Forecast Imperfections Revenue Requirement

For Tariff Year 2016/17

12/05/2016

EIRGRID SONI

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Executive Summary

This year's submission by the Transmission System Operators (TSOs) represents the forecast component of the Imperfections Revenue Requirement. The purpose of the Imperfections Charge is to recover the anticipated Dispatch Balancing Costs (less Other System Charges), Make Whole Payments, any net imbalance between Energy Payments and Energy Charges and Capacity Payments and Capacity Charges over the year, with adjustments for previous years as appropriate. Adjustments for previous years are not included in this submission, but are considered in setting the Imperfections Charge.

The forecast of the Imperfections revenue requirement is €146.8 million in nominal terms for the 12 month period from 01/10/2016 to 30/09/2017. The forecast for previous tariff year (2015/16) was €170.7 million.

Constraint costs represent the largest proportion of the Imperfections Revenue Requirement and this paper describes the methodology employed in the forecasting process. Constraints are a feature of the Single Electricity Market (SEM) and are recognised as part of the SEM High Level Design.

This year there are a number of key factors which have influenced the forecast:

- Lower levels of forecasted interconnector imports during the day and higher exports during the night contribute to a reduction in forecast constraint costs;
- A significant decrease in forecast fuel prices leads to a reduction in forecast constraint costs;
- An increase in wind generation relative to overall demand contributes to an increase in forecast constraint costs; and
- There is a significant programme of capital works, which involve transmission outages on the transmission system scheduled for the 2016/17 tariff year which results in an increase in forecast constraint costs.

This forecast of the Imperfections revenue requirement is based on a number of assumptions and expected conditions for the tariff year 2016/17. However, the Transmission System Operators have also outlined risk factors which relate to events that could have a major impact on constraint costs for the year were they to occur.

1. Introduction

This submission to the Commission for Energy Regulation (CER) & the Utility Regulator for Northern Ireland (UREGNI), collectively known as the Regulatory Authorities (RAs), has been prepared by EirGrid and SONI in their roles as the Transmission System Operators (TSOs) for the island of Ireland.

The submission reflects the TSOs' forecast of expected Imperfections revenue required for the 12 month period from 01/10/2016 to 30/09/17 inclusive, referred to as the tariff year 2016/17. The primary component of the Imperfections revenue requirement is Dispatch Balancing Costs (DBC). DBC refers to the sum of Constraint Payments, Uninstructed Imbalance Payments and Testing Charges.

In addition to DBC, the Imperfections revenue requirement also includes a forecast of Energy Imbalances, Make Whole Payments and Other System Charges for the tariff year 2016/17.

This Imperfections revenue requirement is a major element in determining the Imperfections Charge. However, other elements also contribute to setting this charge, including the Imperfections pot K factor, which adjusts for previous years as appropriate, and the forecast system demand for the tariff year. The Imperfections Charge is levied on suppliers as a per MWh charge on all energy traded through the Single Electricity Market (SEM) by the Single Electricity Market Operator (SEMO).

The TSOs' forecast for the Imperfections revenue requirement is €146.8 million in nominal terms for the tariff year 2016/17. A detailed breakdown of the forecast individual components is contained in Section 2.

This estimate of the Imperfections revenue requirement does not include any charges incurred for the holding or use of required banking standby facilities to provide working capital for the TSOs. The costs incurred as a result of holding banking standby facilities are assumed to be recoverable through the TUoS tariff and SSS tariff in Ireland and Northern Ireland under the respective regulatory arrangements pertaining.

1.1 Context for Tariff Year 2016/2017

There are a number of factors which may influence the forecast Constraint costs, and as such the forecast Imperfections revenue requirement, for the tariff year 2016/17. The most significant influencing factors are described in the following sections.

1.1.1 Participant Bids and Offers

Compared to the tariff year 2015/16 forecast, there has been a significant decrease in forecast wholesale fuel prices across the board. Figures 1-4 outline the difference in the forecast fuel prices for the 2014/15, 2015/16 and 2016/17 tariff years. These reductions, combined with interconnector flows and increasing wind generation means that the merit order has a large amount of generation available to meet demand in the unconstrained market model.

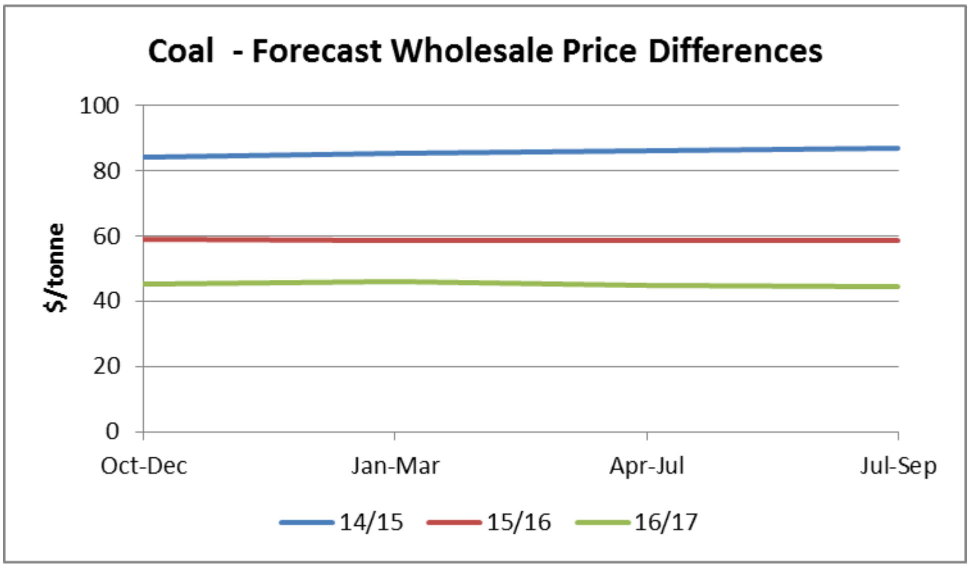

Figure 1: Forecast Wholesale Coal Prices

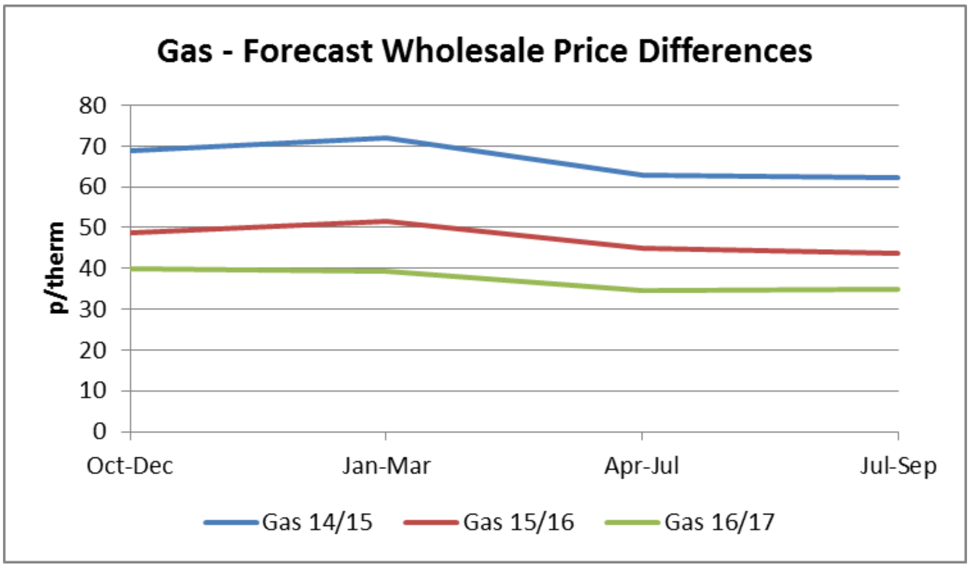

Figure 2: Forecast Wholesale Gas Prices

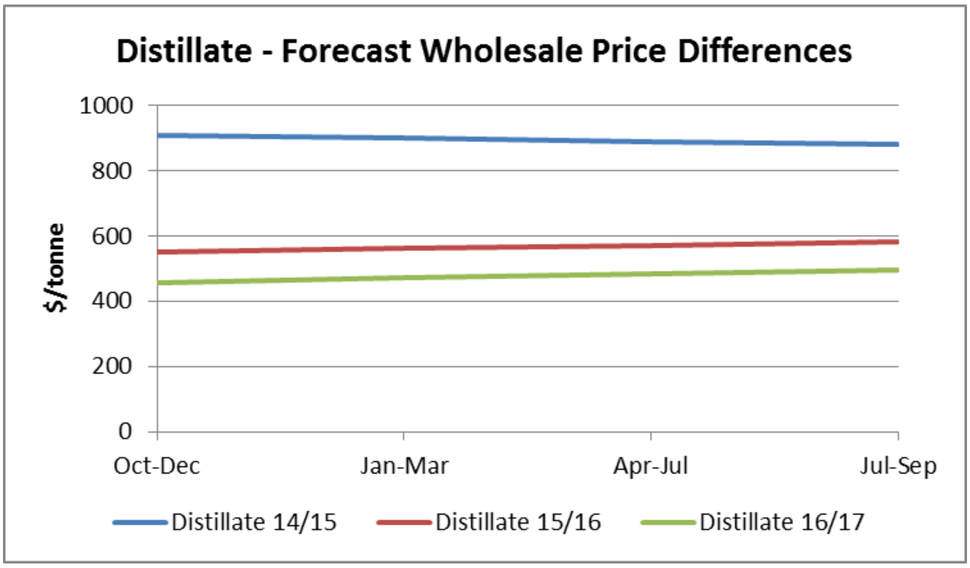

Figure 3: Forecast Wholesale Distillate Prices

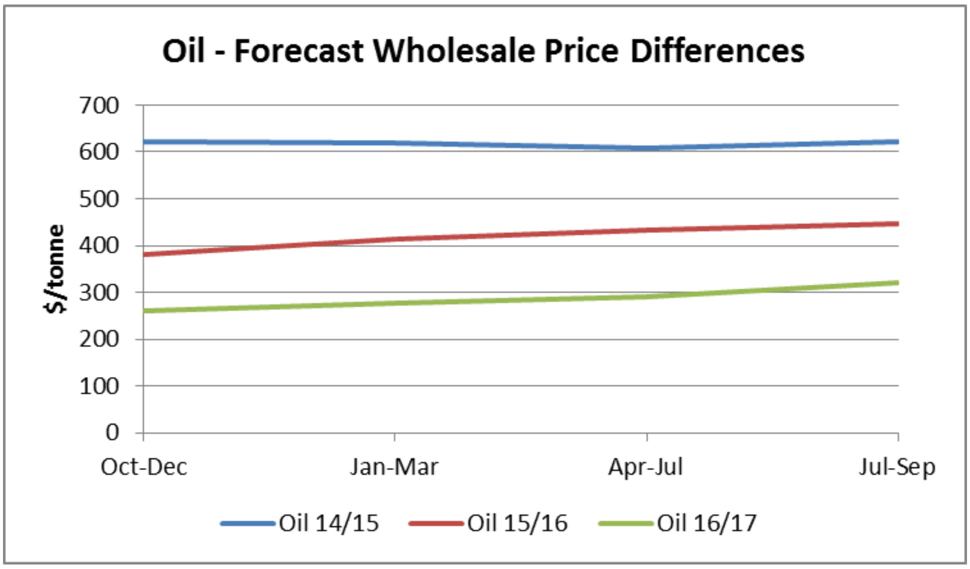

Figure 4: Forecast Wholesale Oil Prices

It has been assumed, based on historical participant bidding behaviour, that nine gas-fired generation units in Ireland are including the cost of particular gas network capacity products into their SEM offers. This increases the bid price of these units and leads to increased constraints costs where they are constrained on in dispatch to meet reserve, transmission or security constraints on the power system. For the purpose of this forecast the TSOs have assumed that the current Gas Transportation Capacity charges in Ireland remain unchanged. UREGNI have consulted on the introduction of gas entry charges[1] into Northern Ireland and what these charging arrangements may consist of. At the time of the data freeze it was unclear whether these charges would be introduced.

[1] Conclusions paper on the introduction of entry charges into the Northern Ireland postalised regime for gas; Utility Regulator; 05/02/2015

The TSOs have assumed that Gas Transportation Capacity charges in Northern Ireland will not be introduced during the 2016/17 tariff year.

1.1.2 Interconnection

Interconnector flows, on both Moyle and the East West Interconnector (EWIC), have predominantly been imports from Great Britain (GB) to SEM in recent years. On the 01/04/2015 the Carbon Price Floor in GB increased significantly, resulting in the price spread between SEM and GB narrowing significantly as seen in Figure 5. This increase in Carbon Price Floor resulted in significant exports from SEM during the night and then imports, albeit at a reduced level, to SEM during the day. There has also been an increase in the number of market participants registered to trade on both interconnectors. The result of this is that there is greater trading on both interconnectors based on price spreads and this can be clearly seen during periods of high wind in SEM. A number of different interconnector profiles have been established to reflect the different flows for weekdays, weekends, high wind periods and low wind periods. Figures 6 and 7 show the flows being used for EWIC and Moyle for the 2016/17 tariff year.

System Operator (SO) interconnector countertrading arrangements allow the TSOs, post SEM gate closure, to initiate changes to interconnector flows for reasons of system security or to facilitate priority dispatch generation, consistent with SEM-11-062. This activity is carried out in accordance with parameters approved by the RAs. The TSOs also introduced the initiative of countertrading for Reserve Co-optimisation in March 2014 to assist in the management of DBC, following a request from the RAs in 2014[2]. Priority Dispatch and Reserve Co-optimisation countertrading have been enabled in the model for EWIC, while Priority Dispatch has been enabled in the model for Moyle. The levels of import on Moyle are assumed not to be large enough to quantify this as the largest single infeed. Furthermore the TSOs need to at times countertrade due to operational export limits on EWIC, in order to maintain system security. This reduction in exports from SEM leads to a lower constrained production cost; however revenue is paid out due to the undelivered energy. The latter cost is accounted for as part of the supplementary modelling. The net result of export countertrading is an increase in DBC.

[2] http://www.eirgridgroup.com/site-files/library/EirGrid/InformationNoteExtensionofTSOcounter-tradingfacilitiesforDBCmanagement.pdf

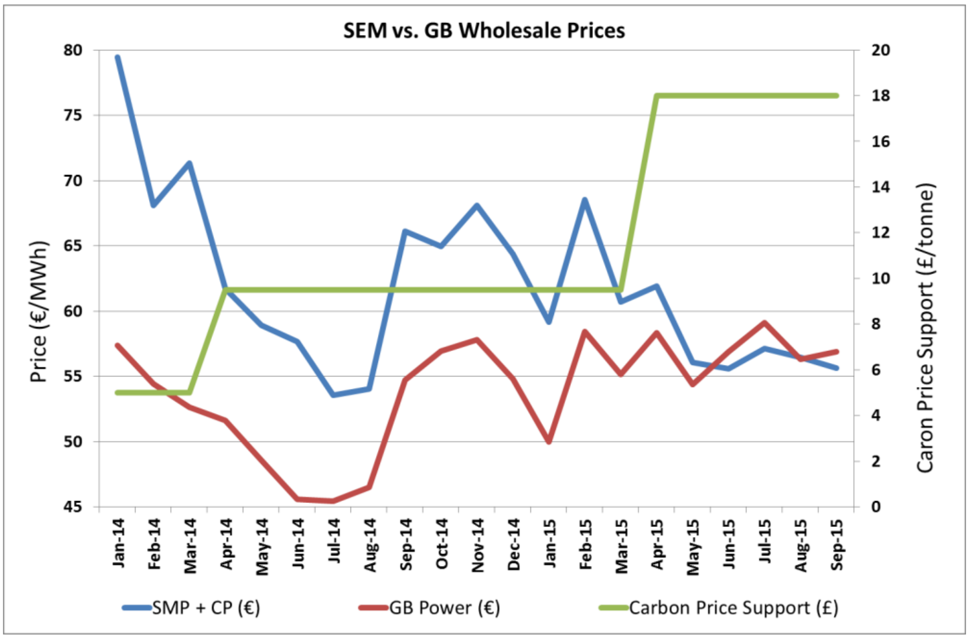

Figure 5: Price spread between SEM and GB

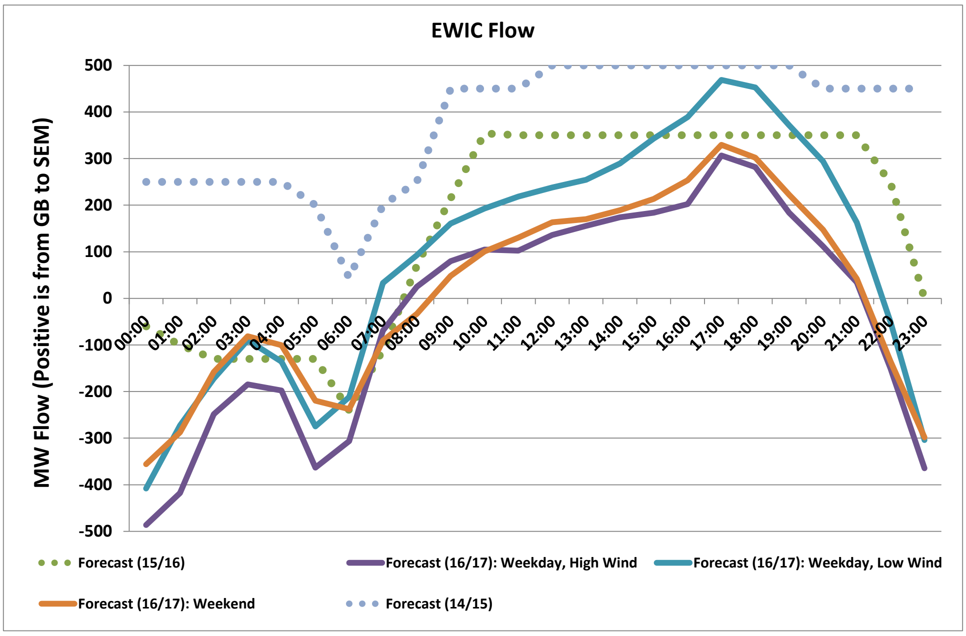

Figure 6: Average Hourly EWIC Flows

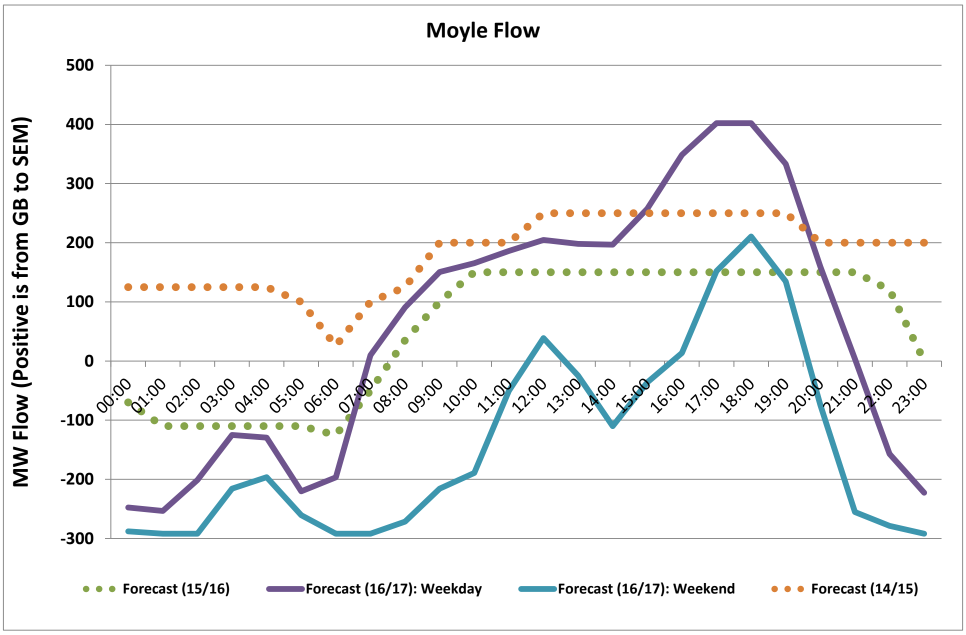

Figure 7: Average Hourly Moyle Flows

2. Results

This section contains the TSOs' forecast Imperfections revenue requirement for the tariff year 2016/17. The results of the forecast constraint costs from both the PLEXOS model and the supplementary modelling are outlined in Sections 2.1 and 2.2 respectively. A summary of how the total forecast Imperfections revenue requirement is determined is then outlined in Section 2.3.

2.1 PLEXOS Results

The forecast cost of the constraints modelled using the PLEXOS model for tariff year 2016/17 is **€125.8 million**. This PLEXOS model portion of the forecast has decreased significantly from the forecast costs of €152.4 million for the tariff year 2015/16.

The most significant influences on forecast constraint costs in the PLEXOS model are:

- Lower levels of forecasted interconnector imports during the day and higher exports during the night contribute to a reduction in forecast constraint costs, as more generating units fall into merit in the unconstrained model, therefore closing the gap between the constrained and unconstrained production costs;
- A decrease in forecast fuel prices leads to a reduction in forecast constraint costs;
- An increase in wind generation relative to overall demand contributes to an increase in forecast constraint costs; and
- An increase in scheduled transmission outages during 2016/17 contributes to an increase in forecast constraint costs.

2.2 Supplementary Modelling Results

The individual components of supplementary modelling, which take account of specific external factors that cannot be captured in PLEXOS modelling, are outlined and discussed in Appendix 1.
The forecast cost of the constraints modelled by supplementary modelling for the tariff year 2016/17 is **€18.5 million**. This represents an increase of €7.4 million from the 2015/16 tariff year.

The largest influencing factor on this increase is the reduction of the impact of SO interconnector countertrading in supplementary modelling. Revenue received for countertraded volumes is not included in the PLEXOS modelling component, therefore a provision for this must be made in the Supplementary Modelling. The following is the approach used for forecasting the 2016/17 countertrading revenue:

- **Priority Dispatch:** As noted in Section 1.1.2 the level of exports from SEM to GB during the night has increased and imports from GB to SEM during the day on both interconnectors has reduced significantly from previous years. This reduces the opportunity for Priority Dispatch countertrading in the model. The historical countertrades from 01/10/2014 to 02/04/2016 were assessed and the average €/MWh revenue from those estimated to be associated with Priority Dispatch was determined. This was then multiplied by the volume of trades estimated to be associated with Priority Dispatch from the PLEXOS model. This value is a negative figure and helps reduce the forecast constraint costs;
- **Reserve Co-optimisation:** As noted in Section 1.1.2 the level of imports from GB to SEM during the day on EWIC has reduced significantly from previous years. The opportunity for Reserve Co-optimisation countertrading in the model is very limited. The historical countertrades from 01/10/2014 to 02/04/2016 were assessed and the average €/MWh revenue from those estimated to be associated with Reserve Co-optimisation was determined. This was then multiplied by the volume of trades estimated to be associated with Priority Dispatch from the PLEXOS model. This value is a negative figure and helps reduce the forecast constraint costs; and
- **Export Limitations:** Due to current operational export limits on EWIC the TSOs are required to countertrade at times when market flows exceed this operational restriction. The historical countertrades from 01/10/2014 to 02/04/2016 were assessed and the average €/MWh revenue from those estimated to be associated with export limits was determined. This was then multiplied by the volume of trades estimated to be associated with the operational export limits from the PLEXOS model. This value is a positive figure and increases the forecast constraint costs. Note that countertrading as a result of the operational export limits generally lowers the production cost in the constrained model, since less energy is required to be produced; however when the revenue is factored in the net effect is an increase in constraint costs. This allowance will be removed from the ex-post adjusted budget as the restriction is deemed to be within the control of the TSOs.

For the 2016/17 forecast a provision for Secondary Fuel start-up tests has been made in the Supplementary Modelling. The Secondary Fuel obligations have been in place in Ireland since 2010[3] and the Fuel Switching arrangements[4] are anticipated to go-live in Northern Ireland for the 2016/17 tariff year. To date testing in Ireland has predominately focused on fuel changeover tests while the generating unit is on load. A small number of units have undergone secondary fuel start-up testing. The TSOs would now like to fully commence secondary fuel testing during unit start-ups. A provision has been made to constrain on Open Cycle Gas Turbines (OCGTs) and to constrain on the marginal unit during Combined Cycle Gas Turbine (CCGTs) tests for a period of time. A provision has been made for one test for all applicable units during the 2016/17 tariff year.

Overall the costs of the perfect foresight effects (changes to demand and generator availability; wind predictability; and long start up and notice times) for 16/17 have decreased from 15/16. This is due to the lower forecast production costs and forecast System Marginal Price (SMP).

[3] http://www.eirgridgroup.com/site-files/library/EirGrid/Summary-Secondary-Fuel-Testing-Arrangements.pdf
[4] http://www.uregni.gov.uk/uploads/publications/Proposed_licence_modification_-_Implementation_of_Fuel_Switching_Agreements_-_FINAL.pdf

The results of both elements of the modelling process are summarised in the table below:

Description		Forecast (€m)
PLEXOS Modelled Constraints for 12 Months		**125.8**
Perfect Foresight Effects	**Changes to demand and generator availability**	**4.9**
	Wind predictability	**8.9**
	Long Start-Up and Notice Times	**1.2**
Specific Reserve Constraints	**Turlough Hill**	**4.4**
Market Modelling Assumptions	**Block Loading**	**0.6**
	Hydro limitations & issues	**0.0**
System Security constraints	**Capacity Testing & Performance Monitoring**	**1.5**
Wind with non-firm access	**Plexos treatment of wind generation with non-firm access**	**-1.5**
System Operator Interconnector Trades - Frequency Service		**0.3**
System Operator Interconnector Trades – Countertrading		**-2.6**
Secondary Fuel Start Up Testing		**0.8**
Modelling Total :		**€144.3**

2.3 Summary of Imperfections Revenue Requirement

A summary of the forecast Imperfections revenue requirement for the tariff year 2016/17, including a breakdown by component, is presented in the Table below. A further description of the individual Imperfections elements is given in Appendix 1 of this document.

Component	Forecast (€m)
Dispatch Balancing Costs	
- Constraints	**144.3**
- Uninstructed Imbalances [5]	**0.0**
- Testing Charges [6]	**0.0**
Make Whole Payments [7]	**2.5**
Net Imbalance between Energy Payments and Energy Charges [8]	**0.0**
Net Imbalance between Capacity Payments and Capacity Charges	**0.0**
Other System Charges	**0.0**
FORECAST IMPERFECTIONS REVENUE REQUIREMENT	**€146.8**

[5] *It is assumed that the constraint costs of* ***Uninstructed Imbalances*** *(for over and under generation) will, on average, be recovered by the Uninstructed Imbalance Payments for the forecast period. In the event that uninstructed output deviations occur within the tariff year, corresponding constraint costs will also arise.*

[6] *A zero provision has been made for the net contribution of* ***Testing Charges****, as any testing generator unit will pay Testing Charges to offset the additional constraint costs that will arise from out of merit running of other generators on the system as a result of the testing.*

[7] *The purpose of* ***Make Whole Payments*** *is to make up any difference between the total Energy Payments to a generator and the production cost of that generator on a weekly basis. Make Whole Payments are a feature of the SEM rules and are generally independent of dispatch and DBC. SEMO is responsible for administering all Make Whole Payments and they are funded by Imperfections. A provision for the Make Whole Payments for the 2015/16 tariff year is included in this submission, based on the experience of the actual Make Whole Payments from 01/10/2015 to 02/04/2016.*

[8] ***Energy Imbalances*** *arise from time to time due to features in the SEM rules. If Energy Imbalances do occur, they are assumed to have an equal and opposite effect on constraints and will offset any increase or decrease accordingly.*

3. Risk Factors

There are a number of risk factors that could have a significant impact on the level of Dispatch Balancing Costs. The main factors are highlighted below, with some discussion on the nature of these risks and potential mitigation measures. These factors have not been accounted for in the total forecast Imperfections revenue requirement but could individually result in a significant deviation from this constraint forecast if they arose.

3.1 Specific Risks

3.1.1 Delays and Overruns of Outages

There is a significant programme of capital works scheduled to take place on the transmission system during the 2016/17 tariff year which is in turn resulting in an increase in DBC. This programme of works is in line with published Associated Transmission Reinforcements (ATRs). Outages by their nature reduce the flexibility of the system due to unavailability of generation and/or transmission plant. Delays in the scheduled start dates and overrun of any outage will extend this state of reduced flexibility and may result in an increase in DBC. The outage requirements for the 2016/17 tariff year are based on best available information and there is a significant risk of delays to the start dates and overruns on these scheduled dates which are predominately outside of the control of the TSOs. The TSOs have carried out a desktop exercise of the indicative transmission outages scheduled to take place during the 2016/17 tariff year and have included the most onerous outages from a DBC perspective in PLEXOS. These outages are listed in Appendix 3 of this submission paper. The TSOs will track these in detail during the 2016/17 tariff year to investigate the impact of any slippages in scheduled dates. Furthermore the TSOs will seek to review the impact of these significant capital works as part of the ex-post review process in 2017 to determine whether they meet the assessment criteria for inclusion in the ex-post adjusted model.

3.1.2 Network Reinforcements and Additions

The PLEXOS model was built with the most up to date data available at the time of the data freeze. The commissioning dates of projects in the future may change and any delays or advancements of dates will have an impact on how the system can be run. Examples of this include delays to network reinforcements, delays to new generator commissioning, unexpected or early generator closures or long-term forced outages. The actual detailed planning of outages is only carried out in the weeks preceding outages as factors such as other transmission outages, generation outages, resourcing, etc. can be fully realised at this stage.

3.1.3 Interconnector Flows

Analysis of historical interconnector trading activity reveals that flows are not purely price-based and are predominantly imports from GB to SEM during the day and exports from SEM to GB during the night. Participant behaviour could result in interconnector flows that differ greatly from those forecast. This, in turn, could result in constraint costs changing significantly. Interconnector flows have therefore been forecast using historical data from SEM from January and February 2016. The TSOs have carried out sensitivity analysis on the impact of significant changes in the interconnector flows and these showed that changes can drive large changes in the constraint costs. The TSOs will closely monitor the forecast flows against actual Modified Interconnector Unit Nomination (MIUNs) during the tariff year and re-forecast if there is a significant deviation.

3.1.4 Significant Bid Variations

The fuel prices used in the PLEXOS modelling process are based on a forecast of long term fuel prices determined at the beginning of 2016. There is significant volatility in fuel prices in both short and long term timeframes. A general increase in fuel prices would lead to higher generator running costs and hence higher Dispatch Balancing Costs. Divergence in the relative price of fuels could also lead to an increase in Dispatch Balancing Costs. Similarly, a reduction in the relative divergence of fuel prices could lead to a reduction in Dispatch Balancing Costs. Other factors such as changes in the cost of carbon, generator Variable Operation and Maintenance (VOM) costs or gas network capacity products could also have a significant impact. There is also uncertainty in relation to whether gas transportation capacity charges will be introduced in Northern Ireland. It was forecast that these would be include in generator bids in the 2015/16 tariff year, however this did not materialise. The inclusion of gas entry charges into participant bids would result in increasing constraint costs. There is also uncertainty in relation to the existing gas charging methodology in Ireland. Again for the purpose of this forecast the TSOs have assumed that the current Gas Transportation Capacity charges remain unchanged.

3.1.5 High Impact, Low Probability Events (HILPs)

In respect of the constraint forecast, HILPs are low probability transmission, generation or interconnector outages that lead to significant increases in constraint costs. For example, a long term unplanned outage of a critical transmission circuit (e.g. due to a fault on an underground cable which could have a long lead times to repair) may result in generation being constrained until the repair can be completed.

PLEXOS does include planned generator outages in the model but these tend to be co-ordinated with transmission outages and they are timed to minimise their impact on constraints. Forced outages for generating units are also modelled to account for some unplanned events. PLEXOS will therefore account for some constraint costs associated with outages but not major HILP events affecting generation and/or transmission plant(s). In such an event involving transmission equipment, the TSOs would obviously seek to implement mitigation measures where possible.

3.1.6 Poor Generator Availability and/or Generation Station Closure

A reduction in the overall availability of generation could lead to an increase in Dispatch Balancing Costs as relatively more expensive generation may be required to provide reserve and/or system support in areas with transmission constraints. Significant deviation from indicative generator scheduled outages and return to service dates could also lead to large variances in Dispatch Balancing Costs.

3.1.7 Outturn Availability

A change to practice in relation to the treatment of outturn availability of generators during transmission outages[9] could have an impact on constraint costs.

3.1.8 Forced Outages of Transmission Plant

The forced outage of transmission plant may lead to increased Dispatch Balancing Costs due to resultant generator and/or transmission constraints. The outage of certain key items of the transmission system can potentially increase Dispatch Balancing Costs significantly. For example, if a generator is radially connected to the system and the radial connection is forced out, the impact on Dispatch Balancing Costs can be considerable. In addition, the possibility of equipment failing due to a type fault affecting a particular type or model of equipment installed at numerous points on the transmission system, for example, could have a major impact on constraint costs.

Forced transmission outages are not modelled in PLEXOS and no explicit provision has been included due to the unpredictable nature of such outages.

3.1.9 Market Anomalies

Unknown or unintended results from the market scheduling software could lead to unexpected market schedules which form the baseline from which constraints are paid. It is expected that any major anomaly would be quickly identified and corrected to prevent major constraint costs arising.

3.1.10 Participant Behaviour

The PLEXOS modelling process has assumed that participants offer into the market according to their fuel costs and technical availability. There has been no extra provision made for any possible bidding strategy by a market participant as it is assumed the Bidding Code of Practice is followed. Therefore the role of the market monitor in monitoring the behaviour of participants and acting in a timely manner is important.

3.1.11 Testing Charges

There is no specific DBC provision for new units that will be under test before they are commissioned or on return from a significant outage. It is assumed that the testing charges will offset the additional Dispatch Balancing Costs incurred, which will primarily consist of constraints due to out of merit running (e.g. for the provision of extra reserve). However, the testing charges do not cover any transmission-related constraints that arise due to new unit commissioning (as these are difficult to predict in advance).

3.1.12 Contingencies

[9] http://www.eirgridgroup.com/site-files/library/EirGrid/The-EirGrid-and-SONI-Implementation-Approach-to-the-SEM-Committee-Decision-Paper-SEM-15-071-Published-10-February-2016.pdf

A list of the principal N-1 contingencies was included in the PLEXOS model. It was assumed that other contingencies had a negligible effect or could be solved post contingency. However, if a significant contingency outside of this list was to occur, and persisted for an extended period, then this could have a significant impact on constraints costs.

3.1.13 Modifications to the Trading and Settlement Code

All assumptions made in this submission were based on the current Market Rules as outlined in the latest version of the Trading and Settlement Code (version 18.0). The impact of future rule changes has not been considered, and must be deemed a potential risk.

3.1.14 Additional Security Constraints

This forecast has been prepared using the best estimate of operational policies that will be in effect for the tariff year. As the system develops, these policies may no longer be adequate, and additional security constraints may be required, resulting in an increase in constraint costs.

3.1.15 SO Interconnector Trades for Security of Supply

SO Interconnector trades may be required to maintain system security in exceptional circumstances, for instance during a capacity shortfall, where generation is insufficient to meet demand. However, due to the unpredictable and infrequent nature of their requirement, no provision is included in this submission. In the event that SO Interconnector trades are required to maintain system security on a prolonged basis, the costs of these trades may be extremely expensive and the impact on Dispatch Balancing Costs can build up to significant levels very quickly, as occurred in 2008.

3.1.16 Increased Connection of Wind

There is a significant amount of wind contracted to connect during the 2016/17 tariff year. The TSOs have forecast the amount of wind which they anticipate will connect during the tariff year, based on a median forecast connection rate for 2016 and a high forecast connection rate for 2017 and the contracted wind has been adjusted on a pro rata basis. If there is an increase in rate of connection this will increase DBC. The TSOs will keep this under review.

3.1.17 Industrial Emissions Directive

In Ireland and Northern Ireland, some units are affected by the Industrial Emissions Directive (Directive 2010/75/EU of the European Parliament and the Council on industrial emissions). These units may need to purchase additional permits for emissions. The impact of this directive on combustion plants is discussed in section 3.3 of the All Island Generation Capacity Statement 2016-2025.[10]

[10] http://www.eirgridgroup.com/site-files/library/EirGrid/Generation_Capacity_Statement_20162025_FINAL.pdf

A provision for costs arising from this has not been included in the 2016/17 forecast.

3.2 Other Risk Factors

While a number of key specific risks have been explicitly identified and outlined in Section 3.1 above, there are many factors that may contribute to unexpected and unforecast increase/decrease in DBC. Examples include significant exchange rate variations, operation of generators on distillate when they are assumed to run on gas in the PLEXOS model, the impacts of two-shifting generation on the reliability of the plant, significant variations in system demand and operation with significant penetration of variable generation.

4. Cost Recovery and Financing

Dispatch Balancing Costs will remain 100% pass through, as per the current arrangements. In the event there is a requirement for intra or inter year balancing this will be provided by EirGrid and SONI in their capacity as licenced TSOs on 75%:25% basis, in accordance with the Specified Proportions, again as per the current arrangements. The costs of putting in place such facilities, including any arrangement fees, commitment fees and interest on imbalance is separately recoverable.

In the event there is a negative imbalance in dispatch balancing costs within the year EirGrid and SONI will notify the SEM Committee when the negative imbalance is equivalent to 50% and again at 75% of the level of standby facility is breached. Should there be an imbalance, or an expected imbalance for the tariff period as a whole, either to the account of customers or to the licensees, then a best estimate of this will be provided for through the 'K' factor in the tariff in the following year (i.e. on a y+1 basis), including interest, as per the current practice.

While the TSOs expect the framework outlined above which has been in place since 2007 to continue, it is important to note:

1. The SONI price control final determination and proposed Licence Modifications as published by URegNI on 24/02/2016 have yet to be finalised and depending on the final outcome may have implications for the above; and
2. If EirGrid and SONI notify the SEM Committee of a negative imbalance of 75% of the standby facility, this may trigger a submission to the RAs for a mid-year tariff change. As such the TSOs request the RAs to consider what timeframes and process would be required for it to implement same.

The TSOs are currently incentivised to manage DBC (SEM-12-033) against the ex-ante forecast subject to an ex-post adjustment framework. The tariff year 2012/13 was the first year this incentive has been in place. It is assumed the existing framework will continue in operation for tariff year 2016/17, but not for I-SEM.

Appendix 1: Overview of Imperfections and Modelling Constraint Costs

1. Overview of Imperfections

The purpose of the Imperfections Charge is to recover the anticipated Dispatch Balancing Costs (less Other System Charges), Make Whole Payments, any net imbalance between Energy Payments and Energy Charges and Capacity Payments and Capacity Charges over the Year, with adjustments for previous years as appropriate. As noted in Section 1, adjustments for previous years are not included in this submission, but are considered in setting the Imperfections Charge.

The diagram below illustrates how these are related; and how they are used to derive the SEM Imperfections Charge.

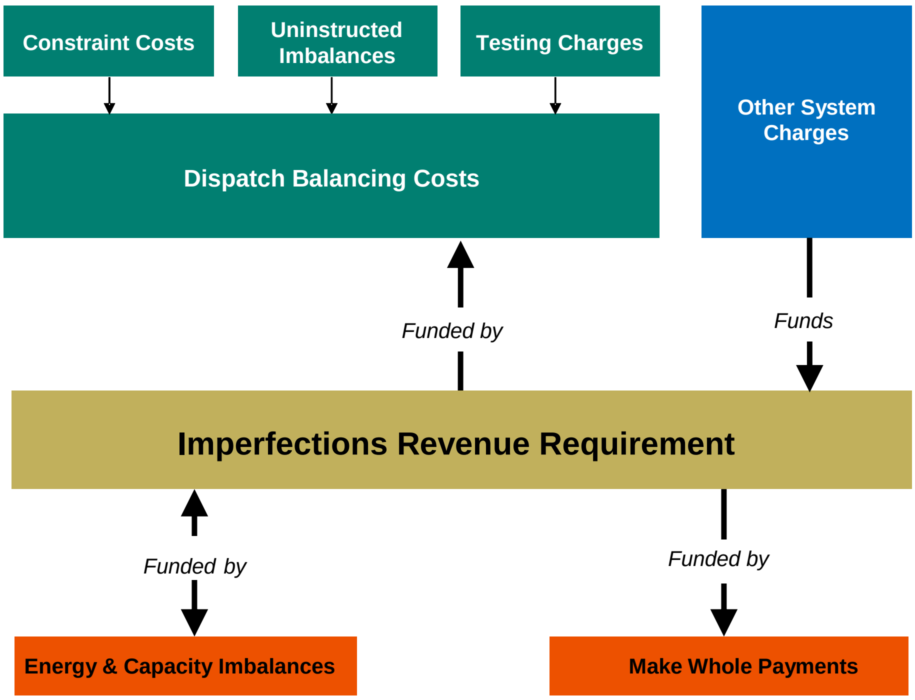

Figure 1 – Relationship between Dispatch Balancing Costs and Imperfections

The three components of Dispatch Balancing Costs, namely Constraints, Uninstructed Imbalances and Testing Charges are described in further detail in Sections 2, 3 and 4 of this Appendix respectively. Other System Charges are detailed further in Section 5. Section 6 describes Energy Imbalances and their interaction with DBC, while Section 7 discusses Make Whole Payments.

2. Constraint Costs

2.1 Overview of Constraint Costs

Constraint costs are the largest portion of the DBC. The TSOs, in ensuring continuity of supply and the security of the system in real time, have to dispatch some generators differently from the output levels indicated by the ex-post market unconstrained schedule. Generators receive constraint payments to keep them financially neutral for the difference between the market schedule and the actual dispatch.

Constraint costs therefore arise to the extent that there are differences between the market determined schedule of generation to meet demand (the 'market schedule') and the actual instructions issued to generators (the 'actual dispatch'). A generator that is scheduled to run by the market but which is not run in the actual dispatch (or run at a decreased level) is 'constrained off/down'; a generator that is not scheduled to run or runs at a low level in the market, but which is instructed to run at a higher level in reality is 'constrained on/up'.

In order to balance supply and demand, a generator that is constrained off/down will always result in other generators being constrained on/up and vice versa. The units that are constrained off/down have to pay back a constraint payment (negative) and the corresponding units that are constrained on/up receive a constraint payment (positive). As the price of the constrained on/up unit is generally greater than the constrained off/down unit, there is always a net cost associated with constraints.

The actual dispatch of generation is based on the same commercial data as used in the production of the market schedule. However, the TSOs must take into account the technical realities of operating the power system. As such, dispatch will deviate from the market schedule to ensure security of supply. Constraint costs arise whenever dispatch and market schedule diverge.

Section 2 below describes the main categories of issues that can lead to a difference between the market schedule and actual dispatch and hence constraint costs.

2.2 Why do Constraint Costs Arise?

2.2.1 Transmission

In order to ensure the safe and secure operation of the transmission network, it may be necessary to dispatch specific generators to certain levels to prevent equipment overloading, voltages going outside limits or system instability. Generators may be both constrained on/up or off/down thus leading to the actual dispatch deviating from the market schedule, as the market schedule does not account for any transmission constraints.

2.2.2 Reserve

In order to ensure the continued security and stability of the transmission system in the event of a generator tripping, the TSOs instruct some generators to run at lower levels of output so that there is spare generation capacity available (known as reserve) which can quickly respond during tripping events. To maintain the demand-supply balance, some generators will be constrained down while others will be constrained on/up, again leading to the actual dispatch deviating from the market schedule, which does not account for reserve requirements.

2.2.3 Perfect Foresight

The market schedule of generation, which is used for energy settlement, is produced after real time (*ex post*) by the market schedule using actual demand, actual wind output and known generator availabilities. However, operating the system in real-time, the TSOs do not have this perfect foresight. They must plan and operate the system to account for possible variations in these parameters.

2.2.4 Market Modelling Assumptions

Due to mathematical limitations, approximations and assumptions in the market schedule software, the market schedule will not always be technically feasible. This is mainly due to a number of generator technical capabilities and interactions not being specifically modelled (e.g. the market assumes that generators can synchronise and reach their minimum load level in 15 minutes, whereas in reality this may take much longer; the market assumes a single generator ramp and loading rate, whereas in reality many generators have multiple ramp and loading rates). In real-time dispatch, the TSOs (and generators) are bound by these technical realities and so the market schedule and dispatch will differ.

2.3 Managing Constraint Costs

Constraint costs will inevitably arise due to the factors described above and they are also dependent on a number of underlying conditions. Some of these conditions, such as fuel costs, generator forced outages, trips, start times, overruns of transmission outages, transmission network availability and system demand are outside of the TSOs' control. However, the TSOs continually monitor constraint costs and the drivers behind them to ensure that costs which are within their control are minimised. The TSOs undertake a number of measures to control and mitigate the costs of re-dispatching the system.

These measures include, but are not limited to:

- Performance Monitoring, which identifies levels of reserve provision and Grid Code compliance. The TSOs also analyse the performance of each unit following a system event and follow up with those units that do not meet requirements or do not respond according to contracted parameters.
- Applying Other System Charges (OSC) on generators whose failure to provide necessary services to the system lead to higher DBC. OSC include charges for generator units that trip, for those which make downward declarations of availability at short notice and Generator Performance Incentives (GPIs). GPIs monitor the performance of generator units against the Grid Code and help quantify and track generator performance, identity non-compliance with standards and assist in evaluating any performance gaps. OSC are discussed further in Section 5 of this Appendix.
- Wind and Load forecasting, which involves continually working with vendors to improve forecast accuracy.

- Introducing additional Ancillary Services which will provide a system benefit, through the new DS3 System Services[11].

2.4 Modelling Constraint Costs

2.4.1 Approach to Constraints Forecasting

Detailed market, transmission system and generation models were developed and analysed utilising the simulation package PLEXOS, which captures the key transmission and reserve constraints. Supplementary modelling was then used to examine factors affecting constraints that could not be accurately modelled in PLEXOS.

As this is an estimate of constraints approximately a year ahead, the assumptions that are made are critical to the forecast. Where possible, data from the SEM, such as Commercial and Technical Offer data, historical dispatch quantities, market schedule quantities and constraint payments, has been used to review key assumptions.

In the following sections, details of the key assumptions, the PLEXOS model and the analysis of specific effects on DBC are presented.

2.4.2 Key Modelling Assumptions

The TSOs have made a number of assumptions in preparing this submission. The principal ones are:

- Where reference is made to the Trading and Settlement Code (T&SC), the version referred to is version 18.0, dated 02/10/2015.
- For the purpose of this submission all expenditure and tariffs are presented in euro. The euro foreign exchange rates from the European Central Bank are used for any money originally in pounds sterling and US dollars.

The following table highlights the key assumptions used in the production of the constraints in PLEXOS for the TSOs' Imperfections revenue requirements forecast. A further summary of the PLEXOS modelling and associated assumptions is provided in Appendix 1.

Subject	Assumption
Data Freeze	All input data for the PLEXOS model was frozen at 11/04/2016
Forecast Period	The forecast period is from 01/10/2016 to 30/09/2017
Currency	All costs are modelled in euro.

[11] http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/#comp_000056cb5b8e_00000006da_78f0

Fuel and Carbon Prices	Fuel prices for 2016/17 are based on the long term fuel forecasts from Thomson-Reuters Eikon [12] and data gathered by the TSOs. Carbon costs and Variable Operation and Maintenance Costs are also forecast.
Participant Behaviour	It is assumed that generators bid according to their short run marginal costs in SEM in line with the Bidding Code of Practice[13].
Demand Forecast	The demand is based on the 2016/17 median forecast for both Northern Ireland and Ireland from the All-island Generation Capacity Statement 2016-2025[14].
Generator Schedule Outages	2016 and 2017 maintenance outages are based on provisional outage schedules. Return Dates for the units are based on the latest available information from the Generator units as of the data freeze.
Generator Forced Outage Probabilities	Forced Outage Rates and Mean Times to Repair are based on historical data held by the TSOs.
N-1 Contingency Analysis	Principal N-1 contingencies, based on TSO operational experience, are modelled.
Transmission Scheduled and Forced Outages	A number of significant indicative scheduled transmission outages for 2016 and 2017 are modelled in PLEXOS. Forced transmission outages are not modelled.
Operating Reserve	Primary, secondary and tertiary 1 and 2 reserve requirements are modelled[15]. The output from open cycle gas turbines and peaking plant generation units is limited in the constrained model to ensure that adequate replacement reserve is maintained at all times.
Louth-Tandragee Tie-Line Transmission Limits	The Net Transfer Capacity (NTC) is modelled for the constrained schedule, which is assumed to be 300 MW N-S and 175 MW S-N. This assumption has been updated from previous years based on TSO operational experience.
Interconnector Flows	Interconnector flows with Great Britain (GB) are forecast to be predominantly imports into SEM during the day and exports into GB during the night. This reflects historical experience of flows on both interconnectors prior to the data freeze and is a best estimate of likely future flows.
Intra-Day Trading	No explicit modelling provision has been made to reflect Intra-Day trading in the PLEXOS model.

[12] https://thomsonreuterseikon.com/
[13] The Bidding Code of Practice - AIP-SEM-07-430
[14] http://www.eirgridgroup.com/site-files/library/EirGrid/Generation_Capacity_Statement_20162025_FINAL.pdf
[15] http://www.eirgridgroup.com/site-files/library/EirGrid/OperationalConstraintsUpdateVersion1_36_Mar_2016.pdf

2.4.3 PLEXOS Modelling

PLEXOS for Power Systems is a modelling tool which can be used to simulate the SEM. It can be used to forecast constraints over an annual time horizon using the best available data and assumptions. However, like all models, it will never fully reflect operational reality and cannot be used to derive an estimate for any one specific day. As the model was set up for a 12 month study horizon it is important that all results are considered according to this timeframe, rather than being considered for specific months and/or periods of the tariff year in isolation.

This analysis used a model of the transmission and generation systems across the whole island, with assumptions around factors such as outage schedules, demand levels, plant availability, fuel prices and wind output. The model also took account of reserve requirements and specific transmission constraints, so that the effect in terms of total production costs could be analysed.

It assumed that, in line with the Bidding Code of Practice, the generators bid their short run marginal cost into the market and this was the basis for setting the system marginal price and determining constraint costs. The difference in production costs between the unconstrained (market) simulation and the constrained (dispatch) simulation represents the constraint costs associated with the modelled transmission and reserve constraints.

2.5 Supplementary Modelling

As it is not possible to model all constraint cost drivers in PLEXOS, further analysis of specific factors affecting constraints was performed. This built on the PLEXOS modelling described above and looked at the impact of:

- Perfect foresight;
- Specific reserve constraints;
- Specific transmission system constraints;
- Market modelling assumptions;
- System security constraints;
- Other factors.

These are discussed, in detail, in the following sections.

2.5.1 Perfect Foresight

The market schedule is determined *ex post* with perfect knowledge of all outturn data. In contrast, the system is dispatched in real time using the best information available at that time. This disparity results in differences between the market schedule and actual dispatch, thereby increasing constraint costs. This perfect foresight effect cannot be captured in the PLEXOS modelling as the model also has perfect knowledge of all outturn data. The main drivers of these differences arising from perfect foresight are described as follows:

2.5.1.1 Changes to Demand and Generator Availability

Since it is calculated *ex post*, the Unconstrained Unit Commitment (UUC) (initial) market schedule[16] has the benefit of perfect foresight of changes in demand and generator availability. The TSOs do not have this advantage and must respond to such changes as and when they happen.

Following the tripping of a generator, the TSO must activate reserves and will typically have to replace the lost generation using fast start plant e.g. peaking units, at a significant cost. Other System Charges, such as Trip and Short-Notice Declaration charges, are levied on generators who fail to provide necessary services to the system[17]. OSC therefore act to take account of the immediate, short-term costs incurred from these events. The monies paid by generators are then used to offset the DBC costs incurred.

However, in addition to replacing lost generation capacity immediately after the event, the TSOs are also unaware of how long the plant will be unavailable for in real time operations. This may result in re-dispatching a number of generating units to ensure that there is adequate capacity to meet demand and reserve requirements where the expected return of the generator is uncertain, The UUC market schedule on the other hand, since it knows that the generator will trip, can schedule the most economic replacement plant in anticipation of the tripping (e.g. by starting another unit in the market several hours before the tripping). It also has perfect knowledge of the duration of the unavailability and can schedule plant in as optimal a manner as possible. This continuous information asymmetry results in considerable constraint costs over the year.

2.5.1.2 Impact of Wind Predictability

Wind is inherently a variable resource. The UUC market schedule, with perfect foresight, can schedule the most economic generation to balance this variability as it knows exactly the level of wind output in every period. The TSO, on the other hand, since it is not always aware of the timing or extent of these variations, must balance them using a combination of part-loaded plant and more expensive fast-start plant. This less optimal schedule will cause an increase in constraint costs.

2.5.1.3 Long Start-Up and Notice Times, Lack of Flexible Plant

The generation portfolio has changed in recent years due to a number of plant closures, and the fact that new build has tended to be larger, less flexible units. This deficit of mid-merit units that can start with relatively short notice periods has resulted in a reduction in portfolio flexibility for reacting to unexpected changes in generation and demand. Previously, when mid-merit units were available, uncertainty over generation, wind and load could be managed within 1 to 2 hours using these flexible mid-merit generator units. Any potential capacity shortages due to generation, wind and load uncertainty in the near future require commitment decisions to be made a number of hours in advance due to the long notice periods required by the generator units available to meet these shortages.

[16] In the Trading and Settlement Code, the UUC is referred to as the MSP software.
[17] http://www.soni.ltd.uk/media/documents/Operations/Ancillary-Services/Harmonised%20OSC%20Methodology%20Statement%201516.pdf

These commitment decisions are made to mitigate against the risk of a capacity shortage and to ensure that sufficient replacement reserve is maintained to deal with any further changes to unit availability, interconnector scheduled flows or forecast demand or wind. Availability of generation with shorter notice times and/or greater flexibility would mean that such commitment decisions could be made nearer to real-time and with better information. With higher levels of wind and interconnection, managing the system in real time with the current generation portfolio remains a challenge.

2.5.2 Specific Transmission System Constraints

Transmission line limits are modelled in PLEXOS. As in previous years there were some other transmission system constraints which it is not possible to model in PLEXOS and for which specific provision had to be made. A brief description of these is given in the following section.

2.5.2.1 Limited Transmission Scheduled Outages in PLEXOS

Transmission outages can result in additional transmission constraints. These additional constraints may include requirements to run out-of-merit generation, restrictions on the maximum tie-line flow and localised export constraints. This year a number of the significant transmission outages have been incorporated into the PLEXOS model based on the indicative transmission outage programme as of the data freeze date.
No specific provision for other expected transmission outages has been included in this submission.

It should be noted that the principal, most onerous N-1 contingencies were included in the PLEXOS model. It was assumed that other contingencies had a negligible effect on constraint costs or could be solved post contingency.

2.5.2.2 Forced Transmission Outages

Forced transmission outages can result in additional transmission constraints, through requirements for out-of-merit generation, restrictions on the maximum tie-line flow or localised export constraints. As such, the outage of certain items on the transmission system can potentially increase DBC significantly. However, due to the unpredictable nature of such outages, it is not possible to calculate a specific provision for this submission or to include them in the PLEXOS model. As such, forced transmission outages are identified as a risk rather than an explicit cost.

2.5.3 Specific Reserve Constraints

PLEXOS includes requirements for primary, secondary and tertiary operating reserves. In addition, regulation and replacement reserve requirements are also met through the constraints in the PLEXOS model.

Turlough Hill is a key source of spinning reserve. However, while reserve provision by the units is modelled in PLEXOS, it is not possible to model all of the operating modes. In particular, the minimum generation mode allows provision of reserve at very low loads but at a much lower efficiency than normal operation. This efficiency reduction effectively reduces the total energy available in the dispatch. This energy must be replaced (by the marginal plant), resulting in additional constraint costs over the day.

2.5.4 Market Modelling Assumptions

The UUC market schedule software makes a number of modelling assumptions and simplifications that are necessary to allow it to generate robust solutions in a reasonable length of time. PLEXOS also makes similar modelling assumptions. These simplifications can result in infeasible schedules that would be impossible in reality, even in the absence of any transmission system constraints. The consequence is that additional constraint costs will arise.

2.5.4.1 Block Loading

The UUC market schedule assumes that, when synchronising, a generator can reach minimum load in 15 minutes. In practice, it can take significantly longer, particularly for cold units. In actual dispatch therefore, it will be necessary to synchronise such units earlier than the UUC market schedule, resulting in out-of-merit running and hence constraint costs. A provision is included to cater for the constraints costs arising from out-of-merit running due to the simplification of block loading in the market model.

Although a number of other market modelling assumptions such as the single ramp rate and forbidden zones diverge from reality, it is assumed that the constraint costs arising from these assumptions will balance out over the course of the tariff year.

2.5.5 System Security

2.5.5.1 Capacity Testing for System Security & Performance Monitoring

In the interests of maintaining system security, it is considered prudent operational practice to verify the declared availability of generators in accordance with the monitoring and testing provisions of the Grid Codes. This ensures that the TSOs are using the most accurate information possible and allows generators to identify any problems in a timely manner.

With increasing amounts of base-load thermal and wind generation, there will be more instances of out-of-merit generators not being required to run. Testing the capacity of such units from time to time will necessitate constraining them on, resulting in an increase in constraint costs. A provision is included in this submission, calculated based on an estimate of the additional start costs and out-of-merit running costs, but taking into account additional starts assumed under the Long Start-Up and Notice Times provision.

Testing of generators for Grid Code compliance and performance monitoring is also necessary for system security. To date, no significant additional costs have been incurred due to this testing and so no explicit provision for this is included here.

2.5.6 Treatment of Wind with Non-Firm Access in PLEXOS

The PLEXOS model does not differentiate between wind generation units with firm and non-firm access. In recognition of this, a provision has been made to reflect the effect of wind with non-firm access dispatched down over the year. Dispatching down of wind generation normally represents a cost in terms of constraints as in order to maintain supply-demand balance, price making generation has to be dispatched to meet demand which was met in the market schedule by price taking wind generation. However, with the implementation of a revision to SEM rules[18] around the treatment of wind generation with non-firm access, dispatching down wind with non-firm access will not result in this cost in terms of constraints, as any dispatched down wind with non-firm access will not be scheduled in SEM.

A negative provision is included in this submission to offset the over-estimation of the cost of dispatched-down wind in the PLEXOS model due to a portion of that wind generation having non-firm access.

2.5.7 SO Interconnector Trades

An explicit provision is made for constraint costs arising from SO Interconnector Trades for the Low and High Frequency Service on Moyle and on EWIC, in line with previous years.

SO interconnector countertrading arrangements allow the TSOs, post SEM gate closure, to initiate changes to interconnector flows for reasons of system security, to facilitate priority dispatch generation, as directed by SEM-11-062 or for Reserve Co-optimisation i.e. reduce the interconnectors as the Largest Single Infeed (LSI).

For the 2016/17 tariff year the flows for both EWIC and Moyle were compared between the constrained and unconstrained PLEXOs models. The volumes of countertrading were then, based on assumptions, divided out to Priority Dispatch, Reserve Co-optimisation and Export Limit countertrading on EWIC and Priority Dispatch for Moyle. The estimated revenue received from 01/10/2014 to 02/04/2016 was used to determine an average €/MWh for these countertrades to determine the revenue which would be received.

This results in a net negative provision for SO Interconnector Trades in this submission.

2.5.8 Secondary Fuel Start Up Testing

A provision has been made to constrain on Open Cycle Gas Turbines (OCGTs) during their tests and to constrain on the marginal unit during Combined Cycle Gas Turbine (CCGTs) secondary fuel start up tests for a period of time. A provision has been made for one test in the 2016/17 tariff year for all applicable units.

[18] http://www.sem-o.com/MarketDevelopment/ModificationDocuments/110607%20SEM%20C%20Decision%20on%20Mod_43_10.pdf

3. Uninstructed Imbalances

3.1 Overview of Uninstructed Imbalances

Uninstructed Imbalances [19] and constraint costs are related, with uninstructed imbalances having a direct effect on constraints costs, as TSOs re-dispatch generators to counteract the impact of uninstructed imbalances on the system.

All dispatchable generation is required to follow instructions from the control centres within practical limits to ensure the safe and secure operation of the power system. Deviation of a generating unit from its dispatch instruction will have a direct impact on system frequency and on the reserve available to the TSOs for frequency control.

Over-generation by a generating unit may result in a need for the TSOs to instruct other generating units down from their dispatched levels to lower levels in order to balance supply and demand. Significant over-generation can necessitate dispatching a generator off load to compensate. Under-generation by a generating unit may result in the need to instruct other generating units up from their dispatched levels to higher levels. In the event of unexpected or large under-generation by a generator the TSOs must act in a quick and decisive manner to restore appropriate system balance and reserve targets. This will generally necessitate dispatching on quick-start generators.

Uninstructed deviations therefore lead to increased constraint costs as the TSOs re-dispatch other generation at short notice. In SEM, the uninstructed imbalance mechanism provides the economic signals to ensure generators follow dispatch instructions and any net accrual of uninstructed imbalance payments offset the constraint costs that the uninstructed deviations gave rise to.

3.2 Forecasting Uninstructed Imbalances

It is assumed that the constraint costs of Uninstructed Imbalances (for over and under generation) will, on average, be recovered by the Uninstructed Imbalance payments for the forecast period.

Any incomings or outgoings are offset by the corresponding constraint costs due to action required by TSOs in response to Uninstructed Imbalances. As in previous submissions, an assumption is made that the current Uninstructed Imbalance mechanism sends the correct signals to generators and that all generators are fully compliant with dispatch instructions. As such, no provision for the constraint costs that would arise due to uninstructed deviations is included in this submission and a zero provision for Uninstructed Imbalances is forecast. In the event that uninstructed deviations occur within the tariff year, corresponding constraint costs will also arise.

[19] Uninstructed Imbalances occur when there is a difference between a Generator Unit's Dispatch Quantity and its Actual Output.

4. Testing Charges

The testing of generator units results in additional operating costs to the system in order to maintain system security. As a testing generator unit typically poses a higher risk of tripping, additional operating reserve will be required to ensure that system security is not compromised, which will give rise to increased constraint costs. The TSOs may need to commit extra units to ensure sufficient fast-acting units are available for dispatch to provide a rapid response to changes from the testing generator unit's scheduled output and to ensure that the system would remain within normal security standards following the loss of the generator unit under test. Additional constraint costs will arise whenever there is a requirement to increases the existing reserve requirement above the normal level on the system.

In SEM, Testing Charges are applied to generator units that are granted under test status.
The actual costs incurred that may be attributed to a testing generator unit are volatile and variable. As such, generators pay for the costs of testing based on an agreed schedule of charges. The Testing Tariffs, which are used to calculate the Testing Charges for each unit, have been set at a level that should, on average, recover the additional costs imposed on the power system during generator testing.

A zero provision has been made for the net contribution of Testing Charges, as any testing generator unit will pay Testing Charges to offset the additional constraint costs that will arise from out of merit running of other generators on the system as a result of the testing.

5. Other System Charges

Other System Charges (OSC) are levied on generators whose failure to provide necessary services to the system lead to higher Dispatch Balancing Costs and Ancillary Service Costs. OSC include charges for generator units which trip or make downward re-declarations of availability at short notice. Generator Performance Incentive (GPI) charges were harmonised between Ireland and Northern Ireland with the Harmonisation of Ancillary Service & Other System Charges "Go-live" on the 01/02/2010.

These charges are specified in the Charging Statements separately approved by the Regulatory Authorities (RAs) in Ireland and Northern Ireland. The arrangements are defined in both jurisdictions through the Other System Charges policies, the Charging Statements and the Other System Charges Methodology Statement.

As DBC and generator performance are intrinsically linked, Other System Charges are netted off DBC in SEM[20]. Since the introduction of Other System Charges, the performance of generators on the system has improved. It is assumed in this submission that generators are compliant with Grid Code and no charges are recovered through Other System Charges. As any deviation from this assumption will result in an increase in DBC, any monies recovered through Other System Charges will net off the resultant costs to the system in DBC.

There are a number of reasons for having a zero provision for Other System Charges:

1. The TSOs assume all generators to be grid code compliant in the imperfections forecasting process. As Other System Charges are event based, it would be inappropriate to forecast them and could be deemed discriminatory;
2. If a generator unit trips or re-declares their availability down at short notice they are required to pay charges to compensate for not supplying the necessary services to the system. Such events would result in an increase in DBC. The TSOs assume that any revenue generated from Other System Charges covers some of the immediate short-term costs that arise as a result of these events; and
3. There is an additional cost associated with the unexpected loss of generation as the exact time the unit returns to service may be unknown and as such the TSOs may need to dispatch other generation to meet demand and reserve requirements. The market schedule, however, has perfect foresight of the unit trip and its outage duration. Therefore it can optimise the generation portfolio around this, for example starting another unit several hours before the trip. This disparity between the market and dispatch schedules result in an increase in DBC. The TSO's have included a provision for this in their forecasting submission under the subheading Perfect Foresight Effects. This is in line with previous years' submissions.

[20] Trading and Settlement Code V18.0, clause 4.155: "The purpose of the Imperfections Charge is to recover the anticipated Dispatch Balancing Costs (less Other System Charges), Make Whole Payments, any net imbalance between Energy Payments and Energy Charges and Capacity Payments and Capacity Charges over the Year, with adjustments for previous Years as appropriate."

6. Energy Imbalances

A continuous balance between system generation and system demand plus losses is required to maintain a secure system. As a result of this, the sum of the loss adjusted Market Schedule Quantities (MSQs) on which generators are paid Energy Payments should equal the loss adjusted net demand on which suppliers pay Energy Charges.

Energy Imbalances occur in SEM in the event that the sum of Energy Payments to generators does not equal the sum of Energy Charges to suppliers. There is an inherent link between Energy Imbalances and Constraints. An Energy Imbalance will generally impact Constraint costs in the opposite direction, artificially increasing or decreasing the total Constraint Costs. For example, Energy Payments will exceed Energy Charges if the sum of the MSQs is greater than the net demand and will result in an Energy Imbalance out of SEM (i.e. more paid out than recovered). In reality, in this example the system would have been balanced and the dispatch of generators will equal actual demand (plus losses) on the system. Constraints are calculated as the difference between the MSQs and the dispatch of each generator. When the sum of the MSQs exceeds the sum of dispatched generation, it will result in a net reduction in the system Constraint costs, as more generators will appear constrained down/off than will be constrained on/up.

Energy Imbalances arise from time to time due to features in the SEM rules. For example, if the Dispatch Quantity of a testing generator unit deviates from the Nomination Profile submitted to SEM, which could occur either due to events that occur during the testing or for system security reasons, an energy imbalance may arise. In this submission, it is assumed no Energy Imbalances will arise and no provision in terms of Energy Imbalances with corresponding additional/reduced Constraints is included. If Energy Imbalances do occur, they are assumed to have an equal and opposite effect on constraints and will offset any increase or decrease accordingly.

7. Make Whole Payments

The purpose of Make Whole Payments is to make up any difference between the total Energy Payments to a generator and the production cost of that generator on a weekly basis. As such, Make Whole Payments are a feature of the SEM rules and are generally independent of dispatch and DBC. SEMO is responsible for administering all Make Whole Payments and they are funded by Imperfections. A provision for the Make Whole Payments for the 2016/17 tariff year is included in this submission, based on the experience of actual outturn from 01/10/2015 to 02/04/16.

Appendix 2: Plexos Modelling Assumptions

PLEXOS is used by the TSOs to forecast constraint costs. PLEXOS is a production costing model that can produce an hourly schedule of generation, with associated costs, to meet demand for a defined study period. The main categories of data that feed into the PLEXOS model are summarised below.

The Transmission Network

These are the lines, cables and transformers operated by SONI and EirGrid. PLEXOS allows for the addition of new equipment, decommissioning of old equipment, up-ratings and periods when items are taken out of service.

Generation/Interconnection

There is a detailed representation of all generators in the PLEXOS model. This includes ramp rates, minimum and maximum generation levels, start-up times, reserve capabilities, fuel types and heat rates which are all modelled. Outages of generators, commissioning of new plant and decommissioning of old plant can all be represented.

Demand

Hourly variations in system demand are modelled down to the appropriate supply point.

Fuel Prices

Fuel prices for 2016/17 are defined in €/GJ based on the long term fuel forecasts from Thomson-Reuters Eikon[21] and data gathered by the TSOs. Carbon costs are also forecast and used, along with fuel costs, to simulate bids.
Detailed below are the key assumptions used in the PLEXOS modelling process:

General

Feature	Assumptions
Study Period	The study period is 01/10/2016 to 30/09/2017
Data Freeze	The input data for the PLEXOS model was frozen on 11/04/2016
Generation Dispatch	Two hourly generation schedules are examined: one schedule to represent the dispatch quantities (constrained) and the other to represent the market schedule quantities (unconstrained).
Study Resolution	Each day consists of 24 trading periods, each 1 hour long. A 6 hour optimisation time horizon beyond the end of the trading day is used to avoid edge effects between trading days.
PLEXOS Version	7.3
Model Reference	Unconstrained: DBC1617 UC v2.0 Constrained: DB1617 C v2.0

Demand

Feature	Assumptions

[21] https://thomsonreuterseikon.com/

Feature	Assumptions
Regional Load	NI total load and IE total load are represented using individual hourly load profiles for each jurisdiction. Both profiles are at the generated exported level and include transmission and distribution losses and demand to be met by wind.
Load Representation	Load Participation Factors (LPFs) are used to represent the load at each bus on the system. LPFs represent the load at a particular bus as a fraction of the total system demand.
Generator House Loads	These are accounted for implicitly by entering all generator data in exported terms.

Generation

Feature	Assumptions
Generation Resources	Conventional generation resources are based on the All-island Generation Capacity Statement 2016-2025[22]. Historical analysis on generators' declared availability was carried out and some units seasonal ratings were adjusted based on this.
Production Costs	Calculated through Plexos using the Regulatory Authorities' publicly available dataset: 2015/16 Validated SEM Generator Data Parameters[23]. 1. Fuel cost (€/GJ) – forecasted for 2016/17 from Thomson Reuters 2. Piecewise linear heat rates (GJ/MWh) 3. No Load rate (GJ/h) 4. Start energies (GJ) 5. Variable Operation & Maintenance Costs (€/MWh) A fixed element of start-up costs is calculated based on historical analysis of commercial offer data. The cost of European Union Allowances (EUAs) for carbon under the EU Emissions Trading Scheme (EU-ETS) are taken from ICE EUA Carbon Futures index.
Generation Constraints (TOD)	Based on the data in the 2015/16 Validated SEM Generator Data Parameters[22], the following technical characteristics are implemented: 1. Maximum Capacity 2. Minimum Stable Generation 3. Minimum up/down times 4. Ramp up/down limits 5. Cooling Boundary Times The capping of the Maximum Generation based on the contracted Maximum Export Capacity (MEC) in Ireland per the CER Decision[24] was not implemented due to this decision being deferred.

[22] http://www.eirgridgroup.com/site-files/library/EirGrid/Generation_Capacity_Statement_20162025_FINAL.pdf
[23] https://www.semcommittee.com/news-centre/ras-sem-forecast-model-end-2016
[24] CER/14/047 – Decision on Installed Capacity Cap

Feature	Assumptions
Scheduled Outages	Draft outage schedules are used for 2016 and 2017 maintenance outages
Forced Outages	Forced outages of generators are determined using a method known as Convergent Monte Carlo. Forced Outage Rates are based on EirGrid/SONI forecasts and Mean Times to Repair information is based on the 2015/16 Validated SEM Generator Data Parameters.
Hydro Generation	Hydro units are modelled using daily energy limits. Other hydro constraints (such as drawdown restrictions and reservoir coupling) are not modelled.
Wind Generation	Wind generation resources are based on MW currently installed plus an anticipated rate of connection based on the All Island Renewable Connection Report 36 Month Forecast (Q4 2013)[25]. This is based on 2406 MW already installed in Ireland and 629 MW in Northern Ireland. For the 2016/17 tariff year the high all-island connection rate from the All Island Renewable Connection Report 36 Month Forecast (Q4 2013) which was 670 MW / year.
Turlough Hill	Modelled as 4 units of 73 MW. The usable reservoir volume is 1,540MWh. The efficiency of the unit is modelled as 70%.
Security Constraints	Since a DC linear load flow is used, voltage effects and dynamic and transient stability effects will not be captured. System-wide and local area constraints have been included in the model as a proxy for these issues.
Demand Side Units (DSU) and Aggregated Generator Units (AGU)	Demand Side Units and Aggregated Generator Units are modelled explicitly.
Multi-Fuel Modelling	Only one fuel is modelled for each generating unit. The coal units at Kilroot, while able to run on oil, almost never do so, and will be modelled as coal only. Note that where units are multi fuel start this is modelled explicitly using one fuel offtake for each fuel. Multi fuel start units are Kilroot units one and two, Moneypoint units one, two and three and Tarbert units one, two, three and four.
Interconnector Flows	Interconnector flows with Great Britain (GB) are forecast to be predominantly imports into SEM during the day and exports into GB during the night. This reflects historical experience of flows on both interconnectors prior to the data freeze and is a best estimate of likely future flows.
Solar	There have been a number of recent enquires about connecting solar generators to the electricity network. At the time of the data freeze on 11/04/2016 there was insufficient information to include solar generation in the 2016/17 model. It is not clear how much, if any, solar generation will connect to the system during 2016/17.

[25] http://www.eirgridgroup.com/site-files/library/EirGrid/All_Island_Renewable_Connection_Report_36_Month_Forecast__(Q4_2013).pdf

Transmission

Feature	Assumptions
Transmission Data	The transmission system input to the model is based data held by the TSOs.
Transmission Constraints	The transmission system is only represented in the constrained model. The market schedule run is free of transmission constraints.
Network Load Flow	A DC linear network model is implemented.
Ratings	Ratings for all transmission plant are based on figures from the Planet database and those provided by SONI.
Tie-Line	The North-South tie-line is not represented in the unconstrained SEM-GB model. The Net Transfer Capacity (NTC) is modelled in the constrained schedule, with flow limits set to 300 MW N-S and 175 MW S-N.
Interconnection	The Moyle Interconnector and EWIC are modelled.
Forced Outages	No forced outages are modelled on the transmission network.
Scheduled Outages	Major transmission outages likely to take place in the tariff year and which would impact on constraints are modelled.

Ancillary Services

Feature	Assumptions
Operating Reserve	Primary, Secondary, Tertiary 1 and 2, and Replacement Reserve requirements are modelled. Negative Reserve at night of 100MW in IE and 50MW in NI is modelled.
Reserve Characteristics	Simple straight back and flat generator characteristics are modelled. Reserve coefficients are modelled where required.
Reserve Sharing	Minimum reserve requirements are applied to each jurisdiction, with the remainder being shared. These requirements are per the current reserve policy at the time of the data freeze[25]
Static Sources	Static reserve provided by STAR (an interruptible load scheme) is modelled. It is assumed that 43 MW of static reserve is available from 07:00 to 00:00. From 07:00 – 16:30, 17:00 – 18:30 and 19:00 – 23:30 the STAR provision is reduced to 17 MW, 12 MW and 17 MW respectively between the 23/12/2016 and 02/01/2017. Static reserve will be available on Moyle if there is sufficient unused capacity available, up to a maximum of 49 MW in Northern Ireland (the reserve is 50 MW, however this is measured in Great Britain). Static reserve will be available on EWIC if there is sufficient unused capacity available, up to a maximum of 70 MW in Ireland (the reserve is 75 MW, however this is measured in Great Britain). An overall maximum limit of 150 MW of static reserve from Interconnection is modelled, as measured in Great Britain. Note that during outages of EWIC it is assumed that 49 MW of additional static reserve will be available on Moyle i.e. up to 98 MW of static reserve from Moyle (as measured in Northern Ireland)

[25] http://www.eirgridgroup.com/site-files/library/EirGrid/OperationalConstraintsUpdateVersion1_36_Mar_2016.pdf

Appendix 3: Transmission Outages

A list of the major outages, based on provisional outage schedules, which were used in the constrained model, is shown below.

		Start Date	End Date
1	Ardnacrusha 110kV T101	01/10/2016	01/11/2016
2	Flagford - Lanesboro 110 kV circuit	01/10/2016	01/11/2016
3	Knockacummer T122	01/10/2016	08/10/2016
4	Cathaleen's Falls - Golagh - Letterkenny 110 kV circuit	01/10/2016	01/11/2016
5	Poolbeg 220kV A4/B4 Busbar	01/10/2016	01/11/2016
6	Aghada - Longpoint 220 kV circuit	17/10/2016	01/11/2016
7	Ardnacrusha 110kV T103	01/03/2017	03/05/2017
8	Booltiagh - Ennis 110 kV circuit	01/03/2017	01/10/2017
9	Booltiagh T121	01/03/2017	01/10/2017
10	Tullabrack tee - Booltiagh 110 kV circuit	01/03/2017	01/10/2017
11	Tullabrack tee - Moneypoint 110 kV circuit	01/03/2017	01/10/2017
12	Tullabrack tee - Tullabrack 110 kV circuit	01/03/2017	01/10/2017
13	Tullabrack T142	01/03/2017	01/10/2017
14	Flagford - Louth 220 kV circuit	01/03/2017	01/10/2017
15	Knockraha - Raffeen 220 kV circuit	01/03/2017	01/09/2017
16	Corduff - Finglas 1 (one) 220 kV circuit	01/03/2017	12/04/2017
17	Aghada - Knochraha 1 (one) 220 kV circuit; Aghada 220 kV A1/B1 Busbar	31/03/2017	21/04/2017
18	Carrickmines - Poolbeg 220 kV circuit	01/04/2017	01/10/2017
19	Poolbeg 220kV A4/B4 Busbar	01/04/2017	01/05/2017
20	Maynooth - Woodland 220 kV circuit	01/04/2017	01/10/2017
21	Corduff - Finglas 2 (two) 220 kV circuit	01/10/2017	12/11/2017
22	Moneypoint T4003	01/05/2017	04/08/2017
23	Dunstown - Moneypoint 400 kV circuit	01/05/2017	01/08/2017
24	Ardnacrusha 110kV T104	04/05/2017	06/07/2017
25	Finglas - Huntstown 220 kV circuit	06/07/2017	17/08/2017
26	Corduff - Woodland 1 (one) 220 kV circuit	05/06/2017	31/07/2017
27	Finglas - Shellybanks 220 kV circuit	31/07/2017	11/09/2017
28	Corduff - Woodland 2 (two) 220 kV circuit	10/07/2017	31/07/2017
29	Binbane - Letterkenny 110 kV circuit	15/07/2017	15/08/2017
30	Corduff - Mullingar 110 kV circuit	01/08/2017	16/08/2017
31	Finglas - Northwall 220 kV circuit	16/08/2017	27/09/2017
32	Glanagow - Raffeen 220 kV circuit	01/09/2017	01/10/2017

Appendix 4: N-1's

A list of the N-1 contingencies which are utilised in the model is displayed below.

Loss of Cathaleen's Falls - Srananagh 1 (one) 110 kV
Loss of Bellacorick - Castlebar 110 kV
Loss of Binbane - Cathaleen's Falls 110 kV
Loss of Clonkeen - Clashavoon 110 kV
Loss of Cathaleen's Falls - Corraclassy 110 kV
Loss of Raffeen - Trabeg 2 (two) 110 kV
Loss of Raffeen - Trabeg 1 (one) 110 kV
Loss of Tarbert - Trien 110 kV
Loss of Corraclassy - Gortawee 110 kV
Loss of Killonan - Tarbert 220 kV
Loss of Louth - Woodland 220 kV
Loss of Flagford - Louth 220 kV
Loss of Cashla - Tynagh 220 kV
Loss of Cashla - Flagford 220 kV
Loss of Clashavoon - Knockraha 220 kV
Loss of Cullenagh - Knockraha 220kV
Loss of Cullenagh - Great Island 220kV
Loss of Oldstreet - Woodland 400 kV
Loss of Dunstown - Moneypoint 400 kV
Loss of Inchicore - Irishtown 220 kV
Loss of Carrickmines - Irishtown 220 kV
Loss of Carrickmines - Dunstown 220 kV
Loss of Gorman - Maynooth 220 kV
Loss of Marina - Trabeg 1 (one) 110 kV
Loss of Dungarvan - Knockraha 110 kV
Loss of Cullenagh - Waterford 110 kV
Loss of Aghada - Knockraha 1 (one) 220 kV
Loss of Moneypoint - Oldstreet 400 kV
Loss of Clashavoon transformer
Loss of Marina - Trabeg 2 (two) 110 kV
Loss of Great Island T2101
Loss of Great Island T2102
Loss of Flagford - Sligo 110 kV
Loss of Sligo - Srananagh 1 (one) 110 kV
Loss of Shannonbridge - Ikerrin 110 kV

Loss of Knockraha - Raffeen 220 kV
Loss of Gorman - Louth 220 kV
Loss of Moneypoint - Prospect 220 kV
Loss of Maynooth - Woodland 220 kV
Loss of Cashla - Prospect 220 kV
Loss of Aghada - Knockraha 2 (two) 220 kV
Loss of Great Island - Kellis 220 kV
Loss of Dunstown - Maynooth 220 kV
Loss of Poolbeg Reactor
Loss of Cathaleen's Fall - Golagh Tee 110 kV
Loss of Cahir - Doon 110 kV
Loss of Corduff - Ryebrook 110 kV
Loss of Cathaleen's Falls - Drumkeen 110 kV
Loss of Ardnacrusha - Singland 110 kV
Loss of Prospect - Tarbert 220 kV
Loss of Arigna Tee - Carrick-on-Shannon 110 kV
Loss of Ardnacrusha - Limerick 110 kV
Loss of Gorman - Navan 3 (three) 110kV
Loss of Killoan - Singland 110 kV
Loss of Coolkeeragh - Magherafelt 275 kV Double Circuit
Loss of Coleraine - Coolkeeragh 110 kV
Loss of Coleraine - Limavady 110 kV
Loss of Coolkeeragh - Killmallaght 110 kV
Loss of Kells - Rasharkin 110 kV
Loss of Omagh - Strabane 110 kV

Appendix 5: Glossary

AGU	Aggregated Generator Unit
ATR	Associated Transmission Reinforcements
CCGT	Combined Cycle Gas Turbine
CER	Commission for Energy Regulation
DBC	Dispatch Balancing Costs
DSU	Demand Side Unit
EWIC	East West Interconnector
GB	Great Britain
GPI	Generator Performance Incentive
HILP	High Impact Low Probability
LPF	Load Participation Factor
MIUN	Modified Interconnector Unit Nomination
MSQ	Market Schedule Quantities
MW	Megawatt
MWh	Megawatt hour
NTC	Net Transfer Capacity
OCGT	Open Cycle Gas Turbine
OSC	Other System Charges
RA	Regulatory Authority
SEM	Single Electricity Market
SEMO	Single Electricity Market Operator
SMP	System Marginal Price
SO	System Operator
SSS	System Support Services
STAR	Short Term Active Response
T&SC	Trading and Settlement Code
TSO	Transmission System Operator
TUoS	Transmission Use of System
UUC	Unconstrained Unit Commitment
UREGNI	Utility Regulator for Northern Ireland
VOM	Variable Operation and Maintenance