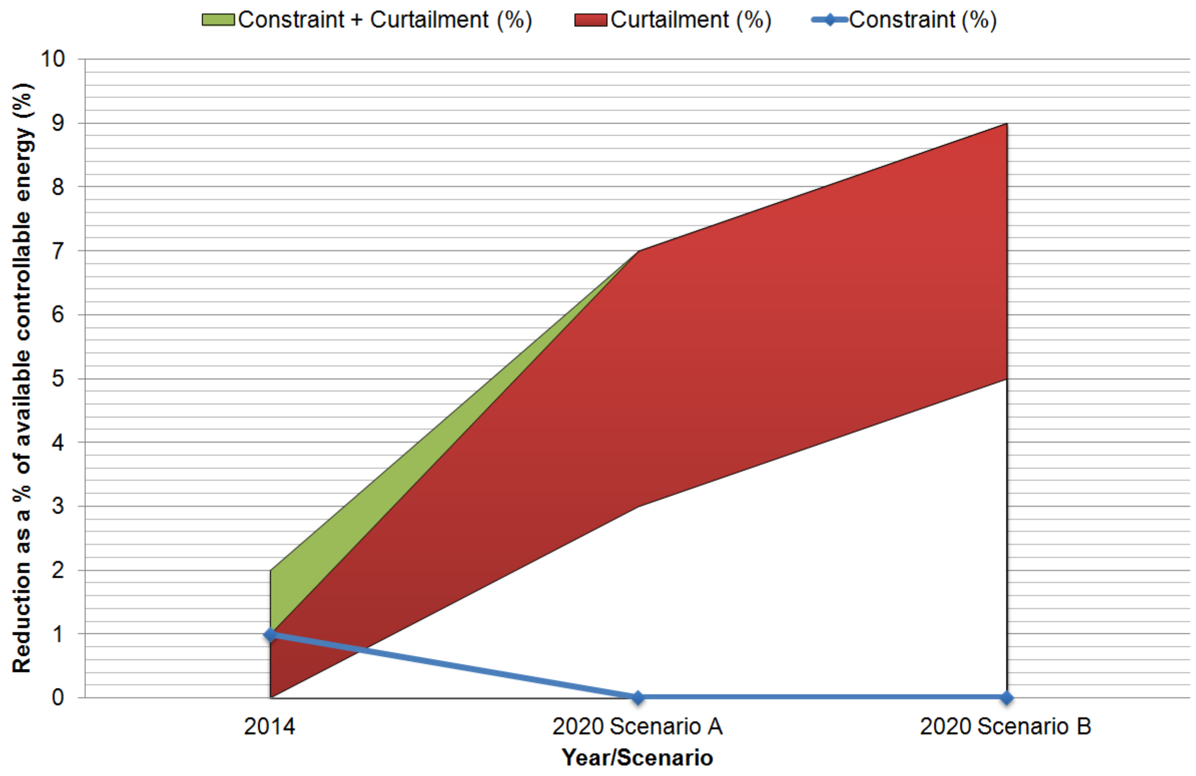

Figure 22: *Strabane results for 2014 and 2020*

6.3.23. TREMOGE

Tremoge – Wind Generation Results			
Year/Scenario	**2014**	**2020 Scenario A**	**2020 Scenario B**
Wind Capacity at Node			
Additional Wind (MW)		75	75
Existing Wind (MW)		0	0
Total Wind (MW)		75	75
Of which is Controllable (MW)		71	71
Results			
Available Energy (GWh)		193	193
Curtailed Energy (GWh)		6 - 12	9 - 17
Constrained Energy (GWh)		0	0
Curtailed + Constrained Energy (GWh)		6 - 12	9 - 17
Curtailment (%)		3 - 7	5 - 9
Constraint (%)		0	0
Curtailment and Constraint (%)		3 - 7	5 - 9

Table 26: *Tremoge Results*

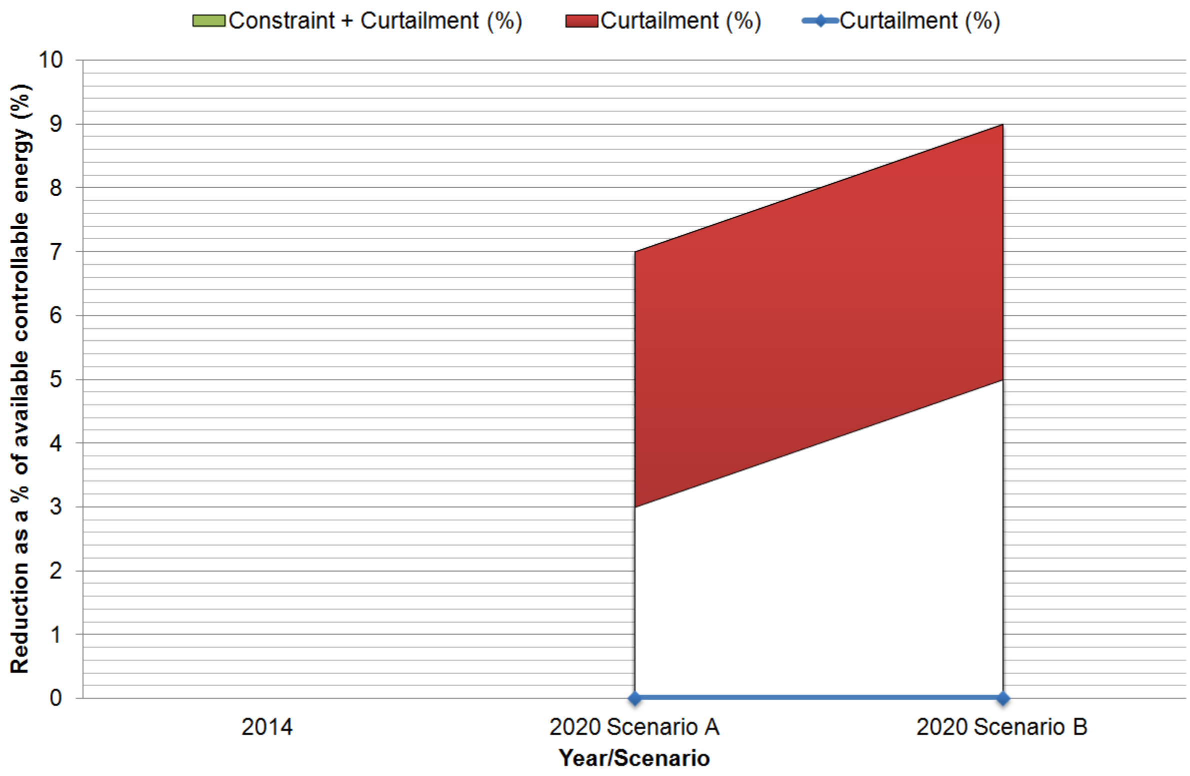

Figure 23: *Tremoge results for 2020*

Appendix A. ALL ISLAND MODELLING ASSUMPTIONS

The assumptions employed in the All Island PROMOD IV models for this GOR analysis are joint EirGrid and SONI assumptions, most of which are aligned with EirGrid's 2013 Gate 3 Constraint Reports. The assumptions presented are:

- Generation
- Demand
- Fuel and Carbon Prices
- Interconnection
- Operational Rules
- Transmission Network

A.1. GENERATION

A.1.1. WIND GENERATION

For the purposes of this model, it is assumed that there is perfect foresight of the output of wind powered generators. This is a slightly optimistic assumption because in real-time operations there is usually some differential between forecasted and actual wind powered generation. However, the option of assuming little or no forecasting ability was thought to be unrealistic given the current level of research and development activity in the area. The assumption of 'perfect foresight' could lead to slightly reduced curtailment levels in comparison to what might be observed in real life, as a result of conventional thermal generation being kept on-line to ramp up in the event that the wind power output is lower than forecasted.

A.1.1.1. WIND REGIONS

For modelling purposes, the island has been split into different wind regions. The wind regions and associated capacity factors for 2008 employed in the studies are listed in Table 27. By using regional wind power profiles in the studies it is possible to account for the geographical variation of wind power across the island. Evidently, this assumption does not take into account possible variations in wind power within each region and it is fair to say that some wind farm sites may have above average wind conditions while others may have below average conditions. But since it is the impacts that constraints and curtailment have on the transmission system and the All Island power system operation that are of interest, it is considered reasonable to assume regional profiles will capture the average behaviour of wind in an area.

Wind Regions		2008 Capacity Factor
Ireland	A	32.8%
	B	30.2%
	C & H1	28.6%
	D	28.1%
	E, F & I	33.3%
	G & J	31.5%
	K & H2	30.9%
	Offshore - East Coast	36.9%
Northern Ireland	NI	29.2%
	Offshore - East Coast	36.9%

Table 27: *Wind generation capacity factors for the wind regions*

In IE and NI, the East Coast offshore wind profile employed was based on amalgamating the 2008 wind profiles of several onshore wind generators that were located near the coast and that had high capacity factors. This was necessary because there is no metered offshore wind data available with the exception of that from the Arklow Banks wind generator. The East Coast offshore wind profile was created specifically for this project to simulate the potential offshore wind profiles and capacity factors in the future.

A.1.1.2. WIND PROFILES

The wind profiles for the base year and each future study year for both IE and NI were created using historical data for 2008. The overall 2008 wind generation capacity factor for Ireland was 31.7% and this was found to be close to average capacity factor from 2004-2009. Given that the 2008 capacity factor is very close to (and marginally higher than) the five year average, it is believed that it is a suitable 'wind year' to reflect what has been historically observed.

It is recognised that developments in wind turbine technology is making higher capacity factors theoretically possible for some projects. However this is balanced against some planning restrictions on turbine tower heights and the argument that some of the best wind sites have already been developed. Taking all this into consideration, it is assumed that on balance, it is reasonable to use the historical wind data as a basis for future wind profiles for the purposes of this GOR study.

Wind generation on the island was modelled in the constraints analysis using an hourly wind power series at every transmission node where wind generation is connected. The wind at each node will be categorised based on FAQ and controllability. In Ireland, wind generation was also categorised based on Gate and connection status (i.e. temporary or permanent). These factors will allow for correct application of GOR.

In NI, the wind profile consists of metered wind generator data (on an export only basis) recorded in 30 minute intervals from generators with Maximum Export Capacity (MEC) greater than 5MW and only those connected and operational at the beginning of 2008. The data was translated into an hourly profile by selecting every other data record with the aim of trying to preserve peaks and troughs in generation. NI is modelled as one single wind region with the same wind profile applied to all wind farms. For future GOR studies, SONI plan to analyse the capacity factors experienced in more recent years in NI, and possibly build additional profiles from high and low wind years to enable sensitivity studies to be carried out.

EirGrid maintains a database which contains the metered output at 15 minute intervals for every wind powered generator in Ireland. By amalgamating the output of the wind generators in a region which have been in commission for a full calendar year it was possible to build up annual regional wind profiles with hourly values.

A.1.1.3. GENERATOR CONTROLLABILITY

It was assumed that there is full compliance with wind farm controllability requirements on the island. It was assumed that all generators with an MEC greater than 5MW were controllable except those wind farms known to have grid code derogations, including those connected before 1st April 2005. The GOR methodology takes into account all uncontrollable wind generation and does not include these generators in any output reductions.

A.1.1.4. WIND GENERATION BUILD OUT RATE

Table 28 shows a summary of the expected wind build out rate, both onshore and offshore, for both Ireland and Northern Ireland for 2014 and 2020.

Year	Scenario	Wind Capacity (MW)		
		NI	IE	All Island
2014	N/A	683	2222	2905
2020	A – 40% Renewables	1222	3884	5106
2020	B – 45% Renewables	1622	3884	5506

Table 28: *Overview of All Island wind capacities for 2014 and 2020*

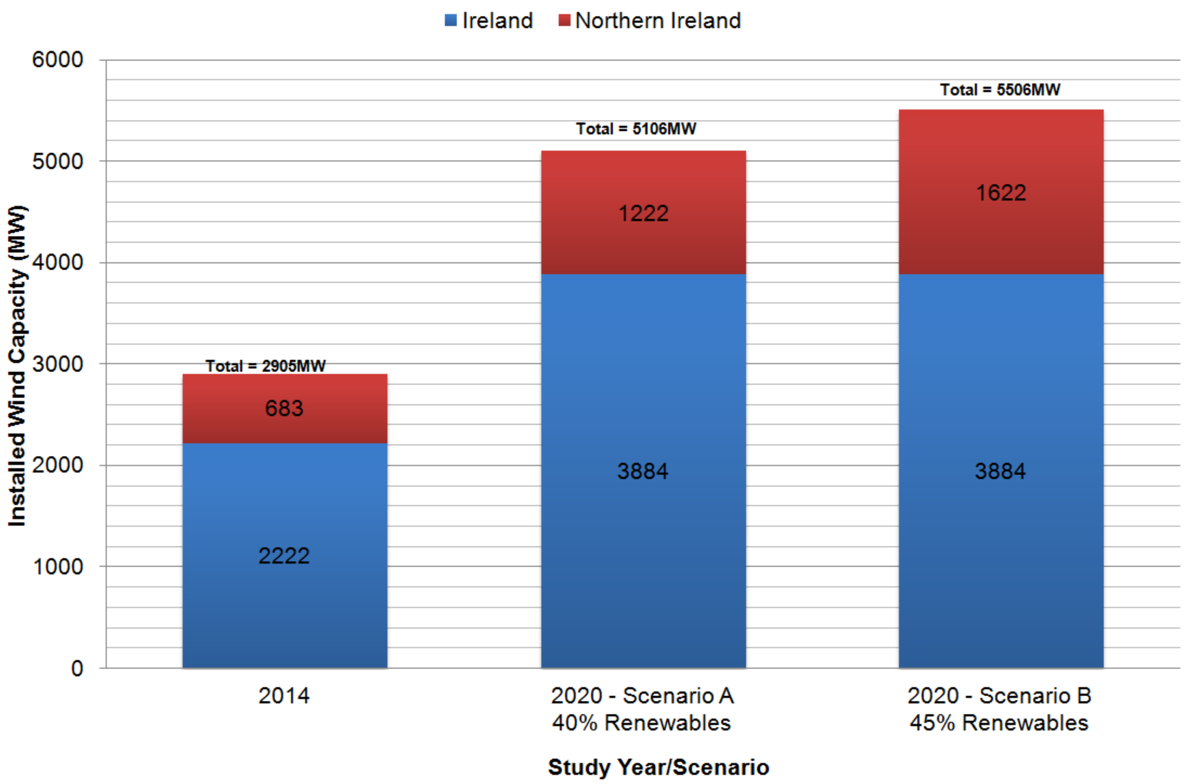

Figure 24: *Installed wind capacity assumptions for 2014 and 2020*

For each study year, generators with an estimated connection date on or before September 30th of the study year were included in the analysis from the start of that year. Generators with an estimated shallow connection date between October 1st and December 31st were added to the model at the start of the subsequent study year.

For onshore wind generation in NI, only one generation build out rate is assumed in this study. It is based on a "best estimate" approach where SONI use the latest generator connection information from NIE to determine the likely generation to connect during each study year. SONI also take into consideration renewable energy targets for 2020, hence the onshore wind installed by 2020 should allow these renewable energy targets to be met. A complete list of NI wind generation connection assumptions on a nodal basis for each study year is provided in Appendix B.

For offshore wind generation in NI, two build out rates are assumed in this study. Scenario A assumes that the capacity of offshore wind generation connected will allow 2020 renewable targets to be met (40% renewable generation by 2020). Scenario B assumes that 100% of the expected capacity of offshore wind generation will connect by 2020 and therefore exceed renewable energy targets (45% renewable generation by 2020).

Year	Scenario	Capacity (MW)
2020	A – 40% Renewables	200
2020	B – 45% Renewables	600

Table 29: *NI offshore wind generation assumptions*

For IE, only one wind generation build out rate has been employed. The installed wind capacity for Ireland is based on build out Scenario 2 employed in the Gate 3 Constraints Reports[9] which assumes 33% uptake of Gate 3 applicants in 2014 and 2020 which is sufficient to meet the 40% renewable targets by 2020.

A.1.2. TIDAL GENERATION

Table 30 shows the build out rate for tidal generation off the North coast of NI. For tidal generation in NI, two build out rates are assumed in this study. Scenario A assumes that the capacity of tidal generation connected will allow 2020 renewable targets to be met (40% renewable generation by 2020). Scenario B assumes that 100% of the expected capacity of tidal generation will connect by 2020 and therefore exceed renewable energy targets (45% renewable generation by 2020).

Year	Scenario	Capacity (MW)
2020	A – 40% Renewables	160
2020	B – 45% Renewables	200

Table 30: *NI tidal generation assumptions*

A.1.3. CONVENTIONAL GENERATION

The portfolio of thermal conventional generation in both Ireland and Northern Ireland included in the All Island model was taken from the SEM Generator Dataset 2011/2012 published by the Regulatory Authorities on the All Island Project website.[10]

The operating characteristics of the existing conventional generation employed in the modelling were principally based on this SEM Generator Dataset. This data provided information such as minimum and maximum operating levels, capacity states, heat rates, ramp rates, fuel type, and minimum up/down times for each conventional generator which were all fed into the model. In some instances, minor changes to the dataset were made due to additional information becoming available to the TSOs. The reserve response capability of units was based on information available from the Operations departments in EirGrid and SONI.

With the exception of the Endesa Great Island CCGT and Derrycarney CCGT for which a set of characteristics were submitted by the project developers, there was no definitive set of operating characteristics available for the other Gate 3 conventional generators in IE. Hence, for these generators, the operating characteristics were derived from characteristics of similarly sized units or similar unit types.

---

[9] Additional information on Scenario 2 can be found in EirGrid's Gate 3 Constraint Reports

[10] www.allislandproject.org

A.1.3.1. CONVENTIONAL GENERATOR RETIREMENT

Table 31 shows conventional generation in NI that is due to be decommissioned during the study period.

Generating Unit	MEC (MW)	Decommission Date
Ballylumford ST4	170	31-Dec-2015
Ballylumford ST5	170	31-Dec-2015
Ballylumford ST6	170	31-Dec-2015

Table 31: *NI Conventional units due to be decommissioned during study period*

Table 32 shows conventional generation in IE that is due to be decommissioned during the study period.

Generating Unit	MEC (MW)	Decommission Date
Great Island 1	54	31-Dec-2013
Great Island 2	49	31-Dec-2013
Great Island 3	113	31-Dec-2013
Tarbert 1	54	31-Dec-2020
Tarbert 2	54	31-Dec-2020
Tarbert 3	240	31-Dec-2020
Tarbert 4	240	31-Dec-2020

Table 32: *IE Conventional units due to be decommissioned during study period*

There is speculation that some additional older plant may retire during the study period but since no official data has been received to confirm this, it is assumed that all other units continue to operate for the duration of the study.

A.1.3.2. CONVENTIONAL GENERATOR COMMISSIONING

For NI it is assumed that there are no new conventional units to be commissioned during the study period.

Table 33 shows conventional generation in IE that is due to be commissioned during the study period.

Unit	Capacity (MW)	Commissioning Date
Ballakelly	445	01/01/2016
Caulstown	58	01/05/2014
Derrycarney	297	01/01/2018
Cahernagh	100	01/01/2018
Rallapane	40	01/01/2016
Ballymakaily	116	01/01/2016
Great Island CCGT	431	01/01/2014
Nore OCGT	98	01/01/2016
Suir OCGT	98	01/01/2017
Cuileen OCGT	98	01/01/2017

Table 33: *IE Conventional units due to be commissioned during study period*

A.1.3.3. CONVENTIONAL GENERATION OUTAGES

Scheduled and forced conventional generator outages are modelled in PROMOD IV using Scheduled Outage Durations (SODs) and Forced Outage Probabilities (FOPs).

For NI, the SODs were provided by the SONI Near Time department. These are based on information from generators on expected outage dates for maintenance. The FOPs employed for NI were based on the high FOP scenario for NI generators used in the All Island Generation Capacity Statement 2012-2021.

For Ireland, the SODs and FOPs employed were the 'Median' values provided by the generators for the preparation of the Generation Capacity Statement 2012-2021.

A.1.3.4. CONVENTIONAL GENERATION EMISSION LIMITS

For the purposes of this GOR study, it has been assumed that for 2020, the coal units at Kilroot (K1 and K2) will have to comply with Industrial Emissions Directive (IED) from the European Commission. This affects the annual NOX emission limits for these units and has been modelled as a cap on their annual energy output to an estimated value agreed with AES Kilroot.

A.1.4. STORAGE UNITS

Currently in NI there are no storage units connected to the system. Although it is anticipated that a Compressed Air Energy Storage Unit (CAES) will be operating on the NI system by 2020, it has not been taken into account in this study.

In Ireland the existing 292MW Turlough Hill plant is assumed to be fully operational from the beginning of the first study year. In addition there is still a live offer for the Knocknagreenan pumped storage project in the Southwest so this has also been included in the study.

Pumped Storage Plant	Minimum Capacity (MW)	Maximum Capacity (MW)	Reservoir Storage Capacity (MWh)	Round-Trip Efficiency (%)
Turlough Hill	5	292	1508	70
Knocknagreenan	5	73	377	70

Table 34: *Pumped storage plant characteristics for the constraints modelling*

A.1.5. SMALL SCALE GENERATION

In the constraints model, Small Scale Generation (SSG) refers to small non-dispatchable, embedded Biomass, Biogas, Landfill Gas (LFG), Hydro, Tidal, Industrial (diesel generators) and Combined Heat and Power (CHP) generation. These types of generators typically have small installed capacities and are therefore often modelled collectively as fixed profiles. As these units are non-dispatchable, they were assigned hourly generation profiles and modelled as load modifier transactions in PROMOD IV and netted off the hourly demand profile.

Small scale generation in NI includes Biomass, Biogas, LFG, Hydro, Tidal and CHP units.

The small scale generation profiles were created from 2011 metered generator data (on a sent out basis) from NIE. The total MEC of small scale non-dispatchable generation modelled is shown in Table 35. The profiles for these small scale units are grouped according to the generation type and are fixed for each study year.

Small scale wind generation in NI has not been explicitly modelled. Small scale wind accounts for around 20MW in NI and has not been accounted for in the models due to some difficulty in mapping small wind generators to transmission nodes. This may be represented in future models.

Although connected at distribution level, these small scale units have been modelled as connected to the transmission system, with each unit being assigned to an 110kV node.

Small Scale Generation	Capacity (MW)	
	2014	2020
Biomass and Biogas	2	2
LFG	14	25
CHP	4	11
Hydro	4	4
Tidal	1	1
Industrial	0	4
Other	6.3	6.3
Total MEC (MW)	**31.3**	**47.3**

Table 35: *NI small scale generation*

SSG in Ireland includes Biomass, Hydro, CHP and industrial units. Table 36 details the assumed levels of installed pre-Gate 3, non-wind small-scale generation included in the constraints model. The non-wind small-scale generation capacities employed are consistent with the capacities assumed to be installed at the end of 2011 in the Generation Capacity Statement 2012-2021. The profiles were based on the historical capacity factors observed by these types of generators on the Irish system. A simple profile was generated based on this information and scaled up to the assumed installed capacity of the generation type for a given year.

Small-Scale Generation	Pre-Gate 3 Installed Capacity (MW)
Hydro	21
Biomass	56
CHP	141
Industrial	9
Total MEC (MW)	227

Table 36: *Pre-Gate 3 non-wind SSG*

A.1.6. BIOMASS PLANTS

There are two new 15MW biomass plants included for year 2020. These are modelled as dispatchable plant similar to other priority dispatch plant on the system.

Unit	Capacity (MW)	Commissioning Date
Maydown Biomass	15	Winter 2015/16
Belfast North Biomass	15	Winter 2017/18

Table 37: *NI Biomass generation*

A.1.7. WASTE TO ENERGY PLANTS

There are no waste-to-energy plants modelled in NI. There are two waste-to-energy plants in IE modelled in the study. These plants are assumed to have priority dispatch since some of the waste input is classified as being renewable. The details of the plants are as follows.

Unit	Export Capacity (MW)	Node	Commissioning Date
Indaver Waste	15	Drybridge 110kV	Already energised
Poolbeg Waste	62	Ringsend 110kV	01/12/2015

Table 38: *Waste-to-Energy plants*

A.1.8. NON-GPA GENERATION IN IRELAND

The term Non Group Processing Approach (Non-GPA) refers to small, renewable and/or low carbon generators that fulfil public interest criteria and are therefore deemed eligible by the Commission for Energy Regulation (CER) for processing outside of the Group Processing Approach. The CER approved the following classes of technology for processing outside the group processing approach: Bioenergy, CHP, Autoproducers, Hydro, Ocean, Wave, Solar, Geothermal, Experimental/Emerging Technology (see the CER decision paper CER/09/099 for more information).

In cases where the non-GPA projects were greater than 5MW it was assumed that they were dispatchable and grid code compliant in regards minimum generation levels etc. Smaller projects were assumed to have fixed profiles based on their technology type. These profiles would have been based on the same data used to construct the SSG profiles.

The non-GPA projects that were modelled by EirGrid's Transmission Access Planning (TAP) department as part of the Gate 3 Incremental Transfer Capability (ITC) study were included in the model.

A.2. DEMAND

A.2.1. PEAK DEMAND AND ENERGY FORECAST

The future study year demand profiles for both Ireland and Northern Ireland were created using the Median Electricity Demand Forecast presented in Appendix A of the "All Island Generation Capacity Statement 2012-2021". Table 39 shows the annual Total Energy Requirement (TER) peak and energy for the study years 2014 and 2020.

Year	Ireland		Northern Ireland	
	TER (GWh)	TER Peak (MW)	TER (GWh)	TER Peak (MW)
2014	28,359	4,931	9,617	1,871
2020	30,668	5,290	10,508	2,040

Table 39: *Summary of the IE and NI TER peak and energy demand assumptions*[11]

A.2.2. DEMAND PROFILE

The hourly system demand profiles employed for each study year for both Ireland and Northern Ireland were based on the historical demand profile for 2011.

The demand profile for NI was created from 2011 metered generator data (on an export only basis) and does not include small scale generation as this data was unavailable at the time of data collection. The metered data was recorded in 30 minute intervals. The data was translated into an hourly profile by selecting every other data record with the aim of trying to preserve peaks and troughs in energy consumption.

The system demand for IE and NI at each hour of the study years 2014 and 2020 was produced by scaling the 2011 historical hourly demand profiles such that the annual TER peak and energy for each future study year were as shown in Table 39.

A.2.3. LOAD DISTRIBUTION

In NI, the load distribution is consistent with the winter peak cases employed in the "Ten Year Transmission Forecast Statement 2013-2023". There are no industrial loads modelled in NI.

In IE the load distribution was based on data used in the Gate 3 Incremental Transfer Capability (ITC) studies by EirGrid's Transmission Access Planning (TAP) department. Industrial loads in Ireland are constant and also taken from the same winter peak case.

[11] *Note this is for a 52 week year i.e. 364 days; values in the model are scaled up to full year values*

A.3. FUEL AND CARBON PRICES

As PROMOD IV operates with commitment and dispatch strategy to provide the most economic solution while satisfying all transmission system constraints, the fuel and carbon prices employed in the model are critical to the decision as to which generators are committed and dispatched. This in turn has a resulting impact on both curtailment and transmission constraint levels experienced by generators.

The coal, gas and carbon prices are based on the International Energy Association (IEA) World Energy Outlook (WEO) 2012. The prices for LSFO, DO and peat are based on information provided to the TSOs from third party organisations.

Fuel Type	Price
Gas	10.10 €/net GJ
Coal	3.59 €/net GJ
Low Sulphur Fuel Oil (LSFO)	13.21 €/net GJ
Distillate Oil (DO)	21.66 €/net GJ
Peat	3.18 €/net GJ
CO2	25 €/tCO2

Table 40: *Fuel prices employed*

The fuel and carbon prices were kept constant for each study year covered by the GOR studies.

The monthly price variations of gas are accounted for by using a historical monthly gas profile while keeping the gas price shown in Table 40 as the time-weighted average.

The PROMOD IV modelling tool factors in the cost of CO2 emissions when committing and dispatching generators.

Edenderry Peat plant's Public Service Obligation (PSO) expires in 2015. From 2016 onwards it is assumed that it will operate based on economic dispatch. Lough Ree and West Offaly Power have PSOs that are valid until 31/12/2019. From 2020 onwards it is assumed that they will also operate based on economic dispatch.

Dublin Bay has a long term fuel contract and is allowed to bid in lower costs to the SEM on account of this. For the purposes of this constraints modelling exercise, it is assumed that Dublin Bay's gas price is 65% of the gas price of other units. The unit will use the same fuel price as other units from 2018 onwards. This will more accurately reflect the merit order but it is not expected to have a large impact on constraints or curtailment.

A.4. INTERCONNECTION

Interconnection on the island consists of a tie line between Ireland and Northern Ireland plus two High Voltage Direct Current (HVDC) interconnectors to GB referred to as the Moyle Interconnector and the EWIC. This section describes the assumptions and modelling methodology employed in the GOR studies.

A.4.1. NORTH-SOUTH TIE LINE

Ireland's electricity grid is connected to Northern Ireland via a double circuit 275kV line running from Louth to Tandragee. In addition to the main 275kV double circuit, there are two 110kV connections, one between Letterkenny in Co. Donegal and Strabane in Co. Tyrone, and the other between Corraclassy in Co. Cavan and Enniskillen in Co. Fermanagh. The purpose of these 110kV circuits is to provide support to either transmission system for certain conditions or in the event of an unexpected circuit outage. Phase shifting transformers in Strabane and Enniskillen are used to control the power flow under normal conditions.

EirGrid and NIE are currently developing a 400kV North-South Interconnector between Meath and Turleenan in Co. Tyrone, which for the purposes of these studies is assumed to connect in 2017.

Table 41 details the modelling assumptions employed with respect to North-South Interconnection power flows for the constraints model.

North-South Tie-Line Power Flow Assumptions
• Prior to the Meath-Tyrone 400kV Interconnection Development being built, the Louth-Tandragee Interconnector is assumed to be limited to flows of 200MW from South to North and 300MW from North to South. • When the Meath-Tyrone 400kV Interconnection Development is in place, this limitation is removed. • It is assumed that the Letterkenny-Strabane and Corraclassy-Enniskillen 110kV connections are not used to transfer power between the two control areas for the purposes of this constraints modelling exercise.

Table 41: *North-South tie-line power flow assumptions*

A.4.2. MOYLE

The Moyle Interconnector, which went into commercial operation in 2002, connects the electricity grids of NI and GB between Ballylumford and Auchencrosh in Scotland. It has a capacity of 500MW and but is currently limited to 250MW flow in either direction due to one of the cables being unavailable. Given the uncertainty around the timelines for repairing of the second cable it is assumed that the export capacity of Moyle stays at 250MW up until 2016.

In 2017 the export capacity from Northern Ireland to Scotland is reduced to 80MW for the duration of the study due to network limitations in GB. The import capacity remains at 250MW but this will not affect the modelling as imports are not modelled in this study.

A.4.3. EWIC

It is assumed that EWIC is modelled for all study years with a maximum export capacity of 530MW. The extra 30MW are to account for losses in the converter stations and on the cable.

A.4.4. INTERCONNECTOR MODELLING

For modelling purposes it is assumed that the export capacity of each interconnector is de-rated by 20% to account for trading imperfections etc. In other words the maximum export possible for the purposes of this modelling is 424MW on EWIC and 200/64MW on Moyle.

For all scenarios, Moyle and EWIC were allowed to export wind that would otherwise have been curtailed. There is an underlying assumption that GB does not have an excess of wind generation or transmission limitations at the same time and that it is capable of accepting the excess wind generation. Also note that for this study, the focus is on the generation output of wind farms and not on the production costs or market modelling.

A.5. OPERATIONAL RULES

This section outlines the operational rules employed in the constraints modelling. The operational rules cover System Non-Synchronous Penetration (SNSP), operational reserve requirements and minimum synchronous generation levels.

A.5.1. SYSTEM NON-SYNCHRONOUS PENETRATION

There is a requirement to limit the instantaneous penetration of asynchronous generation connected to the All Island system to ensure adequate frequency performance and dynamic stability. The following rule was implemented in the constraint model:

$$SNSP\ Limit \geq \frac{All\ Island\ Wind\ Generation + Interconnector\ Imports}{All\ Island\ Demand + Interconnector\ Exports}$$

Figure 25 shows the SNSP limits assumed for the study period. As can be seen, a limit of 50% is assumed for 2010 rising to 75% in 2019. The limit of 75% is maintained for all study years post 2019. Please note that there are risks associated with delivering these SNSP increases and this timeline is for GOR modelling purposed only. Further information is available from the DS3 work stream[12].

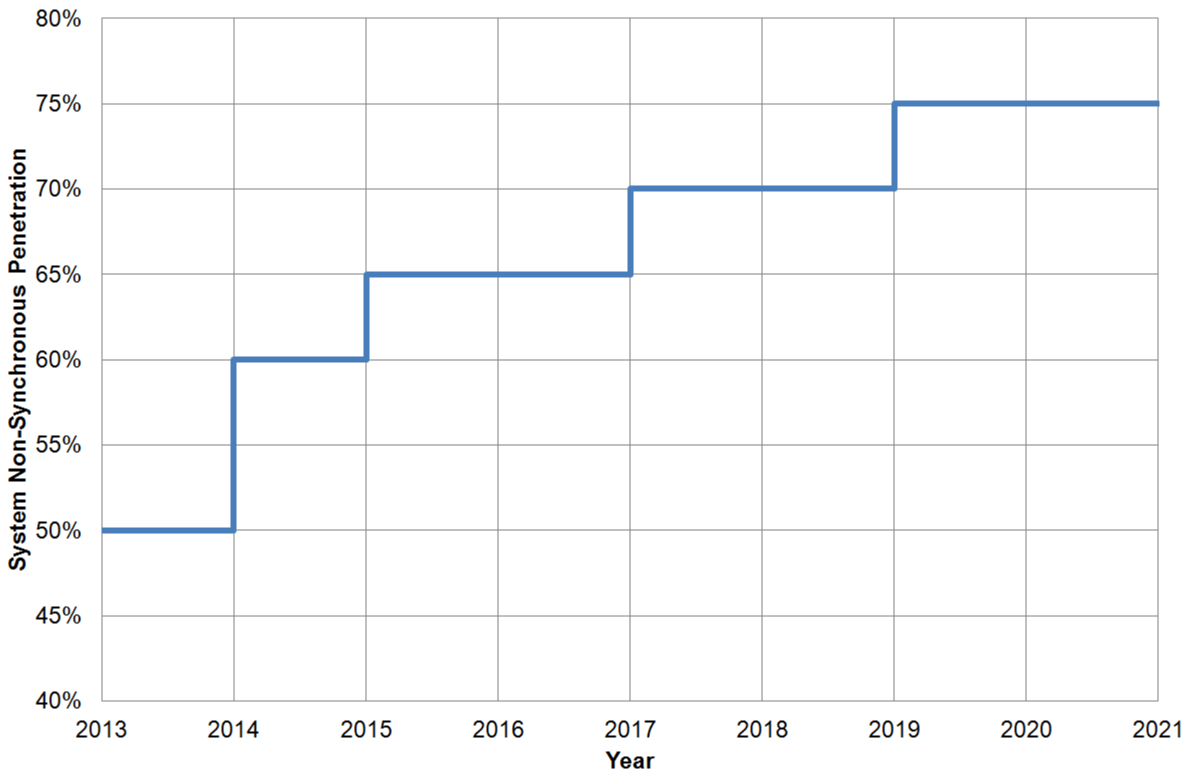

Figure 25: *Limits on the instantaneous asynchronous generation for constraints modelling*

[12] www.eirgrid.com

A.5.2. OPERATIONAL RESERVE REQUIREMENTS

In order to cater for the sudden loss of a large generator or the unexpected rapid reduction in wind generation, operating reserves are carried on conventional generators so that they can quickly increase their output to replace the lost generation and mitigate the risk of load shedding. To provide reserve, some generators are part-loaded i.e. are operated below their maximum output capability to provide a quick acting source of reserve.

The working assumption will be that enough Primary Operating Reserve (POR) will be provided to cover 75% of the loss of the largest infeed. In practice this varies in proportion to the largest infeed by output. For the purposes of modelling, a simplified assumption was made with regards to the largest infeed during day time and at night time. The reserve requirement was then calculated from this assumed largest infeed. Only POR will be modelled as it is assumed to be the most binding reserve constraint.

Negative reserve was modelled by assuming that some units were not dispatched all the way to their minimum generation at times of high wind. This type of reserve is modelled to simulate an ability to maintain frequency control should there be an unexpected increase in generation or decrease in demand which would cause the frequency to rise.

Operating Reserve Assumptions
• The total All Island reserve requirement is assumed to be equal to 75% of the capacity of the largest unit on the system. • This assumes that the 500MW East-West Interconnector is not the largest in-feed because imports are not modelled for the GOR analysis. • 0.75*445MW = 333.75MW (daytime) • 0.75*400MW = 300MW (weekend daytime) • 0.75*300MW = 225MW (night time) • It is assumed that wind is not curtailed to provide reserve. • A total reserve figure of 100MW is assumed to be provided by the Moyle and EWIC. • It is assumed that the Short Term Active Response (STAR) scheme provides 45MW of reserve between 7am and Midnight. • It is assumed that in pumping mode, pumped storage units provide reserve equal to 100% of their MW pumping value. • Each jurisdiction carries a minimum POR before the second NS is in place. Ireland carries 150MW and NI carries 50MW. After the second North-South is in place the All Island reserve requirement is optimised over all generators on the island i.e. no jurisdictional requirements. • Some of the reserve requirement is met by static reserve sources with the remainder being provided by spinning reserve sources. For Ireland, the spinning reserve requirement is 75MW when Turlough Hill is pumping between Midnight and 7am and rises to 105MW during the day when 45MW is assumed to come from STAR. NI is assumed to have a constant 50MW spinning reserve requirement for these studies.

Table 42: *Operating reserve assumptions*

A.5.3. MINIMUM SYNCHRONOUS GENERATION REQUIREMENT

There is a requirement to have a minimum number of conventional generators synchronised at all times to provide inertia to the power system, ensure voltage stability and to ensure that network limitations (line loading and system voltages) are respected.

Table 43 details the assumptions employed with respect to the minimum conventional generation requirements for the constraints modelling.

Minimum Conventional Generation Assumptions[13]		
Ireland	Ensure that at least two large thermal units in the Dublin region are synchronised at all times.	Start – 2016 inclusive
	Ensure at least 5 large units are synchronised at all times (proxy for inertia constraints). In addition, the peat plants and Sealrock are also must run subject to conditions described later.	All years
	Ensure at least one unit from WG1, AD1, AD2, AT1, AT2, AT4, MRT or Great Island CCGT is synchronised during weekdays (defined in the model as 7am to midnight)	Start – 2018 inclusive
	The Edenderry peat plant is a priority dispatch.	Start – 2015 inclusive
	The West Offaly and Lough Ree peat plants are priority dispatch.	Start – 2019 inclusive
	The two Sealrock units are priority dispatch.	All years
	Other priority dispatch plant greater than 5MW MEC were modelled as per the hierarchy in SEM-11-062	All years
	Assume that 3 pump sets are on during the night	All years
Northern Ireland	Minimum of 3 conventional units must be synchronised at all times. Any 3 of B4, B5, B6, B10, B31, B32, C30, K1 or K2	Start – 2016 inclusive
	The requirement for a minimum of 3 conventional units to be synchronised at all times is assumed to reduce to 2 units with the 400kV North-South Interconnecting tie-line. The units that are dispatched are: Any 2 of B10, B31, B32, C30, K1 or K2	2017 onwards

Table 43: *Minimum conventional generation requirement assumptions*

[13] The reduction in the minimum conventional generation requirement over the period of the study assumes that the appropriate capital projects required to manage reactive power can be delivered

A.6. TRANSMISSION NETWORK

The transmission network in Northern Ireland was based on SONI's latest network assumptions and All Island models used in EirGrid's Gate 3 Constraints Reports were updated accordingly. The transmission network in Ireland was modelled using the same transmission network that was used in the Gate 3 Constraints Reports. This section details modelling assumptions associated with the transmission network.

A.6.1. DERATING FROM MVA TO MW

PROMOD IV is a DC load flow simulation tool and is only concerned with active power flows. Transmission plant and line ratings, normally defined in terms of MVA, were converted to MW ratings using an assumed power factor of 0.9 in IE and 0.95 in NI.

A.6.2. OVERHEAD LINE, CABLE AND TRANSFORMER OVERLOAD RATINGS

In formulating an optimum dispatch PROMOD IV takes account of potential overloads that could be caused as a result of certain N-1 contingencies on the transmission system. When determining if the post-contingency flows are within limits, the program uses the overload rating of the apparatus or plant, where specified, instead of the normal rating. The overload rating is typically higher than the normal rating but is only allowed in emergency conditions and for short periods of time. The overload rating is plant specific.

In NI, emergency overload ratings are specified transformers, but not for overhead lines.

A.6.3. TRANSMISSION SYSTEM OUTAGES

The constraint modelling will not take account of scheduled transmission outages except for outages associated with new build and upgrades in Ireland and Northern Ireland. These outage durations will be based on time estimates available at the commencement of the study.

A.6.4. DISTRIBUTION SYSTEM

For the purposes of the constraints modelling, a simplified model of the distribution system was used. All load and generation was assumed to be aggregated to the nearest transmission node. It was checked as much was reasonably possible that this did not impact on potential transmission system flows e.g. parallel paths.

A.6.5. CONTINGENCY MONITORING

A full list of N-1 contingencies will be included in the model for the loss of transmission lines and transformers. PROMOD IV will solve these contingencies and produce a dispatch that will avoid any post-fault overloads.

Some contingencies are not modelled: Dublin 110kV, couplers, tail fed stations and some contingencies that are assumed to be relieved by a Remedial Action Scheme (RAS) or Special Protection Scheme (SPS).

In NI, all 110/275kV transformers as well as all 110kV circuits are considered as N-1 all year round. 275kV double circuit contingencies are modelled such that in winter, the contingency is the loss of the double circuit and in summer is the loss of a single circuit, with the exception of the Coolkeeragh-Magherafelt 275kV double circuit, where the loss of the double circuit is considered all year round.

A.6.6. SPECIAL PROTECTION SCHEMES

The Mulreavy RAS is modelled for these studies. In modelling the post-contingency flows following the loss of either Cathaleen's Fall-Clogher 110kV line, it is assumed that the Gate 2 Mulreavy wind farm will be tripped.

In Operations, when the Coolkeeragh-Magherafelt 275kV double circuit trips, a runback scheme is operated at Coolkeeragh, whereby the CCGT can run at 160MW, 100MW below its minimum recommended operating point. This has been accounted for in post processing of the constraint results.

A.6.7. NETWORK CHANGES

To reflect the differences in constraints modelling compared to steady-state AC load flow studies. Some minor changes were made to the network data such as switching in transformers that are normally on hot standby and not splitting stations for short circuit reasons.

A.6.8. TRANSMISSION REINFORCEMENTS

A full list of transmission reinforcements in NI assumed in the GOR studies is included in Appendix C. It should be noted that the inclusion of reinforcements projects in this study is not confirmation that they will proceed. These are modelling assumptions and should not be considered as fact.

The transmission reinforcements for IE are consistent with those used in the Gate 3 Constraint Reports.

A.7. SEMC DECISIONS RELATING TO GOR

As mentioned in Section 4, the SEMC have recently published decisions relating to GOR rules. These have been implemented in the constraints modelling as accurately as possible. They are summarised as follows:

- In the event of a simultaneous constraint and curtailment, GOR to relieve the constraint is applied before GOR to relieve curtailment
- Constraint groups are modelled in Donegal and the South-West of Ireland (when it comes into effect)
- GOR to relieve a constraint (outside of constraint groups) is achieved by reducing the output of the generator(s) which have the greatest effect in alleviating the constraint. In the event of a tie-break situation where a group of generators have a similar effect in alleviating the constraint, GOR is applied on a pro-rata basis
- GOR to relieve a constraint associated with a constraint group is achieved by reducing the output of the generators on a grand-fathered basis, i.e. generation is reduced in the order of non-firm, followed by partially firm and finally firm
- Modelling SO-SO counter trading as part of the priority dispatch rules, it is assumed that during a curtailment event, the Moyle and EWIC interconnectors are used to export excess generation to GB before reducing wind generation on the island

Appendix B. NI WIND BUILD OUT RATE

Node	Installed Capacity (MW)					
	2014			2020 (Scenarios A and B)		
	Total	Controllable	Uncontrollable	Total	Controllable	Uncontrollable
Aghyoule	**68**	54	14	**68**	54	14
Antrim	**0**	0	0	**2**	0	2
Ballymena	**11**	6	5	**11**	6	5
Brockaghboy	**0**	0	0	**66**	66	0
Carnmoney	**14**	14	0	**14**	14	0
Coleraine	**108**	103	5	**108**	103	5
Drumnakelly	**0**	0	0	**3**	0	3
Drumquin	**0**	0	0	**82**	82	0
Dungannon	**18**	18	0	**18**	18	0
Eden	**3**	0	3	**3**	0	3
Enniskillen	**17**	17	0	**20**	17	3
Gort	**0**	0	0	**87**	87	0
Killymallaght	**21**	21	0	**21**	21	0
Larne	**15**	10	5	**15**	10	5
Limavady	**38**	12	26	**50**	24	26
Lisaghmore	**18**	15	3	**18**	15	3
Magherakeel	**124**	124	0	**124**	124	0
Mid Antrim	**0**	0	0	**38**	35	3
Omagh	**126**	108	18	**96**	78	18
Slieve Kirk	**74**	74	0	**74**	74	0
Strabane	**28**	22	6	**28**	22	6
Tremoge	**0**	0	0	**76**	71	5
TOTAL	**683**	598	85	**1022**	921	101

Table 44: *NI onshore wind assumptions for 2014 and 2020*

Node	Installed Capacity (MW)					
	2020 (Scenario A)			2020 (Scenario B)		
	Total	Controllable	Uncontrollable	Total	Controllable	Uncontrollable
Castlereagh[6]	**200**	200	0	**600**	600	0
TOTAL	**200**	200	0	**600**	600	0

Table 45: *NI offshore wind assumptions for 2020*

Appendix C. NI NETWORK REINFORCEMENTS

Project Type	Project
Included in model from 2014	
Uprate	Coleraine – Kells 110kV circuit
Uprate	Dungannon – Omagh 110kV double circuit (circuit breaker uprate)
Included in model from 2020	
New Build	Mid-Antrim Cluster 110kV
New Build	Coleraine – Mid-Antrim 110kV circuit and Mid-Antrim – Kells 110kV circuit x 2 (Replaces Coleraine – Kells 110kV circuit)
New Build	Limavady – Brockaghboy 110kV circuit
New Build	Drumquin Cluster 110kV
New Build	Omagh South – Drumquin Cluster 110kV circuit
New Build	Gort Cluster 110kV
New Build	Omagh – Gort 110kV circuit
New Build	Gort – Tamnamore 110kV circuit
New Build	Tremoge Cluster 110kV
New Build	Omagh – Tremoge 110kV circuit
New Build	Tremoge – Tamnamore 110kV circuit
New Build	Coleraine – North Antrim 110kV double circuit
New Build	Kells – North Antrim 110kV double circuit
New Build	North Antrim - Fairhead 110kV circuit
New Build	North Antrim - Torrhead 110kV circuit
New Build	Castlereagh – South Down 275kV double circuit
New Build	Belfast North 110kV station, replacing Power Station West
New Build	Airport Road 110kV station
New Build	Castlereagh – Airport Road 110kV double circuit
New Build	1 x 3-winding 110/275kV interbus transformer at Castlereagh (making 4 in total)
New Build	Turleenan 275kV and 380kV stations
New Build	3 x 3-winding 275/380kV interbus transformers at Turleenan
New Build	1 x Turleenan – Woodland 380kV circuit
New Build	Tandragee – Turleenan 275kV double circuit
New Build	Tamnamore – Turleenan 275kV double circuit
New Build	Omagh South – Turleenan 275kV single circuit
New Build	Omagh South 110kV and 275kV stations
New Build	2 x 3-winding 110/275kV interbus transformers at Omagh South
New Build	Omagh South – Enniskillen 110kV double circuit (replacing Omagh – Enniskillen 110kV double circuit)
New Build	Omagh – Omagh South 110kV double circuit
New Build	1 x 3-winding 110/275kV interbus transformer added at Tamnamore (making 2 in total)
Uprate	1 x Dungannon – Omagh 110kV circuit
New Build	2 x Dungannon – Tamnamore 110kV circuits
New Build	Drumnakelly – Tamnamore 110kV double circuit (replaces Drumnakelly – Dungannon 110kV double circuit)
New Build	Magherafelt – Tamnamore 275kV circuit (making 2 in total, with Magherafelt – Tandragee 275kV circuit removed)
New Build	Creagh – Tamnamore 110kV circuit (replaces existing Creagh – Dungannon 110kV circuit
Uprate	Coolkeeragh – Magherafelt 275kV double circuit
Uprate	Coleraine – Coolkeeragh 110kV circuit

Project Type	Project (continued)
Included in model from 2020	
Uprate	Coleraine – Limavady 110kV circuit
Uprate	Coolkeeragh – Limavady 110kV circuit
Uprate	Hannahstown – Lisburn 110kV double circuit

Table 46: *NI Network Reinforcement assumptions for 2014 and 2020*

Appendix D. KEY TERMS

The following key terms in relation to GOR are described below:

A **constraint** is defined as generator output reduction to alleviate transmission network congestion. A constraint can usually only be resolved by reducing the output of one or a small group of generator.

A **curtailment** is defined as generator output reduction for system integrity purposes, such as maximum non-synchronous penetration, system reserve etc. A curtailment can usually be resolved by reducing the output of any generator.

A **tie-break** situation occurs when a number of equally priced generators exhibit a similar impact on alleviating a system security issue.

Firm Access Quantity (FAQ) is defined as the network capacity available to facilitate generator output export under an N-1 contingency.